1. Executive Summary

The goal of this project was to develop an enhanced navigation experience that goes beyond a simple two dimensional (2D) map, or turn by turn directions. To do this augmented reality was used to add visual aids to the user experience in order to more easily display directly to the user, the location of desired points of interest, and a visual path of how to get there. Augmented reality was used to overlay visual cues on top of what the user is seeing on their device. This method ensures that the user can easily confirm that what they see on the map directly conforms to the environment they see around them.

To implement this augmented reality setup, an application was developed that integrated a 2D map interface, augmented reality navigation, Global Positioning System (GPS) location tracking, and customization of points of interest options. This application was installed into an electronic device that is portable, uses a common hardware platform, and a common operating system (OS) foundation. By building for an electronic device that uses common components and software foundations, the developed navigation application will be eminently portable to other electronic devices such as smart phones or tablets.

To design this electronic device, we began with a hardware development kit as a foundation, and added any additional hardware functionality we needed in order to achieve the goals of this project. By starting with a hardware and software platform that is common to the industry, the sourcing of parts, design of the software application and the ability to customize the design was made eminently easier.

To prepare for this undertaking various hardware and software platforms were investigated in order to determine what will best suit our needs. The general design process began with an investigation into various operating system platforms and their various strengths and weaknesses. Since the operating system is what ties the application and hardware together, and to an extent determines what hardware foundation is used, it was a natural place to start.

Once an operating system was chosen, the next step was to choose the hardware platform to run it on. This was needed to be portable, expandable, and easily customizable to enhance the user experience and provide sufficient performance to support the software environment. Any hardware functionality that was not in the chosen platform was designed and added in order to meet the needs of this project. Application research and design was able to begin once the hardware and software platform was selected.

The design team for this project is composed of two senior electrical engineering students, and two senior computer engineering students. The electrical engineers focused on the hardware aspects of this project, which included designing an expansion board that adds hardware functionality to the base

hardware, providing a battery power supply to make the system portable. The computer engineers will focus on the software aspects of this project, including application development and integration into the OS environment and setting up any low level communication between the hardware in the expansion board and the hardware in the base device. They will also ensure proper OS to hardware operation.

2. Project Description

2.1. Project Motivation and Goals

Navigation applications have often required that the user be able to understand and interpret a 2D map, understand their location on a map, and be able to identify significant landmarks identified on the map, such as cross streets, buildings or terrain. Even after the user has accomplished this task, assistance provided by the application to inform the user of where they need to go next on the path to their destination have also been limited to a line on a 2D map, or verbal step-by-step instructions. This is suitable for those who have a natural sense of direction, or an aptitude for map reading, but can be difficult for lay users. It can also be difficult for them to identify specified landmarks that are often labeled with vague outlines.

The inherent difficulties on navigation with a 2D map that displays locations with at best outlines of significant landmarks, or at worst a single point with a title are easy to see. Users can have a difficult time identifying locations on a map because they have no idea what the target destination is supposed to look like. GPS navigation can be very helpful in informing the user of their current location and direction of travel, but it can't point out to the user what they are looking for or how it looks like.

Even turn by turn instructions can be of limited usefulness because the world we live in does not lend itself to fit cleanly in a 2D X,Y space. Anyone who has traveled in an urban environment, especially one that is built up from an older city can understand the frustration of receiving an instruction to "Turn Right", and there be two or three right turn options because the intersection has five or six streets coming off it. Perhaps the intersection it multilevel, with one right turn passing under an elevated roadway that also has an off ramp to the right to get onto the elevated roadway.

These ambiguities can lead to lost time and frustration as the user is forced to guess what the correct path is and determine through process of elimination which one was correct. Signs can be unreliable as well, as they can be placed in hard to notice locations, or be damaged or missing, thus making it difficult to know if the user is at the correct cross street, or at the specified landmark that designates their next turn to their destination.

If a device could be designed and built that not only generated a path to a user's destination, but could actually highlight on the screen precisely what the user is looking for, these issues could be resolved. Imagine a device that when the user holds it up to the landscape they are looking at, the device draws virtual information to its screen that directly super imposes onto what the use is seeing in their landscape. This can enable the user to directly follow visual cues their destination, and be able to precisely identify what it is they are looking for.

With a device like this (See Figure 2.1.1), even the most novice of user would be able to follow the virtual image of say a line or arrow, without having to worry if they passed the street or sidewalk that they were supposed to turn on. They would not need to worry about identifying intermediate land marks along their path that mark the location of their next turn. They also wouldn't need to determine if they are heading the right direction every time they change heading.

Figure 2.1.1: Navigation Tablet Concept Idea

Augmented reality can provide an enhanced navigation experience that overcomes the difficulties mentioned above. The target groups for this enhanced navigation are users who are both skilled, and unskilled with map reading and navigation. Unskilled users will benefit by being able to follow virtual representations of the desired path, and without even needing to look at the map, or know their current location, arrive at their desired destination. Skilled users will find the points of interest functionality very useful in being able to mark on 2D map locations that can be highlighted in the augmented reality space, thus providing additional perspective as to distance and direction from the users current location. This will also allow the user to easily share with others points of interest that they too can see on their augmented reality setup.

This target group can also be expanded to today's war fighter. Often times soldiers can find themselves operating in environments that don't offer easily identifiable landmarks for them to maintain their bearings. Dense urban environments, mountainous terrain, dense jungle and forest, can all conspire to confuse soldiers as to their exact location, the location of their destination, and any important areas around them. A tool that overlays digital information on top of what they are seeing would be invaluable to instantly informing them of their exact path, and providing perspective as to how far, and in what direction in relation to what they are seeing is their objective. The ability to mark enemy positions on a map, and then visually see those positions overlaid onto what they are seeing would allow them to precisely locate hidden or difficult to see locations.

The potential benefits and applications to the modern war fighter can be endless. Whole areas could be marked as unsafe for things such as minefield locations, ambush sights, and large numbers of hostiles. Combining this application with automated visual processing could even allow the device to automatically created landmarks of interest on the map, such as buildings that provide support to the enemy effort.

Although this capability is beyond the scope of this project, the basic foundation for a whole host of supplementary applications begins with an application that provides live visual cues to the user, directly displaying optimal paths to their destination over what they are seeing, landmarks of interests, and information about those landmarks with the added ability to custom add those landmarks.

2.2. Project Solution Goals

Keeping these target groups in mind, the engineering team designed and built a portable tablet that will display augmented reality visuals (via software application installed to the tablet) onto what the user is seeing. This can take several possible forms, such as using the tablets built in camera to display video of what the user is seeing on the screen, and then overlay a virtual image over it to show the user additional information. Another method could be to make the tablets screen transparent, so that the virtual images can be overlaid directly onto what

the user is seeing. A final method would be to display the virtual images to special goggles that contain built in screens that can be used to overlay the virtual images into the user's field of use. Ideally the implementation of this navigation aid would be able to function using any of these methods.

This tablet was built onto a hardware platform that is common to other tablet designs, such as those used for Android or IOS devices. By adopting one of the popular hardware and software standards, the team was able to build a product that can be widely used on all other similar devices. By using a common platform with other devices the software implementation of the augmented reality can be easily installed to other devices that share the same platform.

By using a tablet design that one can hold up to their line of sight with the landscape and allow the software to draw visual cues over, the problems mentioned in 2.1 can be overcome. A tablet design can present a large surface to view virtual visual aids. It can be used to implement any of the possible three forms mentioned above. Whenever the user needs to see where to do they can simply lift up the tablet, which will automatically display visual clues about which way to face, and overlay line and arrows about where to travel directly over what they are seeing.

Designing for a tablet that is built around one of the popular development packages, the navigation aid application could be scaled to work with smaller devices such as smart phones. The attachment of visual goggles to the tablet that display the same images seen on the tablet would even allow the user to avoid having to hold the tablet with their hands, freeing them for other uses.

The goggles implementation is probably the best design solution since it allows the users hands to remain free for task such as driving. For soldiers it would also be the best implementation, since they are already overburdened with equipment to carry and it can be integrated to the anti-ballistic glasses they already wear. Goggles are only a form of display however, which can be plugged into any tablet device and about the data shown on the tablet screen. The tablet still serves as the foundation device in this setup, and thus the tablet will be the focus of design efforts for this project.

In the end, transparent LCD panels proved to be unavailable, and thus could not be used for this project. The group also didn't want to dedicate budget resources to purchase 3D goggles, and thus it was decided to implement the camera combined with a normal LCD panel.

Once the group decided on the size, shape, and nature of the tablet, the augmented reality was implemented in a software application designed to run on the tablet design. This application is able to combine all of the elements of traditional navigation applications, such as a 2D map, and step-by- step

navigation, with 3D augmented reality that provides further visual information to the user.

This application has two main areas of focus. The first involves using augmented reality cues to tell the user exactly where to go when they are looking at the tablet. In other words, a virtual pointer is overlaid live onto what the user is seeing, so that they can follow it easily to their destination. By using a pointer on what they are seeing, the user need not be able to interpret a map. They won't need to be able to identify landmarks, such as streets, intersections, or buildings along the path to their destination.

This implementation solves an inherent limitation of turn by turn instructions. The augmented reality tablet highlights the exact path the user must follow. The user will only need to follow the pointer, without needing to identify intermediate landmarks to get to their destination. This also allows them to easily take the exact path they must take, both locally and in the distance in front of them, adding new perspective to the journey that they previously could only conjure up in their mind with a flat 2D map.

The second main focus of this application will be to allow the user to add landmark references to a 2D map.

Soldiers could use it to highlight enemy foxholes, or gun positions, or mark off entire areas to avoid. It is one thing to mark on a map the location of a point of interest; it is another completely to be able to see where it is in their field of view. By having it displayed in their field of view, they will not waste time trying to match the data they see on their 2D map with the field of view they see in front of them. Instead all of the digital information of the 2D map can be directly displayed on top of their view allowing them to instantly grasp any important information.

2.3. Project Requirements and Specifications

Starting with the application portion of this project and working back to the hardware portion, the feature and performance requirements of this design will need to satisfy the goals defined in 2.2.

The application will need to locate the user’s current location with a precision of less than five meters in error in an outdoor environment. At that distance the user should be to see their destination without difficulty. If this performance can be improved upon, it may be possible to add extra functionality to enable a very fine grain of point to point navigation, such as leading straight to the doorway of a building.

The application will need to match the GPS's level of accuracy when overlaying its virtual images over what the user is seeing. This means that visual cues, such as lines representing the user’s path to destination, and arrows showing the

required direction of travel must overlay accurately to the users visual plane. This will apply equally to landmarks that the user chooses to identify on their map. The level of accuracy achieved will directly translate into how small a landmark the user chooses to identify. Highlighting the floor of a building accurately, is much easier then highlighting a specific window. The same less than five meter accuracy will be used.

Indoor navigation will be attempted, though GPS accuracy decreases noticeably indoors, and may not prove feasible for time allowance of this project. However, if indoor GPS navigation can be achieved reliably, then indoor room to room navigation can be attempted. The device must be able to tell what floor it is on when as it is moving through a building. A barometric sensor will be needed for this purpose, so the tablet must integrate one.

To support the software requirements the tablet must integrate the necessary sensors to feed the needed data to the application. This includes the already mentioned barometric sensor for altitude detection, but it must also be able to fully detect movement, changes in orientation and acceleration. This information will not only be needed to activate the application when the user brings up the tablet into their field of view, but will also be needed to help in determining the users direction of travel, and their current facing when standing still. As such, the tablet must contain a gyroscope, accelerometer, and compass.

This tablet must also be able to offer a level of computational performance sufficient for computing not only the necessary navigational data, but also for generating the 3D imagery necessary for the augmented reality portion of the project. A graphics accelerator will thus be needed, as well as a powerful enough CPU and large enough RAM to support the application.
The display method of this tablet will depend on a number of factors. The simplest version that was mentioned in section 2.2 is to use the onboard camera to record video and stream it to the screen in order to replicate what the user is seeing in their plane of view. Then the virtual visual aids can be super imposed onto the video stream. This method has the advantage of using standard hardware that is commonly available.

The more advanced version is to use a transparent screen so that the user can simply look through the tablet and allowing them to never have to take their eye off of what they are looking at. It will also ensure that the perspective of the user is not altered by the position of the camera in the device. However transparent screens are still an experimental product and using one will depend mostly in being able to acquire one. If one cannot be bought, then the simple method mentioned above will be used.

Should time and budget permit, the use of goggles plugged into the tablet can be explored and possible implemented as an additional feature for this project, this

should not be considered a required goal of the project though, just a future possible path to take the design in the future.

All of this hardware will need to fit into a chassis that a user can elevate to eye level for a useful amount of time. Given the design group's limited manufacturing abilities, a weight limit of no more than three pounds will be aimed for. In accordance with this, a screen size no larger than ten inches will be used, but no smaller than seven inches, in order to provide a comfortable user experience with the tablets interface.

Naturally the design will need to integrate a battery in order to make the device portable. Power consumption and efficiency is not a design priority for this project, so a modest three hour battery life is being aimed for; in order to facilitate final design testing which will take place in real world environments.

Given that UCF's Institute for Simulation and Training have generously agreed to fund this project to the amount of $2,000; the final cost for parts and manufacturing must not exceed this amount. If accomplished, this would prove significant in and of itself, that an augmented reality navigation tablet can be designed and built using standard off the shelf parts for $2,000 or less.

Project minimum Performance goals verses Real Tablet Products

	iPad Mini	**Nexus 7**	**Surface RT**	**Kindle Fire HD 7**	**Project Tablet**
Size	7.87x5.3x0.28 in	7.8x4.72x0.41	10.81x6.77x0.37	7.6x5.4x0.4 in	11x8.5x3.2
Weight	.68 lbs	.75 lbs	1.5 lbs	.87 lbs	4
Screen Size	7.9 in	7 in	10.6 in	7 in	7 in
Battery Life	4490 mAh	4325 mAh	8200 mAh	4400 mAh	2200 mAh
Processor	Apple A5	Tegra 3	Tegra	TI OMAP 4460	TI OMAP 4460
Sensors	Light, accelerometer, gyro, compass	Light, accelerometer, gyro, compass	Light, accelerometer, gyro, compass	None	Light, accelerometer, gyro, compass, barometer
Operating system	iOS 6	Android 4.1	Windows 8 RT	Android Forked	Android 4.0.3
GPS	YES	YES	NO	NO	YES
Bluetooth	YES	YES	YES	YES	YES
Wifi	YES	YES	YES	YES	YES

Figure 2.3.1: Tablet Comparisons

In summation, at a minimum, this project will accomplished the construction of a tablet computer not weighing more than three pounds, with a screen no larger than ten inches, and a three hour battery life. This tablet will power the new navigation application that will provide an augmented reality experience to users in order to aid them in navigating to desired destinations, and in highlighting points of interest relevant to their needs. These design goals should be considered a minimum goal. Figure 2.3.1 above compares these modest design goals against shipping tablet products.

3. Research Related to Software and Hardware Design

3.1. Software Resources Research: Android vs iOS vs WP8

3.1.1. Software Development Kit

A big decision when taking the leap into software development for mobile platforms is the SDK support the platform has to offer. SDK stands for Software Development Kit, and it is basically software development tools that allow for the creation of applications for a certain software package or operating systems (Android, IOS, and Windows Phone). An SDK can also pertain to software framework, hardware platform, computer system or video game console. In our situation, we will be considering the mobile operating system with the most comprehensive SDK for our particular needs [29].

An SDK often comes in the form of a downloadable file that can be interfaced with an Integrated Development Environment or IDE (See IDE Section for more details). Within the IDE, the SDK can help by providing tools such as interface creation, sample code, and device emulators to jump start the learning process for a new platform and assist in a speedy development cycle. These SDK's are provided by the operating system's owners such are Google or Apple to give incentives to third party application programmers to develop on their mobile platform [26].

In this section we picked out the three main areas that pertain to Project AUGI the most. These three areas are: Interface Creation/Editing, Platform and Tools, and Device Emulators and Simulators. Because our group is new to mobile application development, initial requirements are that the setup of the appropriate IDE, API, and SDK be simple and straightforward, creating trivial things like the user interface be simple and almost done for us so there is more time to work on core components and functionality, and all of our current machines be compatible with the respective SDK due to budget limitations [26].

3.1.1.1.Interface Creation/Editing

Interface creation within an application can be a very trivial yet time consuming task. Many times developers find themselves spending too much time on code pertaining to the user interface and not enough time on the core functionality of the application. Thankfully; Google, Microsoft, and Apple have all included interface creation tools that will assist and reduce the amount of time spend on creating a usable graphical interface which in turn, will free up time spent on developing the core functionality. The strengths and weaknesses of the three competitors are described below.

3.1.1.1.1. Android

Androids Layout Editor is Google's answer to building an android interface and underlying functionality within an Android application. Using this layout editor, you have the ability to visually create the graphical interface which that you wish to use. This layout editor is tightly associated with the XML that it generates within your code. Many developers online agree that Google's layout editor seems a bit crude, and they often found themselves editing the generated XML code themselves. Android's Layout Editor does have its advantages though. Android's mechanism for configuring referencing outlets for UI elements is agreed to be the most intuitive of all the competitors. Lastly, the documentation for theming and styles in Android is not as helpful as the others [27].

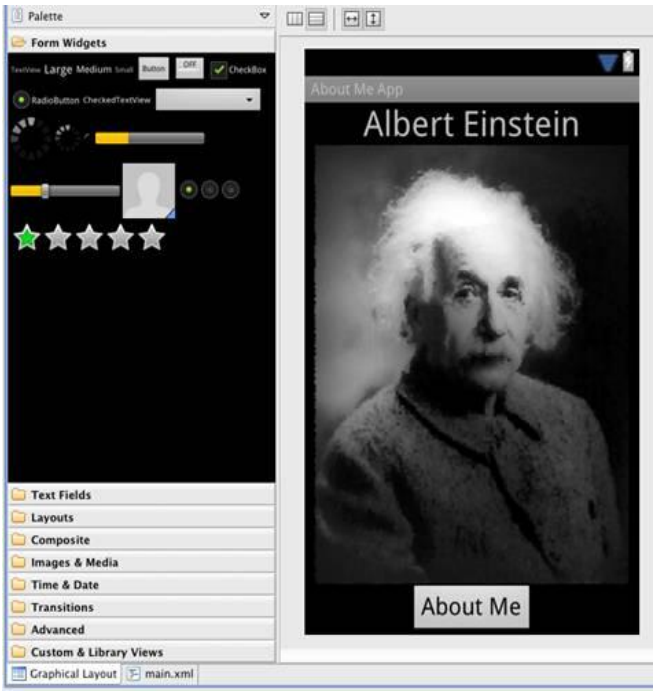


Figure3.1.1.1.1.1: Google's Layout Editor
Google Open Instruction Image

3.1.1.1.2. iOS

Apple has developed an interface building tool called, Interface Builder (See Figure 3.1.1.1.2.1). Apple's Interface builder is the most polished interface creation tool of its competitors. Interface Builder makes manipulating and adding components to your user interface simple. By taking advantage of drag and drop features for almost every graphical situation, directly editing XML becomes almost non-existent. Apple also has the advantage in the user interface

development arena because of its support for only one screen resolution. This means, unlike Android and Windows Phone that layouts do not have to be specified in any specific way to allow them to conform to the standard [34].

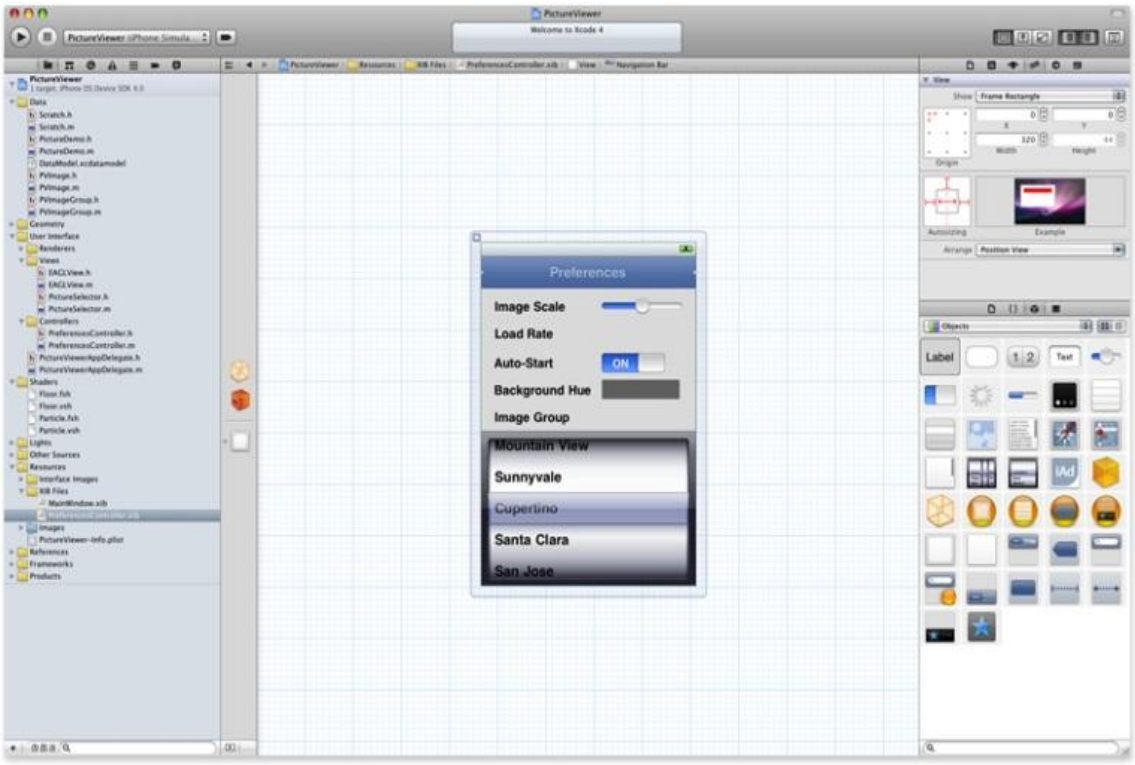


Figure 3.1.1.1.2.1: iOS Layout Editor
Apple Open Instruction Image

3.1.1.1.3. Windows Phone

Windows Phone 8 is a fairly new operating system, so not many people have tried and tested the SDK environment yet. The Windows Phone SDK is basically a subset of Microsoft's rich UI for web enabled content. Because the Windows Phone SDK is so similar to Microsoft's Silverlight, it is logical to understand Silverlight is first before trying to understand Windows Phone SDK. Silverlight is used for running rich internet applications and is very similar to Adobe Flash. Silverlight is most commonly used in web browsers and can be enabled as an add-on similar to Flash. Silverlight is the driving force

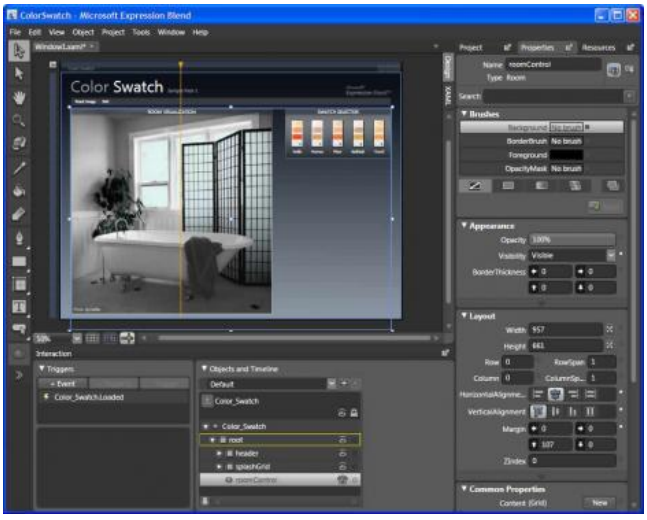


Figure 3.1.1.1.3.1: Windows Phone 8 Layout Editor
Microsoft Open Instruction Image

behind many of Microsoft's web based development. Microsoft has provided the community with downloadable UI templates for developers to use. The user interface design tool Microsoft provides is called Microsoft Expression Blend. This is a separate module sold by Microsoft itself. Expression Blend works seamlessly with Visual Studio (Microsoft's own official Integrated Development Environment) which makes it easy to move objects back and forth without the need for conversions [35].

3.1.1.1.4. Winner

Overall, the Interface creation among the 3 platforms is very competitive; from Android's extremely versatile development environment, to IOS's polished and easy and straightforward Interface Builder, to Microsoft's well-integrated development ecosystem. The two interface creation mechanisms that seemed the most complete were Apple's IOS and Microsoft's Windows Phone. Android fell short when it came to usability and completeness, and when time is of the essence that is a risk that must be considered.

3.1.1.2. Platform and Tools

Development tools are a crucial in a speedy development process. This is an area where these platforms begin to show their differences as far as SDK features goes. This is also an area that Project AUGI is especially concerned about due to our limited budget and the magnitude of the cost of a new computer using a supported operating system. Platform describes the operating system that developers are allowed to build the software on. Tools for an SDK include Integrated Development Environments (IDE's) that are platform dependent. An Integrated Development Environment is a piece of software that offers a large set of tools for programmers to assist in software development. An IDE normally consists of a source code editor, build automation tools and a debugger. A platform can also be replaced by a virtual machine which can run the operating system with another operating system. Utilizing this virtual machine software can solve the problem, but more time and money must be spent in buying new licenses and configuring some virtual machine specific settings (Such as Hyper-V for Windows Phone 8 which is required to run their device emulator).

3.1.1.2.1. Android

Google has allowed software developers to choose between virtually any desktop operating system of their choice which includes: Apple's OS X, Microsoft's Windows, or Linux. This opens up a wide range of IDE's to choose from and allows our group to develop across different desktop platforms which becomes a problem when a tight budget is involved. This is a positive for project AUGI, because of this versatility no funds will have to be wasted on the development portion of the project. Although the use of virtually any Java

development IDE is possible, Eclipse seems to be the IDE of choice for one big reason; Google's SDK has only been fully integrated on Eclipse [26].

3.1.1.2.2. iOS

Apple has made the decision to only allow developers to build IOS applications on computers running their desktop operating system OSX, in other words, a Macintosh. This restriction was crucial in making our decision in picking our mobile platform. Due to this fact, a limited number of IDE's are available for use. XCode is arguably the only useable IDE for developers to use, and because of this also limits options dramatically. There are other IDE's available when programming in Objective-C but XCode seems to be the fan favorite [34].

3.1.1.2.3. Windows Phone

Microsoft's Windows Phone 8 SDK includes Visual Studio 2012 Express as its main IDE. Visual Studio can only be installed and run on a machine running Windows operating system on it. Mac OSX and Linux are not yet supported. Visual Studio supports development in Windows Phone's main programming language which is C#. There are other development environments to choose from when programming in C# such as Monodevelop. Monodevelop is supported across Windows, OSX, and Linux. Although there are some other alternatives to Visual Studio, the programming community is in agreement that Visual Studio Express is the most convenient one [35].

3.1.1.2.4. Winner

The winner of this round will go to Google's Android because of its versatility and many development options. Because of Android's SDK ability to develop on almost any platform, the need for virtual machines and compatibility issues no longer becomes a problem and everything in the end will work as close to seamlessly as possible. Microsoft and Apple have a road ahead of making their SDK's runnable on other machines besides their own, and sadly because of that fact the world may never see them rolled out for other operating systems.

3.1.1.3. Device Emulators and Simulators

Device Emulators have become a necessity in the mobile application development realm. A device emulator is supposed to mimic the user-device interaction without working on the actual physical device. If a device has 1GB or RAM that runs on a 1.3 GHz Snapdragon S3 processor, the device emulator should present the same type of performance that is expected of the physical device. Software nowadays is not developed and run on the same machine like it used to be. Due to this fact, device emulators were created to speed up testing and debugging time. Time and money is a big road block and the ability to run a virtual device's screen on your desktop and test a virtual device instead of a physical one is crucial.

Devices also come in a large amount of configurations and hardware options. For example, a mobile operating system such as Android has countless devices manufactured by Samsung, Motorola, HTC, etc. Each of these devices features different screen resolutions, processors, cameras, and peripheral connectors, all of which has to be taken into account when the development of an application is considered. Device Emulators allow someone to test across all of these with the click of a button. The sections below will describe the device emulators each platform's SDK features.

3.1.1.3.1. Android

Android's device emulator (See Figure 3.1.1.3.1.1) remains unpolished like the rest of the available SDK. It does not have features such as the on screen keyboard and physical device-like navigation like its competitors do (Apple and Microsoft). The illustration shown is an example of the Androids device. On Google's defense, it has a very wide range of devices to support unlike Apple or Microsoft (which have a very limited selection of handset devices). Another consideration would be the manufacturers personalized UI builds, which can also have an effect on the appearance of an application's layout. Although Google's emulator seems to lag behind in its polish and realistic navigation, it is fully functional and perfectly useable. Finally, the speed of the emulator is a bit slower than that of its competitors. This isn't a deal breaker but it is something to consider [26].

Figure 3.1.1.3.1.1: Android Device Emulator
Google Open Instruction Image

3.1.1.3.2. iOS

Apple's iOS continues to be the most polished SDK around offering the fastest and most realistic virtual device interface (See Figure 3.1.1.3.2.1). Apple's simulator also features a completely functional keyboard that behaves exactly like the one on their physical phones. Navigation is also realistic in the sense that it behaves just like its physical look-alike. Swiping gestures on the physical devices is mimicked by clicking and dragging and applications are opened by clicking. Another impressive feature about iOS's device emulator is the speed. It is smooth and on par with its physical devices. The only downside to the iOS simulator is that fact that it is a simulator itself. This can be a downside because when testing the performance of an application, you won't get a real world estimate of how well the application will perform on an actual device. This is also noticeable when keeping track of memory consumption and available disk space. Upon viewing the system specs of a simulated iPhone within the simulator, the development computer's specs will appear rather than the specs of the phone in question [34].

Figure 3.1.1.3.2.1: Apple Device Emulator
Apple Open Instruction Image

3.1.1.3.3. Windows Phone

Windows Phone's SDK package is beginning to gain its reputation as one of the more polished development kits available. With Windows new roll out of Windows Phone 8, many changes were made to both the operating system itself and its software development kit. With these new added SDK features, Microsoft is now upping the system requirements of the development PC you can work on now. With the new Windows Phone 8 SDK comes the addition of Microsoft's very own Hyper-V requirement to run the Windows

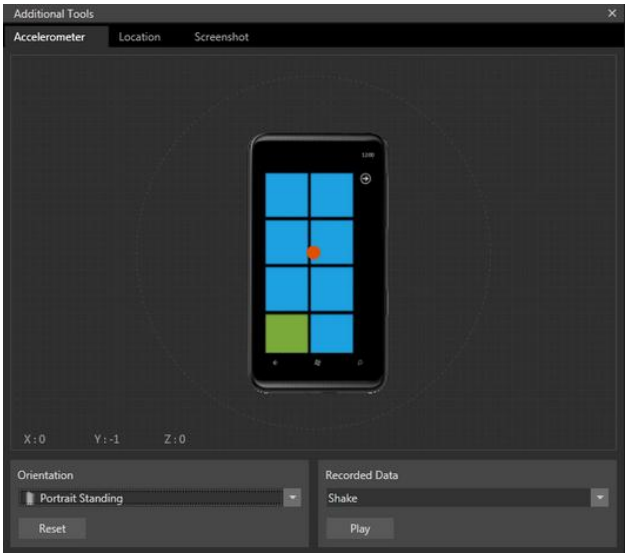


Figure 3.1.1.3.3.1: Windows Phone 8 Device Emulator
Microsoft Open Instruction Image

Phone 8 emulator (See Figure 3.1.1.3.3.1).

Since many developers have the own preference of operating system and prefer not change when switching to a new development platform (because of platform limitations i.e. Apple and Microsoft) they often find themselves running on virtual machines within their preferred operating system to get the job done. To run the Windows Phone Emulator within a virtual environment, Second Level Address Translation (SLAT) is needed and this, in turn, needs Hyper-V on the server. Hyper-V has become somewhat of a hurdle for many developers on the web now having to revamp their systems after the new change [35].

Once the Emulator is setup and running, performance is fast and the interface is sleek. Navigation within the UI is just as it would be on the physical devices and it is smooth and accurate. This fact puts it in direct comparison with the iOS simulator by Apple except for the fact that Microsoft took it a step further and added the extra “emulator” functionality to give it the correctly emulated processor speed, memory support, and storage availability. Options like changing color accents and adding email and administrative accounts are also available in the emulated window.

3.1.1.3.4. Winner

The winner of this Software Development Kit Emulator round will have to be Windows Phone 8’s Emulator. With its highly polished and true-to-life emulation, Microsoft has done their homework when it comes to making an emulator that developers want to work on. Although there is the added hassle of setting up the virtual machine to Hyper-V’s liking, for this project we will not be using any servers to simulate the Windows environment requirement. iOS was in a close second, but due to our application being very hardware intensive, a simulated environment that utilizes hardware far beyond the physical devices just won’t cut it. Android’s emulator is great if a developer is looking for purely functionality, but just cannot compete with Microsoft’s polish and equaled functionality.

3.1.1.4. Programming Language Options

Another aspect when considering which OS platform to choose as the foundation for our project is considering which programming languages are usable for each. For Apple's iOS platform this means using Objective-C. Objective-C is an object oriented programming version of the C programming language. It adds object oriented syntax features to the existing C base, which means it is fully backwards compatible with regular C code. Objective-C is the only programming language allowed for application development on Apple devices [1].

3.1.1.4.1. Android

For Google's Android platform, the programming language that is used for application development is Java through the Android Software Development Kit (SDK). The most popular IDE for application development is Eclipse. Eclipse is a widely used IDE, that is highly flexible and extensible, so that it can be used for coding in a wide variety of languages [27].

3.1.1.4.2. iOS

Apple offers up Objective-C through its Xcode integrated development environment (IDE). Xcode is used to develop all iOS applications. This IDE contains all the necessary pieces that are needed to develop applications for Apple devices, including an integrated Interface builder for graphical user interface construction (GUI), and developer documentation for building applications [34].

3.1.1.4.3. Windows Phone

Application development for Windows Phone 8 is done through the Windows Phone Developer Tools, which can be integrated into the Visual Studios IDE. It supports native C and C++ libraries, and uses a shared runtime known as the Common Language Runtime. This allows easy porting of software between Windows programs and Windows Phone 8 [35].

3.1.1.4.4. Winner

For this project, the criteria for which of the three options listed above best suits the projects needs, are familiarity with the programming language, the openness of the development platform and its accessibility to custom hardware that we can build with.

Since Objective-C is only available through Apple's Xcode, which is further restricted to operating on Apple hardware, it is unsuitable to the needs of this project. Windows Phone 8 also falls through due to these same limitations. The openness of the Android platform however, and its use of Java, which is a very widely used programming language meets the needs of the project perfectly. The design team can build its custom hardware, and install the Android OS onto it. It can further develop the needed navigation aid application using the highly familiar and common Java programming language. This further supports the choice of the Android OS as the software foundation for this project.

3.1.2. Multiple Platform Cross Compatibility and Porting Requirements

In this day and age where there are so many new mobile platforms and operating systems arising, platform cross compatibility and porting requirements are becoming more and more relevant. This is because software development companies now have to convert or port their application from its primary development platform to a new platform to stay relevant. Problems can arise when complex programs are rewritten on another platform due to different API calls and system references. Along with API differences comes the hardware variations associated with respective devices running their mobile platforms. With different hardware also come more compatibility issues. For these reasons, porting an application has become less trivial than the past.

There are many outsourcing availabilities out there in the wild providing platform to platform conversions, one of the most popular being a firm called Two Toasters.

3.1.2.1. Android

Many Android developers nowadays are seeing how beneficial developing an application for one of the most popular mobile platforms in the world can be, and would like to expand their audience.

Google has done a lot of the work for Android developers and created a porting tool to assist in the porting from Android to iOS devices (this includes iPhones, iPod Touches, and iPads). The program is called J2OBJC and is basically a Java to Objective-C translator. J2OBJC achieves this by converting Java classes to Objective-C classes by directly using the iOS Foundation Framework. GUI related elements are not supported, but the core functionality Java source code is. J2OBJC supports the complete Java 6 language and most of its runtime features that are required by client-side application developers and include: exceptions, inner and anonymous classes, generic types, threads and reflection. Also, the translation of JUnit test and execution is built in. Also, many IDE's such as Xcode and Make can take advantage of J2OBJC.

At the moment there is not one-to-one port tool available for Android to Windows Phone 8. Microsoft has released some tools to assist in the API translations between the two platforms. Some of these tools include the formation of an Android to Windows Phone API mapping tool and a service called "App Guy" that scours the internet for porting questions regarding Windows Phone 8 and any porting issues developers may be having. The bottom line is that the application will have to be rewritten in a Windows Phone 8 form factor.

3.1.2.2. iOS

iOS to Android porting is not as simple as Android to iOS, and there is no porting automation available yet. In fact, Objective-C cannot even be re-compiled into Java for Android. Besides that demotivating fact, when trying to rewrite an iOS application for Android, the immense size of device configurations becomes a problem. Android devices come in different sizes, pixel densities, processor speeds, Android versions, etc. In the event that an iOS application uses basic C code then there is a possibility that the code can be reused in Android.

For porting iOS to Windows Phone 8, a code rewrite is also necessary as there is no known porting option. Microsoft has provided the same type of documentation that it's provided for porting Android to Windows Phone. This document is called the iPhone API mapping tool and makes the migration process much less time consuming [34].

3.1.2.3. Windows Phone

Windows Phone 8 is still a new operating system and chances are an application won't initially be developed on it before other platforms. There seems to be no trivial away for anyone to port a Windows Phone Application to any other platform at the moment. Because it is a Windows Phone, there was a lot of discussion regarding porting an application to a Windows desktop environment, but that without any substantial porting tools also. Also, the fact that Microsoft is less interested in making developers move their applications to another platform until it starts to gain some more momentum in the mobile handset realm.

3.1.2.4. Conclusion

To conclude, there is a clear advantage among one of the platforms within this list, Android. Google has developed their own J2OBJC porting application that is the only true porting utility out there on the market to port to iOS. Microsoft also supplies Android to Windows Phone API translations for easy look ups and code rewrites. It is general consensus though, that porting a phones graphical user interface is neither supported nor is it a good idea for developers to do. Taking advantage of a platform's strengths as far as its user interface is a big deal, and if it means code re-writes, so be it.

3.1.3. Hardware/OS Platform Flexibility

When picking a new mobile platform to start developing hard for, one question that hardware developers ask themselves is: "How easy will it be to integrate new hardware into the operating system?" There are some key differentiators when it comes to developing hardware for the big three players in the mobile handset

game. There are also certifications involved when it comes to being eligible to receive their support when it comes to API's and integration. This fact can slow down the development process because of the time it takes a big company like Apple to approve a project and give you access to their integration libraries [29].

Project AUGI will need to communicate to a handset device via some sort of input port. Input methods change because to the input support each device carries. For example, the standard protocol for a USB port will differ from the protocol on iPhones Lightning connector. The design decision will ultimately be chosen and their reasons explained further in the documentation. The sections below will explain the process it takes, for each mobile platform, to develop a piece of hardware. Mobile platform's will often release hardware development kits to jump start and entice developers to start building hardware for their platforms so there is a richer and more option filled experience for the end-user. Companies such as Apple and Google have released their own hardware development kits and it has proven to be successful in luring customers to their platform because of a more accessory rich environment.

3.1.3.1. Android

Google's Android, unlike Apple, does not need a certification to develop hardware. There is no approval process, and in turn, no wait time to begin development. Google supplies an Accessory Development Kit or ADK on their website for anyone looking to get into developing hardware for their platform. The Accessory Development Kit is for anyone and is a reference implementation starting point for building accessories for Android. An accessory includes speaker docks, credit card scanners, or anything else that can interface with a handset running android. These accessories use AOA or Android open accessory protocol in order to communicate between a handset and the piece of hardware; this includes wired connections such as USB or wireless connections such as Bluetooth [29].

The latest version of Android's ADK is based on the Arduino open-source electronics prototyping platform with some modifications that help it integrate with Android devices. With the purchase of an Android Development Kit comes a hack-able Arduino box that contains every sensor imaginable. It can be used to find the right combination of hardware for a developer's specific purpose to then be built and put into production.

There is currently no certification program for new Android hardware, which means that customers can't expect anything from quality of their hardware. It also means that dependable manufacturers are at a disadvantage because of the consumer confusion when shopping for a new accessory.

3.1.3.2. iOS

Apple has always maintained a closed ecosystem, regulating all the device accessories, applications and even the devices themselves. Building a piece of iPhone hardware is no different. The first step in the hardware development process for an Apple iPhone product is to become a member of Apple's MFi program. This program will give a developer access to: the hardware components and documentation, allow you to use the official MFi certified logos, and allow you access to Apple's technical support engineers.

This is a lengthy process requiring things like: a credit review, the write up of an enrollment form, and even Apple's analysis of the developer to determine if Apple thinks Apple hardware development is right for them. Upon becoming an official hardware developer, Apple requires you only use the components that they approve and exclusively buy it through them. Being a company is also another problem area. Apple only accepts certified companies before they even consider looking over any approval papers. There are no fees when applying for the MFi program, but Apple requires you to pass a standard series of third-party tests to demonstrate that the piece of hardware won't interfere with the iOS hardware built in [34].

Among all of these requirements and restrictions, it will be close to impossible for Project AUGI to develop and Apple related hardware in a timely manner. Submitting the application for MFi seems difficult enough, on top of earning the privilege to become hardware for Apple seems near impossible.

3.1.3.3. Windows Phone

Windows Phone 8 is still in early development at this point and does not have any official development kits at the moment. In order to develop any hardware for Windows Phone 8 you must be a Microsoft hardware partner right now. These companies include Nokia, HTC, Samsung, etc. The reason for this is probably so the early adopters get a good end-user experience because they are using hardware made by reputable companies. As the ecosystem and the platform as a whole get stronger we may see Microsoft release a hardware development kit.

3.2. Hardware Resources Research

3.2.1. Reference Board Hardware Summary

The hardware for our project revolves around the PandaBoard ES. The PandaBoard ES is the heart and brains of this project (See Figure 3.2.1.1). It was the platform which the operating system, the latest version of Android, ran on. This board was mounted on the Panda expansion board which has a 7.0 inch LCD screen. A resolution of (800 by 480 pixels); with five point capacitive touch,

and five user keys/buttons. There was also a three-axis digital accelerometer and three axis digital compass which we did not use for our project.

Instead our sensors were from a custom made PCB board that is attached via the USB port into the Panda Board ES. The 7 inch LCD screen, Pandaboard ES, and Panda expansion board are mounted on a plastic frame to neatly and aesthetically hold everything together. The Pandaboard ES does not have sensors, like a barometer, accelerometer or gyroscope. Some of these sensors, like an on board accelerometer are featured on the expansion board, however, instead of using the prebuilt sensors on the expansion board, a custom design PCB board read in all of these sensors.

This custom PCB board has the IOIO circuitry within, which acts as a USB host and interprets commands from our Android app programmed in the Panda Board. The custom PCB board also includes other sensors such as: accelerometer, gyroscope, barometer, GPS, GPS antenna, ambient light/photo sensor, temperature and sensor. Two 2200mAh polymer lithium ion batteries were used to power all the devices, alternating while one was being recharged. Our custom made PCB included circuitry to regulate and a separate charger to recharge the battery packs.

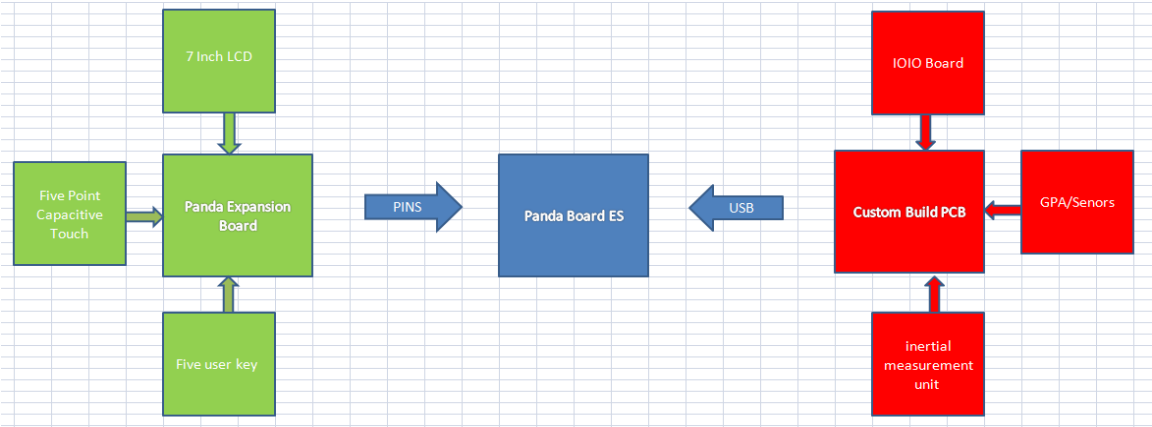


Figure 3.2.1.1: Reference Board Hardware Description Image

3.2.1.1. Primary Microcontroller

The microcontroller is the most essential part of this project. Even before deciding which board to use, we first created a list of requirements our project needs. Unlike typical microcontrollers, which often have under 100 KB of RAM, we needed a system on chip that had a processor powerful enough to run an operating system like Window or Linux, preferably any ARM Cortex-A8 or later. In our case it is the Android Operating system.

We also wanted our microcontroller to be as open source as possible. At first we looked into the Raspberry Pi. When we compared it with the features of the Beagle Board or Panda Board, it seemed to lack many of the features we

needed. Therefore the Raspberry Pi was out of the picture. Next we looked into the Beagle Board. The Beagle board was very open source and could run the Android OS. It had sample codes and step by step tutorials over the internet.

We then looked into the Panda board. The big difference between the Beagle board and the Panda board is that the Panda Board had most of the hardware a smart phone would have, like audio jack, camera expansion and SD slot. Our project is to create an augmented reality via an android app. If our development board has all the features a smart phone has, it would be possible to use the software not only on our device but on any android devices. The Panda board is also very open source so at the end we decided that this microcontroller was our best bet. There are two kinds of Panda board, The Panda Board and The Panda Board ES. The ES version has the OMAP4460 (1.2 Ghz) vs the regular version which has OMAP4430 (1.0 Ghz). Not only was the ES faster, but it also supports TiWi-BLE, has a sysboot control to control the boot order, support AFML/R, and a hand full of other features. Thus we picked the Panda board ES.

3.2.1.2. Pandaboard ES

The Pandaboard ES (See Figure 3.2.1.2.1 Figure 3.2.1.2.2) is based on a system on chip(SoC), the OMAP4460 by Texas Instruments. It is designed to be low-power consumption, cost effective single-board computer for development. The OMAP4460 is a duel-core A9 CPU with a 384 MHz GPU, and has 1 GiB of DDR2 SDRAM (See Figure 3.2.1). The board is completely open sourced and is a community supported development platform.

The PandaBoard ES can run an array of operating systems, such as: Windows CE, WinMobile, Symbian OS, Linux, which includes any of the Android OS, and Palm OS. The Pandabord ES has additional expandability via onboard connectors throughout the board (See Figure 3.2.7). It can output 1080p from either its HDMI or DVI ports. It also comes with Wi-Fi(See Figure 3.2.8), Bluetooth, LAN port (See Figure 3.2.8) and much more [1].

Listed below are the major components used on the PandaBoard.

- OMAP4430 Processor (See Figures 3.2.2, 3.2.3, 3.2.4)
- TWL6030 (Phoenix) Power Management Companion Device (See Figure 3.2.5)
- TWL6040 (Phoenix) Audio Companion Device (See Figure 3.2.6)
- POP Mobile LPDDR2 SDRAM Memory
- HDMI Connector (Type A) – for OMAP4430 HDMI Transmitter output (See Figure 3.2.11)
- HDMI Connector (Type A) – for DVI-D output sourced via OMAP4 parallel display output (See Figure 3.2.11)
- Audio Input & Output Connectors (3.5mm)
- SD/SDIO/MMC Media Card Cage (See Figure 3.2.10)
- LS Research Module – 802.11b/g/n, Bluetooth, FM

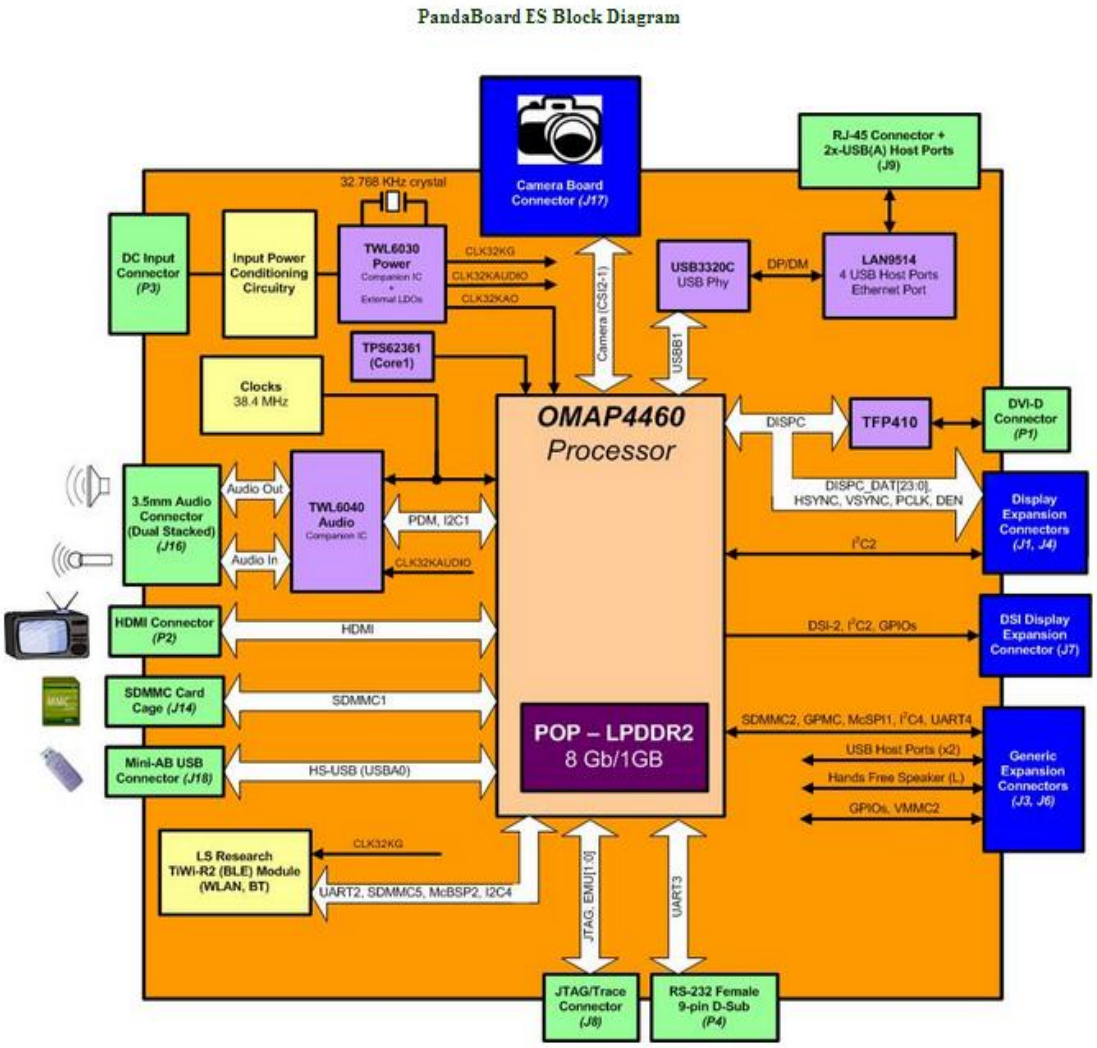


Figure 3.2.1.2.1: Block Diagram for Panda Board ES
Reprinted with Permission from Panda Board [1]

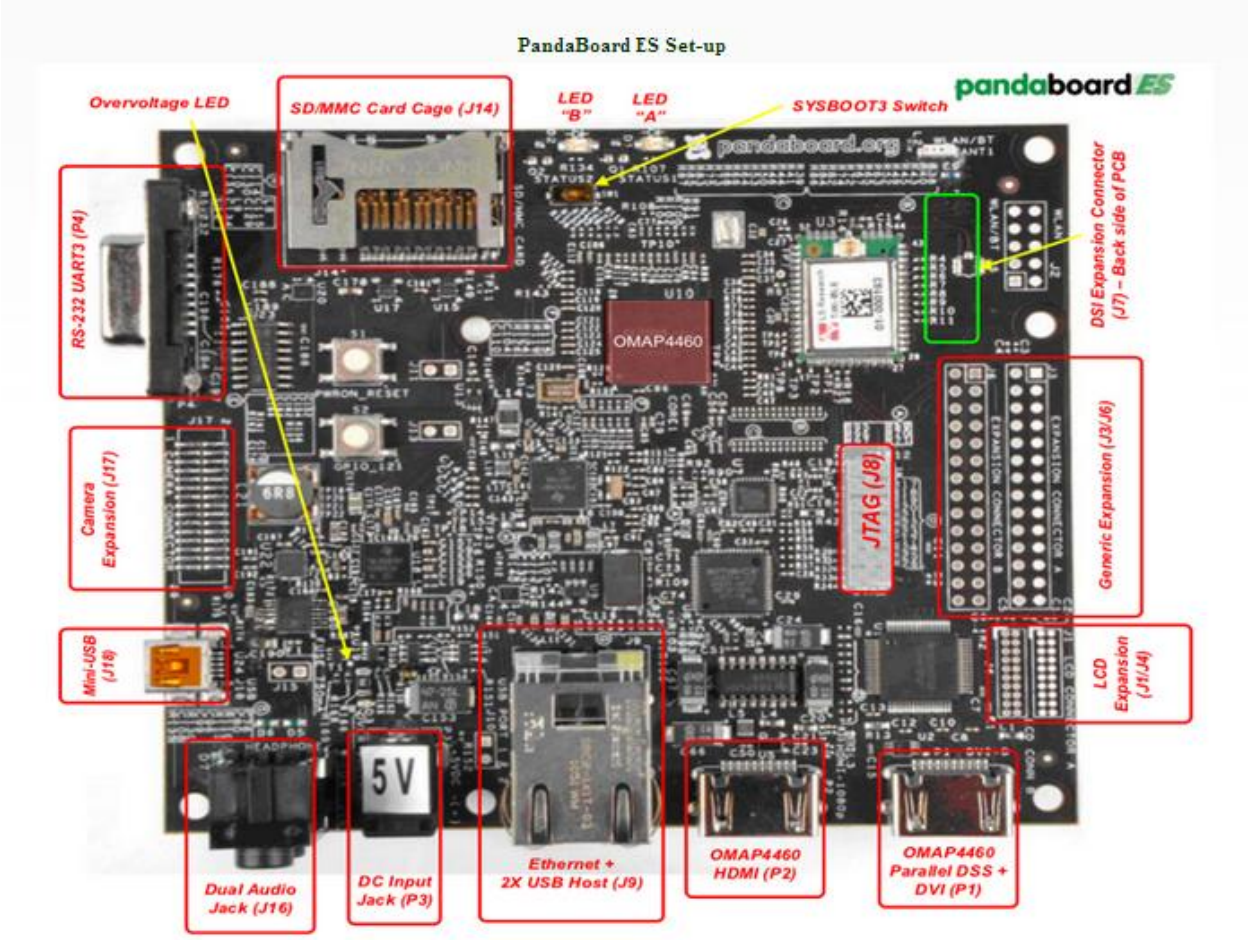


Figure 3.2.1.2.2: Top View of the Panda Board ES
Reprinted with Permission from Panda Board [1]

3.2.1.3. Processor OMAP4460

The Pandaboard ES is a platform for the OMAP4460, which has many powerful multimedia features, while also staying low cost. The OMAP4460 is developed by Texas Instruments and is a category of proprietary, system on chip, (SoC) for portable and mobile multimedia applications. The OMAP4460 is a duel-core CPU with a 384 MHz GPU. It also has 1 GiB of DDR2 SDRAM(double data rate synchronous dynamic random-access memory) The chip uses an Advanced RISC Machine (ARM) architecture and uses 45-nm technology [1].

This type of CPU design (ARM) is the most widely used in portable devices such as the Iphone and other smart phones. The OMAP4460 is designed to provide best in class video, graphics, and image processing for various applications. The PandaBoard ES has an intergrated SGX540 graphics processor and can output 1080p through HDMI and DVI output ports (See Figure 3.2.11). This graphics processor will also support OpenGL ES, OpenVG, and other graphic base

programs. Usually an internal clock in the battery allows devices to keep time. The PandaBoard ES, however, does not have a battery to save the time when the power is disconnected. Instead there is a software clock that can set the clock time during the bootup as the PandaBoard ES starts up. The low power design of this board will prove ideal when the design team attaches a battery to make the platform mobile(See Figure 3.2.12) [1].

3.2.1.4. Operating Temperature of OMAP4460

We are using the OMAP4460 (1.2 Ghz) processor in our system. For reliability and operability concerns, the absolute maximum junction temperature of the OMAP4460 has to be below 125ºC and the maximum average junction temperature has to be below 110ºC.

Depending on the thermal mechanical design (Smartphone, Tablet, Personal Navigation Device, etc), the system thermal management software, and worst case thermal applications; the junction temperature might be exposed to higher values than those specified above. Therefore, it is recommended to perform thermal simulations at the device level (Smartphone, Tablet, Personal Navigation Device, etc) with the measured power of the worst case UC of the device.

The OMAP level thermal policy relies on a PCB sensor. Therefore, it is recommended to have such sensors located on the PCB. In addition, it is recommended to avoid having another significant thermal source near the OMAP4460 by TI. So to be able to run the designed system efficiently at the desired thermal level, we must follow these testing parameters
.
The risks of not managing this junction temperature are hazardous heating, power supply clamping, reliability issues, and malfunction [1].

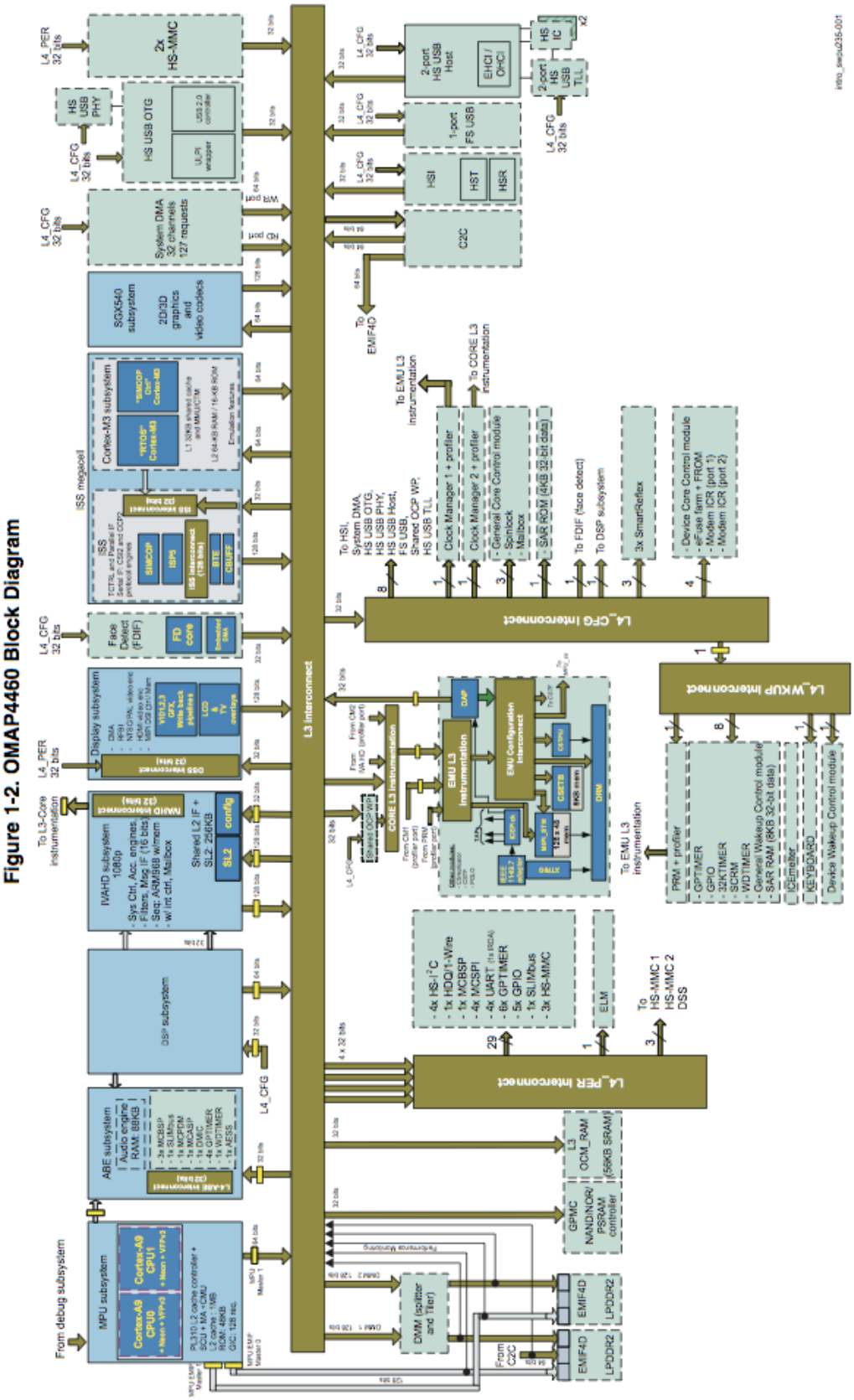


Figure 3.2.1: OMAP4460 Logic Block Diagram
Reprinted with Permission from Ti [22]

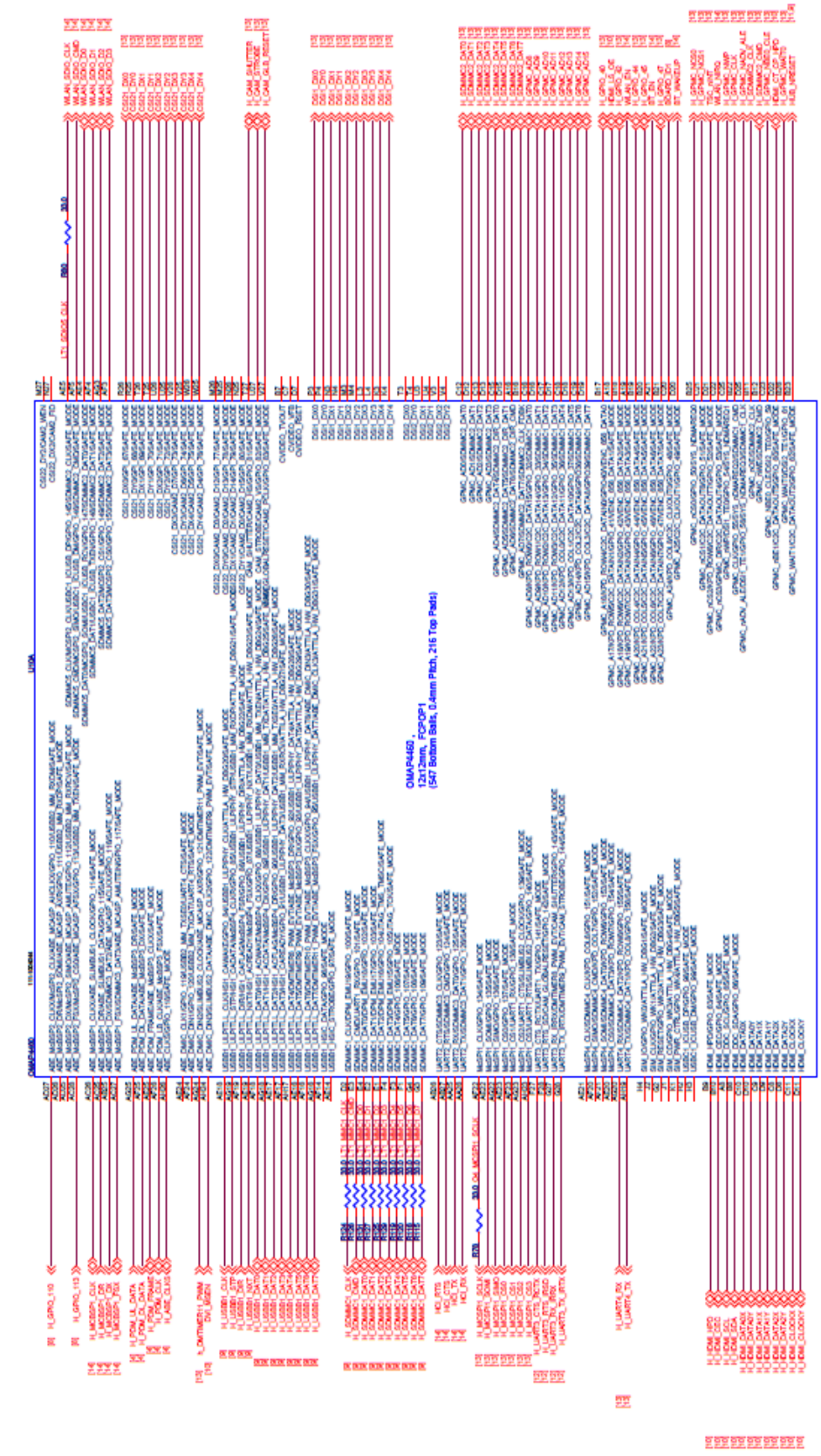


Figure 3.2.2: OMAP4460 Symbol A
Reprinted with Permission from Pandaboard [1]

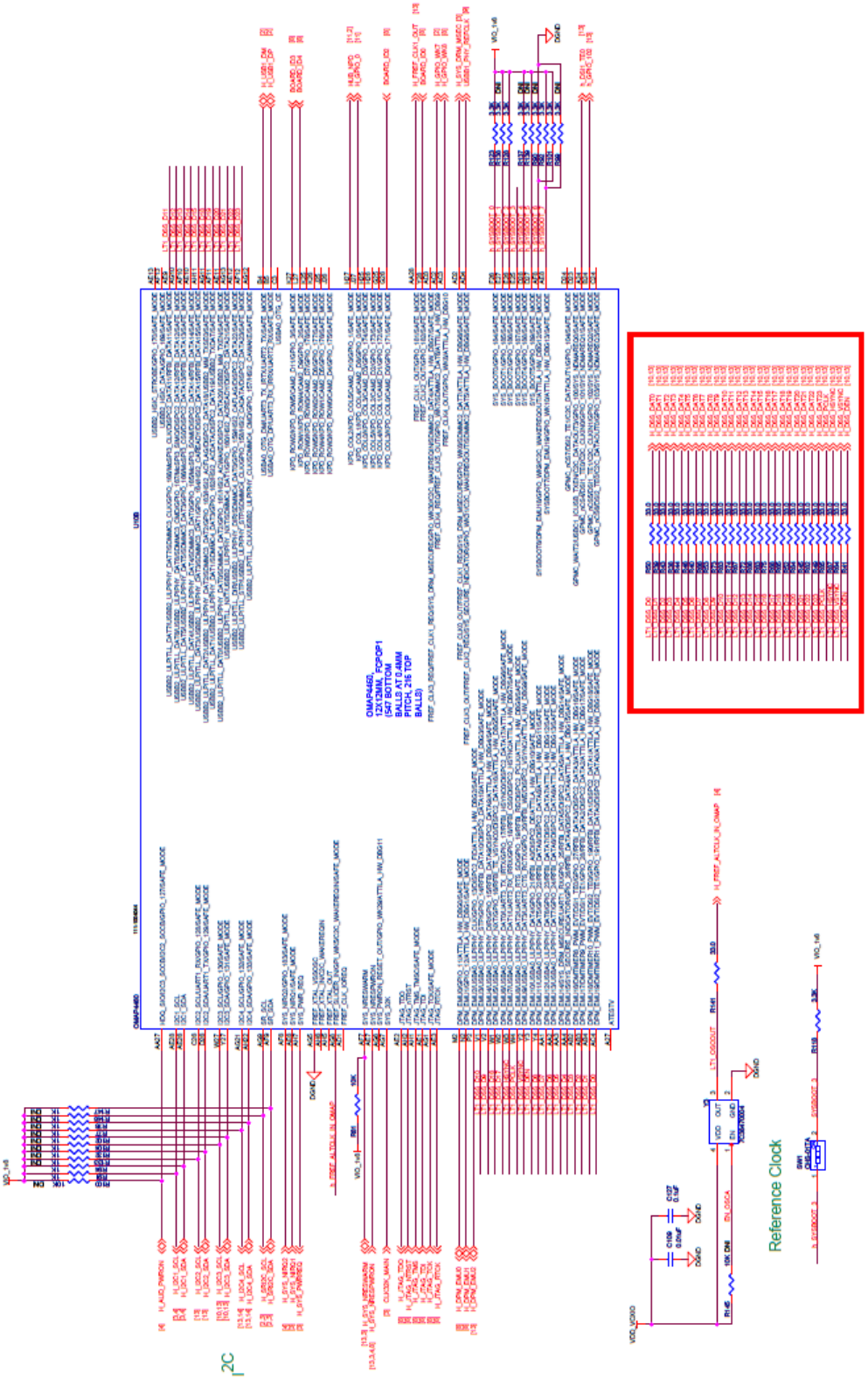


Figure 3.2.3: OMAP4460 Symbol B
Reprinted with Permission from Pandaboard [1]

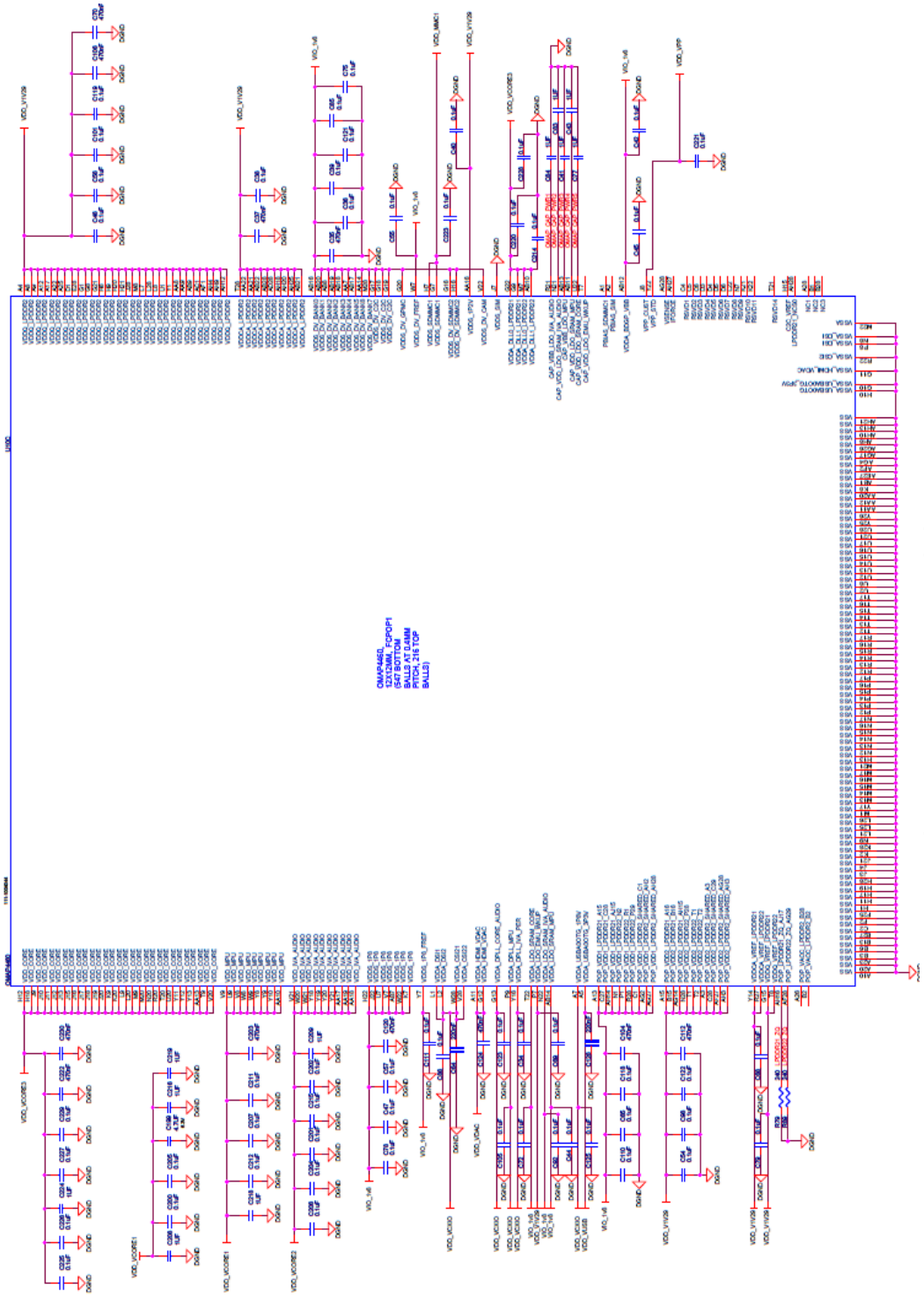


Figure 3.2.4: OMAP4460 Symbol C
Reprinted with Permission from Pandaboard [1]

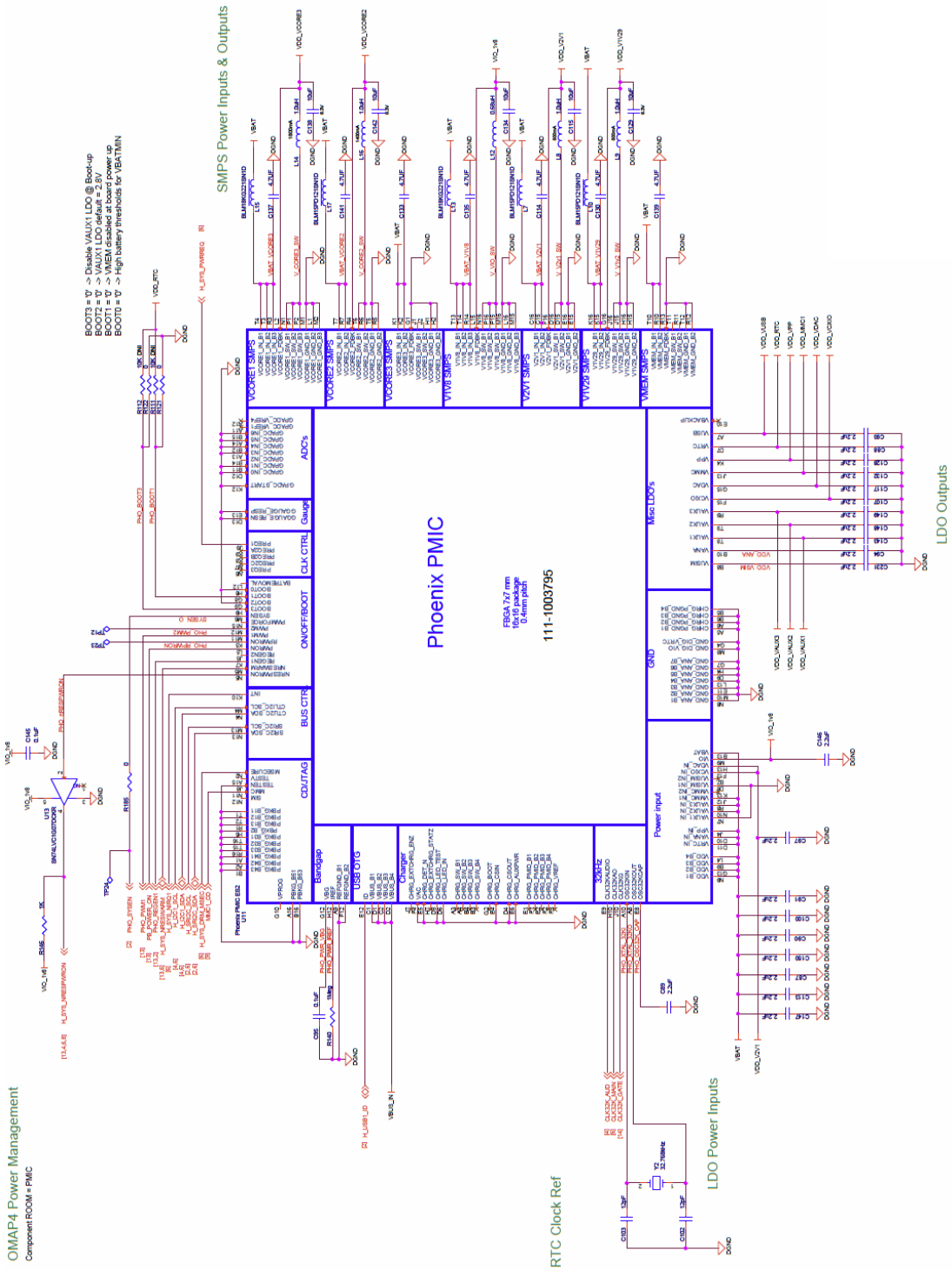


Figure 3.2.5: TWL6030 Power Management Companion Device
Reprinted with Permission from Pandaboard [1]

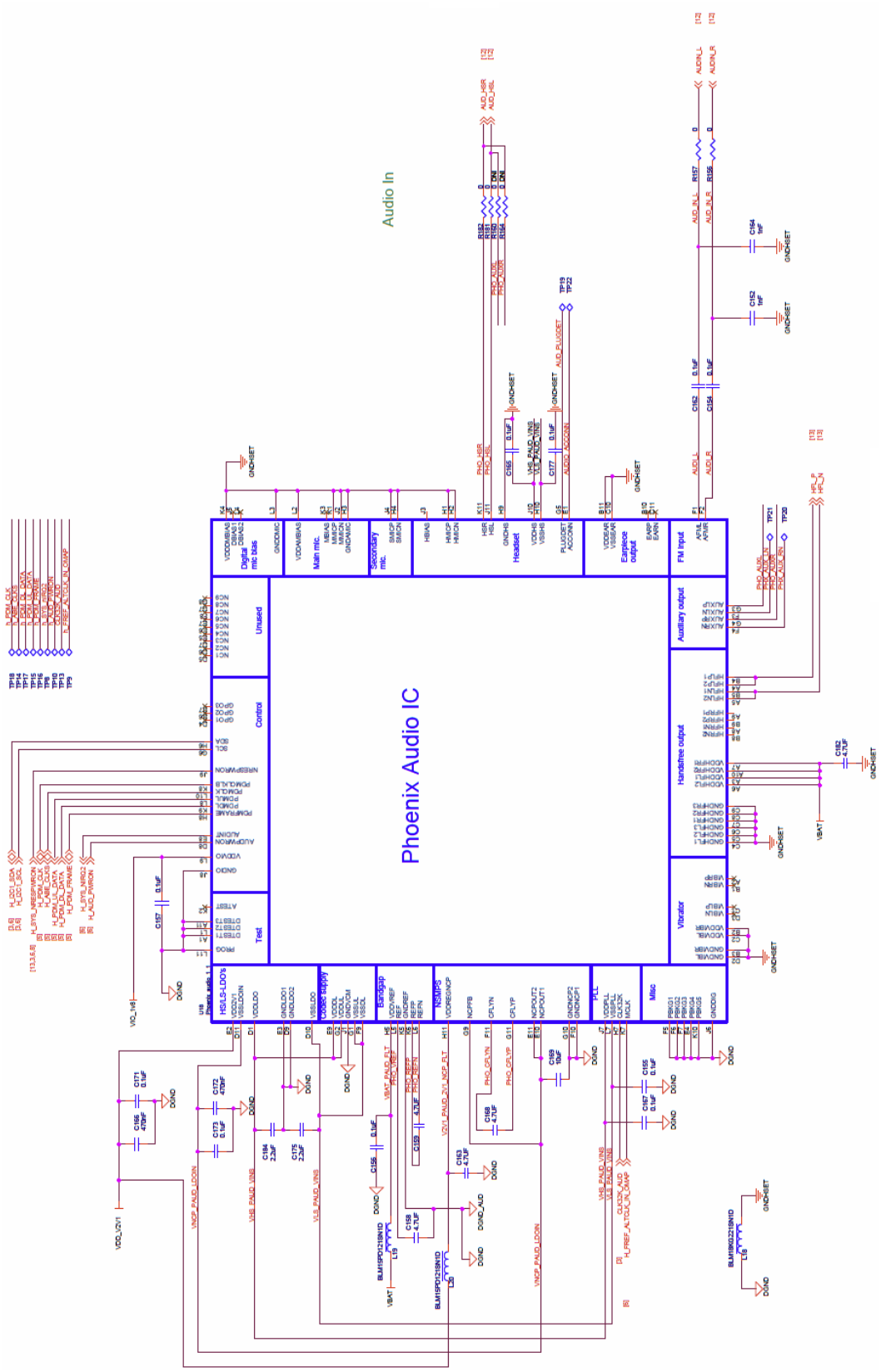


Figure 3.2.6: TWL6040 Audio Companion Device
Reprinted with Permission from Pandaboard [1]

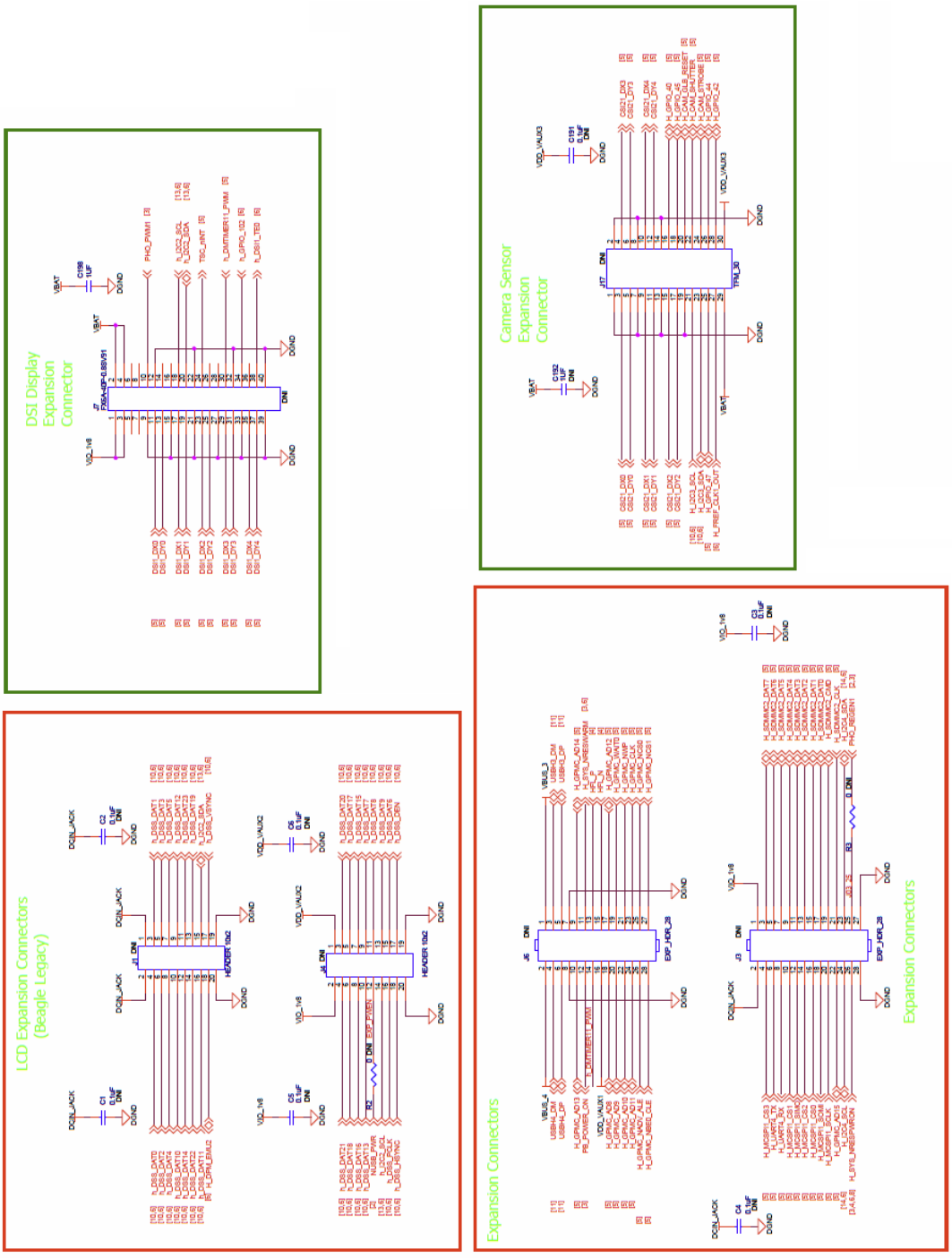


Figure 3.2.7: Pandaboard ES Video and Camera Connections Reprinted with Permission from Pandaboard [1]

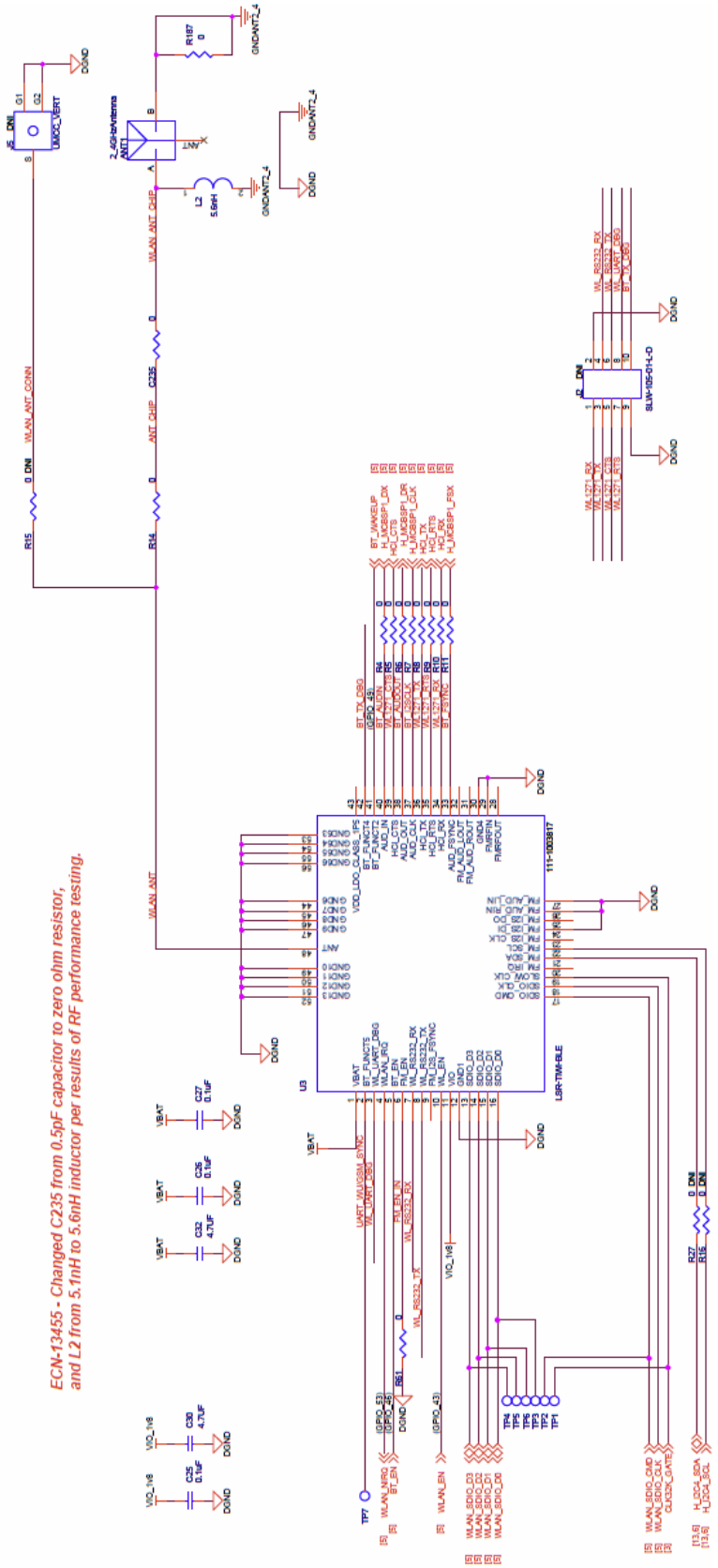


Figure 3.2.8: Pandaboard ES Wifi Connections
Reprinted with Permission from Pandaboard [1]

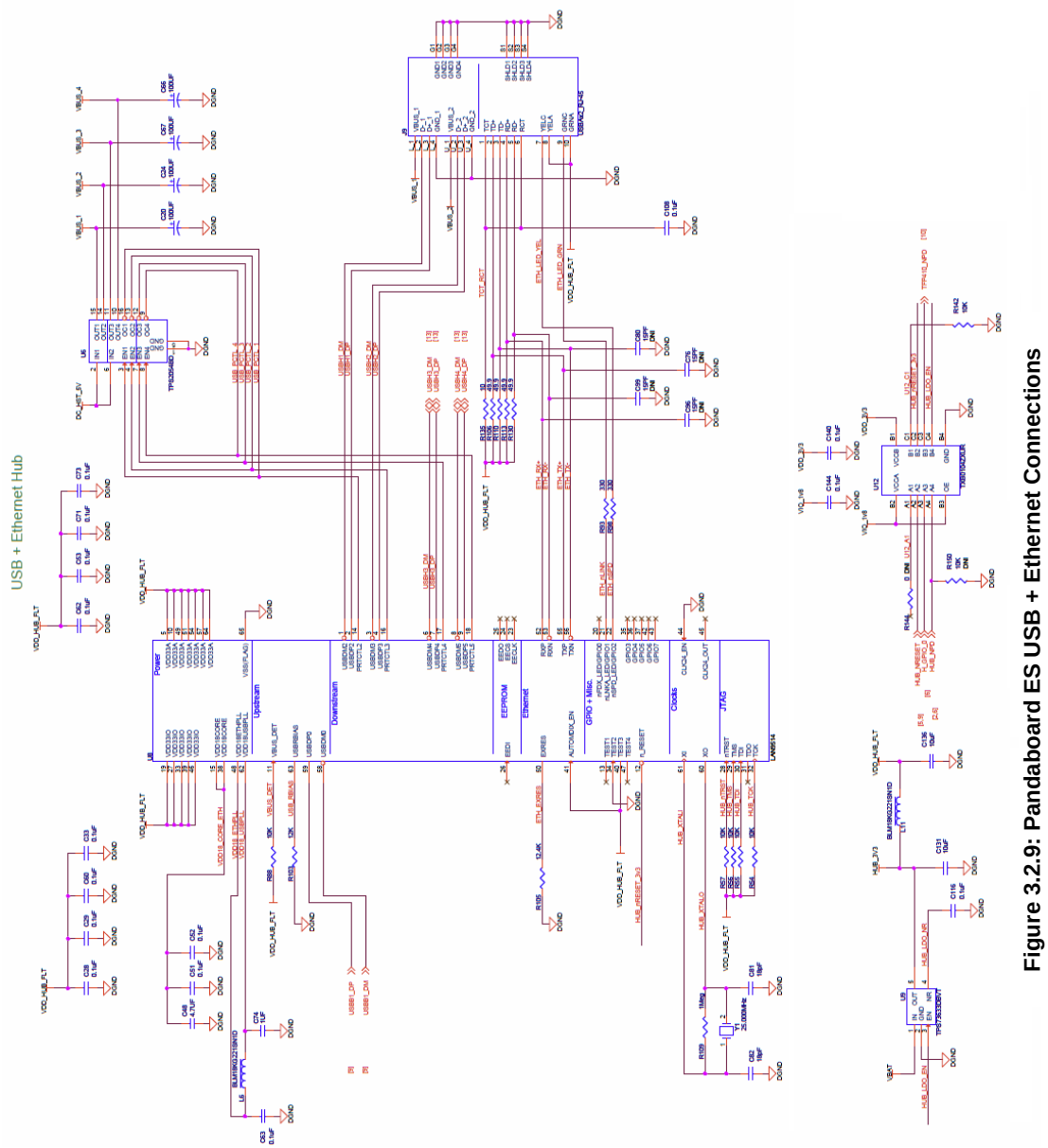


Figure 3.2.9: Pandaboard ES USB + Ethernet Connections
Reprinted with Permission from Pandaboard [1]

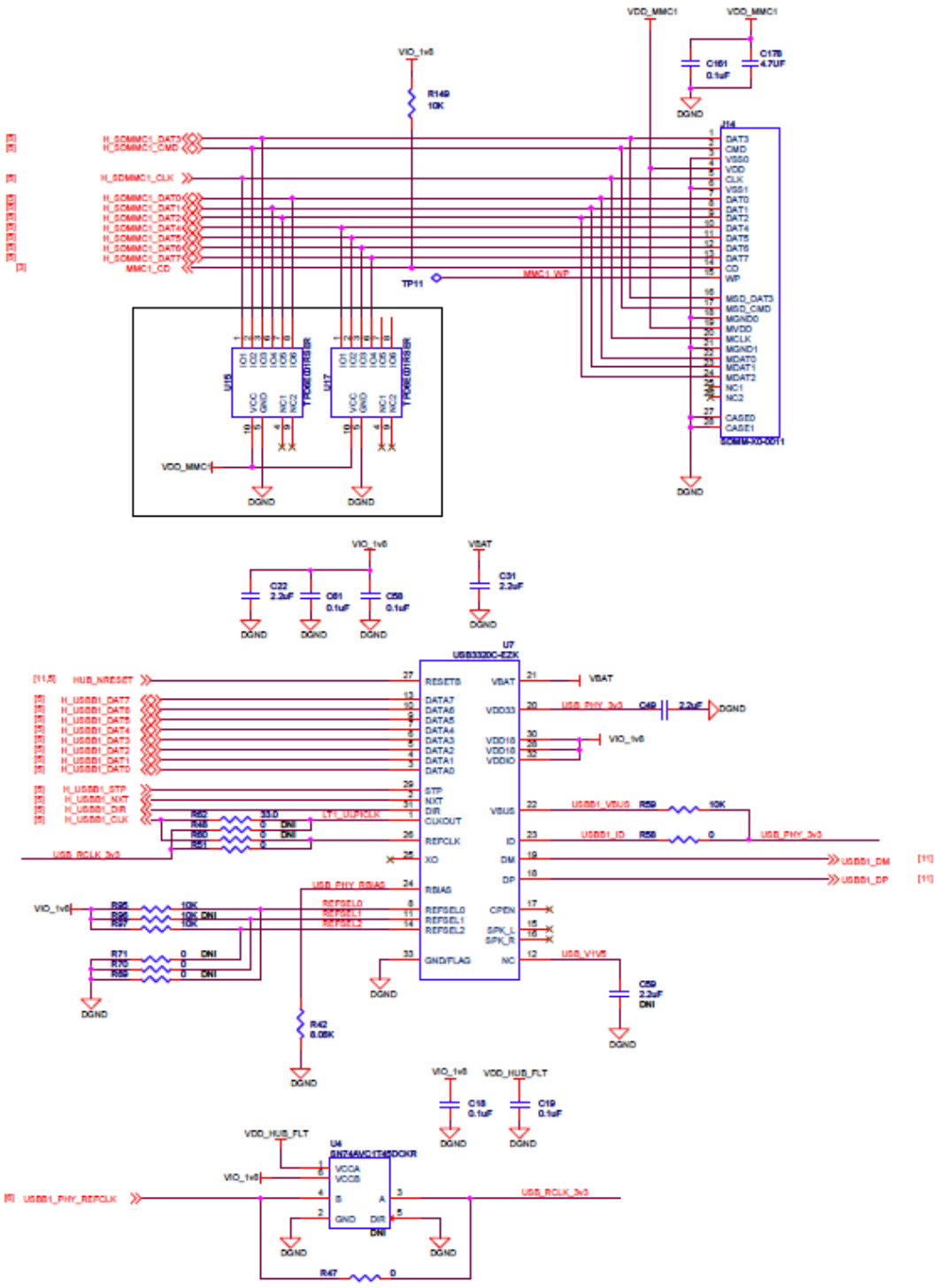


Figure 3.2.10: SSMMC and USB PHY
Reprinted with Permission from Pandaboard [1]

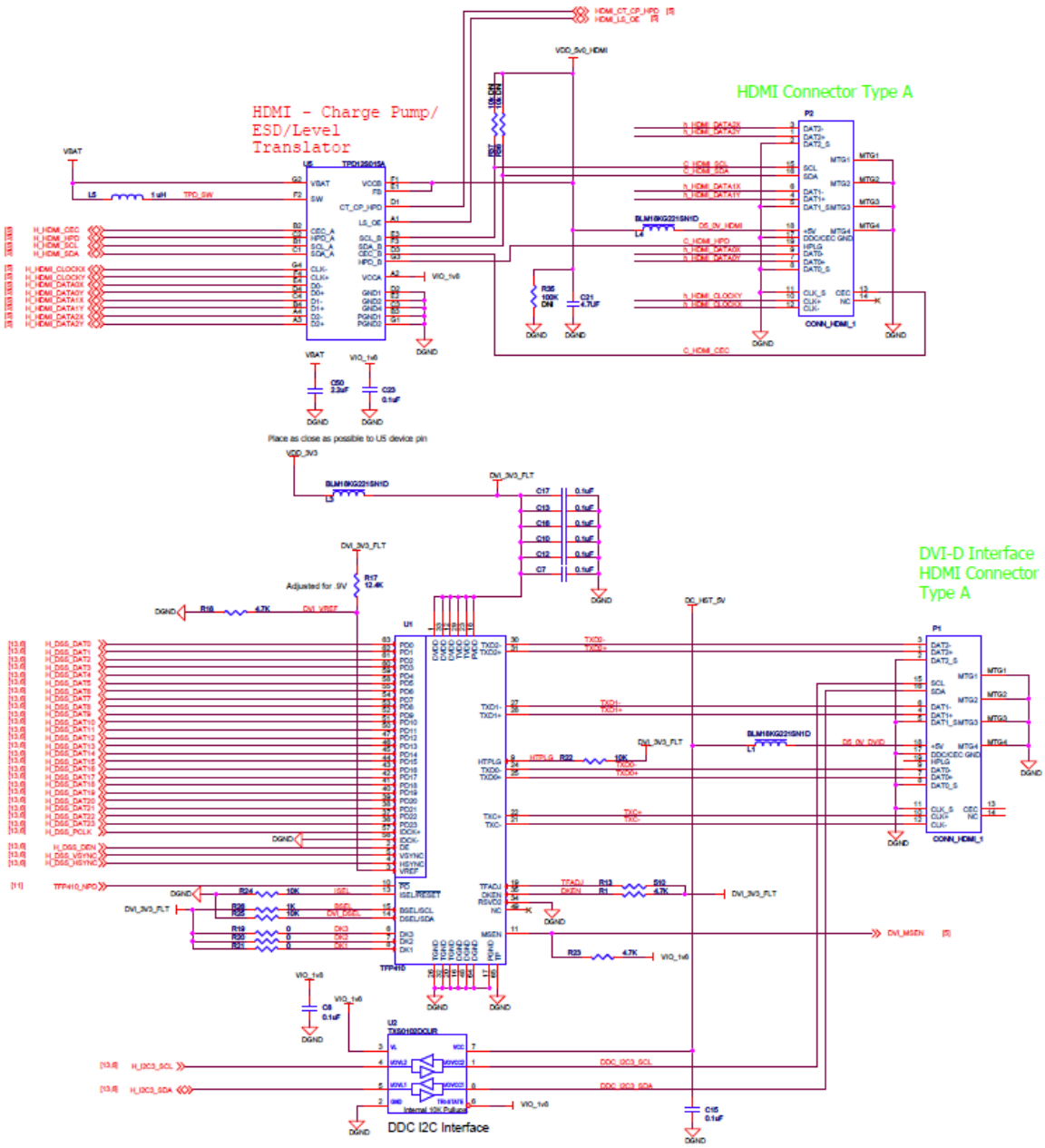


Figure 3.2.11: Pandaboard ES Video output
Reprinted with Permission from Pandaboard [1]

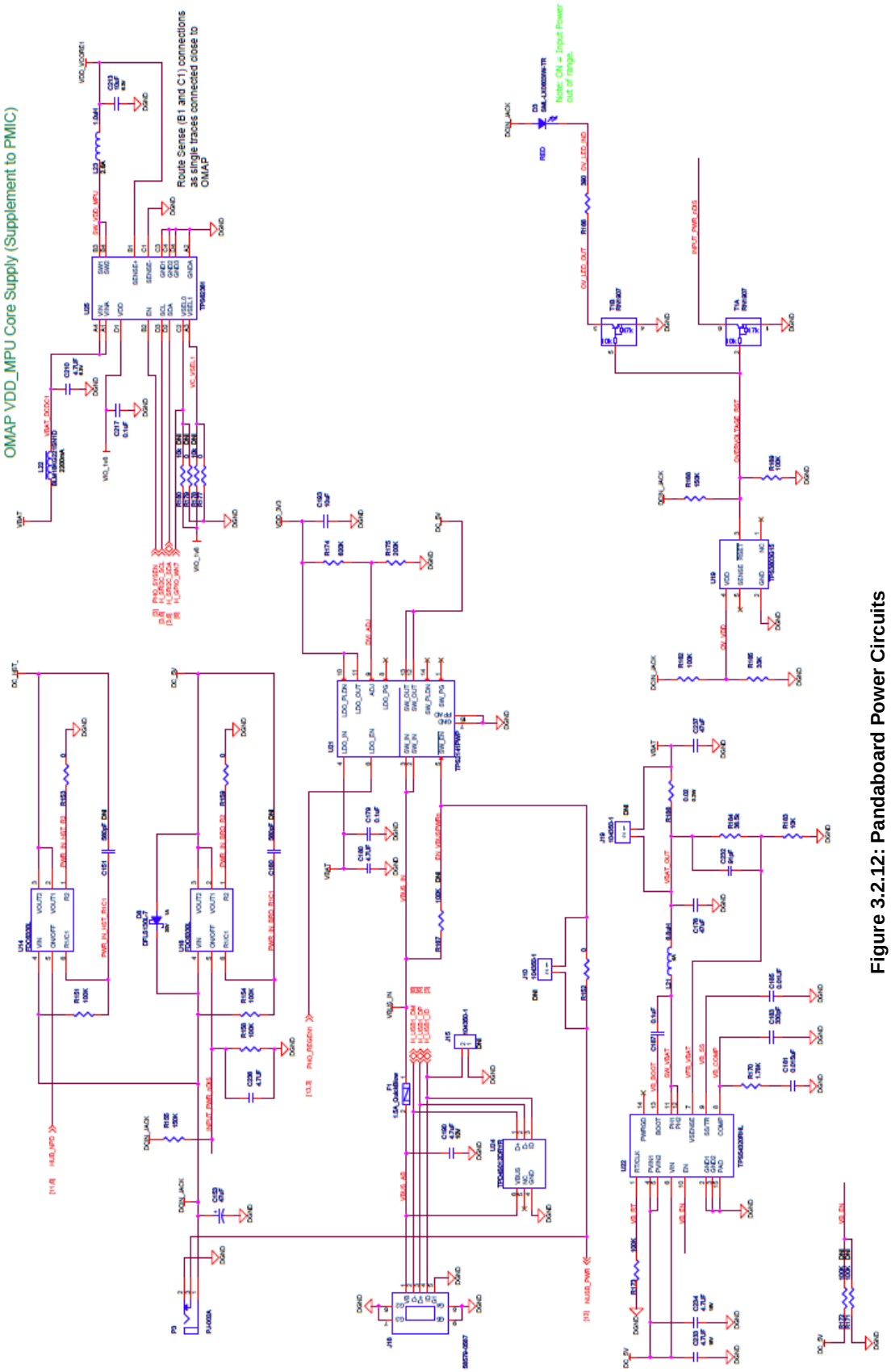


Figure 3.2.12: Pandaboard Power Circuits
Reprinted with Permission from Pandaboard [1]

3.2.1.5. Panda Expansion Board

The Pandaboard ES expansion board, designed and produced by ChipSee, is a board that allows the Panda board ES to plug right into it via several pin connecters (See Figure 3.2.1.5.3). It adds many features that aid developers and speed up the development process. This includes either a four wire resistive touch or capacitive touch screen, a 7 inch LCD screen (See Figure 3.2.1.5.5), three-axis digital accelerometer (See Figure 3.2.1.5.6), three-axis digital compass (See Figure 3.2.1.5.4) and five user keys/buttons.

The capacitive touch is used in this project. It also comes mounted on a plastic board that holds the LCD screen and the circuitry together. There is also a 3G module that supports SIM5320 (See Figure 3.2.1.5.2) which is sold separately. This would support data and voice which include WCDMA, and GPS. We will not be using the wireless capabilities from this board, nor will we use the three-axis digital accelerometer or three-axis digital compass. The main purpose for the Panda Expansion board is to use the 7 inch LCD screen with its capacitive touch and the plastic mount that holds the expansion circuitry. We will also use the five user keys/buttons.

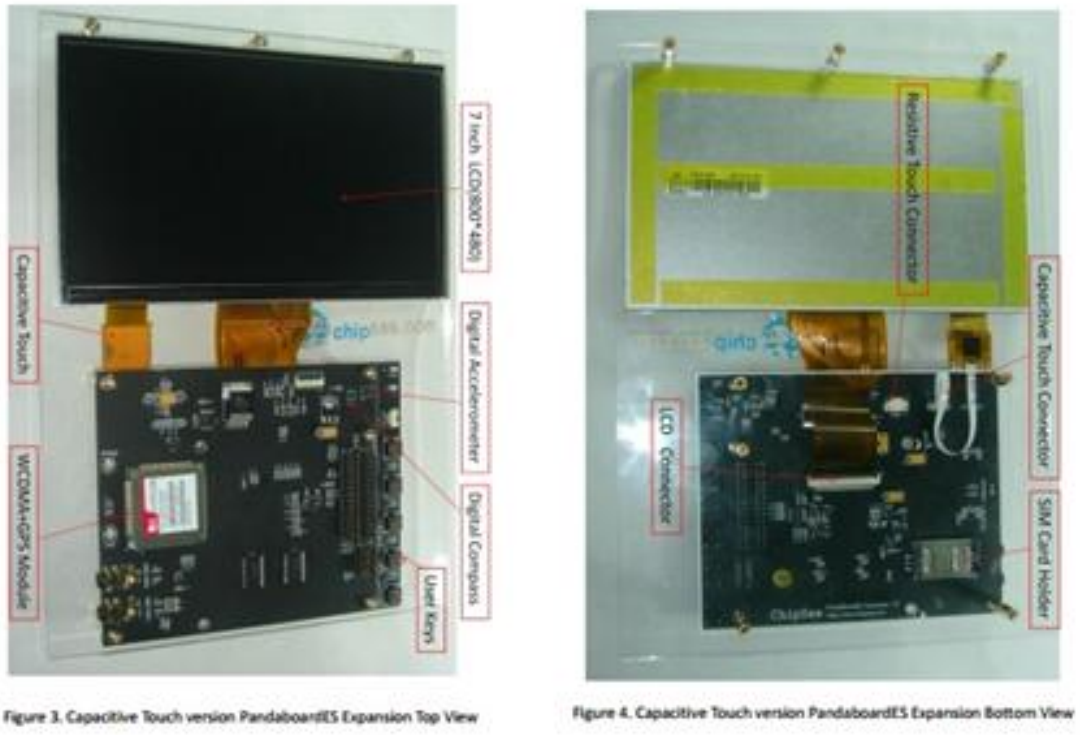


Figure 3.2.1.5.1: Top and Bottom of Panda Board ES
Reprinted with Permission from Parallax [2]

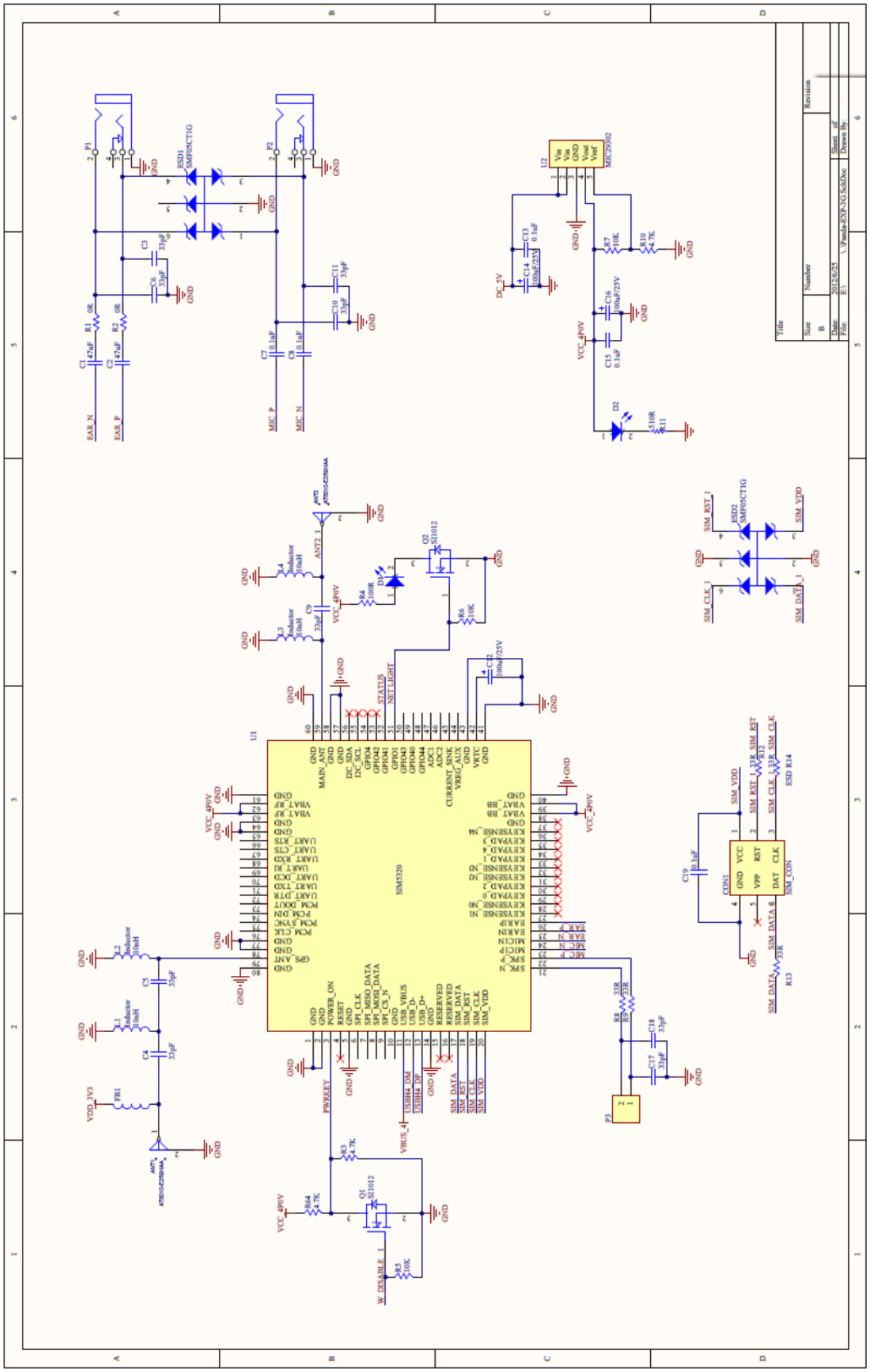


Figure 3.2.1.5.2: SIM 5320 Schematic
Reprinted with Permission from Parallax [2]

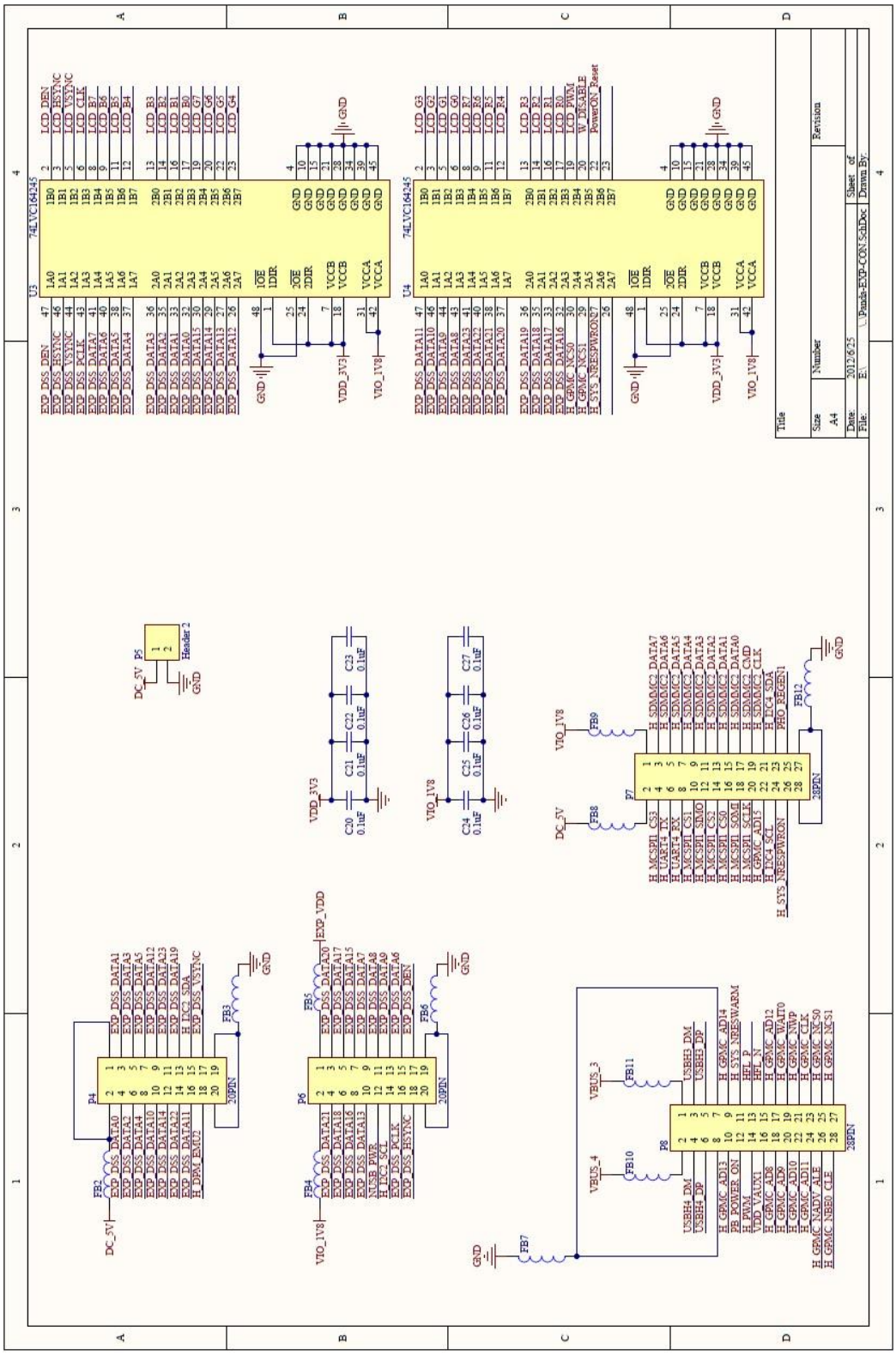


Figure 3.2.1.5.3: Expansion Board Connectors
Reprinted with Permission from Parallax [2]

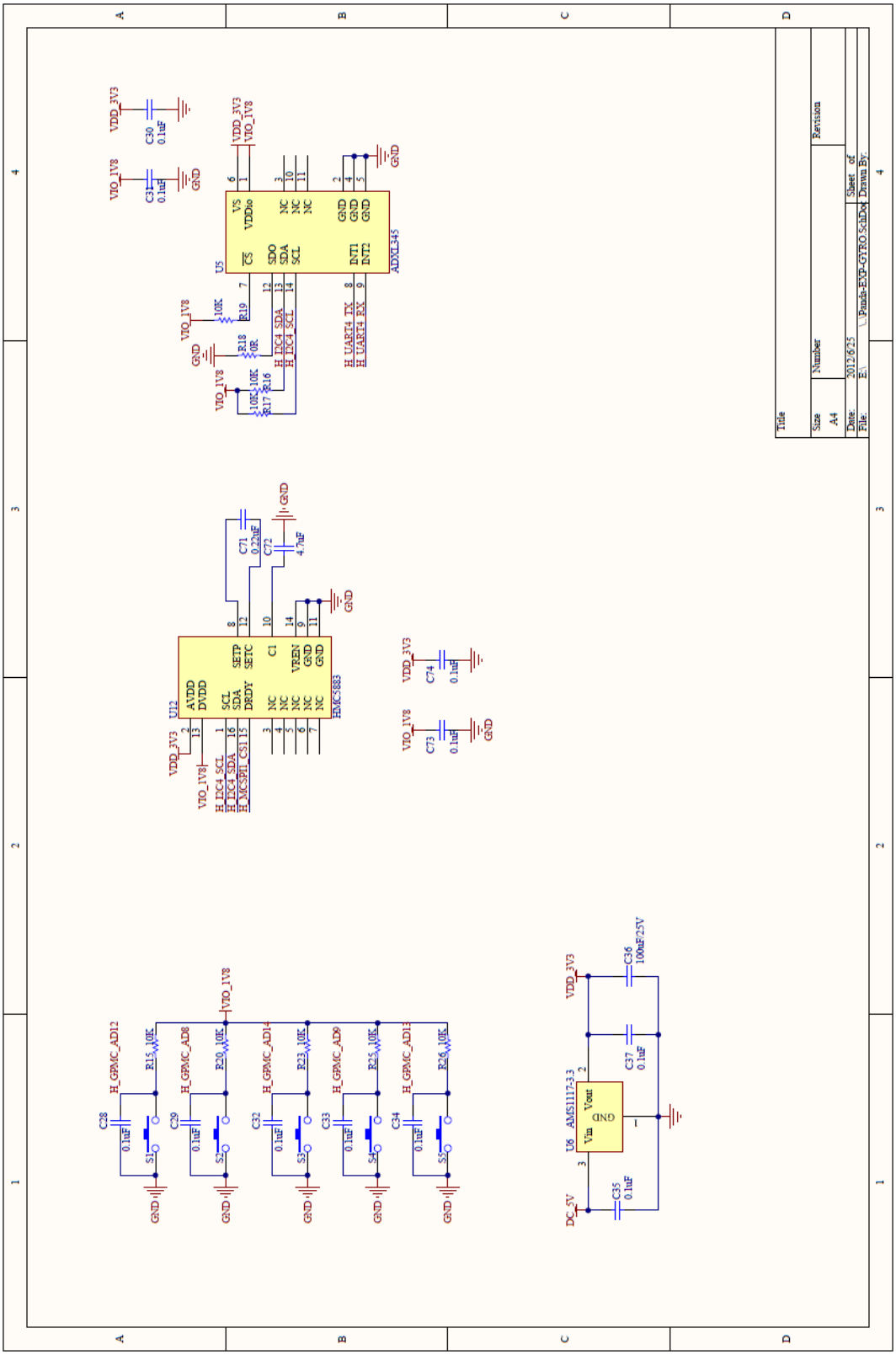


Figure 4.2.1.5.4: Expansion Board Digital Compass
Reprinted with Permission from Parallax [2]

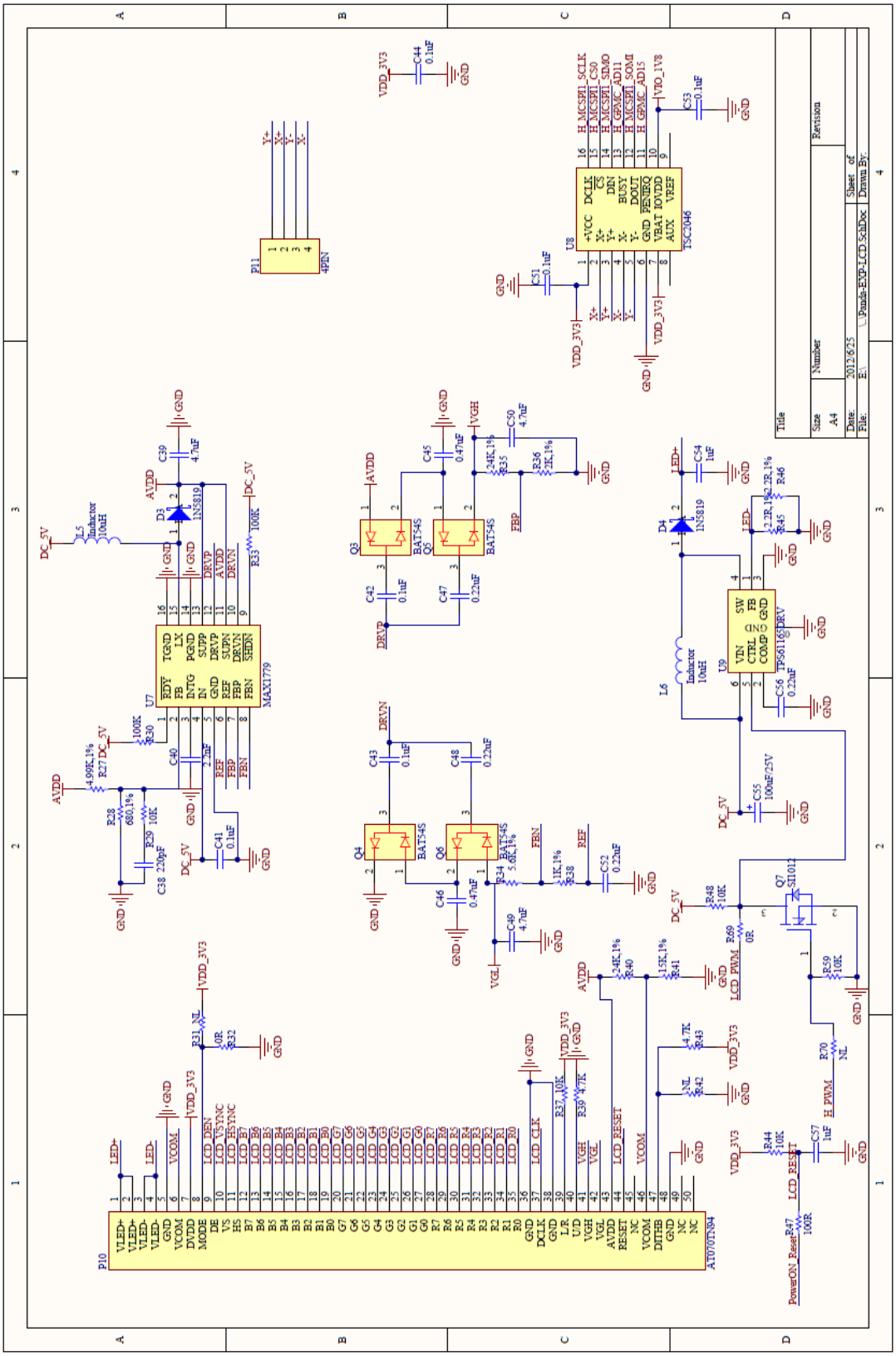


Figure 3.2.1.5.5: Expansion Board LCD Screen Connectors
Reprinted with Permission from Parallax [2]

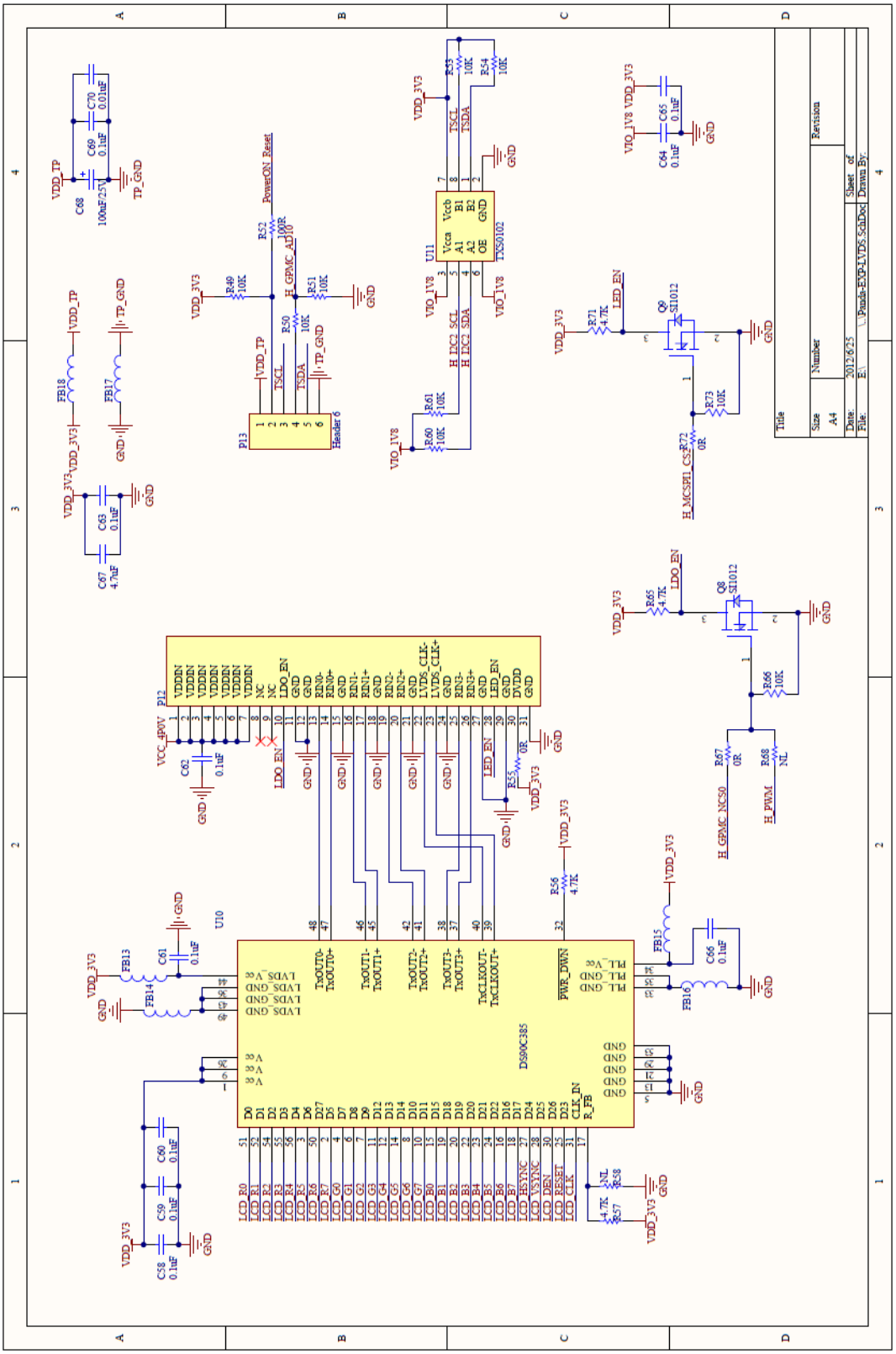


Figure 3.2.1.5.6: Expansion Board DS90C385
Reprinted with Permission from Parallax [2]

3.2.1.6. Seven Inch LCD

The 7 inch LCD screen comes with the purchase of the Panda expansion board designed and produced by ChipSee (See Figure 3.2.1.6.1). When buying the Panda expansion board we had the option to choose between the capacitive touch and the resistive touch screen. We first looked into the resistive touch screen. It was made from a normal glass panel that is coated with three layers. Two of these layers are conductive and resistive and the third layer is a hard cover that covers the hold setup. For resistive touch screens, current flows through these layers when the system is running. With a touch of a finger a change in the electrical field occurs. This is a single touch system. The system then calculates the coordinates of the point of contact and the touch screen drivers passes it to the rest of the system.

The capacitive touch screen on the other hand, is capable of multi touch. The glass panel is made up of a material that can store an electrical charge. The human finger also stores an electrical charge. When a finger touches a capacitive touch screen, some of the charge transfers from the screen to the finger. The oscillator circuit within the circuitry of the screen detects the change in electrical charge and the exact location of where the touch occurred. This data is then transfer to the touch screen driver for processing.

After we understand how both touch screens functioned, we needed to see which screen fit our project needs. The first and most apparent feature was the multi touch on the capacitive touch. Because our application may use multi touch we wanted our LCD to be able to grow with the software needs. Next is the fast response of the capacitive. Like most smart phones, the touch needs to be very responsive and fast pace. The capacitive touch was the clear winner in this department as well. It also had a nice glossy finish, and was much more visible over sunlight. And because this device is intended for outdoor use, this was a major deciding factor. Overall the capacitive touch came out to be the better screen for our project. Thus we picked the capacitive for this project.

Figure 3.2.1.6.1: Expansion Board LCD in Action

Below in Figure 3.2.1.6.2 is a list of pros and cons for both resistive touch and capacitive touch screens:

Resistive Touch	Capacitive Touch
PROS of Resistive Touch: It's relatively cheaper compared with capacitive touch. Can function with any pointing device, pen, nail, etc. Can operate at any level of humidity More accurate than capacitive touch	PROS of Capacitive Touch: Supports Multi touch Visible under sunlight Glossy look and feel More sensitive to finger touch, easier to use More responsive
CONS of Resistive Touch: Multi touch is not available Reflective layer cause poor visibility in sunlight More vulnerable to scratches More vulnerable to unwanted pointing device/dust	CONS of Capacitive Touch: 5% humidity to achieve capacitive effect More expensive than resistive touch screen Does not work with inanimate objects

Figure 3.2.1.6.2: Touch Screen Type Comparison

3.2.2. Output Screen Options

The design team has given careful consideration to the output screen options for this project. Initially the idea of building a tablet with a transparent LCD screen was considered (See Figure 2.1.1). This had a certain level of "coolness" going for it, and would provide for a more seamless user experience, since the user would have the feeling of directly interacting with the world they are using their tablet for to augment.

The biggest problem with transparent LCD screens however is that transparent LCD screens are mostly in a prototype stage, and thus are hard to come by. At the time of this writing there were none that the design team was able to purchase.

There are a few engineering issues that the team would have to overcome as well with the use of a transparent LCD screen. The first is that LCD pixels do not generate their own light. LCD screens normally rely upon a florescent lamp to provide the light needed to see the image. A transparent LCD screen however has no such lamp, and thus relies entirely upon ambient light to operate. This means that in low light conditions, or at night, it would be difficult or impossible to see anything on the transparent screen.

One possible solution to this problem that was derived by the engineering team is to use a clear piece of glass with white LED's arraigned along the outer edge of

the glass to shine light into its edges. The glass should distribute the light along the glass panel, and provide the needed illumination that the transparent LCD needs, while still remaining transparent. However, until a supply of transparent LCD panels is made available for purchase, it is not possible to pursue this path.

One other solution to the transparent LCD is to use a transparent OLED screen. OLED pixels generate their own light, and thus don't rely on ambient light to operate. Although there are many demonstration exams out there, there are no products available for purchase at the time of writing. If a product should become available during the Spring 2013 Semester, the design team will consider its integration to the tablet.

The next alternative considered is a more conservative approach, which involves combining the tablets onboard camera, to feed a video stream to the tablets regular LCD screen, in an attempt to replicate what the user would have seen had the screen been transparent. This approach has the benefits of being simple to implement from a hardware perspective and is the approach the design team has chosen to adopt for the time being.

The final visual output option is to connect a pair of goggles that contain integrate screens, capable of displaying to the users eyes, what they normally would have seen on the tablet screen. This option has the benefit of freeing the users hands when viewing the navigation application, and they also would grow tired of holding the tablet up while navigating. However an alternative method for controlling the tablet would need to be devised, since the user no longer has a touch screen to manipulate the tablet.

For soldiers in the field, this is by far the best option. Soldiers often have very heavy loads to carry as it is, and their hands are already busy handling their weapons and equipment. By using the goggles, they can be integrated into the ballistic glasses that soldiers already wear on the battlefield. With this key target audience in mind, the design team will first focus on building the tablet with a normal LCD screen, and if there is sufficient time and resources, attempt to add the goggles feature via the video out port of the panda board.

3.3. Custom Expansion Board

3.3.1. Secondary Microcontroller

The PandaBoard ES, our primary microcontroller, runs the augmented reality application, while a second microcontroller processes all the data from our sensors. This secondary microcontroller will then send the data via USB to the PandaBoard ES. This way it will free up the PandaBoard ES and let it focus on the application. There are many different microcontrollers on the market today and finding the best one to fit our project was not easy.

3.3.1.1. IOIO Board

The IOIO board (Called “yo-yo”) is the microcontroller of choice for our secondary microcontroller. The main reason we chose this particular board is because it is designed specifically to work with the Android operating system. Also, since the PandaBoard ES will be running the Android operating system, the IOIO board fits perfectly for our project. The chip is actually the same used in a PIC microcontroller but with a boot loader programmed to let Android applications control the 48 pin outs. This is all done with a simple and intuitive Java API, and does not need an external programmer to program the chip[15].

3.3.1.2. IOIO Peripherals

The IOIO board interacts with its peripherals, or pin outs, much the same way most microcontrollers do. The pins are digital input, digital output, pulse width modulation (PWN), analog input, I2C, SPI, and UART, and can all be controlled (Figure 3.3.1.2.1) [20].

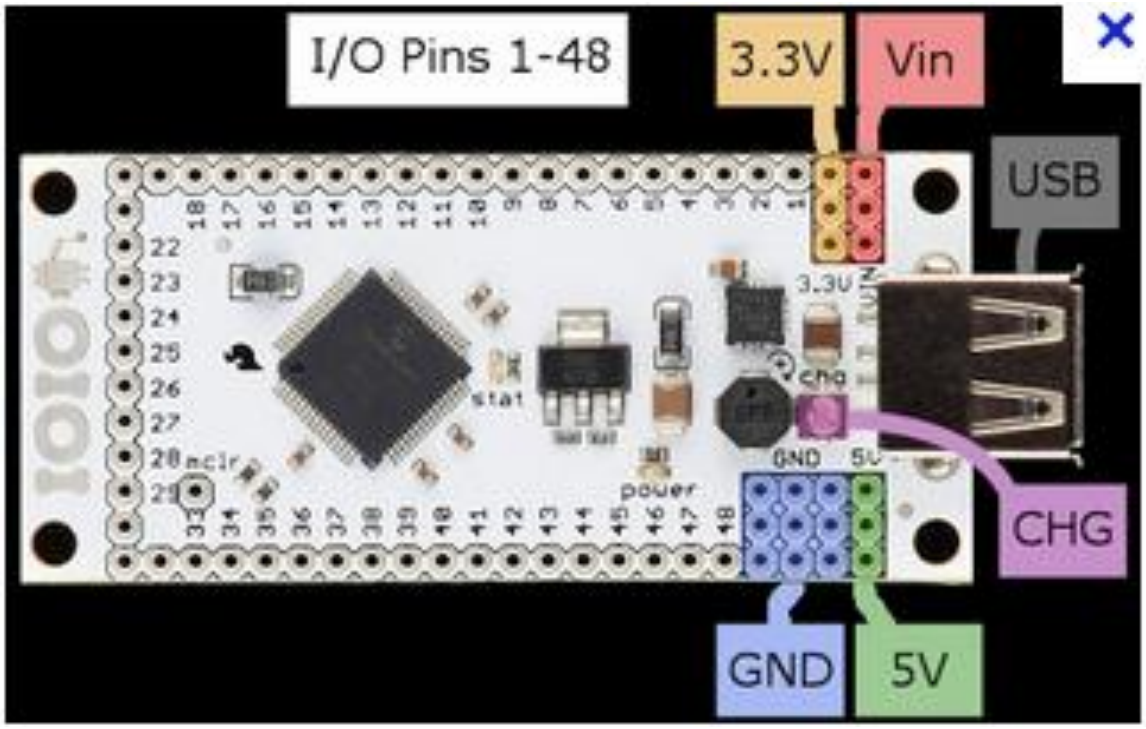


Figure 3.3.1.2.1: IOIO Pinout
Reprinted with permission from Sparkfun.com[3]

1	USB Connector	The female connector that connects to the PandaBoard ES
2	Ground Pin	The ground connection, power supply's negative terminal
3	Vin	The power supply's positive terminal (5-15v)
4	5V Pin	5v output after the power supply is regulated
5	3.3 Pin	3.3 output after the power supply is regulated
6	I/O Pins	48 Pins, some are General purpose, some have special function
7	Power LED	LED that light up when there is power
8	Stat LED	Lights up when under application control
9	MCLR Pin	Used to reprogram the boot loader firmware
10	CHG	Charge current trimmer, used to adjust how much current is supplied into the USB port and into the device

Figure 3.3.1.2.2: IOIO Pinout Description

The input and output pins are labeled to more easily identify which port has what functions. Pins that have a square around them mean that they can be used as 3.3V analog input pins. Those with circles mean that they are 5V tolerant and can be used as 5V logic output using an open-drain mode. You would also need a pull-up resistor for this function. Next to the port with the "P" mark, means they can be use as a peripheral input and output. These include pulse width modulation, UART, and SPI. These "p" marked pins are especially important for our project as they are what the sensors will be communicating through. The pins marked with "Pi" can be used as a peripheral input but not output. And lastly the pins marked with "DAx" and "CLx" are used for two wire interface (See Figure 3.3.1.4.1) [15].

3.3.1.3. IOIO Power Supply

In order to power the IOIO board we need a DC voltage ranging from 5V to 15V. A switching regulator steps the Vin to 5V with a limiting current of 1.5A. This is

where the positive terminal from the battery goes into Vin of the IOIO board. The negative terminal from the battery goes into the ground pin on the IOIO board. When there is a connection and the board is supplied with the correct voltage, the red power LED should light up. One other method to power the IOIO board is the use of a surface-mount JST connector. Our prototype IOIO board actually has one of these connectors. This makes connections much cleaner and robust. Also users cannot connect the wrong terminals which can destroy the board.

3.3.1.4. PandaBoard ES with IOIO connect

The IOIO charges the PandaBoard ES with 5V through the USB line. Although the PandaBoard ES and the IOIO shares the same battery pack, it still needs this 5V to let the PandaBoard ES know that a USB host is connected. A trimmer pot on the IOIO can be turned on to control the amount of current going through the USB line. This is achieved via a screwdriver and turning it clockwise. The reason a trimmer pot is used because devices connected to the IOIO board may not "connect" without the proper current. Unfortunately these current amounts can vary from, device to device. Thus a trimmer pot can be used to adjust the current until the device detects a USB host connection.

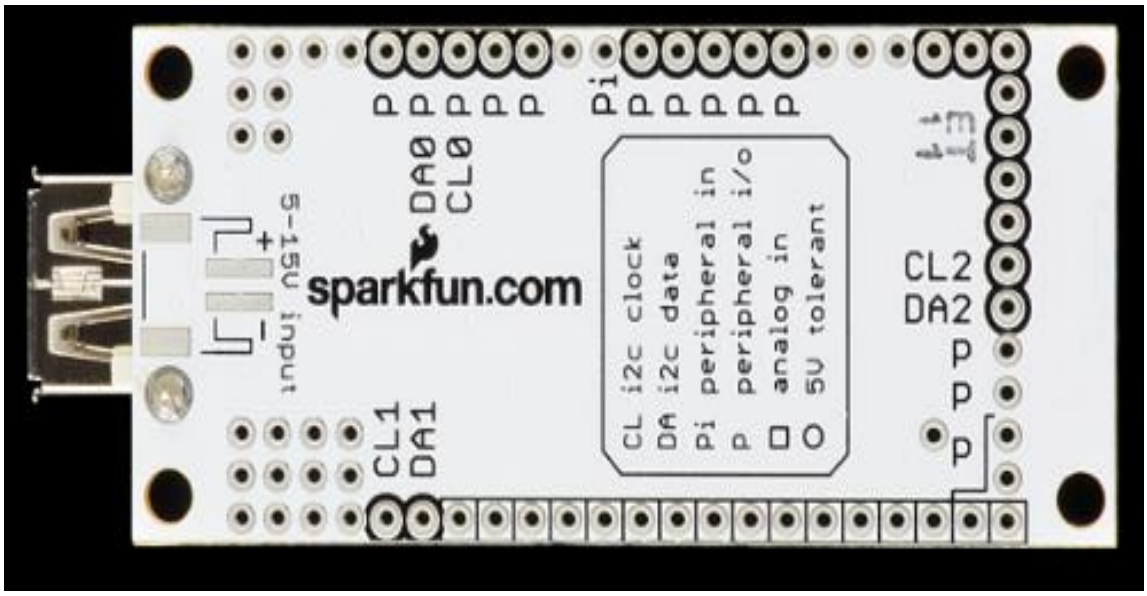


Figure 3.3.1.4.1: IOIO connection board
Reprinted with permission from
Sparkfun.com[3]

3.3.2. Other Considered Microcontrollers

3.3.2.1. Parallax Propeller

The Propeller chip by Parallax was another microcontroller we considered. There are 8 “cogs” or processors that can operate simultaneously. This operation can be either independent from each other or work cooperatively. A central hub is where all 8 pg these cogs share their resources. Both high level spin, or Propeller assembly can be used, which can execute up to 160 MIPS or 20 MIPS each cog.

Below in Figure 3.3.2.1.1, are some of the packages the Propeller chip comes in. On the very left we have DIP though-hole, Gull-wing, solder ball surface mount, and a zoomed in version of the bat-wing.

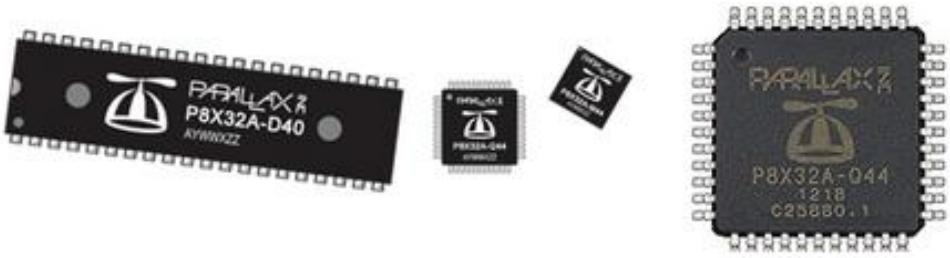


Figure 3.3.2.1.1: Parallax Propeller Chip
Reprinted with permission from Sparkfun.com[3]

3.3.2.2. MSP430

The MSP 430 is a low cost, low power microcontroller with a 16-bit CPU from Texas Instruments. The price, however, is the most attractive for our project. At only $4.30 with shipping included. Although this microcontroller is the most cost effective, we did not choose this board because of its IDE or integrated development environment. The chip can be difficult to program and with the selection on the market today, there were better chooses for our project [23].

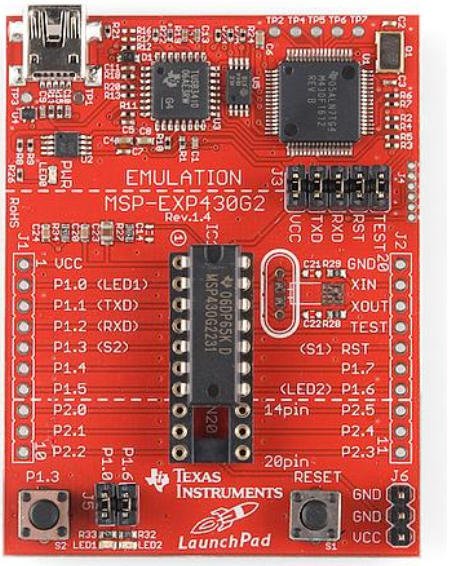


Figure 3.3.2.2.1: MSP430
Reprinted with permission from Sparkfun.com[3]

To the right in Figure 3.3.2.2.1 is the MSP 430. It is very compact and cost effective. This is easily the cheapest microcontroller we found and packs some serious features. Some of the features include:

- Comparator

- Digital to analog convertors
- Op Amps
- Sigma Delta
- Timers

3.3.2.3. Arduino

The Arduino is hands down the most popular microcontroller today for hobbyist and senior design students. The board has an Atmel AVR processor with on-board input and output pins. The Atmel AVR processor has a preprogram boot loader that uses "Wiring-based"; a language similar to C++. This microcontroller is easily the most documented and one can easily find sample code to start on almost any project (See Figure 3.3.2.3.1).

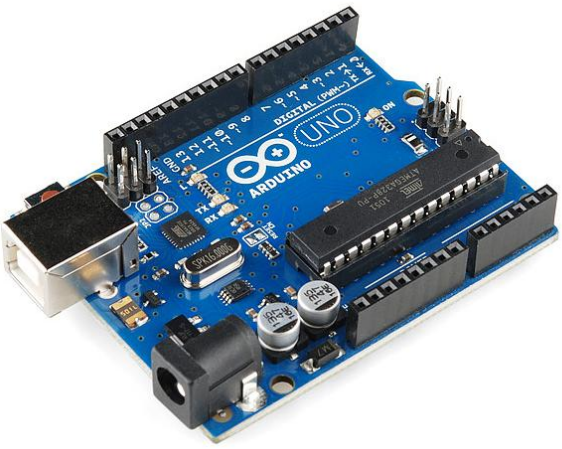


Figure 3.3.2.3.1: Arduino Microcontroller
Reprinted with permission from Sparkfun.com[3]

3.3.2.4. PSoC

The PSoC by Cypress Semiconductor is another microcontroller we considered. It is a programmable System-on-chip that includes a CPU and a mixed-array of configurable integrated analog and digital peripherals. What is unique about this chip is it has an array of embedded hardware within the chip itself. No longer do you need an external DAC or ACD. It is already built into the chip. Another nice feature about PSoC is its IDE, which includes an easy to use graphical design editor which makes programming hardware a breeze (See Figure 3.3.2.4.1).

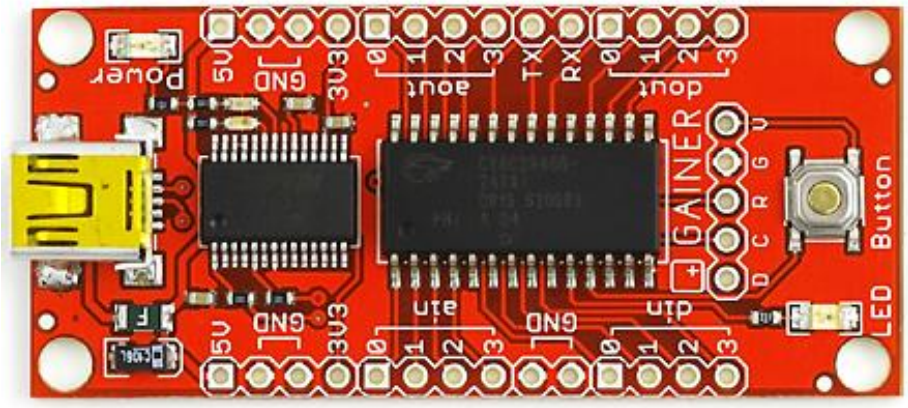


Figure 3.3.2.4.1: PSoC Microsontroller
Reprinted with permission from Sparkfun.com[3]

3.3.3. Sensors

3.3.3.1. Magnetometer

Magnetic field detectors use the Earth's magnetic poles to sense its direction. Magnetic sensors or compasses are the bread and butter of navigation control systems and will prove an essential element to the proper operation of the software application, and its accuracy (See Figure 3.3.3.1.1)[5].

Figure 3.3.3.1.1: Magnetometer Reprinted with permission from Sparkfun.com[3]

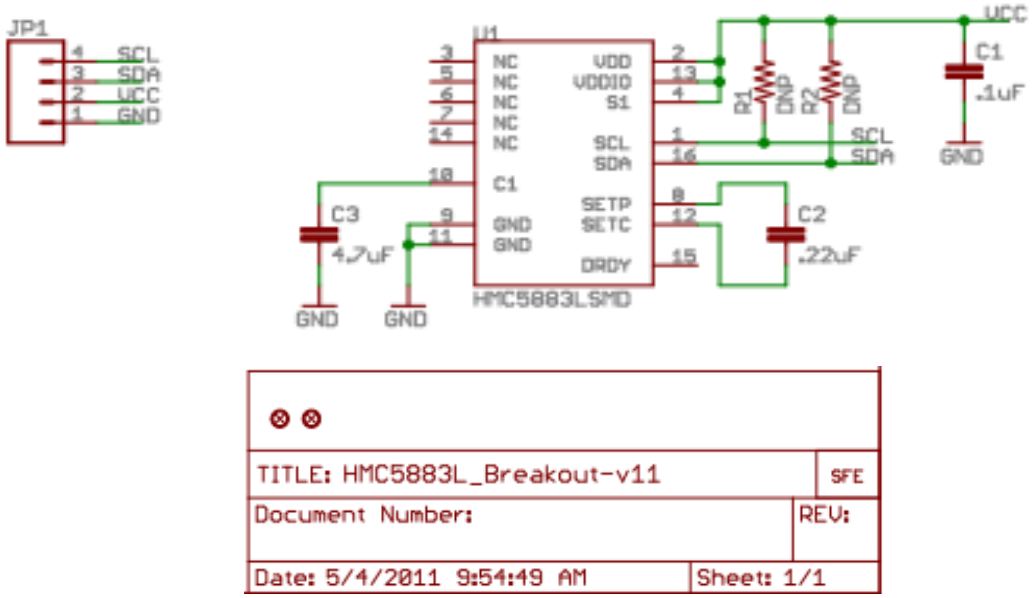


Figure 3.3.3.1.2: Magnetometer Schematic Reprinted with permission from Sparkfun.com[3]

Above is the HMC5883L magnetometer breakout by Sparkfun (See Figure 3.3.3.1.2). It breaks out 4 pins for easy prototyping, Ground, Vcc, data, and clock. It features a simple I2C interface, draws low power, and has a 5 milli-gauss resolution. This board is exactly what we need for our tablet, and is selling for $14.95 on Sparkfun. With this chip, our tablet will know what directions north, south, east and west are.

3.3.3.2. Gyroscopes

The gyroscope is another important sensor to our project. Similar to the function of the accelerometer, it will measure the tilt and orientation of our tablet. Essentially this sensor measures the angular velocity; the speed of which an object spins on its axis. One very significant difference between the gyroscope and the accelerometer is that the gyroscope is immune to gravity, thus both of these sensors make a great compliment to each other. The axis of rotation corresponds to X for roll, Y for pitch, and Z for yaw. They are measured in angular velocities which are represented by rotation per minute (RPM) or degrees per seconds. A gyroscope will be a great addition to our sensors that will compliment the accelerometer to achieve an even more accurate reading. There are still things to consider when selecting the right gyroscope[6].

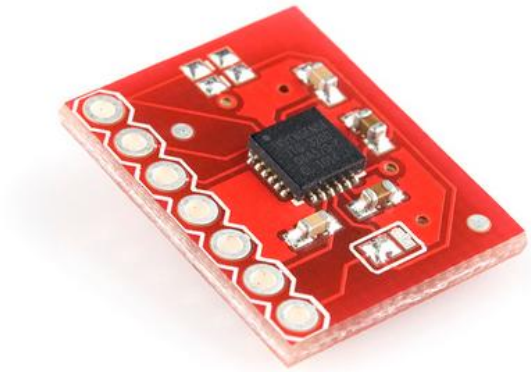


Figure 3.3.3.2.1: Gyroscope
Reprinted with permission from Sparkfun.com[3]

Range:
When looking at range it is important to find a gyroscope capable of reading the maximum and minimum value of our tablet. Next we have to make sure that the range measured, is within the range of the gyroscopes measurement limits and that the sensitivity works with our device.

Interface:
There are two ways a gyroscope will communicate with its data to the users. The first method is with an analog signal output. This is the case with almost all gyroscopes. Next is a digital interface, with either SPI(Serial Peripheral Interface) or I2C(Inter-Integrated Circuit).

Number of axis:
Like accelerometers, gyroscopes can have up to 3 axis to measure. Unfortunately gyroscopes are much more expensive since the technology is fairly new when compared to the accelerometer. Different gyroscopes measure

different axis, like yaw and roll, or roll and pitch. It is essential that our tablet is capable of measuring all axis as its orientation can rotate on any of the three axis.

Power Usage:
Similar to the accelerometer, the gyroscope consumes around the 100uA range. It is possible to find gyroscopes that have a sleep function and will only turn on when the sensor needs to be used.

Bonus features:
Some additional features for gyroscopes are temperature sensors that can compensate for drift.

The picture to in Figure 3.3.3.2.1 is the ITG-3200, a 3 axis digital output gyro, by Sparkfun. It operates with a low current consumption of 6.5mA and with a standby current draw of 5uA. It uses the I2C (400kHz) serial interface. This board sells for $49.95. This was one of the main gyroscopes we considered but ended up picking an IMU board for our tilt sensor[6].

3.3.3.3. Accelerometers

The accelerometer is one of the primary sensors since we need to know the orientation of our tablet. This sensor essentially measures the units of meters per seconds squared (m/s^2), or G-force(g), which is about 9.8 meters per second squared. Other factors like the mass of the planet and the elevation will alter the readings. The accelerometer can sense two forces. First is the static force, like gravity. This is a constant force that is always acting upon us. Next is dynamic acceleration. This includes sudden speed up or stops. But the main reason we are using an accelerometer is for the tilt-sensing capabilities. This is widely used in many applications such as phones and tablets. You may ask; “Just how does measuring the gravity or the sudden start or stop tell us about the orientation”? Well, we first have to understand that our tablet will be under a constant force, gravity. This is a static force. We can then tell where the bottom of the Earth is because gravity is always pulling downward. Because there are so many different types of accelerometers in the market, we had to narrow the selection. For our tablet, there were several key factors to consider before deciding on the right accelerometer. That includes range, interface, the

Figure 3.3.3.3.1: Accelerometer MMA8452Q
Reprinted with permission from Sparkfun.com[3]

number of axis measured, its power consumption, and any other features it has [7].

Range:
The range is how accurate our accelerometer will be. Because we are working with a tablet that will sustain very low G-forces, our accelerometer needs to be very precise. If we used a 200g-ranged accelerometer we probably will not get much data. Therefore, we need a very precise accelerometer that can measure very low g-forces.

Interface:
The interface is how the accelerometer will tell us the forces. There are several ways to do this. First with an analog signal, the voltage output is directly proportional to what is measured by the acceleration. The next type of interface is pulse-width modulation or PWM. This is basically a square wave with a set frequency, and with a varying duty cycle. As the acceleration changes, the duty cycle will change as well. Next and lastly is the digital interface, SPI(Serial Peripheral Interface) or I2C(Inter-Integrated Circuit). The benefit of these digital interfaces is they are more noise resistant, and usually include more features. For our tablet we would like it too be as noise resistant as possible and additional features would only help.

Number of axis:
The number of axis is pretty self explanatory. It is the number of possible axis on the X, Y, and Z plane. The more axis the more data that can be used; which for our project we would want the maximum number of axis, which is three.

Power usage:
The power usage is how much the accelerometer will consume, the more current it draws the more power it is using. Most accelerometers will be drawing roughly in the 100uA range. Some additional features may include a sleep function which will not power the accelerometer when it does not need to be in use. This function is very attractive for this project since we will only use the accelerometer when the orientation is required.

Bonus Features:
There are a handful of additional features that an accelerometer can come with. These include but not limit to tap sensing, G-force detection, sleep function and measurement range. For our tablet we would like to have as many functions as possible at a reasonable cost.

The picture above (See Figure 3.3.3.3.1) shows the MMA8452Q 3 axis accelerometer breakout. It has 12-bit and 8-bit resolution output, I2C interface, dynamically selectable full-scales (±2g, ±4g, ±8g) and a current consumption of 6uA – 165uA. This chip has an array of features and sells for $9.95 on Sparkfun. We did not, however, choose this as our tilt sensor for our final design.

3.3.3.4. Inertial Measurement Unit (IMU)

After long consideration on which gyroscope or accelerometer would be best for our tablet we decided on an Inertial Measurement Unit as the best alternative. Both the gyroscope and accelerometer are great sensors however they do not always give enough information to accurately calculate orientation, position, and velocity. We wanted our device to be as precise as possible. The inertial measurement unit or IMU is a combination of the two sensors which provides 2 to 6 degrees of freedom. Although IMU's are much more expensive then gyroscopes or accelerometers, as they are able to calculate the exact position. IMU's are widely used in robotic arms and even missiles [8].

Figure 3.3.3.4.1: IMU MPU-6050
Reprinted with permission from Sparkfun.com[3]

Below is a list of features the MPU-6050 has:

- Digital-output temperature sensor
- Digital output I2C
- 6 or 9-axis Motion Fusion
- Data in raw, Euler Angle, quaternion, rotation matrix format
- Digital Motion Processing
- Embedded algorithms
- Build in accelerometer and gyroscope
- Optional external magnetometer sensor can be added

The picture above (See Figure 3.3.3.4.1) is the MPU-6050, triple axis accelerometer and gyroscope breakout by Sparkfun. This board also includes a magnetometer that acts as a compass. The board basically combines a 3 axis accelerometer with a 3 axis gyroscope together with a Digital Motion Processor (DMP). This DMP can process complex 9 axis Motion Fusion algorithms. Interfacing with the auxiliary master I2C bus and can also access external sensors like a magnetometer. And at a price point of $39.95 on Sparkfun, we decided this will be our tilt sensor for our tablet [8].

The picture above is the logic schematic for the MPU-6050. As can be seen, it uses either I2C or SPI to communicate with the MPU to process the data. It also includes extra AUX_CL and AUX_DA for external sensors like a compass.

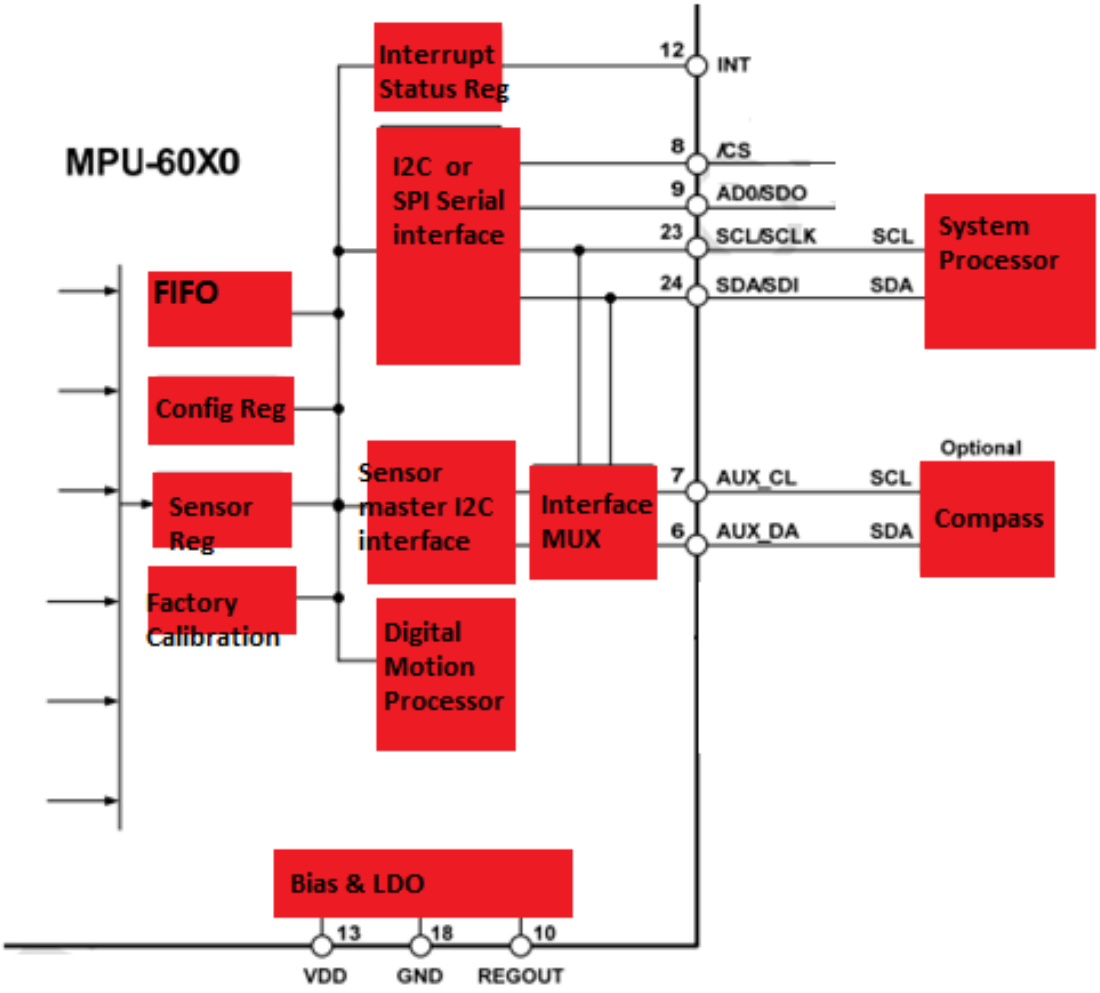


Figure 3.3.3.4.2: MPU 6050 Block Diagram
Reprinted with permission from Sparkfun.com[3]

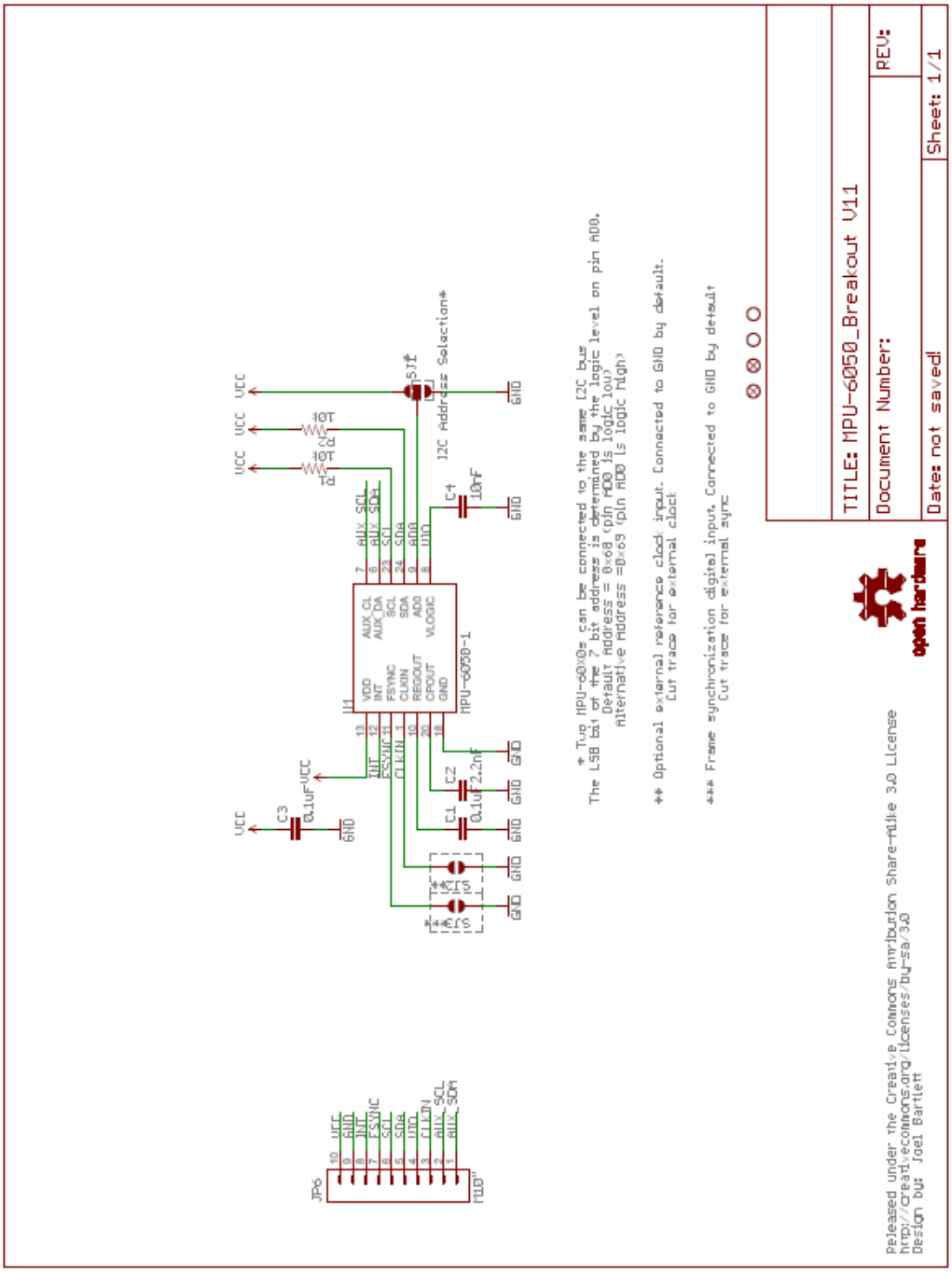


Figure 3.3.3.4.3: MPU 6050 Schematic Diagram
Reprinted with permission from
Sparkfun.com[3]

3.3.3.5. Global Positioning System (GPS)

The global positioning system or GPS is the bread and butter for our application. This sensor will tell us our tablet's location with exact coordinates. This handy little sensor can figure out where it is from almost anywhere on Earth, and with a good map it is virtually impossible to get lost. This is possible through the use of 35 satellites all roughly 20,200km above Earth. When the GPS is powered on, it is using 24 active satellites at any given time. There are many different types of GPS on the market today, although they all pretty much do the same thing. To narrow our selections we first had to set a few parameters [9].

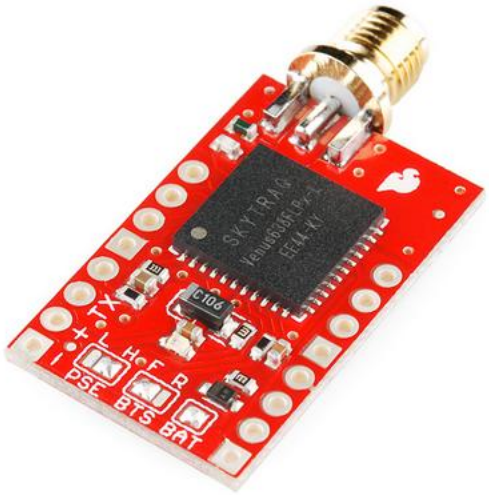


Figure 3.3.3.5.1:Venus 638FLPx GPS Chip Reprinted with permission from Sparkfun.com[3]

Size:
The size of our GPS device is extremely important. The design team needs it to be as compact as possible since it will be soldered on to the custom PCB. Real estate is limited on our board. The design team also needs to know the exact dimensions and also fit the antenna on to it.

Update Rate:
The update rate is how fast the next set of data can be processed so the GPS module can recalculate and reposition itself. Usually for most GPS devices it is about one second (1Hz). However with faster vehicles, like a boeing 777, the GPS needs to have a faster refresh rate to stay on route. This also puts a heavy load on the microprocessor that is processing the data. For this project we do not need a fast update rate since we will be walking with the tablet.

Number of channels:
The more channels the GPS module has the faster it can pick up satellites when it initially starts. After that it may shut off some of the channels to preserve battery life. The GPS for this project needs to find a fixed signal as soon as possible, more channels also mean more cost. For the tablet we will keep the number of channels as low as possible to make it more cost effective for us. The GPS should still find a fix signal within minutes of powering.

Antennas:
The antenna is very important to the GPS. It is designed to pick up the GPS L1 frequency of 1.57542 GHz. Furthermore, it is essential that we place the antennas pointing into the sky to get the best reading. We will pick a simple GPS

antenna that does not require additional amplification and filtering that other GPS antenna technologies require (chip, helical).

Accuracy:
If you have used a GPS for traveling you know that it might not be exactly where you are. This is where accuracy comes into play, but the more accurate the GPS usually the more expensive it becomes. GPS can have an accuracy of ±100meter which is pretty amazing. For this project, however, that may not be enough. If possible we need one that can get down to ±3meter.

Above (See Figure 3.3.3.5.1) is the Venus 638FLPx breakout with SMA connector. This small yet powerful GPS module outputs standard NMEA-0183 at 9600bps. It updates at a rate of 20Hz which fits our project needs. One of the main reasons we choose this chip because it comes with a breakout board and an SMA connector. This allows for easy connection to the antenna. Not only will this speed up the prototyping process, but this would make testing and debugging our circuit much more efficient [9].

Below are some of the features on Venus638FLPx:

- 20Hz update rate
- 29 second cold start
- 1 second hot start
- 2.5meter accuracy
- Work with active/passive antenna
- Supports SPI data logging
- Single 2.7/3.3v power supply
- Dimension 10m x 10mm x 1.3mm size

Below (See Figure 3.3.3.5.2) is our GPS antenna, VTGPSIA-3. The unit of measurement is in millimeters.

The antenna needs to point towards the sky to get the best readings. Its performance, both indoors and outdoors will effect the overall performance of the software navigation application[18].

Figure 3.3.3.5.2: VTGPSIA-3 GPS Antenna
Reprinted with permission from Sparkfun.com[3]

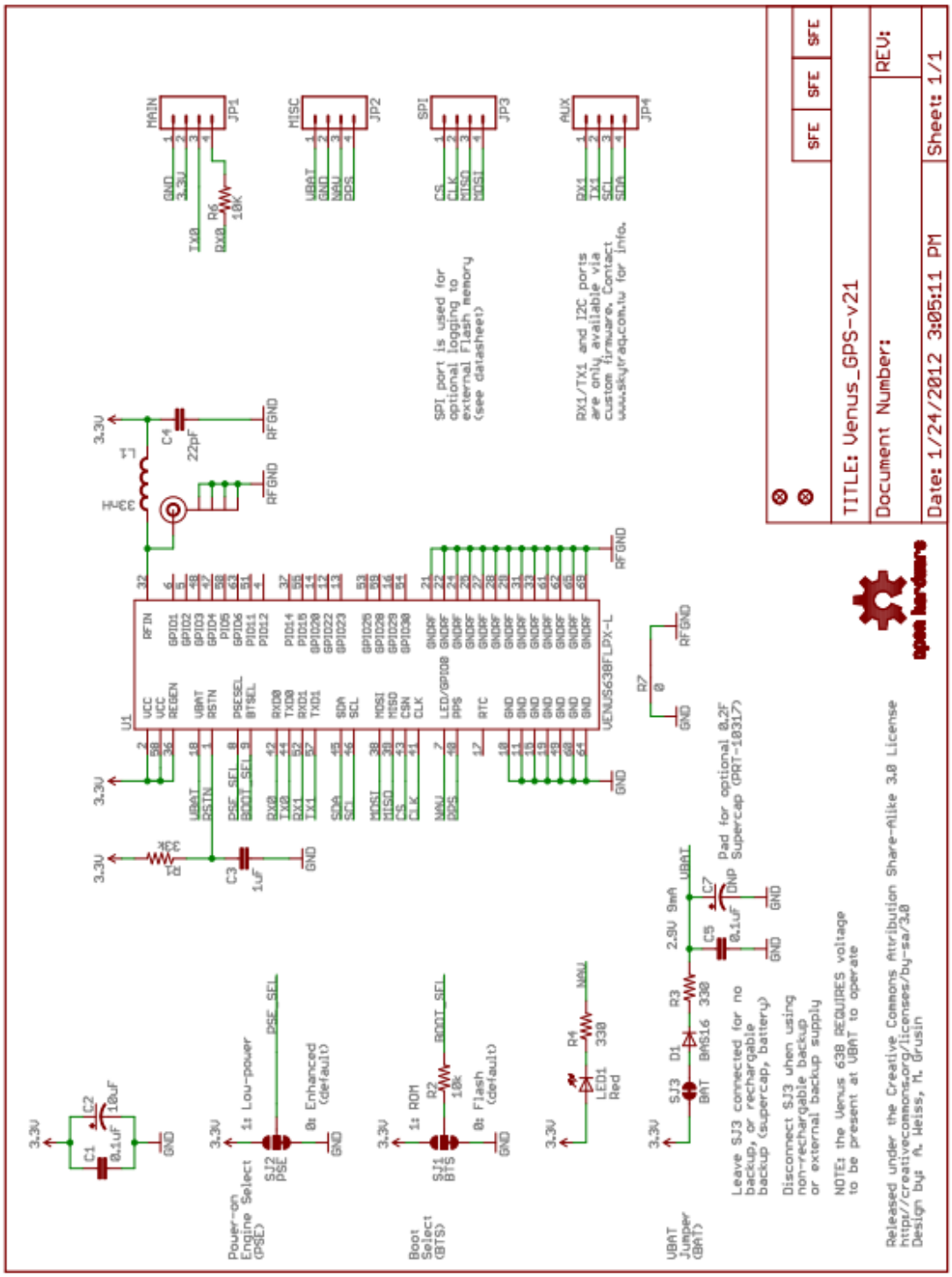


Figure 3.3.3.5.3: VTGPSIA-3 Schematic
Reprinted with permission from Sparkfun.com[3]

3.3.3.6. Barometric Pressure Sensor

The barometer is used to measure the atmospheric pressure. The higher the altitude we go above sea level the lower the air pressure and vice versa, the lower we go below sea level the higher the air pressure. Thus with a barometric pressure sensor, and the correct equation conversion, we are able to calculate the altitude of our tablet.

To the right is the Bosch BMP085 high-precision, low-power barometric pressure sensor. It comes with a breakout board for easy prototyping.

Figure 3.3.3.6.1: Barometric Sensor
Reprinted with permission from Sparkfun.com[3]

This breakout allows us to access the 6 pins, ground, Vcc, data, clock, xclear, and EOC. This sensor interfaces with I2C (See Figure 3.3.3.6.3) [10].

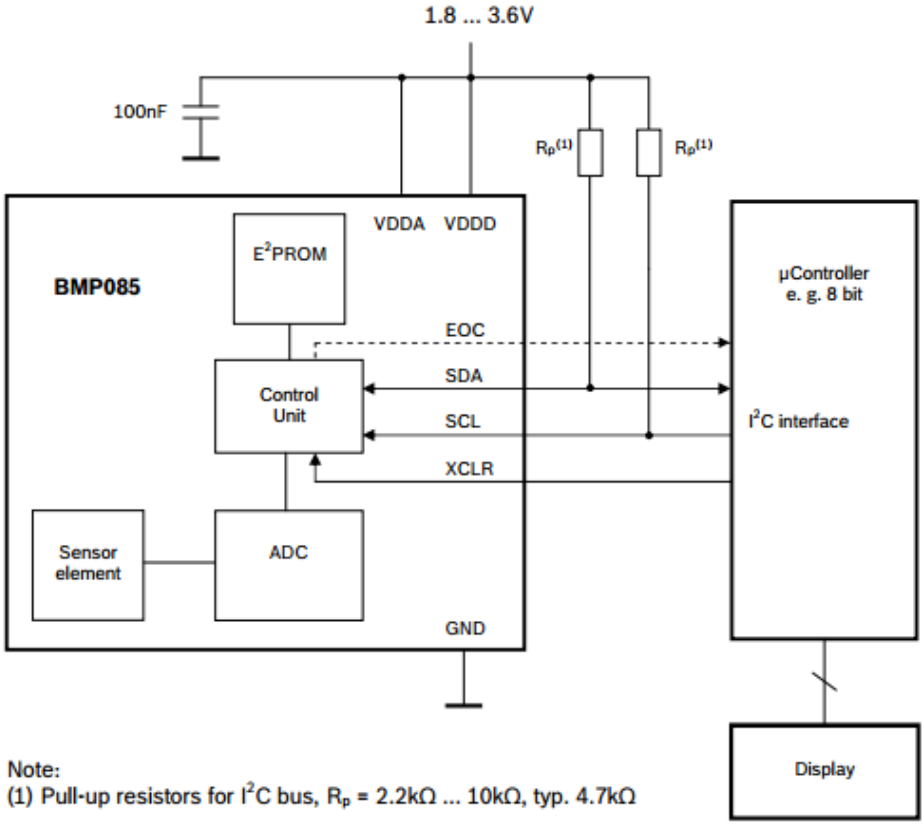


Figure 3.3.3.6.2: Block Diagram for BMP085
Reprinted with permission from Sparkfun.com[3]

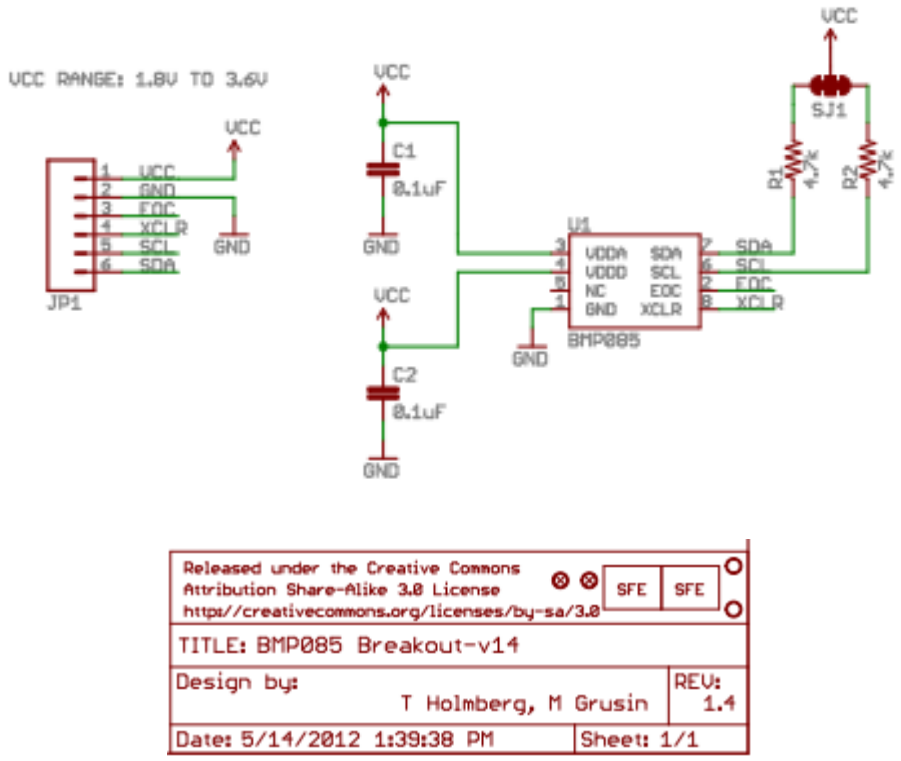


Figure 3.3.3.6.3: BMP085 Schematic Diagram
Reprinted with permission from Sparkfun.com[3]

3.3.3.7. Camera and Adapter

A camera is needed for our applications, augmented reality. We chose the Pandaboard 5MP camera from OmniVision, because of its compatibility with the PandaBoard ES. It uses the Pandaboard camera adapter that connects the Pandaboard ES's J17 with the 30-pin connector on the Pandaboard camera (See Figure 3.3.3.7.1)[11][12].

Here are some of the features this camera supports:

- 60 Frames per second
- 720p HD video
- 2592x1944
- Output format: 8/10-bit raw RGG data
- Shutter: rolling shutter
- Len size: 1/32'
- Sensitivity: 1300 mV/lux-sec

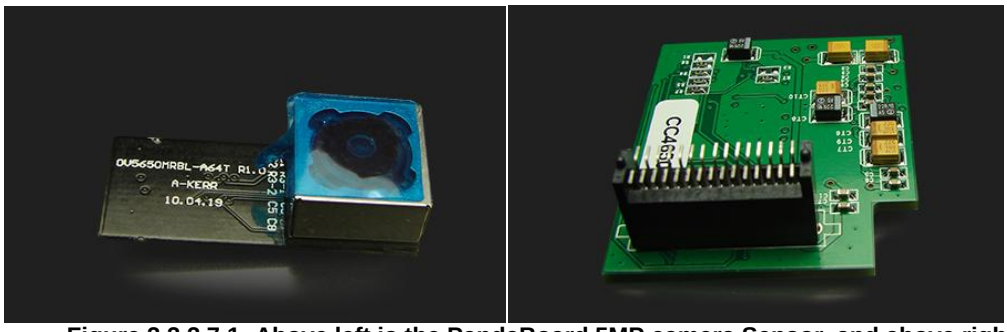


Figure 3.3.3.7.1: Above left is the PandaBoard 5MP camera Sensor, and above right is the Pandaboard camera adapter.
Reprinted with permission from Sparkfun.com[3]

3.3.3.8. Mini Photocell

Photocells act much like resistors. A photocell's resistance, however, changes with the amount of light that hits the cells; the more light that strikes the cells the more current is able to flow through. Most photocells are able to detect light ranging from a dark room to direct light, although calibration is required. The Mini Photocell (Figure 3.3.3.8.1) is used in the project to detect the amount of ambient light and adjust the brightness of the 7 inch LCD screen. Figure 3.3.3.8.2 is a graph showing the resistance in the photocell is proportionate to the amount of light (measured in lux); the greater the amount of light, the lesser the resistances [13].

Figure 3.3.3.8.1: Photocell
Reprinted with permission from Sparkfun.com[3]

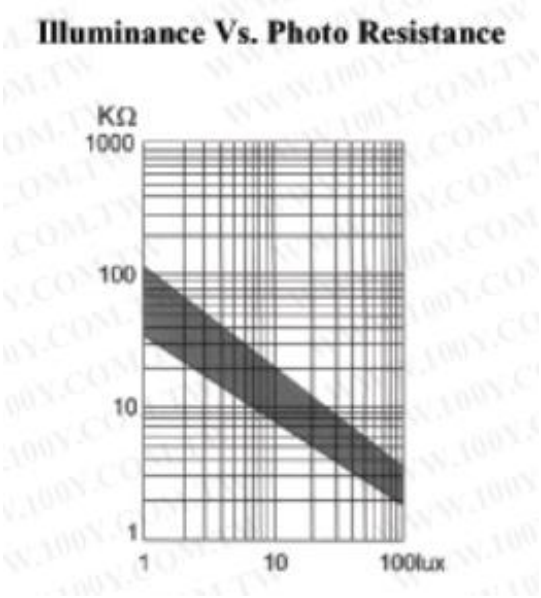


Figure 3.3.3.8.2: Photocell Performance Stats
Reprinted with permission from Sparkfun.com[3]

3.4. Custom PCB design Intro

The custom PCB is the only hardware design of this project. The rest of the hardware, like the PandBoard ES and the expansion board are already designed and built. Therefore, this hardware was the most time consuming during the prototyping phase. It had to function as described in the specifications.

3.4.1. Sensors on the Custom Board

The custom PCB includes all of the sensors for our project. This includes the barometric pressure sensor, the global positioning system (GPS), inertial measurement unit (IMU), and the magnetometer (compass). This board is the back bone of our project; if the sensors do not work then we will not be able to implement our augment reality application. First let us break down the sensors mentioned earlier. To understand where we are, we need the global positioning system. This gives us the exact location in coordinates and so the application can place an icon that defines where the user is on a map. Then another question arises, which direction are we facing? In order to figure out where north vector is a magnetometer or the compass was used. With the northern direction calculated, we easily pinpoint the direction the device is facing. Next, how high are we? We can be at sea level or on top of a skyscraper. With the barometric pressure sensor the application figured if the user is on the first or fifth floor of any given building. Lastly what orientation are we looking at? To find out the tilt and positioning of our device we used a inertial measurement unit which is the combination of a gyroscope and an accelerometer.

3.4.2. Sensors and IOIO Interaction

At the center of the custom PCB board is the IOIO board. The task of the IOIO board is gathering all the raw data from all of the sensors, processes it into useable data, and sends it back to the PandaBoard ES. This is no easy task and the IOIO board has 48 pins with an array of features to accomplish this. Either through I2C, PWM, UART or just analog, the IOIO communicates with each sensor. Furthermore, we figured out the additional math involved in converting raw data into usable data [15].

3.4.3. Building with Eagle

EAGLE stands for Easily Applicable Graphical Layout Editor. Essentially, it is a powerful and affordable circuit board editor, perfect for students to make custom PCB designs, and that's exactly how the hardware team will make the custom PCB design. The Professional version called "Eagle Professional" is available through UCF. This version of Eagle allows up to 999 schematic sheets, up to 16 signal layers in design, and can be 4m by 4m (routing area). This is more than enough to fit the specification for the microcontroller and sensors.

3.4.4. Powering the Custom Board

To power the board we used a portable power supply. Lithium batteries are perfect for this project; they are light in weight, compact, and pack a lot of power. An external charging unit is used to safely recharge the batteries. These batteries also power the PandaBoard ES as well as the Panda Expansion Board.

3.4.5. Power Supply Parameter

The IOIO has two on-board voltage regulators:

- A switching regulator that can take 5V-15V input and outputs up to 1.5A of stable 5V.
- A linear regulator that feeds off the 5V line and outputs up to 800mA of stable 3.3V.

5V is used for charging the Android device as well as powering any 5V peripherals we might have in future development. It is available on any of the three pins marked "5V". Android devices can draw up to 500mA of current when charging, leaving about 1A for external devices. The switching regulator is very efficient. It should run fairly cool and thus does not waste a lot of energy. When powering it from a high-voltage source, the current drawn from this source will decrease accordingly.
3.3V is being used for powering the IOIO's MCU. It draws about 30mA-40mA under normal operation, leaving a little over 700mA for any external 3.3V peripherals. It is available on any of the pins marked "3.3V". It is very useful for connecting to potentiometers, as the IOIO's analog inputs are 0-3.3V. Never *feed* this line 3.3V. It is to be used as output only.

4. Project Hardware and Software Design Details

4.1. Hardware Design Schematics

The Printed Circuit Board (PCB) designed for our tablet is based on the IOIO development board which is specially designed for the Android OS. We used the IOIO board as a base or reference board for our design since we are choosing this development board to run all of our test and debugging procedures for our system. We integrated all of the sensors such as the accelerometer, gyroscope, GPS, barometer, and lights or photo sensor with the IOIO board. We used Pandaboard ES also in our system since we used the Android OS as our operating system. We integrated the camera sensor PB-CAM05-01 to the Pandaboard ES. We used the Eagle software to design our custom circuit board which included all sensors such as gyroscope, accelerometer, barometer, GPS

module. Finally, the team connected the custom designed circuit with Pandaboard ES through USB.

We used the following hardware components:

- Pandaboard ES powered by OMAP4460 microcontroller
  - SD Card Slot (to install Android operating system)
  - JTAG (for debugging)
  - Camera Sensor PB-CAM5-01
  - Camera Adaptor PB-CAME-01
  - Capacitive touchscreen
  - RS 232 connection
- IOIO Board
  - Gyroscope MPU-6050
  - GPS Module GPS-00177
  - Accelerometer MPU-6050
  - Barometer BMP085
  - Inertial Measurement Unit (IMU) MPU-6050 (Alternate option)
  - Status LEDs Triple Output LED RGB – SMD COM-007844
  - Power supply/ battery pack (MCP73843-410)

The above mentioned hardware is for the entire system. For our custom circuit design considered components listed under the IOIO board. These components listed above are not all included in the development board, instead they are for our Augmented Reality Tablet, which needed those components such as the gyroscope, accelerometer, barometer or compass, camera, camera adaptor, and light sensor. There are many components also present on the development board Pandaboard ES that we do not need. Therefore, we came up with the schematic captures for the components we needed. The schematics for each layer of the processor OMAP4460 are shown in the figures.

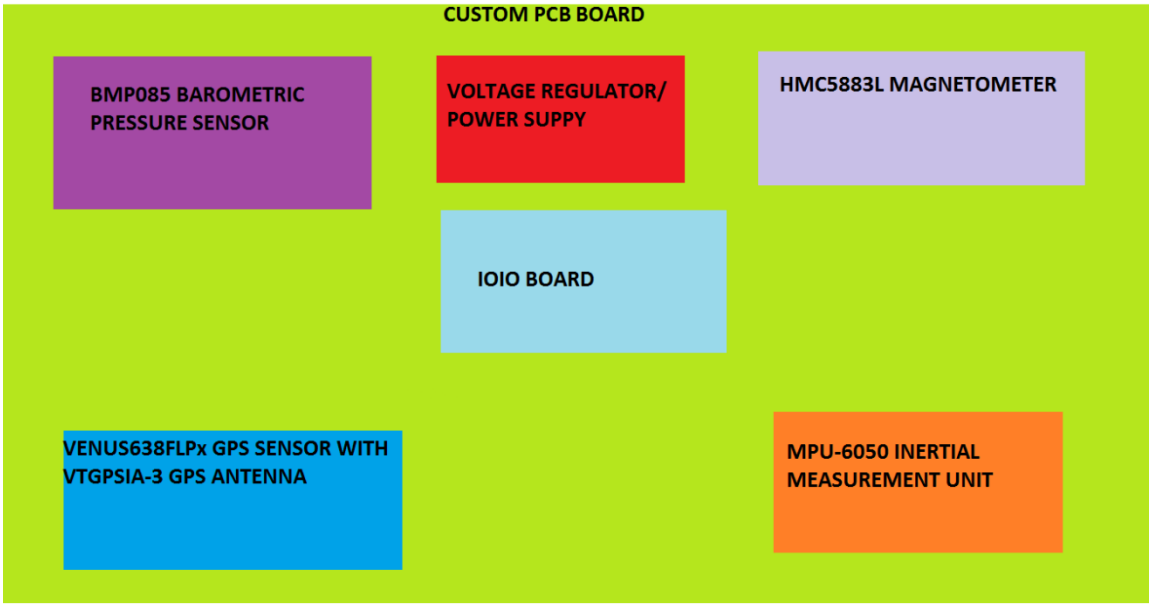


Figure 4.1.1: Block Layout for Custom Expansion Board

4.1.1. IOIO Board

We used the IOIO board as a reference board for our Augmented Reality Tablet. The IOIO acts as a USB host and connects to most Android devices that have a USB slave (device) capability. We used the Pandaboard ES as our Android device with a supported expansion board that provided camera connectivity with a camera adaptor and the capacitive touchscreen [20].

4.1.1.1. I/O Pins

The I/O pins are the essence of the IOIO. They are used to connect to external circuits using different interfaces. The common denominator to all pins is that they can all serve as 3.3V digital inputs or 3.3V digital outputs. In addition, many of the pins are capable of other functions as detailed in the table at the bottom of this page [20].

For convenience, the common pin functions are presented graphically on the bottom of the board (See Figure 4.1.1.1.1 Below), with a legend:

- Pins surrounded by a square can be used as analog inputs (3.3V). For more details, see Analog Input.
- Pins surrounded by a circle are 5V-tolerant, i.e. can be used as 5V logic inputs or product 5V logic output when used in open-drain mode with the help of a pull-up resistor. For more details, see Digital I/O.

- Pins marked with "P" can be used as peripheral inputs and outputs. Mainly, this includes PWM, UART, and SPI.
- The pin marked with "Pi" can be used as peripheral input (but not output).
- Pins marked with DAx and CLx are used for TWI.

- We will power the IOIO *either* from 5V-15V input on the VIN line *or* from 5V directly on the 5V line. We have to cautious to avoid accidental contact between the power lines and other pins / conductors.
- Not all of the IOIO pins are 5V tolerant. Some of them can only tolerate up to 3.3V. We should input 5V to the IOIO only on those pins marked with a circle on the back side of the board. If we need 5V output, we can also choose one of those pins, connect a pull-up resistor (10K-47K) from the pin to the 5V line, and use it in open-drain mode.

Legend:

- A/D: pin can be used as analog input
- I2C: pin can be used as I²C: DAx - data pin if I²C module number x, CLx - clock pin if I²C module number x
- PPSi: pin can be used as input for remappable peripherals (input capture, UART, SPI)
- PPSo: pin can be used as output for remappable peripherals (UART, SPI, comparator output)
- 5V: pin is 5V tolerant: can be used as 5V input or 5V output in open-drain mode
- Comp: pin can be used as comparator input number as specified
- Prog: pin can be used for ICSP: use Vpp and either C1/D1, C2/D2 or C3/D3 which are clock and data, respectively

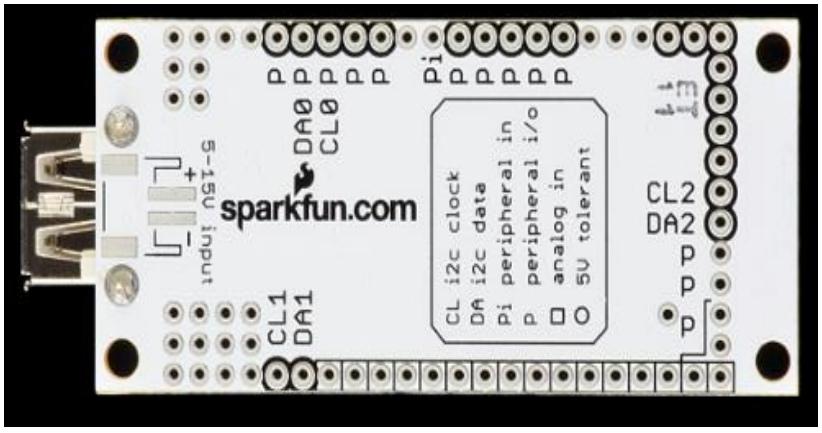


Figure 4.1.1.1.1: IOIO connection board
Reprinted with permission from
Sparkfun.com[3]

4.1.1.2. Analog and Digital I/O

Each of the IOIO pins can function as a digital input or a digital output, depending on the our sensor or device requirement we can have a choice in software, as demonstrated below. The on-board stat LED is also considered a pin, and can be controlled as a digital output.

4.1.1.3. Digital Output

When used as output, in their default operation modes, the IOIO pins represent the logical levels as following:

- A logical LOW will cause the pin to force a voltage of 0V ("ground") on whatever is connected to it.
- A logical HIGH will cause the pin to force a voltage of 3.3V on whatever is connected to it.

Many digital electronics will accept this representation, correctly reading the LOWs as LOWs and the HIGHs as HIGHs. As an example, an LED connected between a digital output pin (LED anode), through a 220ohm resistor to ground will light when the pin state is high.

For some components an "open-drain" operation is required. In "open drain" mode the pins will represent the logical levels slightly differently:

- A logical LOW will cause the pin to force a voltage of 0V ("ground") on whatever is connected to it, just like in normal mode.
- A logical HIGH will cause the pin to not force anything on whatever is connected to it, as if it were physically disconnected.

4.1.1.4. Digital Input

When used as inputs, the IOIO pins never force any voltage on whatever is connected to them, but rather sense the voltage level and report their state accordingly.

- When 0V is detected, the pin reads LOW.
- When 3.3V is detected, the pin read HIGH. 5V-tolerant pins, will tolerate up to 5V, and also treat it as HIGH.
- When nothing forces a voltage on the pin, the pins can be told to either:
    - Not influence the pin in any way. The read value will be rather chaotic and can't be relied on. This is called "floating" mode, and it is the default mode for input pins.
    - "Gently" pull the pin to 3.3V, so that the value will be read HIGH unless someone forces 0V on it. This is called "pull-up" mode.

- "Gently" pull the pin to 0V so that the value will be read LOW unless someone forces 3.3V (or 5V in designated pins) on it. This is called "pull-down" mode.

Open-drain can be useful in several situations. The most common is that some electronic components require a 0V / 5V signal rather than 0V / 3.3V. The way to achieve that is very simple. First, for this purpose you need to select a 5V tolerant pin. If we attempt to implement this method on a non-5V-tolerant pin, we risk permanently damaging our pin or the entire board. 5V-tolerant pins are designated on the bottom of the board with circles around the pin.

4.1.1.5. Analog Output

IOIO has 16 pins, commonly known as "Analog Inputs", which are capable of measuring voltage levels between 0V-3.3V, with a precision of about 3mV. We must ensure not to supply voltage levels outside this range on those pins, or we will potentially damage our hardware. In some cases where the input to measure is outside of this range, a simple resistor ladder we can use to scale down the voltage, while in other cases an amplifier circuit will be needed. At the time of writing this, the answers to these questions seem a little bit over-long for this guide.

Internally, as soon as we open an analog input, the IOIO starts sampling the voltage at even intervals, and sends these samples to the Android device. When reading them, we have a choice on whether to read the most recent value captured, or to read them on a sample-by-sample basis.
The analog pins are marked on the back-side of the board by squares surrounding the pins.

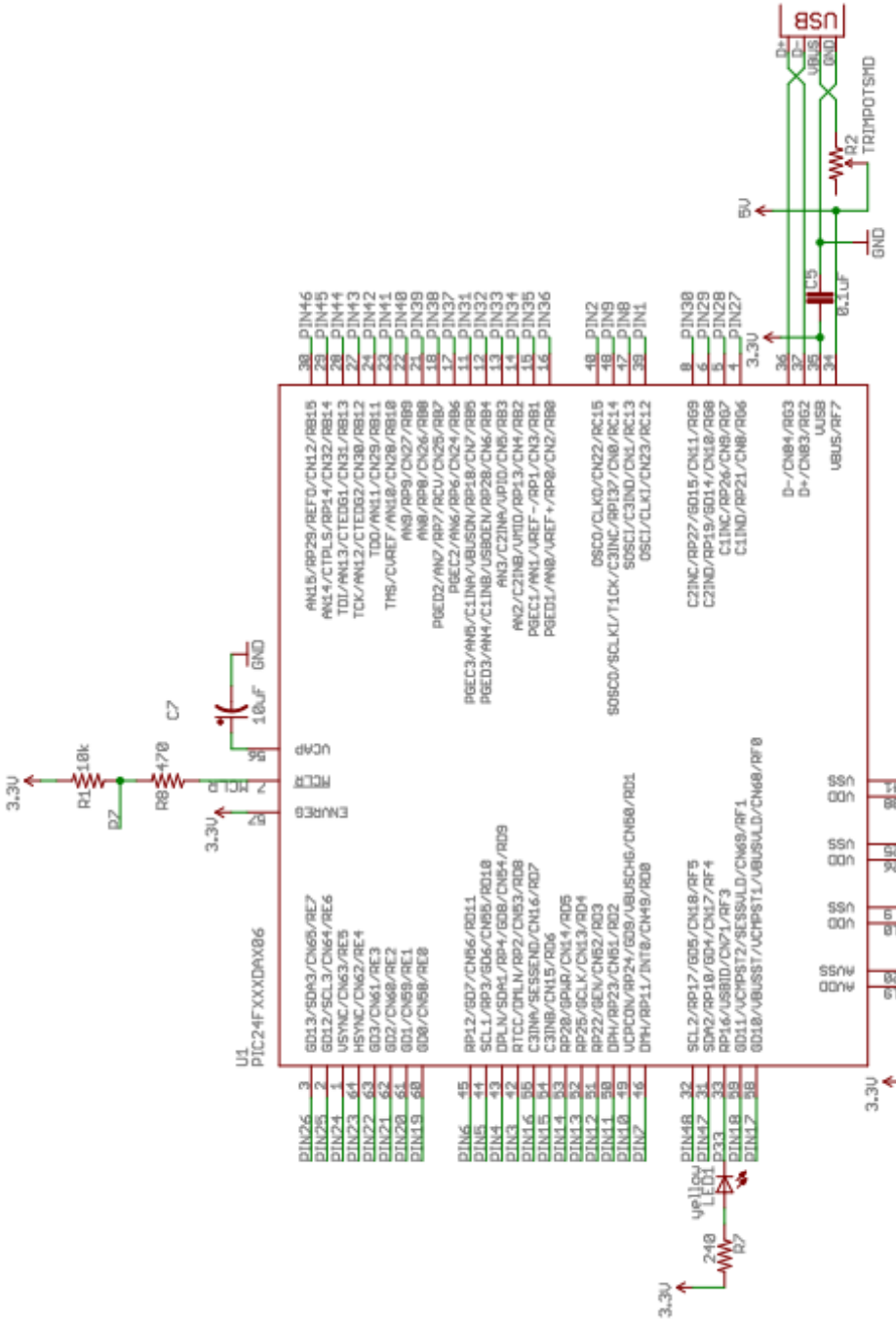


Figure 3.3.1.4.1: IOIO connection board Schematic
Reprinted with permission from Sparkfun.com[3]

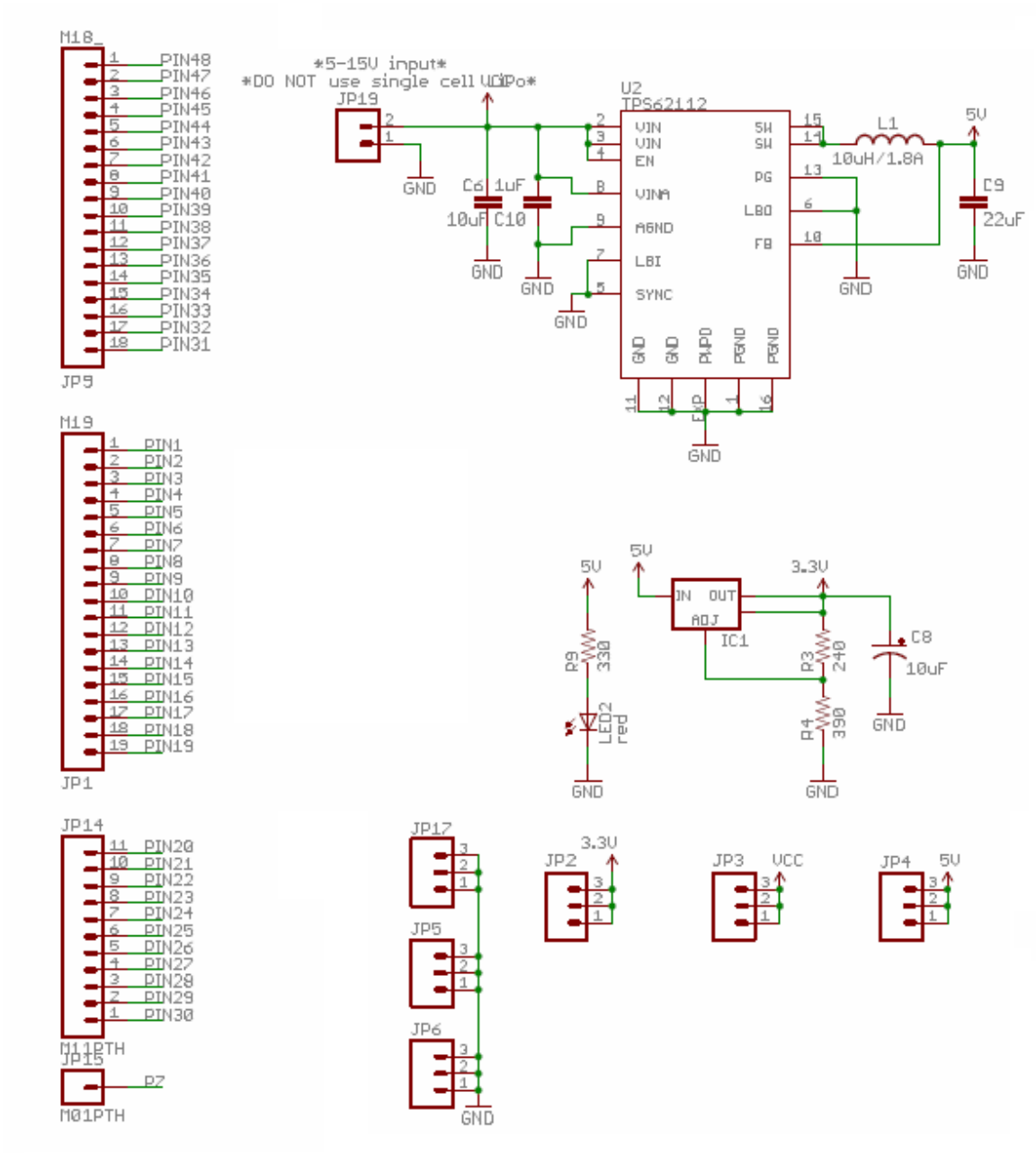


Figure 4.1.1.1.2: IOIO Board Pin Connections
Reprinted with permission from Sparkfun.com[3]

4.1.2. Gyroscope

We used a Triple-Axis Digital-Output Gyro ITG-3200 to integrate with IOIO board. This is a breakout board for InvenSense's ITG-3200, a groundbreaking triple-axis, digital output gyroscope.

Communication with the ITG-3200 is achieved over a two-wire (I^2C) interface. The sensor also features a interrupt output, and an optional clock input. A jumper on the top of the board allows us to easily select the I^2C address,

Provided below is the summery the features:

- Digital-output X-, Y-, and Z-Axis angular rate sensors (gyros) on one integrated circuit with a sensitivity of 14.375 LSBs per °/sec and a full-scale range of ±2000°/sec
- Three integrated 16-bit ADCs provide simultaneous sampling of gyros while requiring no external multiplexer
- Enhanced bias and sensitivity temperature stability reduces the need for user calibration
- Low frequency noise lower than previous generation devices, simplifying application development and making for more-responsive motion processing
- Digitally-programmable low-pass filter
- Low 6.5mA operating current consumption for long battery life
- Wide VDD supply voltage range of 2.1V to 3.6V
- Flexible VLOGIC reference voltage allows for I2C interface voltages from 1.71V to VDD
- Standby current: 5µA
- Smallest and thinnest package for portable devices (4x4x0.9mm QFN)
- No high pass filter needed
- Turn on time: 50ms
- Digital-output temperature sensor
- Factory calibrated scale factor
- 10,000 *g* shock tolerant
- Fast Mode I2C (400kHz) serial interface
- On-chip timing generator clock frequency is accurate to +/-2% over full temperature range
- Optional external clock inputs of 32.768kHz or 19.2MHz to synchronize with system clock
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

4.1.2.1. Hooking it Up

We confirmed how to read data from the ITG-3200 before we start examining the sketch we need to hook the sensor up to the IOIO board. Here's a table that shows how to connect the pins on the ITG-3200 to the pins on the IOIO. We can use stripped wire, or our fancy jumper wires to connect the two devices for testing and will integrate finally with our custom circuit board.

IOIO Pin	ITG-3200 Pin	ITG-3200 Pin No
DA0	SCL	23
DA1	SDA	24
GND	GND	18
3.3v	VIO	8
3.3v	VDD	13

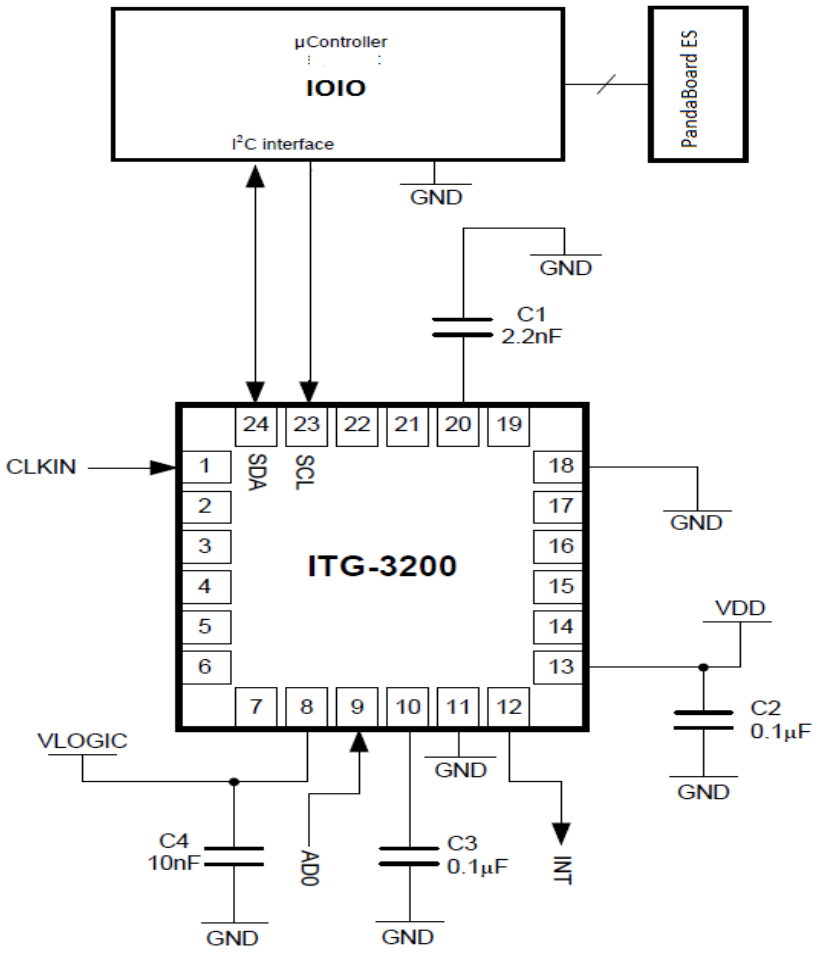


Figure 5.1.2.1.1: Typical IOIO Circuit
Reprinted with permission from Sparkfun.com[3]

To use the basic functions of the ITG-3200, there are only 5 pins that need to be connected to the IOIO board. Ground pins (GND) should almost always be connected together when combining multiple devices, so that's an easy connection to figure out.

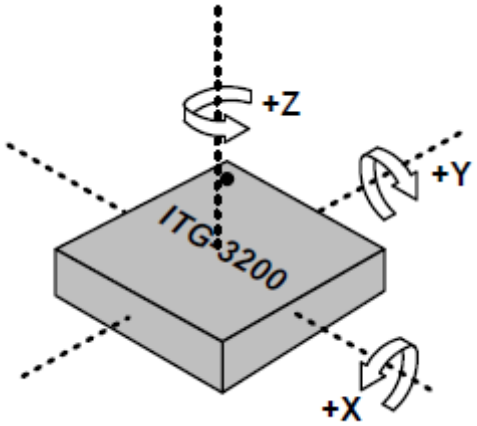


Figure 4.1.2.1.2: Orientation of Axis of sensitivity and polarity of rotation
Reprinted with permission from V-torc.com[4]]

Next let's look at SCL and SDA. These are the communication pins. The ITG-3200 uses a communication protocol called I2C to talk with other devices in our system the IOIO. All I2C devices have the SDA and SCL signals.

4.1.3. GPS Module

We used the Antenna GPS Embedded SMA for our system powered by Module VTGPSIA-3. Embedded antenna for small, mobile applications. Basic unpackaged antenna with LNA. 5inch cable terminated with standard male SMA connector. Match it with any SMA interface cable to create a truly small GPS prototype

Features: Gain 26dB, VSWR <2.0, Voltage 3.3V +/- 0.5V, Current 12mA, Weight 18g

Mechanical

Form 3 No.	Item	Specification
1	Cable	RF 1.13/ RG 178/RG 174
2	Connector	IPEX/MMCX
3	Plastic Housing	Gray or Black or Brown
4	Mounting	Internal
5	Weight	0.015kg（Without Connector and Cable）

Table: Reprinted permission pending from V-torc.com

4.1.4. Accelerometer

We hused an accelerometer in our system or tablet. We have selected as an option to use MPU-6050 triple-axis accelerometer. The triple-axis MEMS accelerometer in MPU-6050 includes a wide range of features:

Features:

- I2C Digital-output of 6 or 9-axis MotionFusion data in rotation matrix, quaternion, Euler Angle, or raw data format
- Input Voltage: 2.3 - 3.4V
- Selectable Solder Jumpers on CLK, FSYNC and AD0
- Tri-Axis angular rate sensor (gyro) with a sensitivity up to 131 LSBs/dps and a full-scale range of ±250, ±500, ±1000, and ±2000dps
- Tri-Axis accelerometer with a programmable full scale range of ±2g, ±4g, ±8g and ±16g
- Digital Motion Processing™ (DMP™) engine offloads complex MotionFusion, sensor timing synchronization and gesture detection
- Embedded algorithms for run-time bias and compass calibration. No user intervention required
- Digital-output temperature sensor

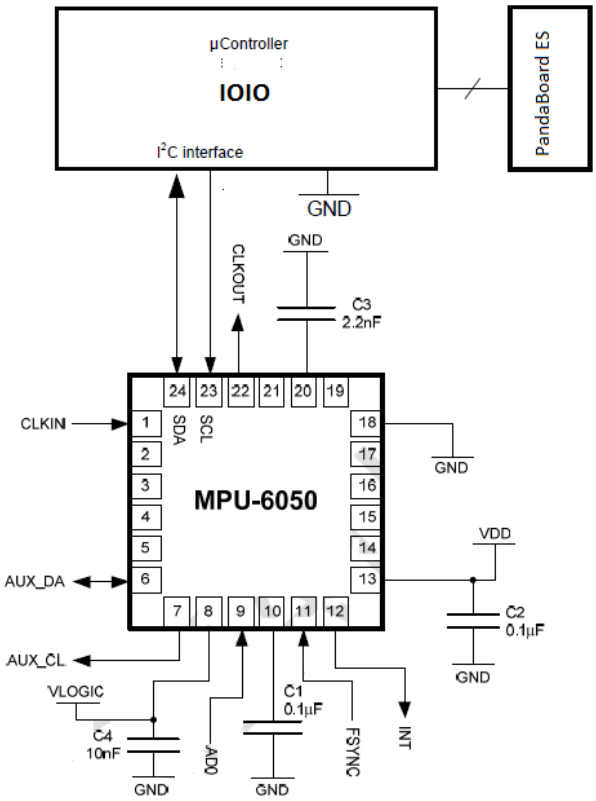


Figure 4.1.4.1: Typical Circuit for MPU-605
Reprinted with permission from Sparkfun.com[3]

4.1.5. Barometer BMP085

The BMP085 is a high-precision, ultra-low power barometric pressure sensor. It offers a measuring range of 300 to 1100 hPa with an absolute accuracy of down to 0.03 hPa.

The BMP085 has a digital interface, I^2C to be specific. This means there may be a bit more overhead to get it talking to IOIO board or microcontroller, but in return we get data that is much less susceptible to noise and other factors that may hamper an analog signal. I^2C is a synchronous two-wire interface. The first wire, SDA, transmits data, while a second wire, SCL, transmits a clock, which is used to keep track of the data.

While we are using an IOIO to talk to the BMP085, the wire library will conveniently take care of most of the work in communicating with the sensor.

BMP085 Pin	Pin Function
VCC	Power (1.8V-3.6V)
GND	Ground
EOC	End of conversion output
XCLR	Master Clear (low-active)
SCL	Serial Clock I/O
SDA	Serial Data I/O

The bottom side of the BMP085 Breakout labels of all six pins: 'SDA', 'SCL', 'XCLR', 'EOC', 'GND, and 'VCC.' **VCC** and **GND** are obviously the power pins. **SDA** and **SCL** are the I^2C communication lines. SDA being where the data is transmitted, and SCL is the clock that keeps track of that data. The last two pins, XCLR and EOC, are a couple extra functions of the BMP085. **XCLR** acts as a master reset. It's active-low, so if it's pulled to GND it will reset the BMP085 and set its registers to their default state. **EOC,** standing for "end of conversion", is a signal generated by the BMP085 that's triggered whenever a pressure or temperature conversion has finished. These last two pins are optional, we don't need to use them we will just leave them as they are now.

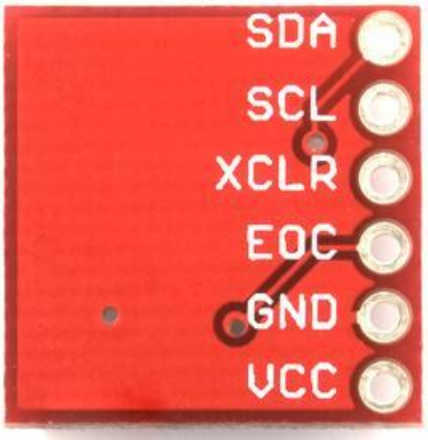


Figure 4.1.5.1: BMP085 Pin Connection with IOIO
Reprinted with permission from Sparkfun.com[3]

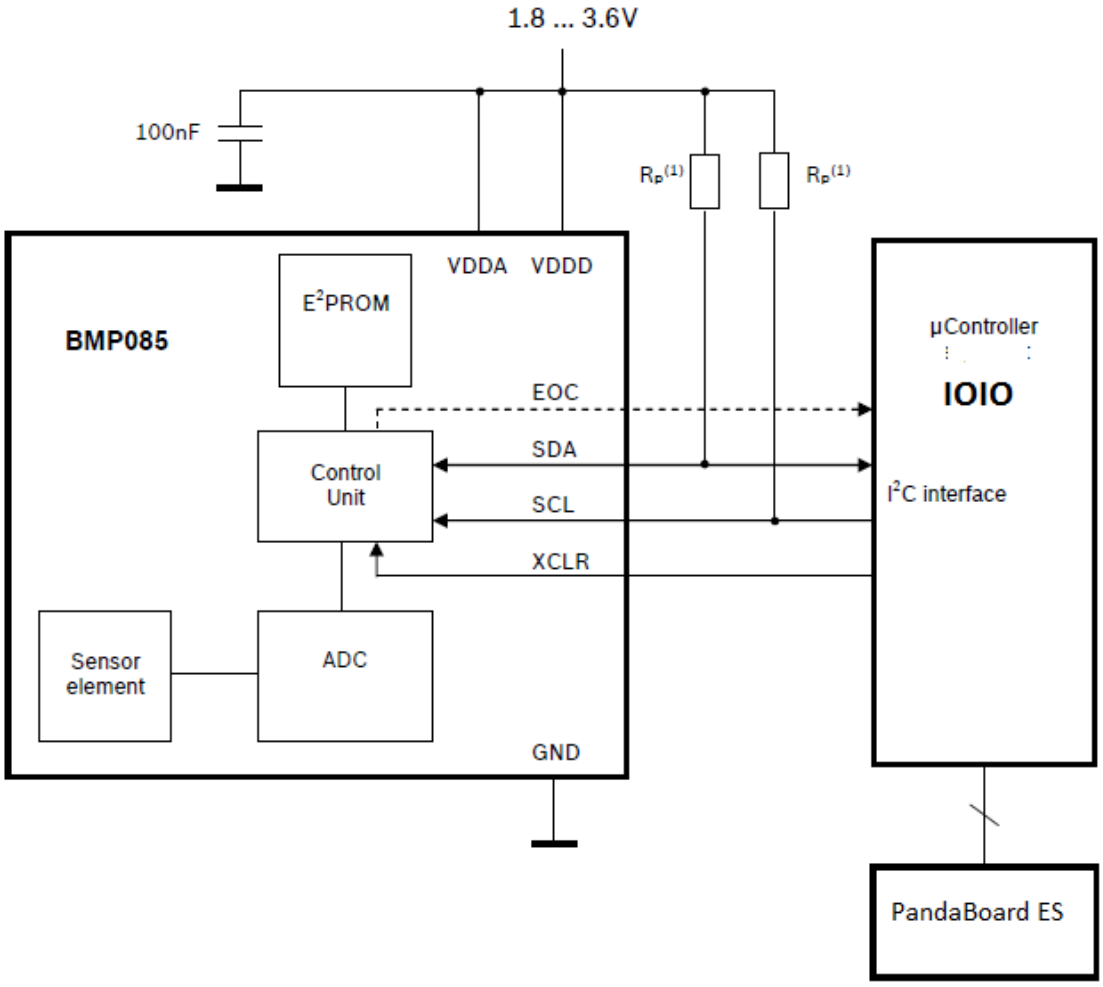


Figure 4.1.5.2: Typical BMP085 Circuit
Reprinted with permission from Sparkfun.com[3]

4.1.6. Camera Sensor

The PandaBoard 5MP Camera Sensor is a 1/3.2" 5 megapixel camera sensor from OmniVision. It is designed for digital still camera (DSC) quality imaging in mobile phones. PandaBoard 5MP Camera Sensor is able to provide high frame rate 720p HD video at 60 frames per second with complete user control over formatting and output data transfer.

- Followings are some specifications:
- Active array size: 2592 x 1944
- Output format: 8/10-bit raw RBG data
- Lens size: 1/3.2"
- Sensitivity: 1300 mV/lux-sec

The PandaBoard does not support the camera sensor directly. So, we need to use PandaBoard Camera Adaptor. The Pandaboard Camera Adapter is designed to provides camera capability for the Pandaboard. This adapter comes with a 30-pin connector that can be soldered to camera expansion J17 on Pandaboard.

4.1.7. Status LED's

We included a status RGB LED in our custom designed circuit for indicating different status of different components such as when the tablet is moving the Accelerometer (MPU-6050) will start changing values on a pin, same way when the position changing the GPS sensor (GPS-00177) will start changing position values according to the signal that will be received from the satellite, the gyroscope will change values as well when the orientation of the tablet starts changing. Our goal of integrating the status LED's is to make the Augmented Reality Tablet more interactive with the response of different sensors, reliable with accurate and expected results and dependable by indicating when the tablet should work [14].

We have selected Triple Output LED RGB – SMDCOM-07844 for our custom designed circuit since we need various combinations of color to indicate many status's that could be possible.

4.1.7.1. RGB Color System

RGB color space or RGB color system comes from the name of the three principal colors, which can construct all of the colors from the combination of the following three principle colors:

- **R**ed,
- **G**reen
- **B**lue

The red, green and blue use 8 bits each, which have integer values from 0 to 255. This makes 256*256*256=16777216 possible colors. From above description it is cleared that RGB ≡ Red, Green, Blue. Each pixel in the LCD monitor displays colors this way, by combination of red, green and blue LEDs (light emitting diodes). When the red pixel is set to 0, the LED is turned off. When the red pixel is set to 255, the LED is turned fully on. Any value between them sets the LED to partial light emission.

4.1.7.2. Triple Output LED RGB

This is a very popular RGB combo but in SMD (Surface Mount Devoce) form. These units have four pads with a common anode configuration. Use this one LED for three status indicators or pulse width modulate all three and get mixed colors [14]!

Some possible color combination are given below

Color	Hex Code	Active Components
White	#FFFFFF	Gyroscope
Blue	#0000FF	
Red	#FF0000	Accelerometer
Green	#00FF00	
Gray	#808080	GPS sensor
Yellow	#FFFF00	
Orange	#FFA500	Barometer
Violet	#EE82EE	

Simple breakout board also available which are given below.
Iv (Typical):

- Red: 81mcd
- Green: 130mcd
- Blue: 54mcd

Vf (Typical):

- Red: 2.0V
- Green: 3.5V
- Blue: 3.5V

Wavelength (λD - nm):

- Red: 615nm
- Green: 530nm
- Blue: 470nm

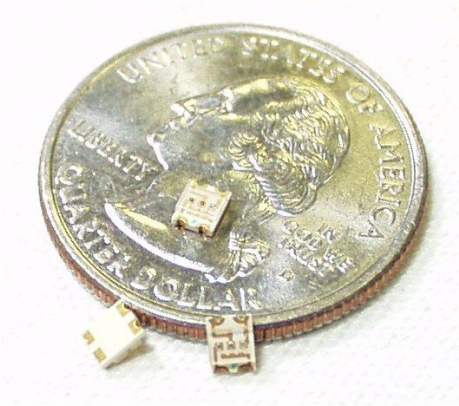


Figure 4.1.7.2.1: LED Size Reprinted with permission from Sparkfun.com[3]

Feature

- Package in 8mm tape diameter reel
- Compatible with many equipment
- Compatible with infrared and vapor phase reflow solder process

- Full color type.

4.1.8. Power Supply

The power supply of the Augmented Reality system contains two parts as usual for flexibility and portability.

- Rechargeable Li-on Battery pack
- Charging unit

4.1.8.1. Rechargeable Li-on Battery 2200mAh 7.4V

Description: This high discharge LiPo is a great way to power any R/C, robotic, or portable project. This is an excellent choice for anything that requires a small battery with a lot of punch. The voltage is low enough not to tax your regulating circuits, and the discharge rate is high enough to accommodate a lot of electronics and a few small motors.

The battery has two cells and outputs 7.4V storing 2200mAh of charge. Because this is a dual cell battery pack, a special charger is needed. This battery is not compatible with single cell chargers.

Figure 4.1.8.1.1: Polymer Lithium Ion Battery PRT-08484
Reprinted with permission from Sparkfun.com[3]

Note: Care should be taken not to short circuit or overtax these batteries because they don't have any built-in protection circuit.

Features:

- 7.4V 2-cell pack
- 2200mAh of charge
- 30C continuous discharge rate
- JST-XH charge plug
- 8AWG bare discharge leads

Dimensions: 138.5mm x 47.5mm x 24.5mm

Weight: 206g (7.26oz)

4.1.8.2. Polymer Battery Charger and Balancer

Description: This charger accurately balances and charges Lithium Polymer, LiFe (A123), NiCd and NiMH batteries. It will handle LiPo/LiFe up to 6S and NiMH/NiCd up to 15S and shows individual cell voltage during charge with realtime updates throughout the charge cycle.

Figure 4.1.8.2.1: Battery Charger and Balancer Reprinted with permission from Sparkfun.com[3]

The intuitive menu system means charging and cycling is an easy process and can be done quickly and accurately either in the field, by using a 12V input such as a car battery, or at home with a 12Vpower supply.

Bundled with the charger are a number of input and output wires which should satisfy most any charging requirement. This charger has a JST-XH charge plug, which makes it compatible with Zippy, HXT, iMax and any pack with a JST-XH adapter.

Note: A power supply is not included. The DC input jack is not the same as the standard 5.5mm size we use. It has a larger pin diameter. Thankfully, it does come with a barrel jack to alligator clip adapter.

Note: Although the enclosure is labeled as an Imax B6, this is not the same charger as the more expensive charger by the same name.

Dimensions:

- 133x87x33mm
- Weight: 277g

Features:

- Ni-MH/NiCd cells: 1~15
- Li-ion/Poly cells: 1~6
- Delta-peak sensitivity (NiMH/NiCd)
- Large range of charge currents
- Store function, allows safe storage current
- Time limit function
- Input voltage monitoring (protects car batteries in the field)

- Data storage (Store up to 5 packs in memory)
- Battery break in and cycling
- Input Voltage: 11~18V
- Circuit power: Max Charge: 50W / Max Discharge: 5W
- Charge Current Range: .1~6.0A
- Pb battery voltage: 2~20v

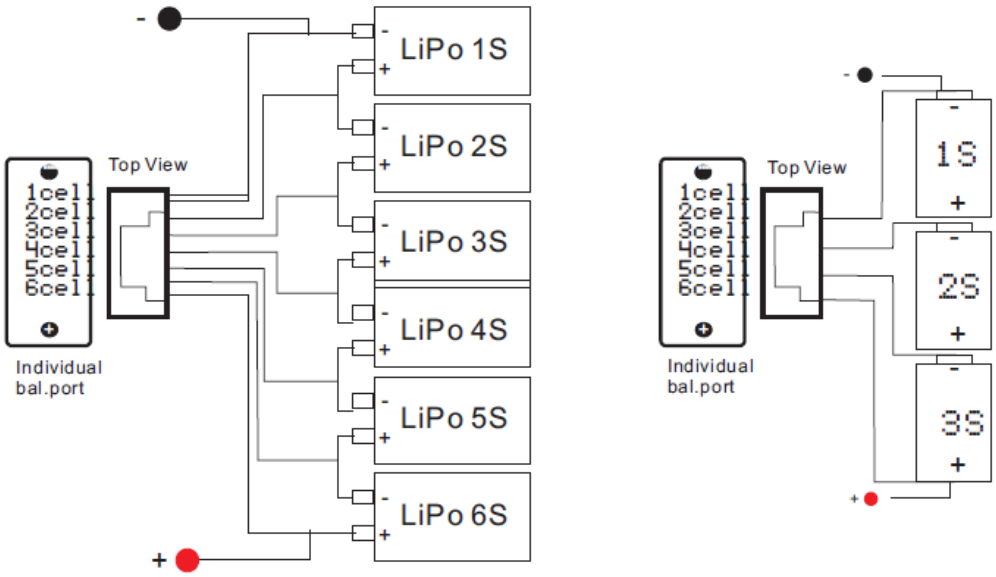


Figure 4.1.8.2.2: Pinout of the charger

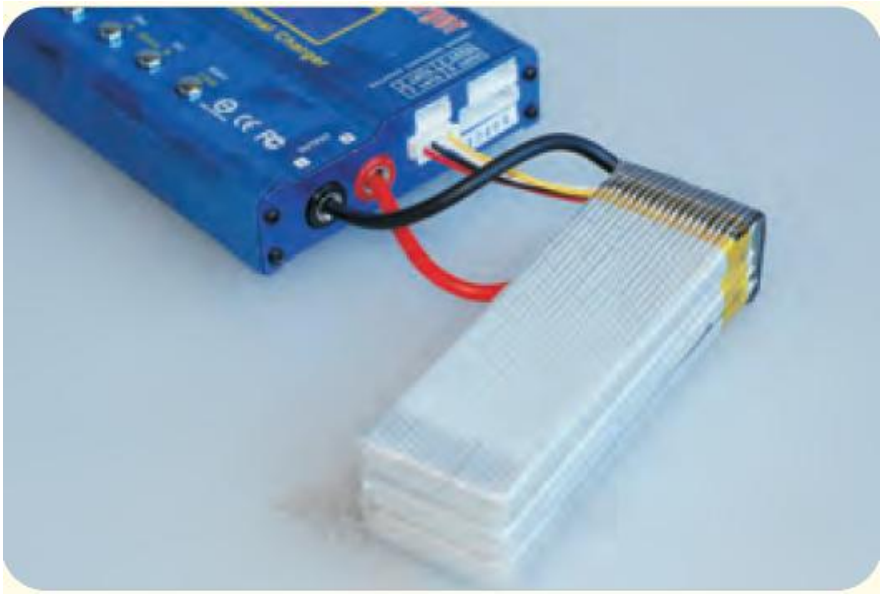


Figure 4.1.8.2.3: Pinout of the charger

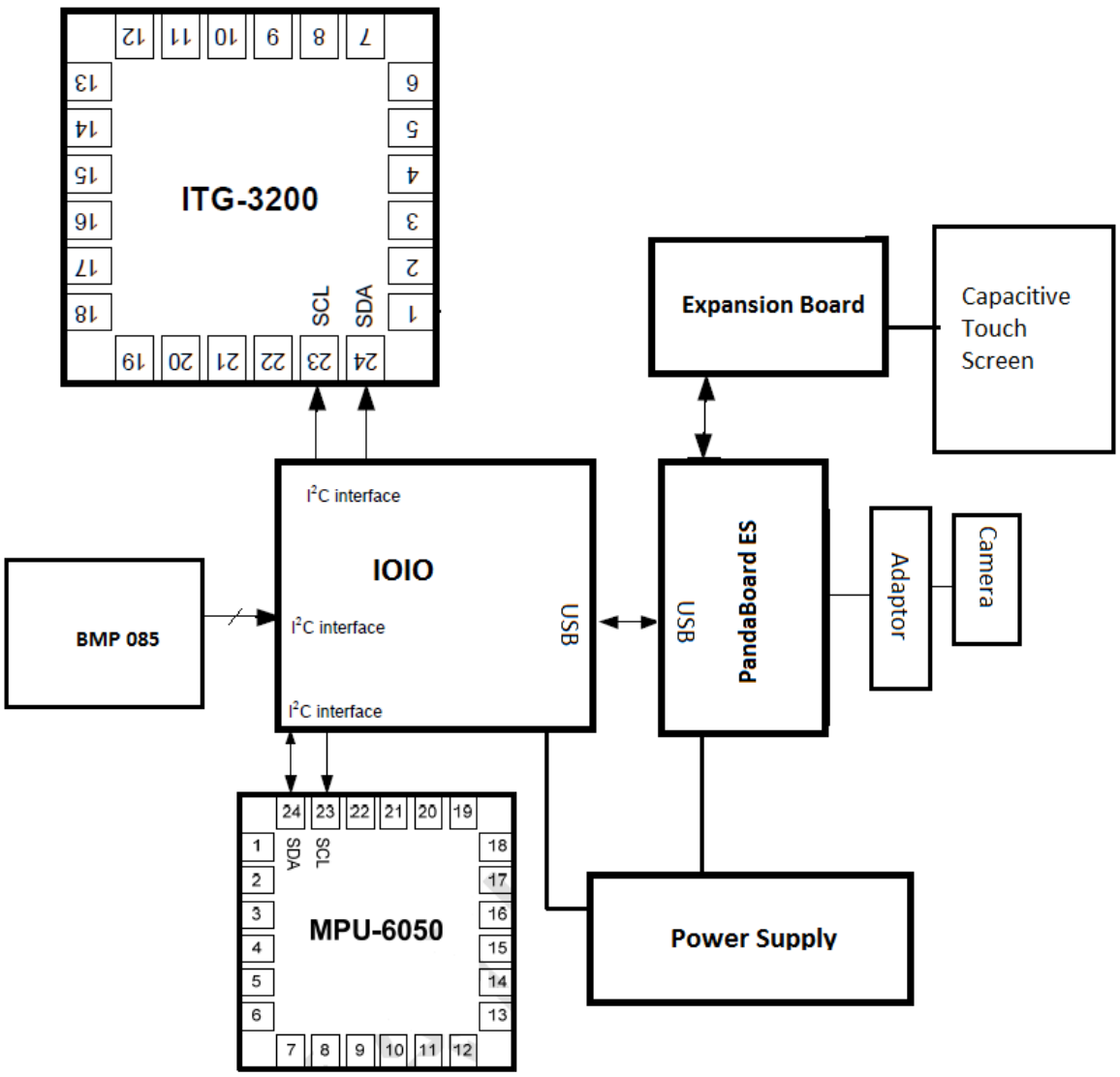


Figure 4.1.9.1: Augmented Reality Tablet Block

4.1.9. PandaBoard ES Connection

As we mentioned earlier the PandaBoard ES will be used as a platform for supporting the Android operating system with the expansion board. Our custom build circuit will be connected through USB connector with the PandaBoard ES. Expansion Ability to connect external device (See figure 4.1.9.1 above).

- 1x USB 2.0 High-Speed On-the-go port

- 2x USB 2.0 High-Speed host ports
- General purpose expansion header (I2C, GPMC, USB, MMC, DSS, ETM)
- Camera expansion header
- LCD signal expansion using a single set of resistor banks

4.2. Software Design Details

One of the main features to the software component of Project AUGI is the Augmented Navigation Application. This section of our software project is divided up into three basic components: the IOIO Service, the Map Activity and the Augmented Navigation Activity. Each of these components will be making system calls using the Android API and will be discussed in further detail later within this documentation. These three components will deliver three unique sets of functionality that will result in one grand delivered UCF Navigation product.

The Augmented Navigation Application will have three parts, but in an effort to keep features and usability to end users both powerful and simple we have decided to intelligently combine them into one application. This is going to be possible by both using concepts Google has already implemented within their system delivered applications and combining those concepts with built-in Google Maps API calls and house developed algorithms.

4.2.1. Google Maps API

Google Maps is a built in mapping and routing application that is delivered with every Android device. It also has many other features such as: detailed 3D maps, positional based turn-by-turn navigation, public transit, real-time traffic updates, access to a large database filled with information on local businesses and establishments, any many more. This feature is going to be the heart of our Augmented Navigation Application [33].

Because Google wants developers to maintain the high level of quality in applications they'd like, Google has supplied developers with a portion of their API devoted to mapping and navigation tools. The Maps Library includes classes that deliver map rendering, multiple display options, and touch enables controls. This is also coupled with a large database of locations and establishments at our disposal [28].

The Main areas within the Google Maps API that we will be using are the following: the centralized locations database that Google uses, the routing algorithms to achieve the shortest path from point A to point B, and the mapping display objects to view an on-screen map.

4.2.1.1. MAP Class

A map, as implemented by Google within their API, is basically a behavior or a portion of user interface in an Activity (Or single activity that a user can be doing at one time, usually within a focused window that the user is working in). This MAP activity polls the IOIO service for GPS and heading data in order to display to the user their current position.

When the user decides to add a custom landmark, the activity will convert the touch screen coordinates into longitude and latitude coordinates. This data for the landmark is then stored in a landmark list where all the other landmarks are stored.

When the user selects a destination, a JSON request is sent to Google, which will automatically calculate all of the waypoints along the path that the user needs to follow. It will return the longitude and latitude of these waypoints which are stored in a waypoints list. The user can then view the plotted path on the map or start the Augmented Navigation Activity to see the 3D pointer to the next waypoint. [32]

4.2.1.2. IOIO Service Class

The IOIO Service handles all of the communication between the application and the sensors. It constantly polls the sensors for new data, provides post processing on that data, and then makes it available to the other program activities.

This class was implemented as a service in order to allow it to always run in the background even as other activities are running. The Map and Navigation classes will poll the IOIO Service for updated sensor data.

The IOIO Service starts by establishing a connection to the IOIO microcontroller over the USB port. It then initializes the I2C and UART ports to establish communication with the sensors. Once communication with the sensors is established, it proceeds to calibrate and initialize each of the sensors. The service then creates a new Looper object which cycles through a loop in which each sensor is polled for new data.

The new data is in raw form however and requires a large amount of post processing in order to convert it to usable data. The data sheets for each sensor were carefully studied in order to derive what needed to be done to the raw sensor data.

4.2.2. Navigation Application Class

The Navigation tool is going to be a tool UCF Students will use to get from classroom to classroom effectively and on time. Many times students will be caught using the map keys beside sidewalks at UCF, and Project AUGI hopes to eliminate these trips to the physical mapping keys. Project AUGI's navigation tool is going to include a camera driven user interface and feature on-screen routes to the students destination. These routes will be configured the moment the student inputs a location within UCF. The screen and suggested route will constantly be refreshed depending on the location and orientation of the student whom contains the device [28].

This component of our project will essentially be a combination of the Google Maps locational database and the augmented reality features of this application. Since Google Maps has already mapped out all of the routes throughout UCF from which a student will regularly travel, this will provide a starting point for constructing the application. This is important because Google's Street view builds off of these coordinates so the application can use these to draw a realistically augmented line following these coordinates.

The application will call for these coordinates from Google's map database and combine them with the augmented line functionality of Google Street View when a route containing a destination is input from the user. The users GPS location will supply Google Maps with the location of the user [30].

Once the user's location is known, the built in compass can inform the application of the users facing. With these two pieces of information, the application will be able to calculate the bearing to the user's next destination. This will all be used to control the overlaid pointer on the camera feed of the user's device to point them to the next waypoint. [31].

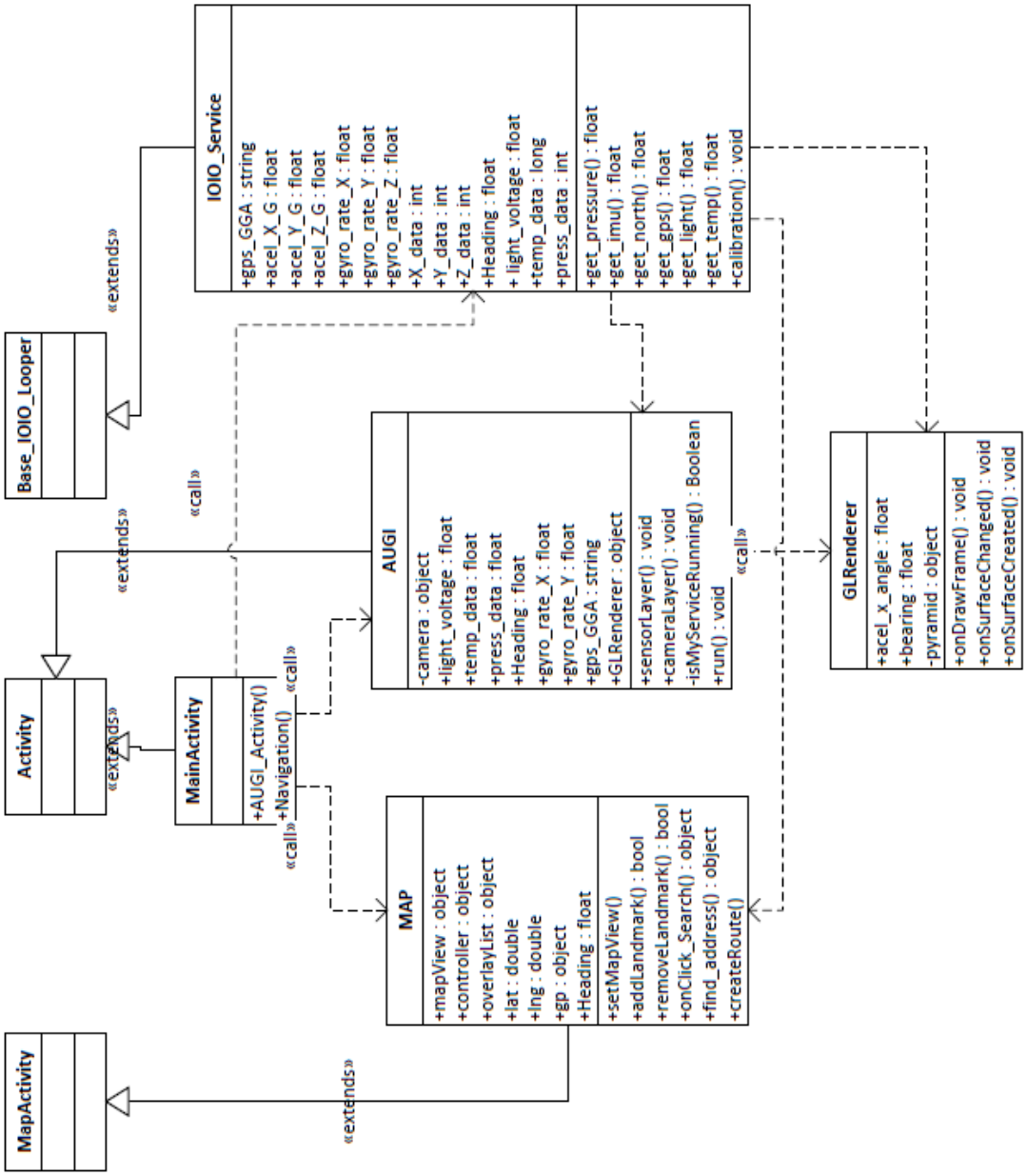


Figure 4.2.3.1: Class Diagram for Navigation Application

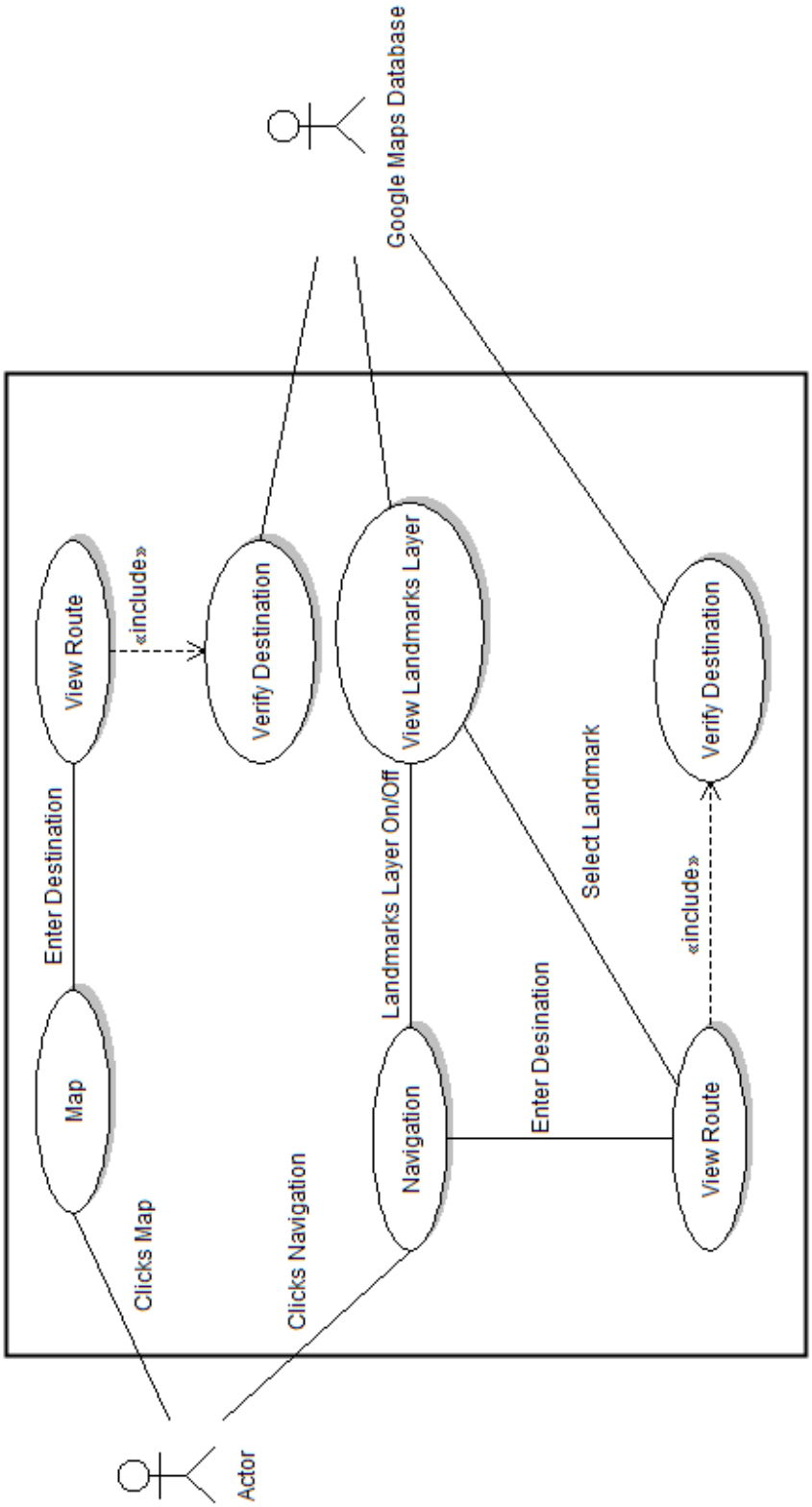


Figure 4.2.3.2:Use Case Diagram for Navigation Application

Google supplies its Layers abstraction to developers within their downloadable API. Layers are graphical overlays the user can turn on and off with information pertaining to the information displayed on the screen. Some available included Layers include: traffic, transit, satellite, etc. The digital map remains in the background while the Layer on top displays additional information. Only small pieces of this API will be utilized in the final product, due to the fact that the Landmarks Layer will be unlike any of the built in layers available now. Google's included layers work very closely with the Map View in the background to make sure the overlay is seamless and understandable; Project AUGI will be taking the Landmarks Layer one step further and adding an unpredictable dynamic camera feed in the background, overlaid with a continuously updating Landmarks Layer due to the gyroscopic orientation of the users device. To call a layer within the MapFragment, call the method setMap(), which passes the map object on which to display the layer [33].

5. Project Construction

5.1. Hardware Construction

5.1.1. PCB Manufacturing

5.1.1.1. Building with Eagle

Eagle stands for Easily Applicable Graphical Layout Editor. Basically it is a powerful and affordable way to make custom PCB designs, and that's exactly how we made our custom PCB design. The Professional version called "Eagle Professional" is available to us through UCF. This version of Eagle allows up to 999 schematic sheets, up to 16 signal layers in design, and can be 4m by 4m (routing area). This is more than enough to fit our microcontroller and sensors [21].

Drawing the Schematic:
The first step into designing our PCB is drawing out the schematic. We knew all the parts necessary for all of our hardware. Because most of our sensors we picked are breakout boards from Sparkfun, or prebuilt PCB, we combined their design into ours. Sparkfun's breakout boards gave us easy access to the pin outs, especially when most if not all the sensor chips are surface mounts. Accessing its pins can be very difficult. However, these breakout boards have other electronic components to make the board function. Fortunately Sparkfun provides schematics to all of their boards and we can incorporate it into our design. We will definitely use these schematic as a reference.

Checking the Schematic:
After we had all the schematics drawn, we made sure all the connections are correct. That meant there are no conflicting outputs, all power terminals are connected with the correct polarity. Check if there are any short-circuit or isolated

circuits on the board. Another check is if the power require by all the sensors is not limited and the components' are capable of handling the currents drawn [21].

Creating the Board:
Now we can create the actual physical board. First is laying out the schematic we design into the board. When creating our board it is crucial that we keep in mind the physical constraint of our setup. Can the schematic fit our board? Some components needs more space than others and we need to design our layout to best use the space.
How many layers is our board? Do we need a heat sink? Drill holes?

Placing the parts:
A list of parts is necessary to build our circuits. Which parts do we use and are they readily available. How much do the parts cost and can we get those parts can be a big factor if we can get this board made.

Routing the signals:
Next is routing the connections. Can the parts connect or do we need to adjust the layout? These are all considerations we have to take into account. We can use the Auto router in Eagle to automatically route our signals or we a manually route it. There are some cases where we would need to do both to make a functional design. Vias will be added automatically as needed through the Eagle routing software.

Checking the Board:
After we finish the physical layout we need to make sure everything is connected correctly. Are there any overlaps? There are also a minimum distance and need not to violate it. Eagle also has an Error command to make it easily to find errors.

Editing the board:
Because you can always edit your design, modifying it is easy. Any mistakes made during designing our PCB can be changed. Moving or rotating components to make them fit the board.
Processing:
Producing CAM data
The CAM data is the data create by Eagle after you finish your design. This data is need to manufacture our PCB. Drill station, photoplotters, postscript machines and pen plotters all use the CAM data [21].

5.1.1.2. Prototyping

Before we design and manufacture our custom PCB we need to prototype and test it. That will be for the prototyping step. We have done all the research, bought all the parts, now we need to put everything together and see if it really works. This phase of our project is extremely important and we need to make sure the combination of hardware is a feasible task.

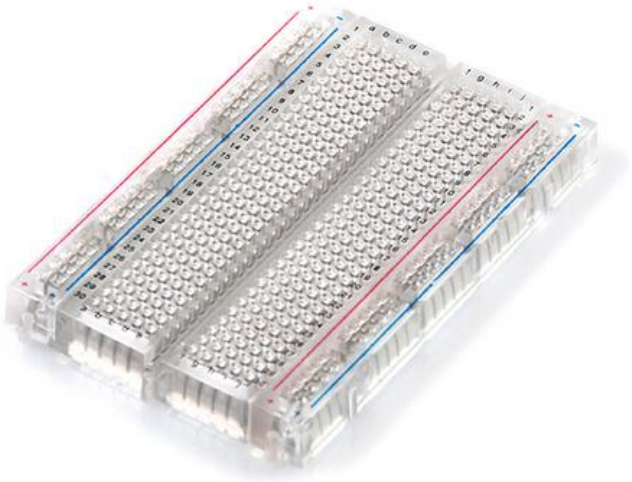


Figure 5.1.1.2: Prototyping Breadboard
Reprinted with permission from Sparkfun.com[3]

Prototyping Platform - The Breadboard:

To construct a prototype we need something all the components can stand on. A breadboard is commonly used as a base for prototyping electronics. What is great about breadboards is that is does not require you to make soldering connections. This allows for a fast and convenient way to interchange parts and easy to isolate for debugging your circuits. Breadboard can also be reused after you finish your prototyping. Figure is the Breadboard Clear Self-Adhesive from Sparkfun. It has 2 power buses, 30 columns, and 10 rows. That is a total of 400 tie in points. Pins are standard 0.1" and two sets of five rows are spaced 0.3" apart. This spacing allows for DIP packages to fit on to the board. Furthermore, this board accepts wire size from 29-20 AWG [3].

Breakout Boards:
Breakout Boards are very popular in the prototyping world. It is pretty much what the name applies, take a electrical component and all its wirings, and "breaks out" each of the wiring terminals so that can easily accept a hook-up wire from another component. These "break outs" end up being on design PCB boards that primary open the pin outs. If you look at the sensors section of this report you will find that most if not all our sensors are breakout boards. That is so we can prototype our project in a timely manner. These boards are just for prototyping, the actual custom PCB will be a single board with all the chips and components on it [3].

5.1.1.3. Selecting PCB Prototyping Company

PCB prototyping is important part for our custom designed PCB. We are using CADSoft Eagle software for our custom design circuit. As we mentioned earlier in the custom PCB design part, we will build our own circuit depending on our

project requirement. Our reference board contains lots of features but we will only extract the features that related to our project requirement; as a result we need to build our own compact PCB where we will integrate all of our sensors and external device.

For PCB prototyping we have selected Elelment14 among many PCB prototyping providers for a number of reasons. One of the reasons is the software we are using. Eagle professional is a very powerful PCB design software which is available in our lab for senior design. Moreover, all the sensors and components we have selected come with Eagle supported files and Eagle have a built in feature that allow us to make a components list easily and order directly to Element14 website.

Element14 are one of the biggest PCB prototyping service providers with lots of features. Some of the services they provide are given below.

- PCB Prototyping
  - PCB Fabrication Service: Manufacturing the PCB to specified specifications
  - PCB Assembly Service: Soldering electronic components to the PCB

Element14 are partner with many leading company in fabrication and assembly service with years of experience and lots of supports for end user. We are listing bellow few of the company in different fields working with Element14

Few partners of Element14

- PCB Fabrication Service
  - Sunstone Circuits: With 40 years of experience in manufacturing innovative and reliable PCB solutions, Sunstone Circuits has a an on-time delivery rate exceeding 99%.
  - Pentalogix : A provider of full range PCB fabrication services that range from single layer PCBs with a free DFM review to full service Mil-Spec & ITAR complaint boards.
- PCB Assembly Service
  - PCB Assembly Express: With state-of-the-art assembly plants PCB Assembly is able to handle all types of PCB assembly, from basic thru-hole PCB assembly to standard surface mount PCB assembly to ultra-fine pitch BGA assembly.
  - Screaming Circuits: They will assemble virtually any component onto virtually any PC board. Quickly putting parts onto small numbers of PC boards is their specialty.

Now we are listing some of the features from Element14's partner that are very important feature for our PCB.

PCB Fabrication Features

- Quick turn (1-2 days)
- No minimum orders
- Easy web upload
- Free technical assistance
- Mil spec & ITAR compliant boards
- Wide range of Board Materials Available
- Single sided to high count multi-layer boards

In summery we can say our PCB design software Eagle has some integrated features to select Element14, they also have some experienced partner, some features such quick turn in 1 to 2 days, no minimum order requirement, easy web upload, free technical support. So compared to cost effectiveness and features with other PCB prototyping company we have chosen Elemnt14. Figure 5.1.1.3.1 shows the custom board designed in EAGLE, while Figure 5.1.1.3.2 shows the finished, manufactured board.

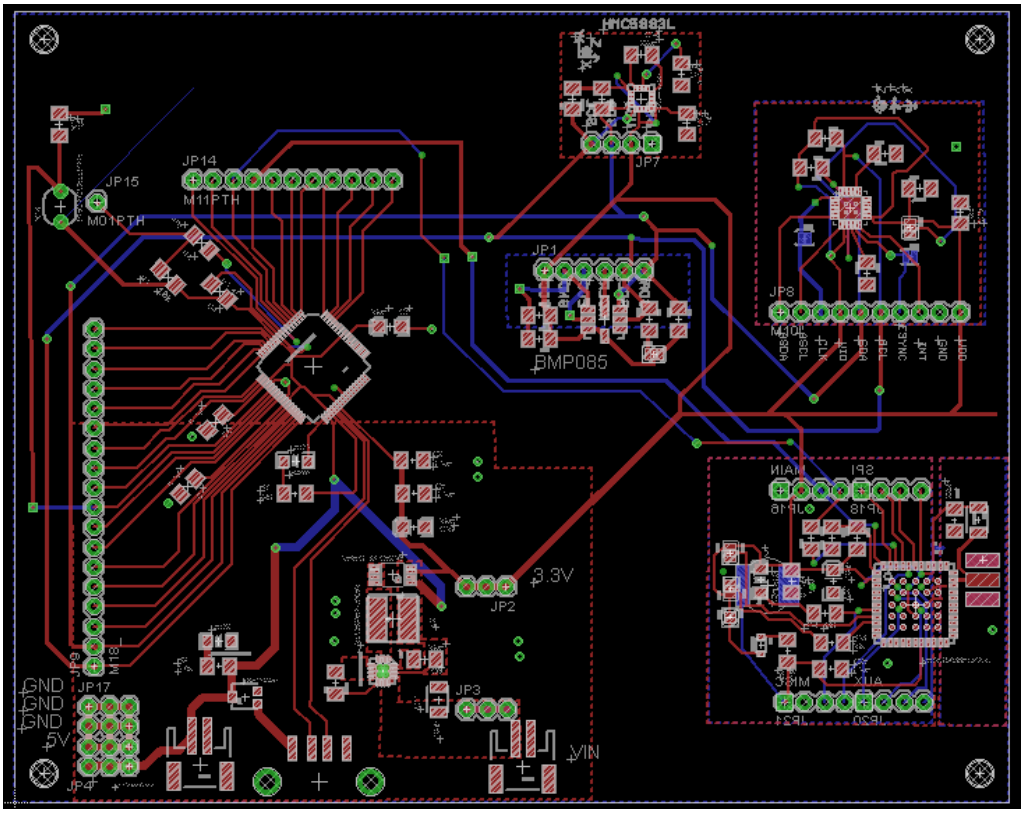


Figure 5.1.1.3.1: Custom Circuit board in EAGLE

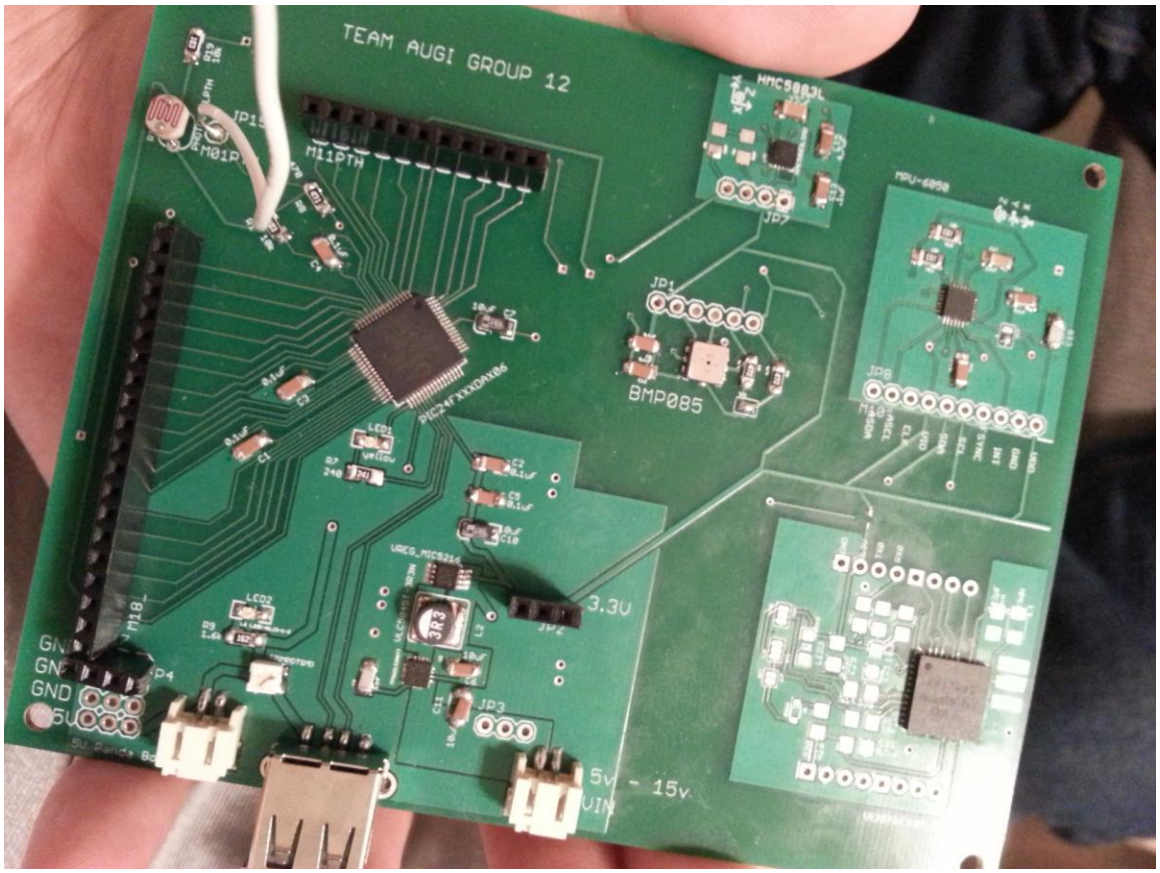


Figure 5.1.1.3.2: Finished Circuit Board. Manufactured from EAGLE design.

5.1.1.4. Prototyping Power Supply

During the prototyping stage of this project, a different source of power will supply the project. Instead of the lithium batteries, which will be used after the prototyping stage, a 9V dc battery or other source will be used. The reason behind this is because recharging the lithium batteries after use will drain the battery life. With each recharge, lithium batteries can hold a smaller charge then before. Therefore it is preferable to use an alternative power source. Regardless of our source, either a switching regulator or linear regulator is needed [24].

Linear regulators:

Linear regulators are very popular and can be found almost every low power device. They are fairly cheap and simple to implement, however how do they compare with switching regulators? The way linear regulators work is they take the difference of the input and output voltage and convert it into heat. The larger the difference between the input voltage and output the more heat is generated and more energy is lost. Therefore, linear regulators are actually very inefficient, with efficiencies about 40%. These not only drains the batteries, it makes the device very hot [24].

Switching regulators:
Switching regulators, like linear regulators, maintain a steady voltage but are far more efficient. Even with high input voltage, switching regulators can handle loads over 200mA, something linear regulators cannot do. The way switching regulators work is that they take small amounts of energy at a time from the input source; this results in efficiency around 85% or higher.

5.1.2. Project Total Part List

Component Part	Part Number
Barometric Pressure Sensor	BMP085
Camera Sensor	PB-CAM5-01
Camera Adaptor	PB-CAME-01
Charger	MCP73843-410
Inertial Measurement Unit	MPU-6050
IOIO Board	DEV/10748
GPS	Venus638FLPx
GPS Antenna	VTGPSIA-3
Lithium Ion Battery Charger	MCP73843-410
Magnetometer	HMC5883L
Photocell	SEN-09088
Polymer Lithium Ion Battery 6Ah	PRT-08484
Status LEDs Triple Output LED RGB	SMD COM-07844
Step-Up Breakout	NCP1402-5V

5.1.3. Housing

The focus of this project is on PCB Construction and application programming; nonetheless we built a PlexiGlass container that can hold all of the electrical components, including the screen and battery. The simple design is laid out in 5.1.2.1 and meets the basic needs of this project.

In this design, the circuit components are mounted in a stacked manner. This is done in order minimize the square area needed to house the components in the X and Y plane. This does lead to a perceptible increase in thickness in the tablet, but this is not considered as a serious issue. The design does allow for a power button and 5 push buttons (to represent the buttons found on normal Android smart phones) as is shown in the final product image Figure 5.1.2.2 and Figure 5.1.2.3.

Space has been allocated to the battery that will power the unit along the right hand side. The GPS antenna has been mounted in the upper left hand corner of the device. Underneath the main touch screen sits two circuit boards, one being the Pandaboard, and the other being the expansion board to connect a screen to

it. The third circuit board, which is the custom sensor board is positioned below the screen for easy viewing.

The final dimensions of the box are 8.5in x 11in x 2in. The Plexiglass is 1/4in thick and chemically bonded together forming an extremely sturdy device.

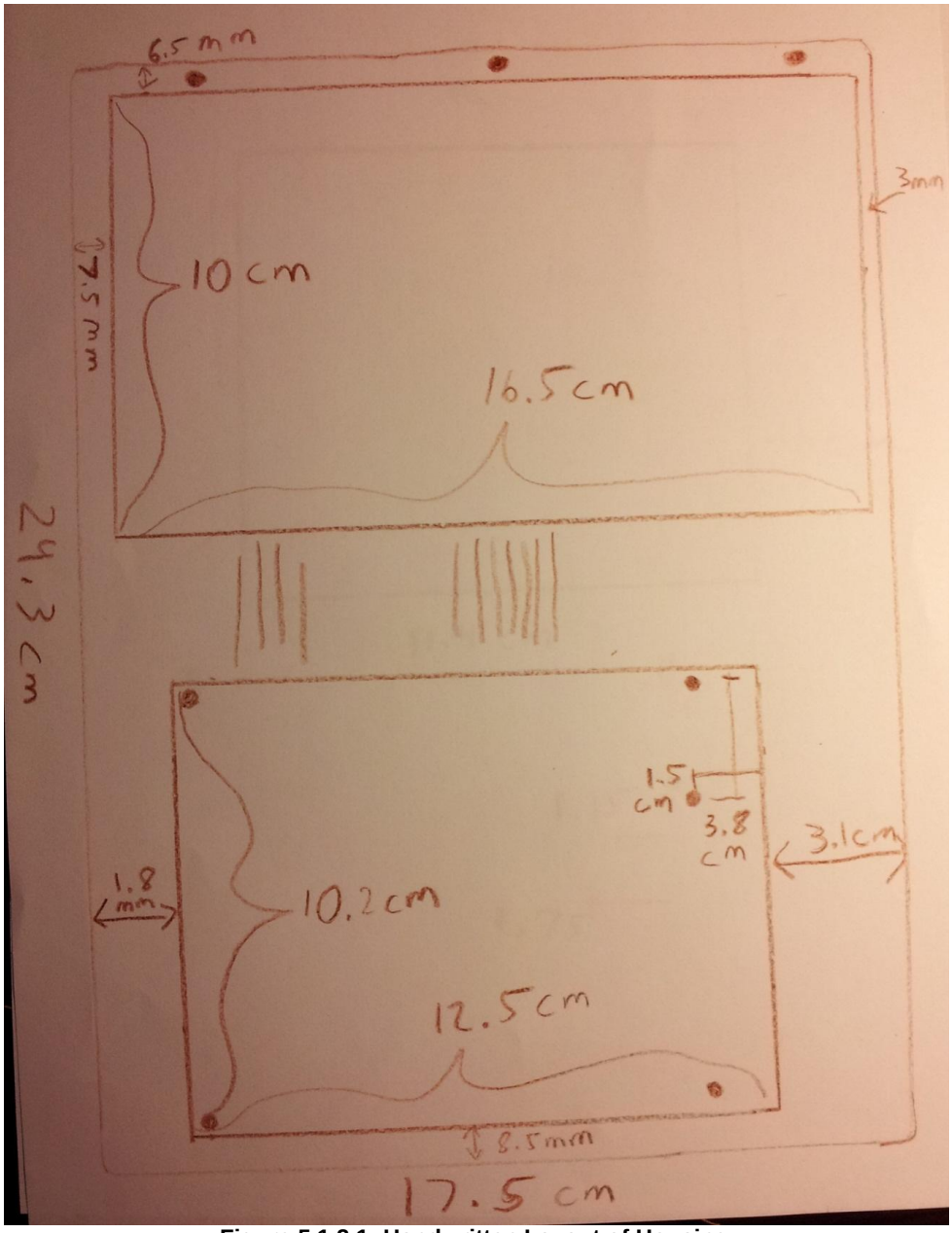


Figure 5.1.2.1: Handwritten Layout of Housing

Figure 5.1.2.2: Front view of the Tablet Housing

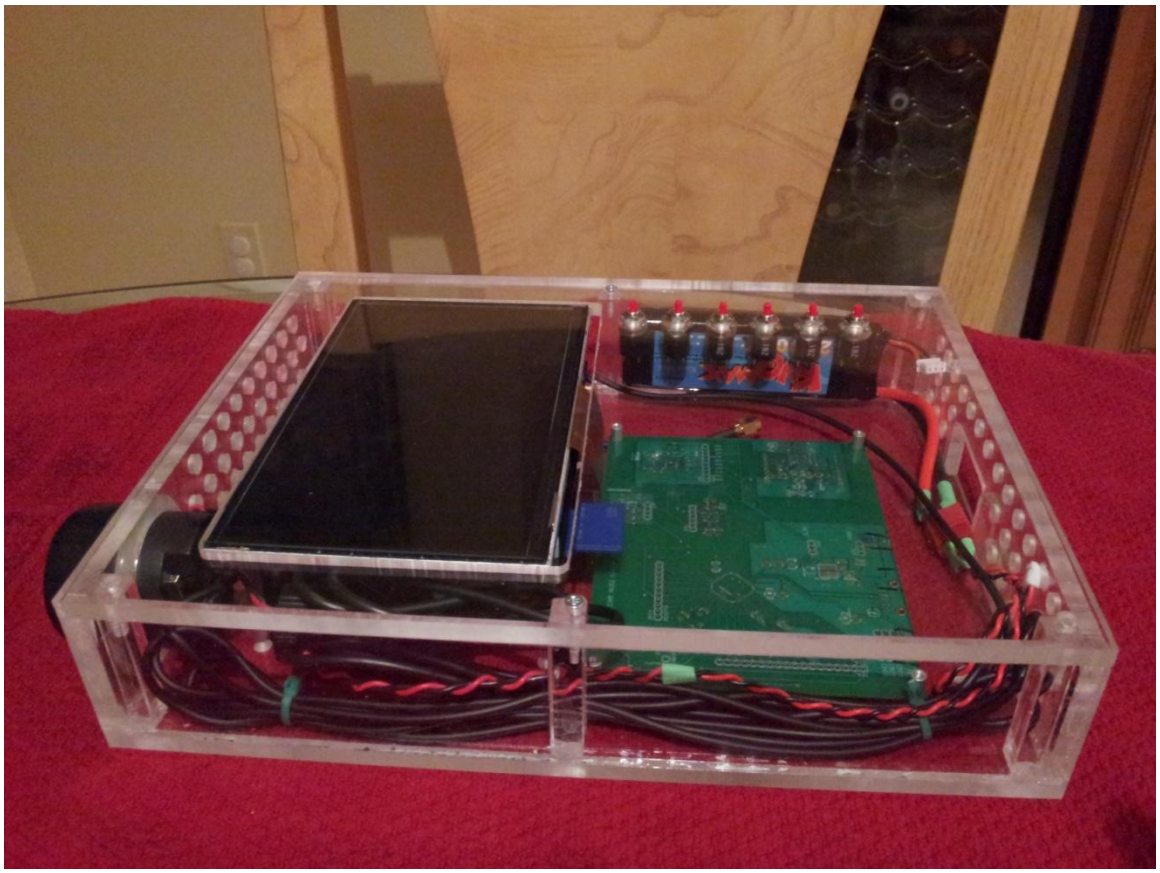


Figure 5.1.2.3: Side view of the Tablet Housing

5.2. Software Coding

5.2.1. Project Development Lifecycle

Project AUGI is venturing into new territory. With new territory come unknown questions and problems that may have and even more unknown timeframe before they are resolved. When boldly going into new territory, software developers and hardware alike need a plan or proposed lifecycle to which they can model their efforts upon. A development lifecycle is essential to the breaking ground when it comes to new technology, and because of this there have been many proposed Development Lifecycle models tried for different applications [25].

Project AUGI has chosen to use the Transformational Model to which we will model our development lifecycle off of. The Transformational Model tries to reduce the opportunity for error by eliminating many of the major development steps. The transformational development process applies a series of transformations to change a specification to a deliverable system. This model will work perfectly for Project AUGI, being that we have never done a project of this magnitude and none of our group members have done extensive work with

Android. With these deficiencies, to map out a project of this size for the first time in a specifications sheet might be troublesome if there is no room for transformation of the product specifications. Transformations include: changing the data representations, selecting algorithms, optimizing, compiling.

This projects transformation will most likely include utilizing what algorithms Google already has in place as far as routing and user interface is concerned and modifying/optimizing them to suit our needs [25].

The figure below shows an example of Transformational Model displayed graphically. The process is as follows.

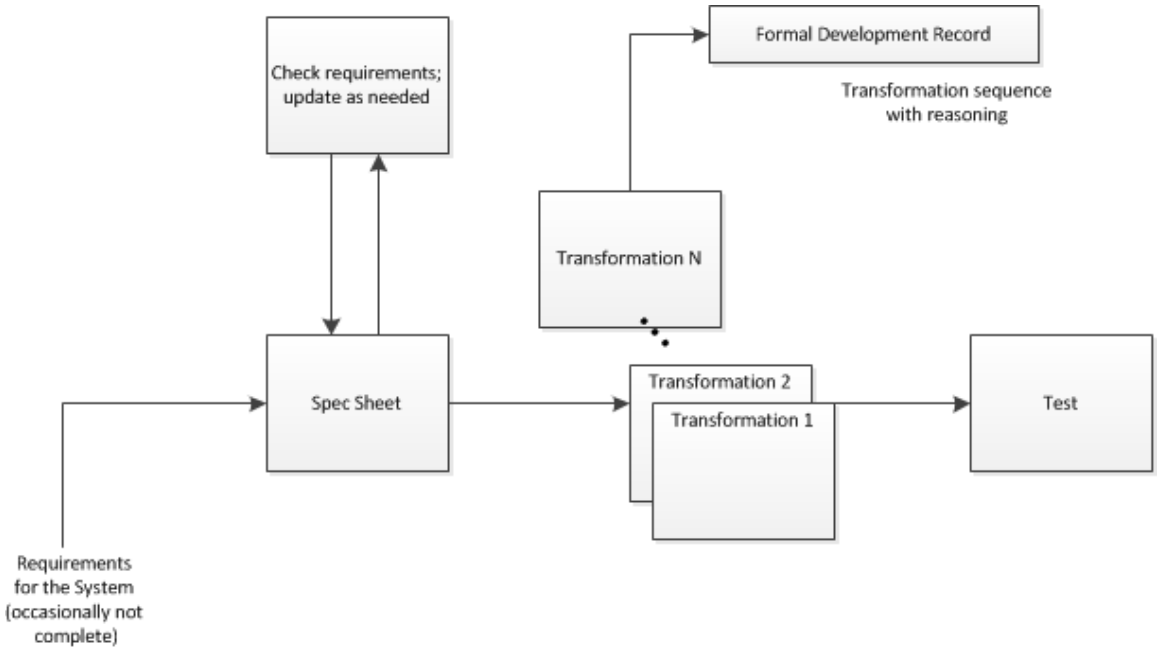


Figure 5.2.1.1: Project Transformational Model

5.2.2. Project Development Architecture

An architectural style is also known as an architectural pattern. A software-based architectural style is a basic set of fundamentals or rigid designs that provide a hypothetical framework for a system. Defining an architectural style is important when reaching road blocks or problems pertaining to design as they can map out the generic procedure for solving them.

The Architecture that we will be utilizing within our project is called a Pipe-and-Filter model. The pipe-and-filter model is attained by receiving input data from a source and the manipulating and converting this data into something that can be utilized in the program. The concept of a pipe is basically a connector or roadway to transfer the data from one filter to another, eventually traversing it to

the program termination. Filters are the components that do the data manipulation to utilize for our application.

In terms of the software version of project AUGI, the hardware being built will be feeding data in from the integrated sensors. These sensors will include: gyroscope, magnetometer, barometer, ambient light sensor, and GPS. With the information fed to the operating system, the proposed algorithms in our design and the system delivered algorithms from Google should act as the filters for our development architecture[25].

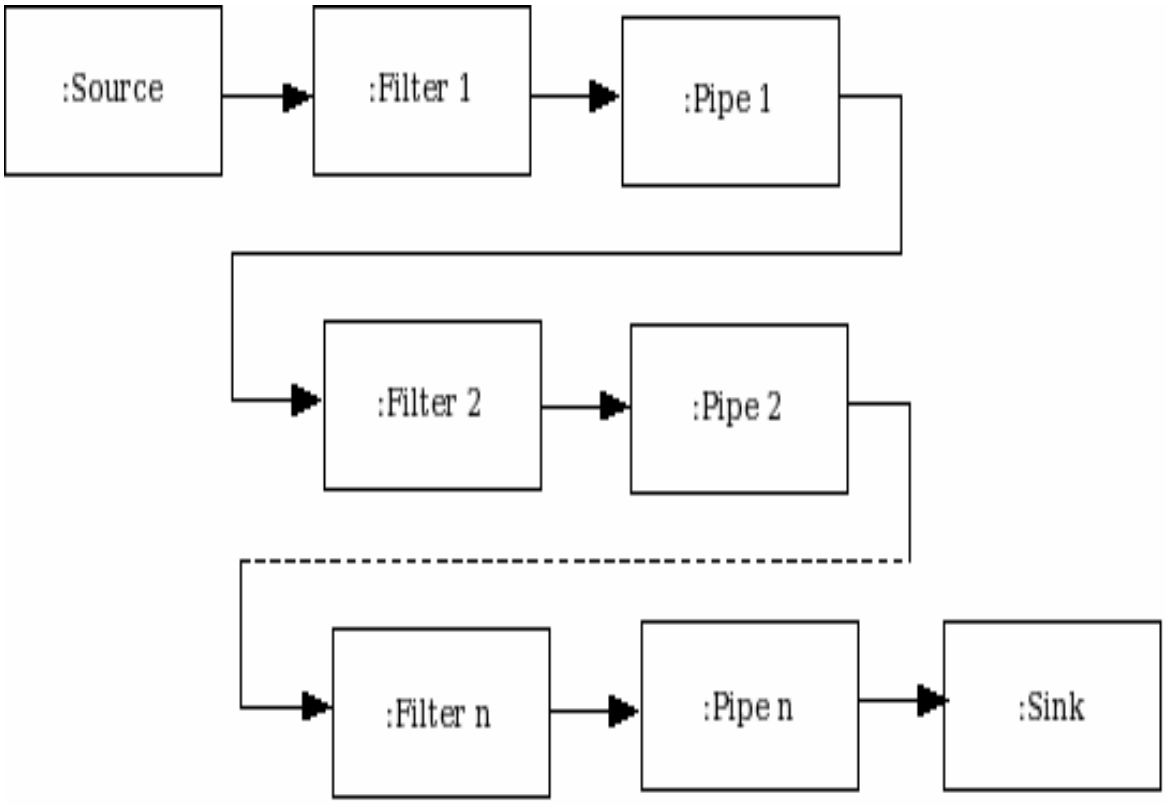


Figure 5.2.2.1: Project Development Architecture

6. Project Prototype Testing

6.1. Hardware Testing

In testing our hardware we chose to consider some real life situations such as navigating around campus from one building to another. We will pick several different buildings around campus, and select different destinations. BY doing so we will be able to see how ell waypoints are plotted to each destination. These waypoints will be viewable in the AUGI Navigation view along with other detailed sensor data, in order for us to get a close and detailed understanding of how the

device is operating. In this way we will test all of our hardware, and sensors as they are all needed to successfully navigate around campus. After passing all of the testing processes, the project will be able to function as expected meeting all of the required technical issues.

We are using

- LCD capacitive touchscreen,
- Gyroscope,
- Accelerometer,
- Photometer,
- Camera,
- IOIO board,
- PandaBoard ES,
- Expansion board,
- GPS,
- Battery pack.

6.1.1. Capacitive LCD Touch Screen

We tested the LCD display by connecting it to the appropriate level of power supply just to see if it turns on. If the LCD lights up then we can perform the next test.

Capacitive touchscreen is very sensitive to system noise, to eliminate system noise we used a battery pack. Different variables such as the light source, the viewing angle, and the system's graphics card can have a significant effect on an LCD display's performance. To maintain consistent and ideal viewing conditions, all testing was performed in an appropriate lighting environment, which helps to preserve accurate color perception. Additionally, the CLD display was adjusted to perform optimally, based on contrast settings recommended by default [1] and the input provided by the ambient light sensor.

6.1.2. Camera and Adapter

The specifications given in the design are require the testing o the camera as well as the camera adaptor. The camera and the adapter was used with the expansion board and the PandaBoard ES before integrating to the project separately. The built in apps for Android that came on the Pandaboard for supporting the camera were used to ensure that it operated as intended. This simply involved turning the camera on and making sure that it could properly take pictures, and show a live video stream to the user.

6.1.3. PandaBoard ES

The Pandaboard ES was tested before it was integrated with the IOIO board. We installed the Android operating system on the built in SD card location and tested all the required components for our intended system. The board came with a number of test applications, such a simple app to test the touch screen, run system diagnostics, and use the internet.

Debug

- JTAG (See Figure 6.1.3.1)
- UART/RS-232
- 2 status LEDs (configurable)
- 1 GPIO Button
- Sysboot switch available on board

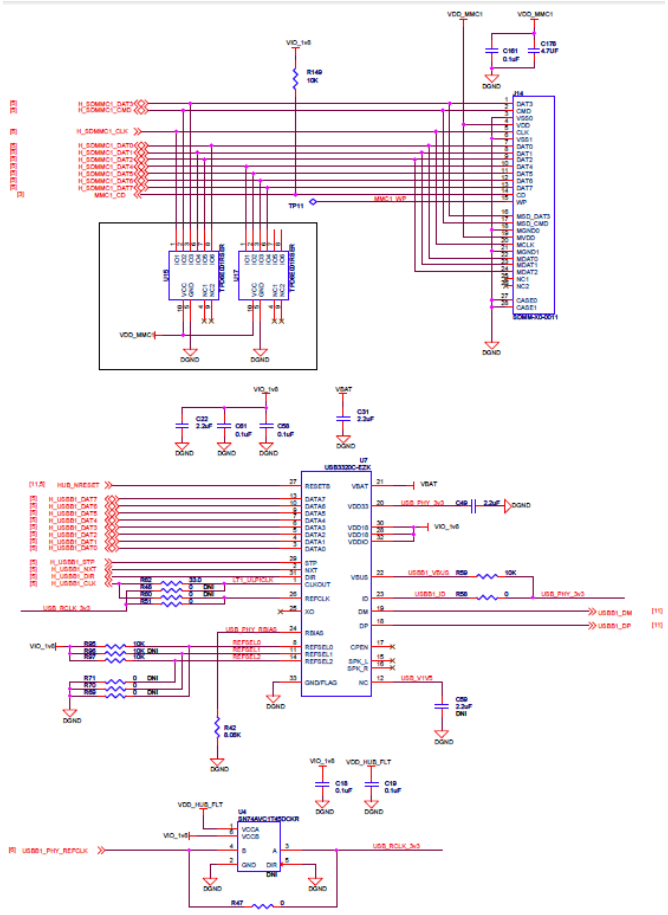


Figure 6.1.3.1: Pandaboard OMAP4460 Debug Port
Reprinted with Permission from Pandaboard [1]

6.1.4. IOIO Board

Basically while we were testing the IOIO board, we also tested all of the sensors such as the gyroscope, accelerometer, barometer, and charging circuit. We also tested connecting devices with the IOIO board which is in our Pandaboard ES system. For connecting devices with the IOIO board we had to consider the power requirements of the IOIO board since it has some specific requirements with regards to the maximum power draw it can sustain during operation [20].

Limiting Charge Current:
It is important to realize that limiting charge current inevitably decreases voltage on the USB VBUS line. We know according to the USB specification, decreasing VBUS under a certain threshold below 5V is illegal. It will not damage our Android device in any way to do so, but at a certain point our Android device will stop sensing that it is connected to the IOIO. To make things a bit more interesting, the exact point where this happens varies from device to device, and varies slightly depending on the battery charge level [20].

The simplest way to adjust this for a specific device is by starting from full charge current (trimmer all the way clockwise), and with the Android device connected, slowly turn the trimmer counter-clockwise, keeping an eye on the battery icon on the screen. When the charge icon (flashlight icon over the battery icon) disappears, we have choked the current too much. Turn it back a notch or two to be on the safe side. When the Android devices battery discharges substantially, we might have to increase a bit further in order to maintain a stable connection. In the end we decided to leave the trimmer at full charge to ensure there would be no shortage of power supplied to the Pandaboard.

6.1.5. Gyroscope

While testing the system we ensured to keep the following Absolute Maximum ratings for the gyroscope. Stresses above those listed as “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these conditions is not reconmended. Exposure to the absolute maximum ratings conditions for extended periods may affect device reliability.

Parameter	Rating
Supply Voltage, VDD	-0.5V to +6V
VLOGIC Input Voltage Level	-0.5V to VDD + 0.5V
REGOUT	-0.5V to 2V
Input Voltage Level (CLKIN, AD0)	-0.5V to VDD + 0.5V
SCL, SDA, INT	-0.5V to VLOGIC + 0.5V
CPOUT (2.1V ≤ VDD ≤ 3.6V)	-0.5V to 30V
Acceleration (Any Axis, unpowered	10,000*g* for 0.3ms
Operating Temperature Range	-40°C to +105°C
Storage Temperature Range	-40°C to +125°C
Electrostatic Discharge (ESD) Protection	1.5kV (HBM); 200V (MM)

Figure 6.1.5.1: Absolute Maximum Ratings

6.1.6. GPS Module

While testing the GPS module we gave attention to the following information that could effect the reliability, performance

- Reliability
  Condition：
  Temperature: 40±5℃
  Load: DC=5V±0.5 V
  Quantity: 2000pcs
  Sustained Time: 480h
- Environmental Specifications
  Condition：
  Post Environmental Tolerance
  Temperature range 25±3℃
  Relative Humidity range 55~75%RH
  Operating Temperature range -40℃~+85℃
  Storage Temperature range -40℃~+100℃
- Moisture Proof
  The device should satisfy the electrical characteristics specified above after exposed to the temperature 40±2℃ and the relative humidity 90~95% RH for 96 hours and 1~2 hours recovery time under normal condition.
- Vibration Resist
  The device should satisfy the electrical characteristics specified above after applied to the vibration of 10 to 55Hz with amplitude of 1.5mm for 2 hours each in X , Y and Z directions.
- Drop Shock

The device should satisfy the electrical characteristics specified above after dropping onto the hard wooden board from the height of 30cm for 3 times each facet of the 3 dimensions of the device. Which is a feature of the Module VTGPSIA-3 but we will skip.

- High Temperature Endurance
  The device should satisfy the electrical characteristics specified above after exposed to temperature 80±5℃for 24±2 hours and 1~2 hours recovery time under normal temperature.
- Low Temperature Endurance
  The device should also satisfy the electrical characteristics specified above after exposed to the temperature -40℃±5℃for 24±2 hours and to 2 hours recovery time under normal temperature.
- Temperature Cycle Test
  The device should also satisfy the electrical characteristics specified above after exposed to the low temperature -25℃ and high temperature +85℃ for 30±2 min each by 5 cycles and 1 to 2 hours recovery time under normal temperature.

6.1.7. Power Supply

Rechargeable Battery Pack

The power supply plays significant roll on the overall performance of the tablet, consequently while testing the battery pack we tested the following criteria.

Charge

1. Charging current should be lower than values that recommend below. Higher current and voltage charging may cause damage to cell electrical, mechanical, safety performance and could lead heat generation or leakage.
2. Batteries charger should charging with constant current and constant voltage mode;
3. Charging current should be lower than (or equal to)1C5A;
4. Temperature 40 degree Celsius is preferred when charging;
5. Charging voltage must be lower than 8.25V.

Discharge

1. Discharging current must be lower than (or equal to)2C5A;
2. Temperature 60 degree Celsius is preferred when discharging;
3. Discharging voltage must not be lower than 7.0V.

Over-discharge

It should be noted that the cell would be at an over-discharge state by its self-discharge. In order to prevent over-discharge, the cell shall be charged periodically to keeping voltage between 7.0-8.0V.

Over-discharge may cause loss of cell performance. It should be noted that the cell would not discharge till voltage lower than 6.5V.

6.1.8. GPS Accuracy

Our senior design project is “Augmented Reality Tablet” which activities, performance, reliability are significantly depends on GPS sensor’s accuracy; consequently, we considered GPS accuracy as important criteria for the system. We had to deeply analyze GPS accuracy to confirm our expected performance of the system as accurate as possible as well as reliable in any possible conditions.
The **Global Positioning System** (**GPS**) is a space-based satellite navigation system that provides location and time information in some scientific way, anywhere on or near the Earth, when there is a straight line of sight or path to four or more GPS satellites.
GPS is now widely accepted as significant component or system for many applications for daily use. There are some factors to consider when we deal with the GPS system but not limited to mentioned factors only. Those factors place some limitation when we calculate some GPS data and play a negative roll for GPS system accuracy.

Most observed factors affecting the accuracy of GPS:

- GPS Technique employed (i.e.: Autonomous, WADGPS, DGPS, RTK, etc.)
- Atmospheric errors
- Surrounding conditions such visibility or obstacles issues.
- Number of satellites in view.
- Satellite Geometry (HDOP, GDOP, PDOP etc.)
- Distance from Reference Receiver(s) (non-autonomous GPS ie: WADGPS, DGPS, RTK)
- Ionosphere related conditions
- Troposphere related conditions
- Clock timing and receiver rounding errors
- Quality of GPS receiver

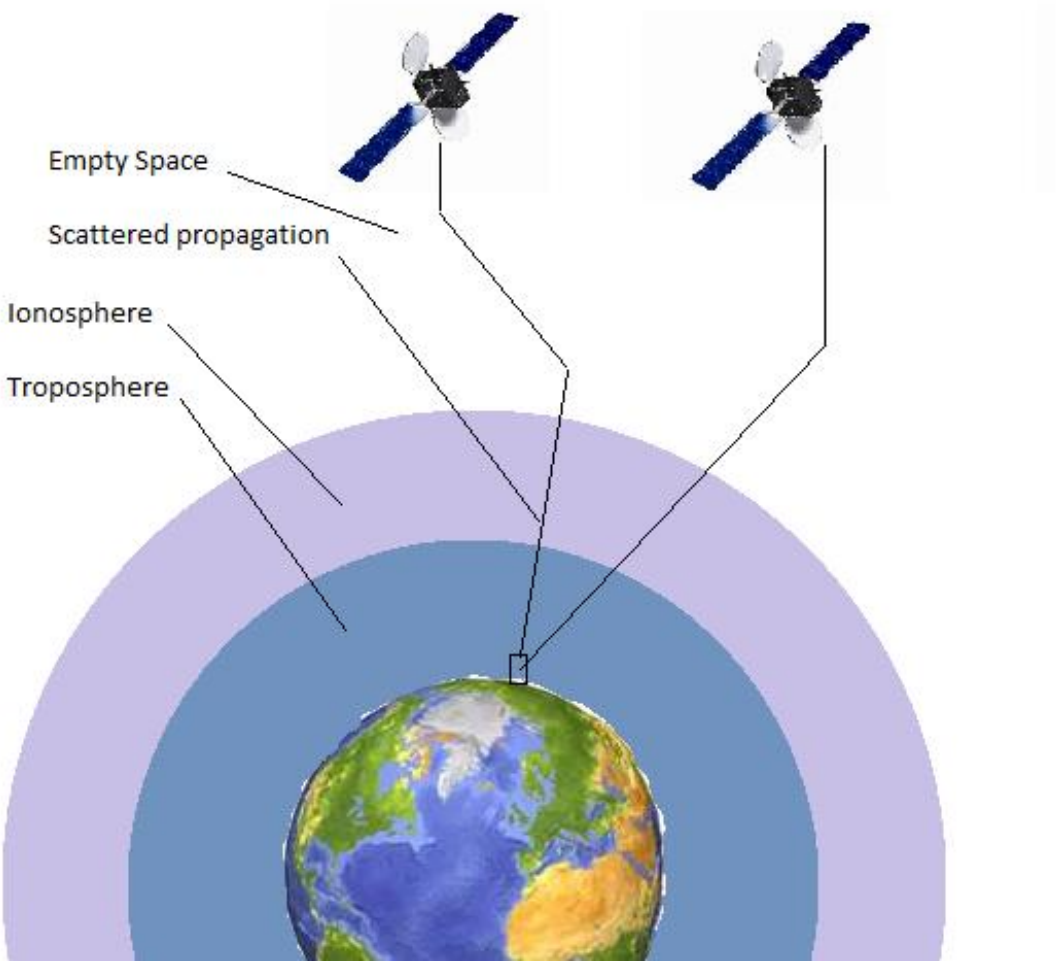


Figure 6.1.8.1: Atmospheric Errors
Reprinted with permission from Brittanica.com[38]

Summary of considerable errors

Ionospheric effects	± 5 meters
Calculation- und rounding errors	± 1.1 meter
Clock errors of the satellites' clocks	± 2 meter
Multipath effect	± 1 meter
Tropospheric effects	± 0.5 meter
Shifts in the satellite orbits	± 2.2 meter

6.1.8.1. Precision and Accuracy

We need to mention precision and accuracy since we are considering GPS accuracy significantly important in our project idea. A measurement system can be accurate but not precise, precise but not accurate, neither, or both. Precision and accuracy are often assumed to be the same thing, technically they are slightly different. Precision refers to the closeness to the mean of observations and accuracy refers to the closeness to truth.

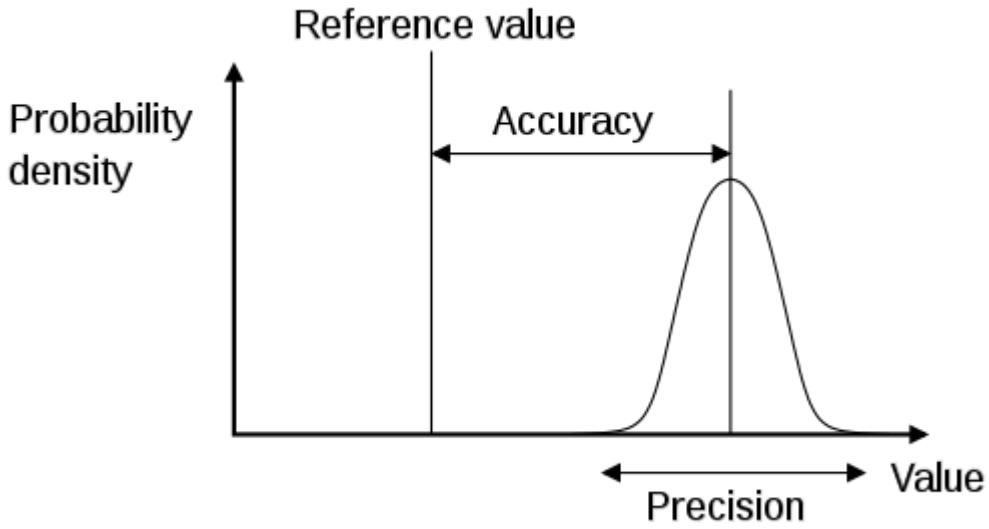


Figure 6.1.8.1.1: GPS precision graph
Reprinted with permission Britannica.com[38]

Care must be taken particularly when using differential GPS to the accuracy of the results (closeness to truth) as reference points used can and often are inconsistent with truth.

The precision or accuracy quoted by many GPS manufacturers is mostly computed using a statistic known as circular error probable (CEP) (also circular error probability or circle of equal probability is an intuitive measure of a weapon system's precision.

It is defined as the radius of a circle, centered about the mean, whose boundary is expected to include the landing points of 50 percent of the rounds

- sp = standard deviation of latitude
- sl = standard deviation of longitude

CEP = (59/100)×(sp+sl)

As we mentioned earlier CEP is the radius of the circle that will contain approximately 50 percent of the horizontal position measurements reported by the GPS receiver. This also means that 50 percent of the positions reported by related GPS will be outside of this circle. If we consider the percent rate it is big enough for accuracy problem.

Distance Root Mean Squared (DRMS) is also used to measure accuracy with the above mentioned CEP as follows

- 2×DRMS = 2×(sp×sp+sl×sl)^0.5

Standard deviation of latitude and longitude always doesn't match; consequently probability varies between 95 percent and 98 percent. In summery we can

conclude that accuracy measured by DRMS will be within limit of 95 percent to 98 percent.
Two plots are shown below (Figures 6.1.8.1.2, Figures 6.1.8.1.3), each has been created using 24 hours of data taken at 20 second intervals in the south western USA.

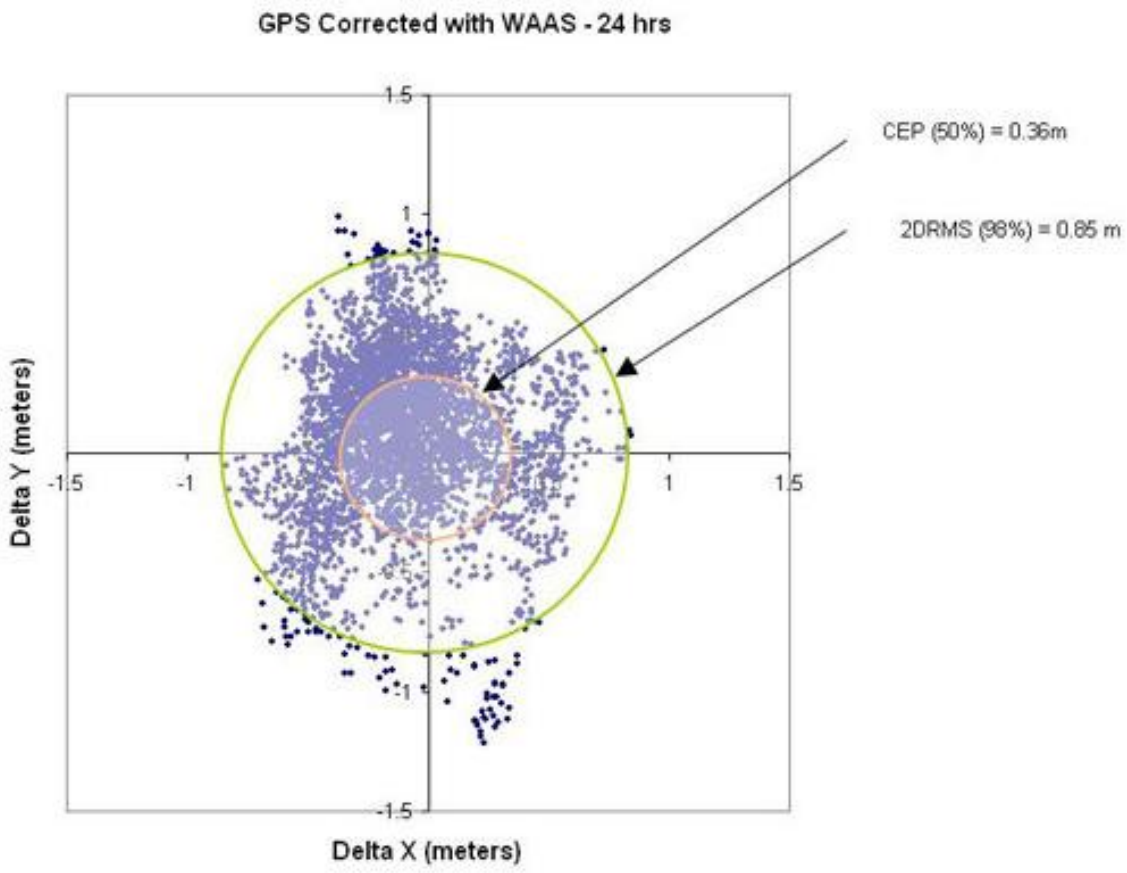


Figure 6.1.8.1.2: GPS Accuracy Correction Technique - WAAS
Reprinted with permission Britannica.com[38]

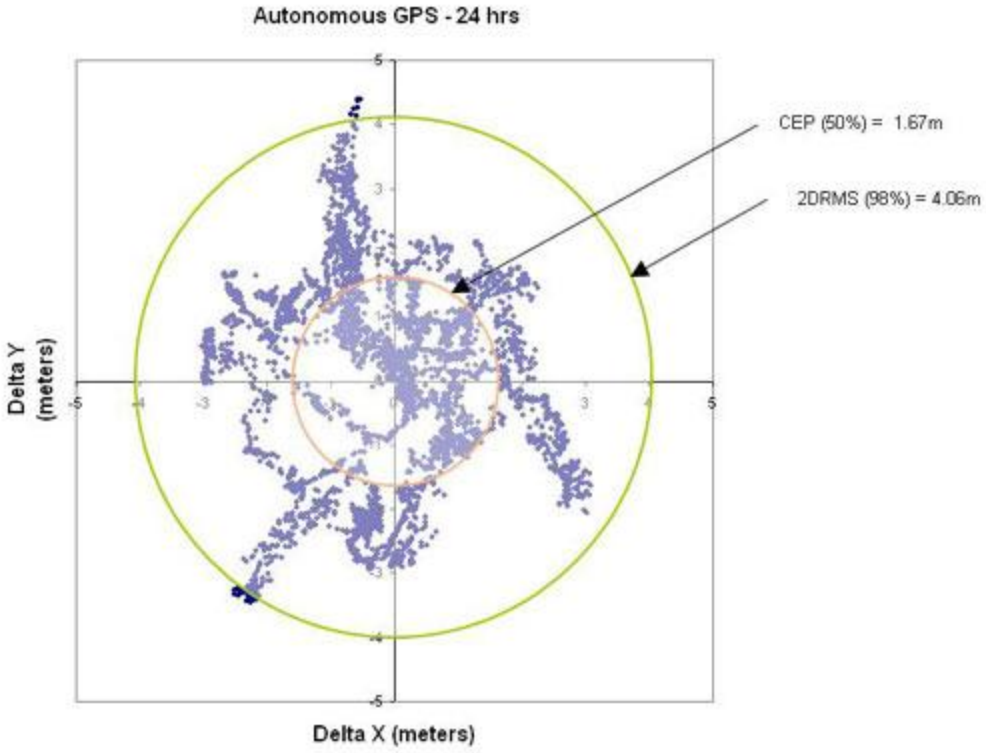


Figure 6.1.8.1.3: GPS Accuracy Correction Technique - Autonomous
Reprinted with permission Britannica.com[38]

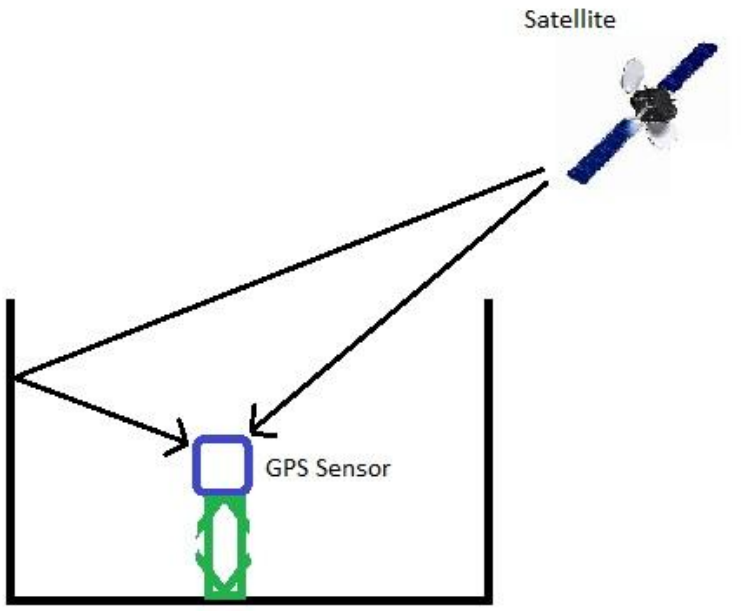


Figure 6.1.8.1.4: Direct and reflected signal from same satellite
Reprinted with permission Britannica.com[38]

Sources of error could be

- Troposphere causes some signal delay
- Ionosphere causes some signal delay
- GPS satellite position inaccuracy or Orbital inaccuracy
- SNR or Signal to noise ratio

6.1.8.2. Ideal Conditions

We decided ideal conditions for GPS sensor to be a clear view of the sky with no visible interruption from within 5 degrees. We expected the path of the satellite signal to be in clear view without any kind of visible interruption. The interruption could be any building, trees, tower, or any large obstacles. All kind of obstacles could significantly effects the GPS accuracy.

The following effects can cause inaccuracy:

- Less number of visible Satellites by sensor
- Reduced strength of satellite geometry (Dilution of Precision (DOP) values)
- GPS measurement error
- Reflected Satellite signal

Overall the system performed adequately for our needs. By establishing waypoints to certain specific intersections, and then testing when the GPS concluded we had reached the desired waypoint, we were able to get a general estimate that the accuracy of the GPS was to within less than 5 meters.

7. Administrative Content

7.1. Project Milestones

This Senior Design Project had proposed to build a tablet that will run an augmented reality navigation application. This proved to be an ambitious project because it involved both the design and construction of custom hardware, and the creation of an augmented reality navigation application from scratch. There are a lot of things that needed to be accomplished in a short amount of time, so it was very important to subdivide the project into sub-parts that can be more easily managed.

The first division was simple enough. The hardware and software portions can be separated and worked on in parallel. For the hardware, the team began with a base system composed of an Android development board, and an expansion board designed to operate with the development board. The development board houses the CPU, RAM, and I/O, while the expansion board connects a touch screen to the board.

The development and expansion boards do not have all of the hardware necessary to the project however. Particularly in the area of the onboard sensors that were needed to make the software application work. A whole host of sensors and a GPS communication chip needed to be added, leading to the design and construction of a circuit board that was connected via the USB port on the computer.

The design and construction of this board involved several phases with the first being the choosing of sensors and the GPS communication chip that went into the board. The design team then needed to work out how to integrate them and communicate with them via the main development board. After that, designs had to be drawn up and ready for inclusion in the first design report due at the end of the Fall 2012 Semester.

For the Spring 2013 Semester, the board needed to be manufactured as quickly as possible so that testing and verification could begin. Like any design project there was a need for a lengthy period of testing, tweaking, and rebuilding of the board in order to iron out several issues arose during development.

There were also a number of other hardware projects that needed to be accomplished, such as the design of the housing which encloses all of the internal computational components, and the integration of the battery that powers the system. This work proceeded in parallel with the board work since none of them were really reliant upon the other.

As such for the Fall 2012 Semester, the hardware milestones we achieved were as follows: 1. Research of system components and choosing exact parts; 2. Completing the design of the board that integrates the parts together; 3. Designing the communication protocols that these parts will use to communicate with the development board via a shared USB interface; 4. Researching the battery components to integrate into the board; 5. Completing the designs for battery pack, and 6. Designing the housing for all internal components (See Table 8.2.1).

As for the Spring 2013 Semester, the hardware milestones we achieved were as follows: 1. Completion of the initial versions of all hardware components; 2. Complete an extended period of testing to ensure required performance metrics are met; 3. Completion of the final device revisions; 4. Complete hardware testing to ensure proper operation and meeting expected performance metrics (See Table 8.2.2).

With regards to the software the main focus was on the application development. This application had two main areas of development. One was the navigation aid feature, which provides visual cues to users, to help them navigate to their

destination. The other was the map where custom landmark identifications could be highlighted to the user.

The navigation aid feature was broken down into several sub-components. The first was tracking the user's current location and facing. The code for this portion feeds off of signals from the GPS, and compass. It also pulls data from the Google Maps API, in order to state exactly where the user is located. The next portion needs to pull data from the gyroscope and accelerometer to determine the tablets position and orientation, in order to take the users position data, and calculate what the user is looking at through the integrated camera. This operates without any input from the camera. The last portion draws the visual aids to the screen representing the summation of calculated data from the previous two portions.

Given these programming portions, the milestones for the software work for the Fall of 2012 were as follows: 1. Completion of research into the calling and use of the Google Maps API; 2. Completion of research into the needed class structure and algorithms for both portions of the software application; 3. Design Unified Modeling Language (UML) charts to demonstrate the high level operations of the software (See Table 8.2.1).

The milestones for the Spring of 2013 were: 1. Completion of all software classes up to Alpha version levels; 2. Thoroughly test the Alpha build to determine performance issues against the metrics and programming bugs; 3. Complete the Beta version of the of application; 4. Thoroughly test the Beta version to determine performance issues and programming bugs; 5. Complete the final version of the application and 6. Test the final version of the application (See Table 8.2.2).

These milestones were largely achieved during the project.

7.2. Project Development and Construction Timeline

When working out a viable plan for this project there were a number of important ideas that needed to be kept in mind. The first is that it cannot be underestimated how important and how long testing and bug fixing can take. It is a common mistake to allocate only a small amount of time to this very vital process, seemingly thinking that the initial version of the product will be in near perfect working order. Given that this navigation aid project will involve both the design and construction of new hardware, and creating an application from scratch; the likely hood that there will be a lot of problems to work out is very high.

An extension of the idea mentioned above is that the project needs to ramp up as quickly as possible. First the research and then construction work needs to operate at a high level from the very beginning. A project of this scale will require

every bit of allocated time. There is a tendency for projects to slowly ramp up, then time passes quickly, and before it is realized, there is little time left. This causes "crunch" in the last 10% of a projects allocated time, where there is an al out effort to finish on time.

To avoid this problem the general goal will be for this project to be to be 80% complete with research, design and construction with only 50% of the allocated time having passed. Research and design will be performed in the Fall Semester 2012. The goal will be to have all research complete, a test bed for research purchased and running, and to be in the process of creating the design schematics by mid semester. This will allow sufficient time to finalize the design, and allow a full four weeks to write the minimum 120 pages needed for the final design document due at the end of the Fall Semester 2012.

For the Spring 2013 Semester it will be vital to have a running prototype as soon as possible in order to allow performance testing and provide feedback on how well the project is progressing. This will also mean that there will likely need to be a redesign with a follow up re-testing, in order to work out un-anticipated issues. It will thus be important to ensure most of this work is completed midway through the allocated time. The goal will be then to complete two construction and testing cycles by the midpoint of the semester. This will allow sufficient time after the midpoint to refine the design, and to do further testing to prove that the tablet meets or exceeds the desired performance metrics.

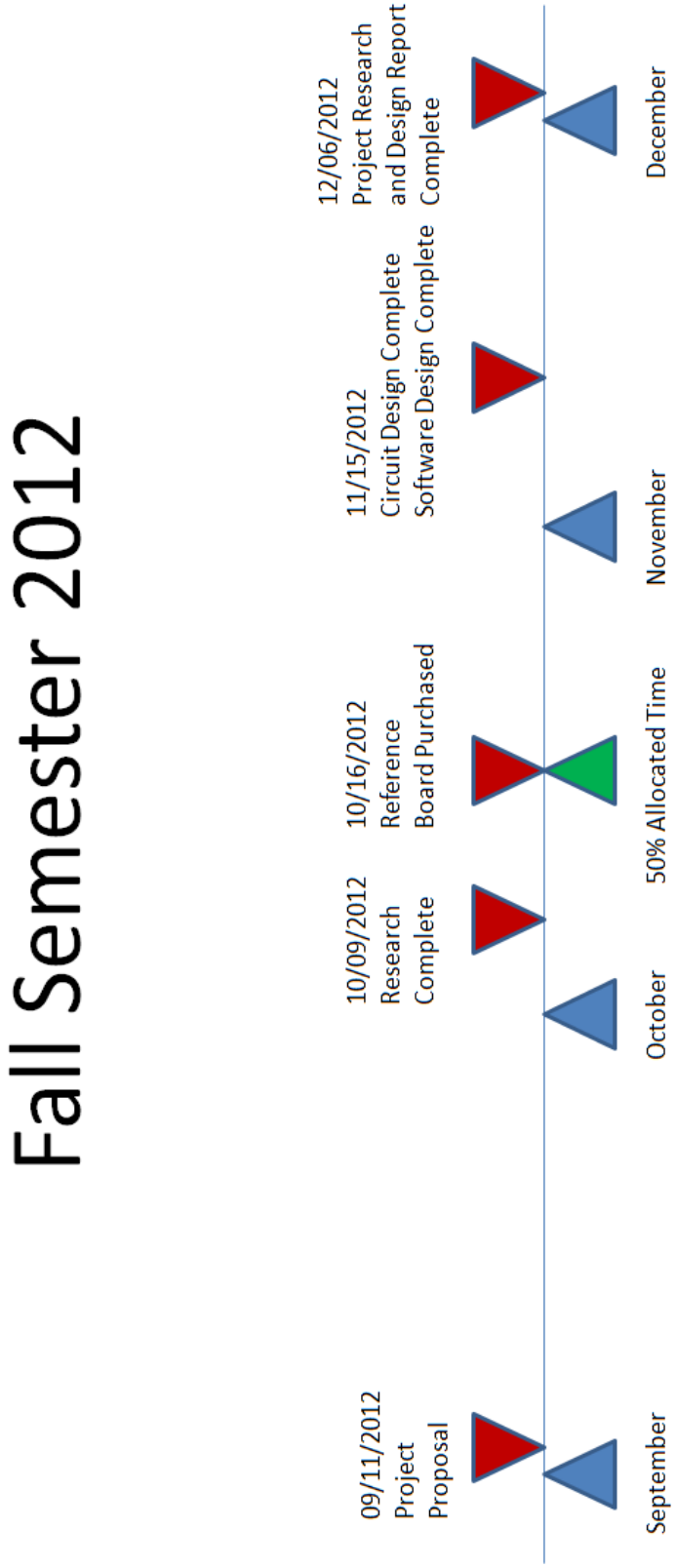
By keeping to the 80% complete at 50% timeframe rule, this project will have sufficient time to correct for any un-anticipated problems that may arise. It will also allow the design team to possibly add extra features, or refine the design to exceed the desired minimum performance metrics. What follows below is a table laying out specific milestones, and their expected completion date broken up in the Fall 2012 Semester and the Spring 2013 Semester.

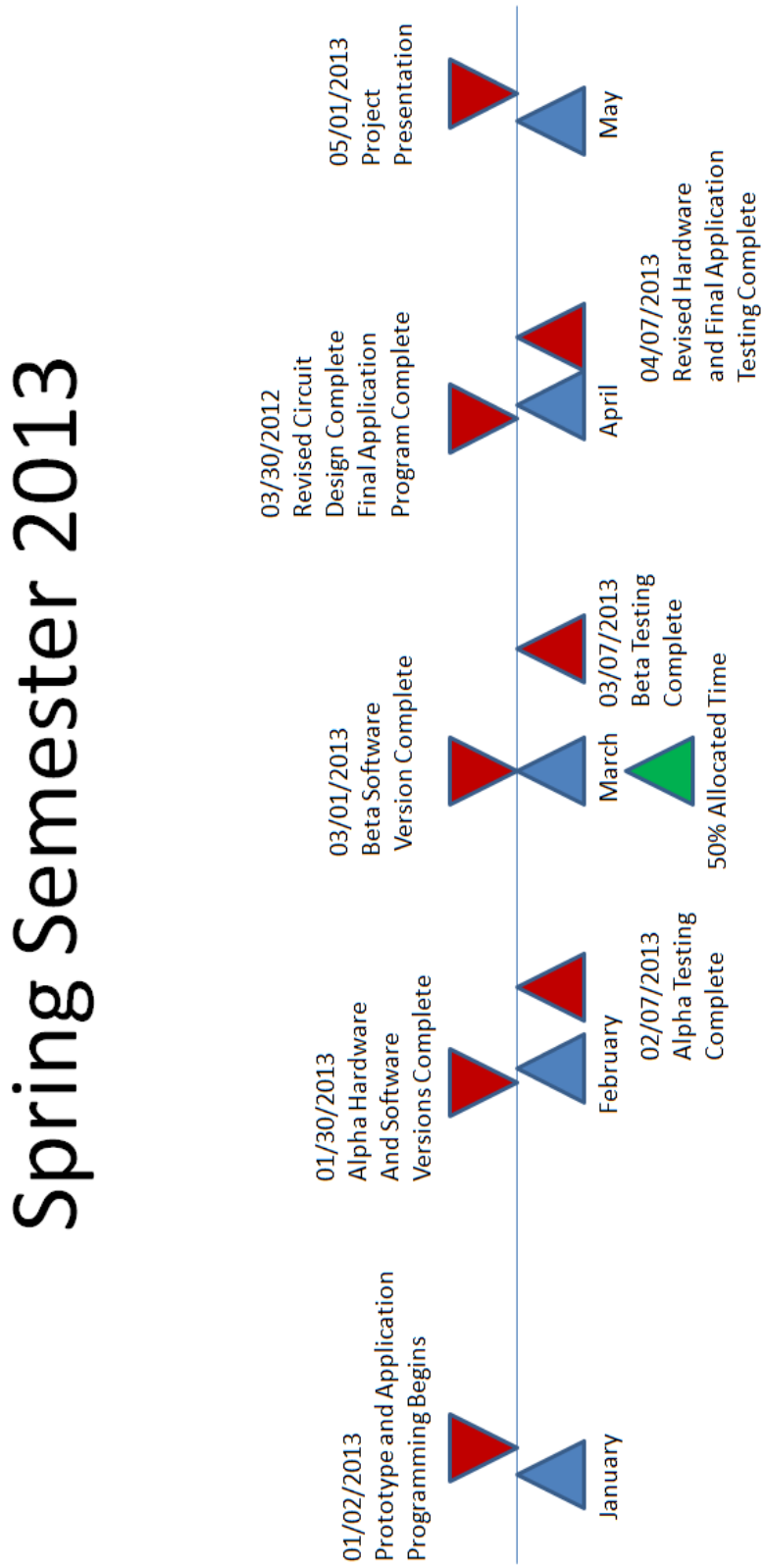
	Milestones Fall 2012	Completion Date
1.H	Research of system components and choosing parts	October 9, 2012
2.H	Complete design of expansion board	November 15, 2012
3.H	Complete design of communication of protocols	November 15, 2012
4.H	Research of battery components	October 9, 2012
5.H	Complete design of the battery pack	November 15, 2012
6.H	Design the housing for all internal components	November 15, 2012
1.S	Research of Google Maps API	October 9, 2012
2.S	Research of program class structure	October 9, 2012
3.S	Complete high level class design in UML	November 15, 2012
	Turn in 120 Page Research and Design Report	December 6, 2012

Table 8.2.1: Milestones Fall 2012

	Milestones Spring 2013	Completion Date
1.H	Complete initial hardware construction	January 30, 2012
2.H	Complete test initial hardware version	February 7, 2012
3.H	Complete construction of revised hardware design	March 30, 2013
4.H	Completion of testing revised hardware design	April 7, 2013
1.S	Program Alpha version of the Application	January 30, 2012
2.S	Test Alpha Version	February 7, 2012
3.S	Program Beta version of the Application	March 1, 2013
4.S	Test Beta Version	March 7, 2013
5.S	Complete Final version of the Application	April 1, 2013
6.S	Test Final Version of Application	April 7, 2013
	Presentation of Project	May 01, 2013

Table 8.2.2: Milestones Spring 2013


Fall Semester 2012
09/11/2012
Project
Proposal
September
10/09/2012
Research
Complete
October
10/16/2012
Reference
Board Purchased
50% Allocated Time
November
11/15/2012
Circuit Design Complete
Software Design Complete
12/06/2012
Project Research
and Design Report
Complete
December


Spring Semester 2013
01/02/2013
Prototype and Application
Programming Begins
January
01/30/2013
Alpha Hardware
And Software
Versions Complete
February
02/07/2013
Alpha Testing
Complete
03/01/2013
Beta Software
Version Complete
March
03/07/2013
Beta Testing
Complete
50% Allocated Time
03/30/2012
Revised Circuit
Design Complete
Final Application
Program Complete
April
04/07/2013
Revised Hardware
and Final Application
Testing Complete
05/01/2013
Project
Presentation
May

7.3. Project Sponsors

This project received a generous sponsorship from the U.S. Army's Simulation and Training Technology Center (STTC), which operates in a partnership with the University of Central Florida's Institute for Simulation and Training (IST). IST is a UCF research institute that focuses on advanced human-centered modeling and simulation technology. STTC more narrowly focuses on enhancing the modern warfighters readiness through the research and development of applies simulation technologies.

Figure 7.3.1: Simulation and Training Technology Center Logo

One of Group 12's project members has a student internship with STTC attained through UCF's Experiential Learning Center. This put him in contact with a highly professional team of engineers who were happy fund a research project that could further work in the simulation field, and have possible benefits for warfighters in the field. A number of these benefits are explained in the Projects Motivations section of Section 2.

The sponsors are especially interested in the application of augmented reality for aiding in navigation, and the usefulness of the landmark marking tools that will be a part of the software application that is being designed for this project. They were available to offer guidance and answer technical questions the design team may have.

7.4. Project Budget and Finance

As stated in Section 8.3 above, STTC has agreed to sponsor this design project and made available $2,000 for parts and construction of tablet and navigation application. The money was spent in three phases.

The first phase was in the Fall 2012 semester, with the purchase of a development board that was used as the basis for the future tablet. This allowed the design team to experiment and test the performance characteristics of the base line computer, and thus get a clearer picture of what needed to be designed in order to meet the project goals.

The second phase took place at the beginning of the Spring 2013 semester, when parts for the expansion board were purchased for the first version of the board. This allowed for the construction of the expansion board based on the designs developed in the Fall 2012 semester. After a thorough testing was carried out, it was expected that revisions to the hardware design needed to be made.

The third phase was carried out which involved purchasing any new parts and paying for any new manufacturing that was needed to correct a few bugs with the previous hardware design. By dividing up the money in this fashion that team was able to have the flexibility needed to deal with any unforeseen occurrences in the design. Which did occur at the last moment, which the custom board was accidentally shorted, necessitating the manufacture of another board.

Based on this spending this project needed, the following expenditures for this project is shown below in Table 7.4.1.

Component	Cost
Panda Board ES	$162
Panda Expansion Board	$250
5MP Camera + Adapter	$120
Microcontrollers	$354
GPS + Antenna	$50
Sensors	$120
Board Construction	$457
Battery	$70
Housing Material Cost	$100
Miscellaneous Materials	$100
Shipping Cost	$200
	$1,983

Table 7.4.1: Project Expenditures

This budget proved to be sufficient to meet the needs of this project. The funds were allotted as needed, so any un-used funds remained with the sponsor.

8. Project AUGI Tablet User Manual

8.1. Launching Activity and Main Activity

To launch the application click in the icon on the Project AUGI icon located within the app drawer or the home screen. See Figure 8.1.1 for a visual description. Upon launching the application, the main activity will be initialized. This screen can be recognized by the UCF Knights logo in the background. There are two different activities that can be initialized from the home screen: Navigation and AUGI Lens. These activities will be explained in the section below. See Figure 8.1.2 for and illustration of the Main Activity.

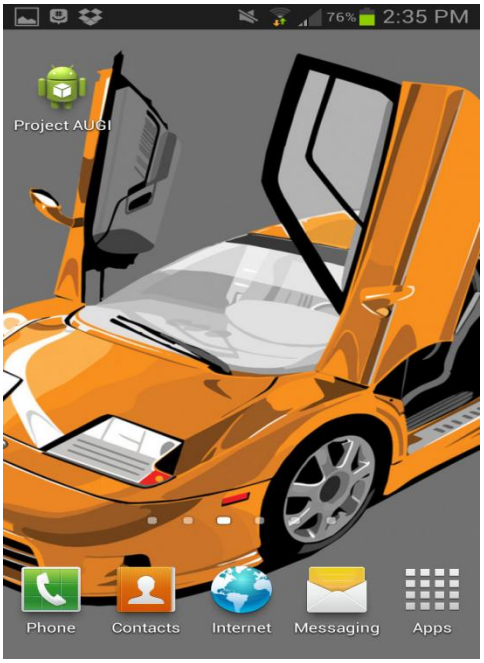


Figure 8.1.1: Launch Application

Figure 8.1.2: Main Activity Screen

8.2. Navigation

Once the navigation activity is initiated, it will display the User Interface located in Figure 8.2.1. The Navigation Activity has a couple simple buttons: Directions, Satellite, and Find Me. These three buttons deliver the bulk of the functionality of the Navigation Activity with the exception of creating custom landmarks. There are a couple miscellaneous features thrown into the application. These features include a graphical compass and a heading indicator located in the top left hand corner of the screen. This compass utilizes the tablets on board compass and is mostly used for the debugging of the customs board's compass. The heading will calculate the Euler angle to North and basically acts as a custom compass from our custom board. These two are always on the graphical user interface and are updating in real time.

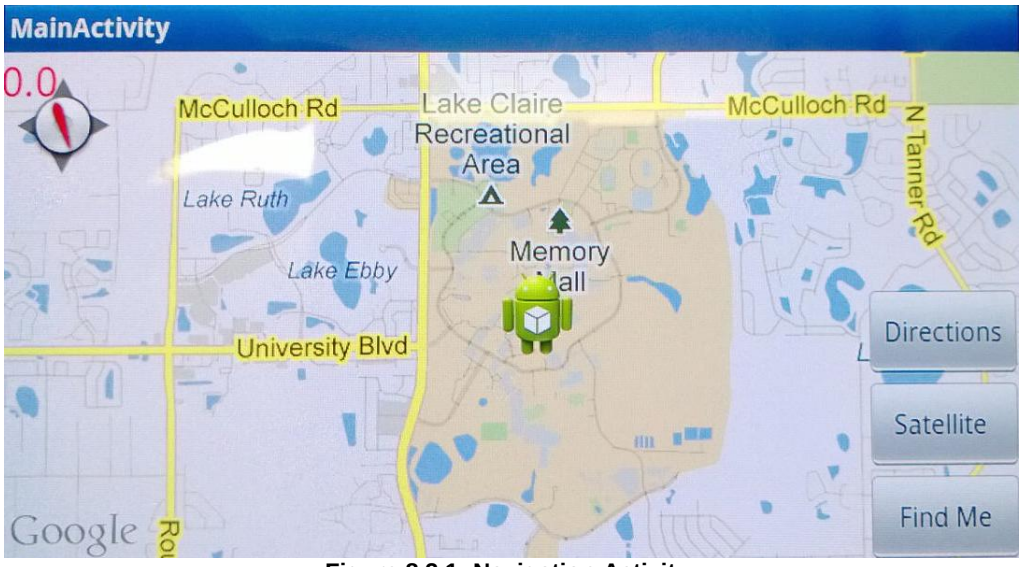


Figure 8.2.1: Navigation Activity

8.3. Custom Landmarks

Custom landmarks are an essential part of the application and allow the user to create landmarks for anything they desire. To create a custom landmark all the user has to do is press their finger anywhere on the map and hold their finger for two seconds before a dialog will appear asking for the user to name the landmark. Once you have named the landmark, press OK and a marker will be placed onto the map where you have touched. This landmark will now be available when asking for direction from your current location. See Directions for more details. Team AUGI has also included some built in landmarks for you so you don't have to add popular landmarks like: Business, Student Union, or Engineering. Figure 8.3.1 below illustrates the pop up window that will be displayed after releasing your finger from a two second hold.

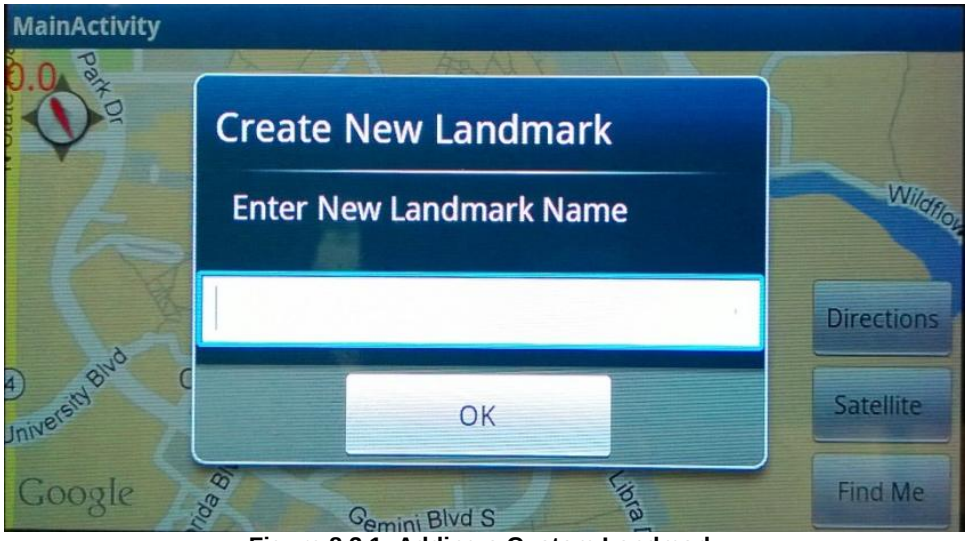


Figure 8.3.1: Adding a Custom Landmark

8.4. Directions

The Direction button can be pressed at any time. Directions will route you from your current location using the GPS sensor from the custom board to a destination within your Landmarks archive. The Landmarks archive is populated by system delivered landmarks and custom landmarks that the user has entered. Upon pressing the Directions button, a spinner will appear displaying both the custom and system delivered landmarks for you to route to. The spinner is illustrated in Figure 8.4.1 below.

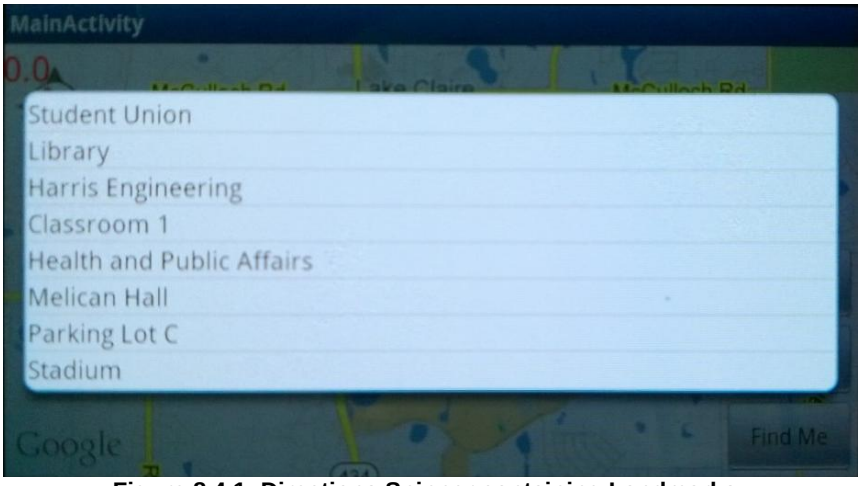


Figure 8.4.1: Directions Spinner containing Landmarks

Upon choosing a destination to route to, the program will immediately return to the map and begin calculating the path to the selected destination via by method Walking. It will display markers labeled “A” and “B” indicating the start and destination respectively. A dark line will be drawn on the screen to give a visual representation of the route’s waypoints to reach your destination. To view the textual directions more explicitly, click on the distance from your destination in the top left hand corner. A screen with textual direction in chronological order will appear with the appropriate distances from each waypoint. Figure 8.4.2 below illustrates the routing in action.

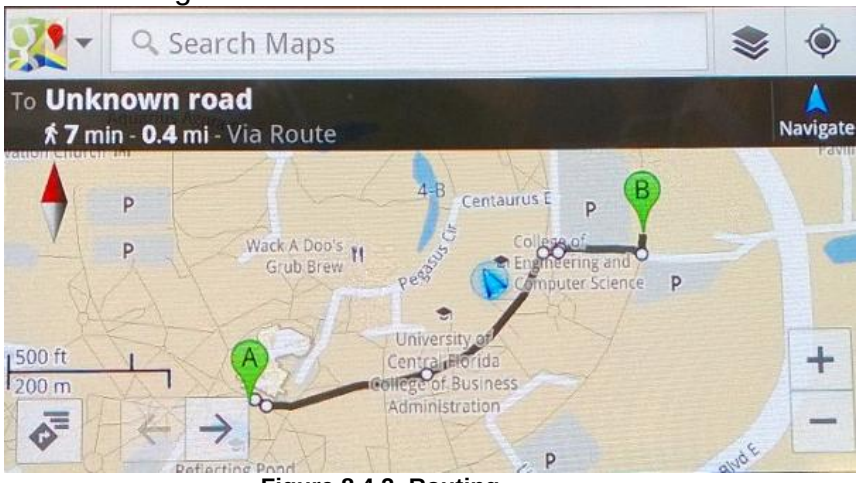


Figure 8.4.2: Routing

8.5. Satellite View

Another feature-rich button is the Satellite button. This button will toggle between the Google Maps standard view and its Satellite view. Figure 8.5.1 below illustrates the map view in satellite mode. To toggle back to the standard map mode, click the Satellite button again.

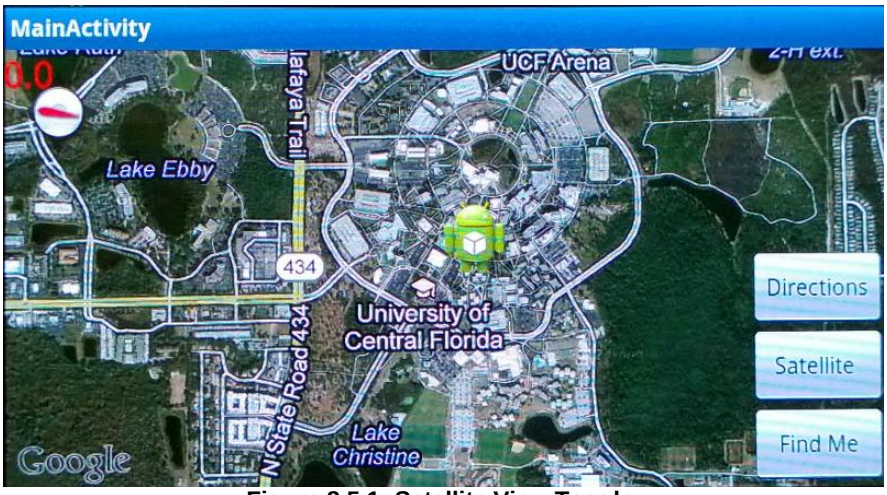


Figure 8.5.1: Satellite View Toggle

8.6. Find Me

The Find Me button will poll the GPS sensor on the custom board from the IOIO Service for your current location. It will then send the location via longitude and latitude coordinates to the Map Activity which will display a little android marker to your current location on the lap. It will also pan the map and center you on the location on the screen no matter where you are. The find me button functionality is illustrated in the image below in Figure 8.6.1.

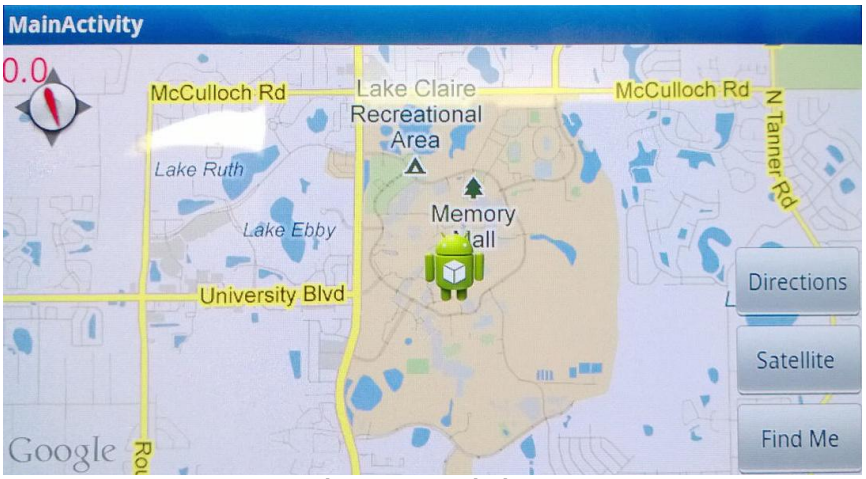


Figure 8.6.1: Find Me

8.7. AUGI Lens

The AUGI Lens is an activity that allows you to navigate to a destination of your choice that was chosen from the Navigation Activity. This Activity will contain a three dimensional arrow that will point you in the direction of the next waypoint to your destination. This three dimensional arrow was designed to be multicolored to be able to distinguish the unique points of the pyramid. The most important thing to know about the pyramid is the red peak. The red peak will always be pointing to the heading of your next waypoint, and in turn will be the point that you will follow to navigate to your destination. A Bearing and Distance indicator will be shown in the top right corner of the screen displaying the current bearing to the next waypoint and updated distance from the next waypoint. These two calculations will not be relevant until a destination is selected within the handle.. To access the rest of the features, touch the arrow itself to bring up a **Handle** of options. The Handle is described below in more detail.

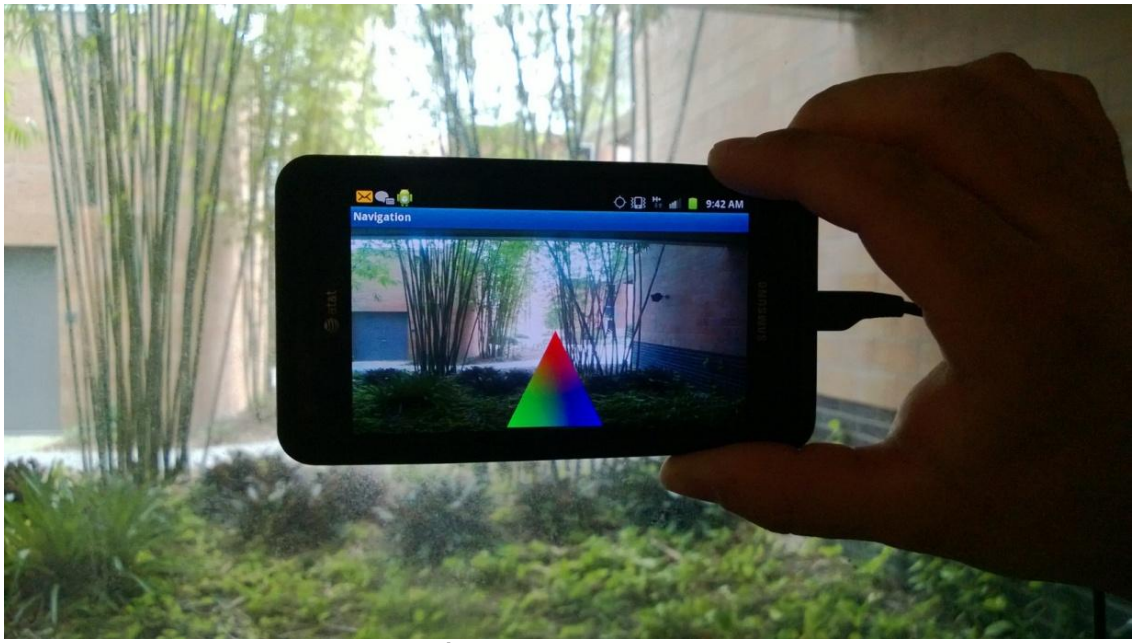


Figure 8.7.1: AUGI Lens

8.8. Handle

The Handle can be activated by touching the three dimensional arrow in the main careen of the AUGI Lens. This handle will contain four main buttons that will control how you interact with the AUGI Lens and dynamically change its functionality. An illustration of the handle is shown below with all of its containing buttons.

Figure 8.8.1: Handle

8.9. Sensor Data

Sensor Data will display an overlay of all of the relevant sensor data that is being received from the custom board. This is generally used for debugging purposes but can also give insight to the user of the specific data that is being polled from each sensor. Sensor data includes data from: an LED ambient light sensor, a altitude determining barometer, the current heading calculation, three dimensional gyroscopic data, accelorometer data given in euler angles, and the current users longitude and latitude. An illustration of the sensor data is shown below with all of its containing information.

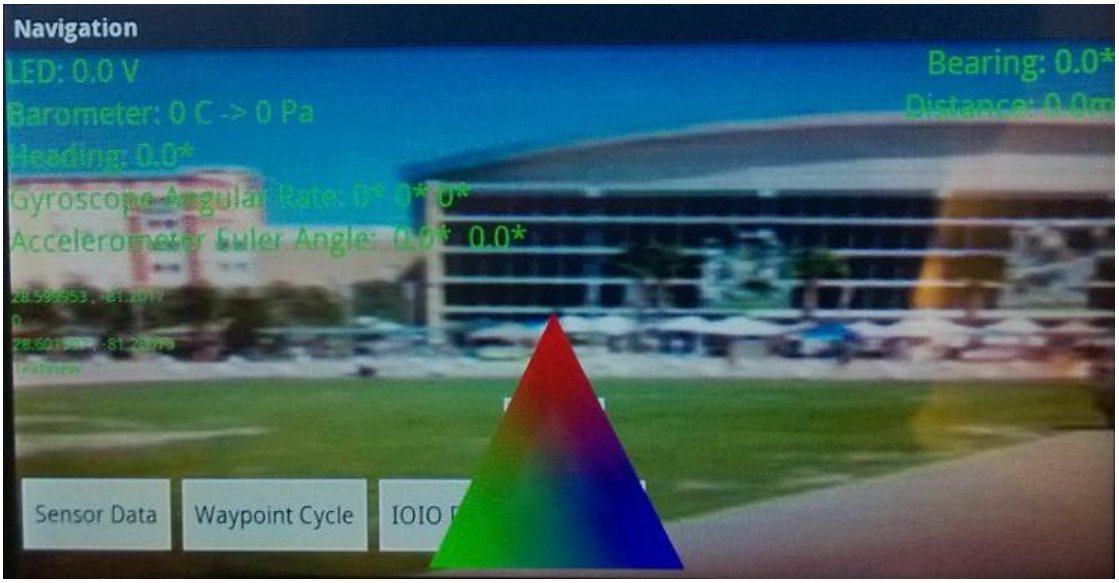


Figure 8.9.1: Sensor Data

8.10. IOIO Service

There are times where the logic from the interface of the custom board will cease to update the sensor values. If this situation occurs while in use, IOIO Service button will restart the service that is running in the background polling the data and will fix the problem. Be careful to not press this button twice quickly because it will shut the application down.

8.11. Waypoint Cycle

To find the next heading to a future waypoint, select the Waypoint Cycle button. This button will increment the current waypoint by one, resulting in setting the next waypoint as the bearing's trajectory.

8.12. Landmarks

The Landmarks button retrieves data directly from the Navigation Activity. Selecting this button will display a spinner of all of the landmarks that have been created in the Navigation Activity along with the system delivered landmarks for your convenience. Just select a landmarks from the spinner and the Bearing for the three dimensional arrow will automatically update to the relevant waypoint to get to the selected destination. The Bearing can be changed at any time using this Landmarks button. To add more landmarks, you must go back to the navigation activity and follow the instructions on creating a new landmark.

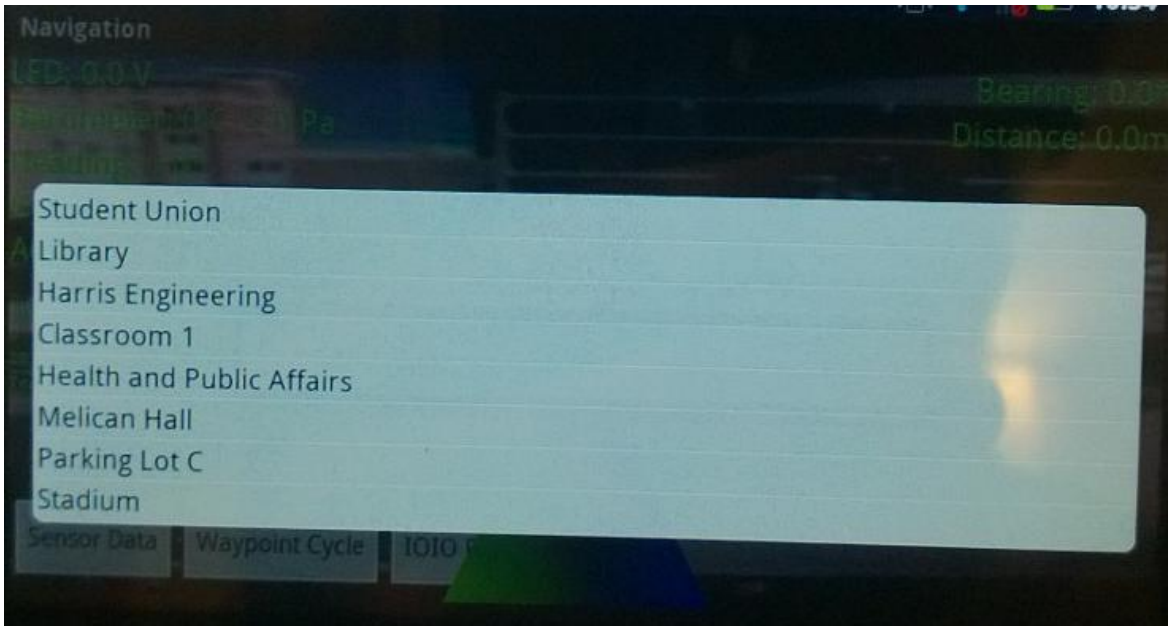


Figure 8.12.1: Landmarks

9. Bibliography

1	**From:** ChipSee客服 [service@chipsee.com] **Sent:** Monday, November 19, 2012 10:18 PM **To:** zulkafil **Subject:** Re: Asking Permission to use images for educational report Dear Ahamed: Sorry for the delay to reply to you We feel honored that you use our picture in your research project. Do you need a formal Permission document? 2012/11/16 zulkafil <zulkafil@knights.ucf.edu> To whom it may concern, I am a student at the University of Central Florida, currently working on a engineering design, group of four people as part of a course (Senior Design) requirement. We would like to ask if it is ok to use the figure of Pandaboars ES and the expansion board since we are using them in our design as a reference board. According to school rules we need permission as well as we have to quote the source in our report.
2	**From:** Parallax Support [support@parallax.com] **Sent:** Monday, December 03, 2012 3:41 PM **To:** phillip_lee@knights.ucf.edu **Subject:** [SUPPORT #XYA-602-14933]: Permission to use images Hello Phillip, Our documentation and products are open source so feel free to use them in your project. Best of luck and I wish you well with your project! -Nick
3	**From:** Level 1 [level1@sparkfun.com] **Sent:** Friday, November 16, 2012 12:21 PM **To:** Phillip_Lee **Subject:** Re: Sparkfun copyright permission Hi Phillip, You can use the schematics for you project! Under the image of each component on the product webpage there is a link that says *CC BY-NC-SA 3.0*. The link goes to a summary of the creative commons license [http://creativecommons.org/licenses/by-nc-sa/3.0/] for the boards which basically says that you may share (copy, distribute, transmit) the work. As long as you cite where you got the datasheet/schematic/images from or who created the circuit (if it says on the schematic), you can use it and do not need our permission. Maybe when you get to the part of the license where you start selling the components to make money for commercials purposes, then you would need our permission. Other than that, you're good! Good luck on your project and happy hacking!

4	**From:** zulkafil **Sent:** Saturday, December 01, 2012 8:43 PM **To:** info@v-torch.com **Subject:** Asking copyright permission To whom it may concern, I am a student at the University of Central Florida, currently working on a engineering design, group of four people as part of a course (Senior Design) requirement. We would like to ask if it is ok to use some figures and data of GPS internal Antenna Model: VTGPSIA-3 since we are using them in our design. According to school rules we need permission as well as we have to quote the source in our report. Thanks in advance, Sincerely, Zulkafil Ahamed
5	**https://www.sparkfun.com/products/10530**
6	**https://www.sparkfun.com/products/9801**
7	**https://www.sparkfun.com/products/9269**
8	**https://www.sparkfun.com/products/11028**?
9	**https://www.sparkfun.com/products/11058**
10	**https://www.sparkfun.com/products/11282**
11	**http://boardzoo.com/product_info.php?products_id=101**
12	**http://boardzoo.com/product_info.php?products_id=100**
13	**https://www.sparkfun.com/products/9088**
14	**https://www.sparkfun.com/products/7844**

15	https://www.sparkfun.com/products/10748
16	https://www.sparkfun.com/products/8293
17	https://www.sparkfun.com/products/8484
18	https://www.sparkfun.com/products/177
19	https://www.sparkfun.com/products/10968
20	https://github.com/ytai/ioio/wiki
21	http://www.cadsoftusa.com/shop/pricing/?language=en
22	From: TI Cares Customer Support [ti-cares@ti.com] Sent: Wednesday, December 05, 2012 12:24 PM To: Phillip_lee@knights.ucf.edu Subject: Re: US, EdPrograms, # [REF:74708594739] Hello Phillip, Thank you for contacting Texas Instruments. I understand that you would like permission to use images for your project. If you are not using any of TI's materials for your project, then TI's permission is not needed. In fact, if you take your own photo of TI's products and/or use your own screen shots, then you don't need permission to use those images. If you are using our images or photos, please use the following credit: Photo used with permission from TI. http://education.ti.com. You will not need special permission for using our manuals. To help you become familiar with your calculator, TI has Web-based tutorials available that answer common questions students and teachers may have when learning to use our products. http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials I hope that you find this information helpful. If you have further questions or comments, please feel free to send me an email. Happy Holidays, Maria

23	bit_msp430/overview.page?DCMP=MCU_other&HQS=msp430
24	http://www.dimensionengineering.com/info/switching-regulators
25	Pfleeger, Shari. “Software Engineering” pg. 223-290. Prentice Hall 2010
26	Mednieks, Zigurd. “Programming Android” pg. 111-163. O’Reilly 2011
27	Mednieks, Zigurd. “Programming Android” pg. 211-243. O’Reilly 2011
28	Mednieks, Zigurd. “Programming Android” pg. 371-386. O’Reilly 2011
29	Deitel, Paul. “Android for Programmers” pg. 35-67. Pearson 2012
30	Deitel, Paul. “Android for Programmers” pg. 226-256. Pearson 2012
31	Deitel, Paul. “Android for Programmers” pg. 291-318. Pearson 2012
32	Deitel, Paul. “Android for Programmers” pg. 390-459. Pearson 2012
33	https://developer.mapquest.com/web/products/featured/android-maps-api
34	http://blog.hsoi.com/2010/11/10/ios-vs-android-programmer-first-impressions/
35	http://www.pcadvisor.co.uk/reviews/software/3412010/windows-phone-8-sdk-review/
36	
37	

38	From: Britannica Customer Service [customerservice@eb.com] Sent: Monday, December 03, 2012 4:53 PM To: zulkafil@knights.ucf.edu Subject: Re: Britannica.com Customer Inquiry Form (KMM5867015C0KM) Dear Zulkafil Ahamed, Thank you very much for your inquiry concerning the use of Encyclopaedia Britannica content. Encyclopaedia Britannica's copyright and permissions policy is described in detail in our Terms of Use statement, which can be found at the following Web address: http://corporate.britannica.com/termsofuse.html The Terms of Use statement should answer your question regarding your responsibilities and ability to use our content. If you have any other questions, please feel free to contact us again at your convenience. We appreciate your interest in Britannica products and services. Sincerely, Rob Britannica Customer Service