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UNDER THE SUN DRINK MIXER

Senior Design I Documentation

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1.0 EXECUTIVE SUMMARY

The purpose of the Under the Sun Drink Mixer (also referred to as The Drink Mixer) is to simplify and automate the creation of mixed beverages through the use of an internet capable mobile device. The Drink Mixer is engineered with four main systems: the client application, the dispensing system, communication system, and the power system. The client application consists of the capability to communicate with the Drink Mixer and facilitates the reservation and creation of the mixed beverages. The dispensing system consists of the vending unit assembly which contains electric solenoid valves, a cup detecting IR sensor, a tank regulator, a compressed air tank, and ingredient containers. The communication system within the Drink Mixer allows the client application to control the dispensing system; this includes a web server, a wireless network connection, and the power system. Finally, the power system consists of a solar panel, a battery, and a MPPT controller. All of these four main systems together allow the user to order a mixed drink through a mobile device in which allows the Drink Mixer to dispense without the user touching a bottle.

The Under the Sun Drink Mixer will be controlled by an application running on a mobile device in an effort to reduce human interaction with the mixing machine and providing convenience to the user. Each customer can easily make a request through their mobile device which would in turn provide the user with a reservation code; this code will then be scanned on the Drink Mixer so the machine can then dispense the user's drink. The Drink Mixer will have a sensor that detects the presence of a cup before starting to dispense the drink. Once the drink has been dispensed, the user will be able to enjoy their drink hassle free.

The first objective for the design of the Under the Sun Drink Mixer is to be an efficient and reliable dispensing system. By focusing on reducing the amount of time it takes for the drinks to be dispensed, the user can focus on other things like socializing in a tailgate or while at a BBQ. Ensuring that the time from order until drink pickup is kept as low as possible will provide an incentive for the user to continue to use the product.

The second objective of the Under the Sun Drink Mixer is to create a reliable and high efficient product that will use renewable energy to function. With the use of a solar module and onboard battery backup, the Drink Mixer will maintain an environmentally friendly status. Thanks to the solar module and the onboard battery backup, the Drink Mixer will be more convenient when it is used at a BBQ

or other outdoor venue where a steady source of Utility Power may be unavailable.

2.0 PROJECT DESCRIPTION

2.1 MOTIVATION AND GOALS

Living in the sunshine state is a huge motivation in wanting to build a drink mixer; Under the Sun Drink Mixer will be ideal for BBQs and tailgating to increase hydration. In the midst of summer, people want to be hydrated at all times and what better way than a solar powered drink mixer. The idea of building a drink mixer is influenced by the American culture and lifestyle of having convenient things at hand and it is also influenced by the Floridian weather which makes it more appealing to have an automated drink mixer. However, it is known how hot Florida Summers are and with tailgating season coming soon what a perfect way to enjoy the time than by having an automated solar powered drink mixer!

Another incentive to build a drink mixer is to avoid long queues when everyone is trying to serve a drink at the same time. By ordering through the phone, the client application will provide the user with a unique code. With this code, the user can obtain their customized drink with Under the Sun Drink Mixer.

Some of the goals during this project are to create a social environment among its users by minimizing the amount of time spent at serving drinks and increasing social interaction. If less time is spent at serving, one could interact more with the guests, family, and friends. Also, with tailgating season approaching, people usually put all beverages in a shared cooler and lose track of their drinks while socializing. Having all the beverages in the drink mixer apparatus, people don't have to worry about other people grabbing their drinks.

2.2 OBJECTIVES

The main objective was to be able to use the finished project during the tailgating season which is when users most likely would want to use it. It will make mixing drinks very convenient and people don't have to worry about mixing them themselves while tailgating. Also, for people that don't know how to mix drinks they will find this apparatus very useful.

Usually at tailgating people don't consume fancy or mixed drinks since it's not easy to make them at a tailgate tent. There are no tables or convenient ways to

mix drinks, so people just drink beer or water bottles. One of the objectives is to make mixing of drinks convenient to the consumer in matters of second without having to stop socializing to make their drinks. Having cocktails and fancy drinks will become a reality during tailgating.

Sunny Florida provides the perfect environment to use Under the Sun Drink Mixer since it will take advantage of hot summer days to use the energy for power, using clean and renewable energy is one of the main objectives.

2.3 PROJECT REQUIREMENTS AND SPECIFICATIONS

While designing the project, it is planned to have a product size that is easy for carrying to various locations as necessary. Keeping the size portable would ensure that the finished product can be carried around and maximize its use. Having a heavy and difficult to carry apparatus will diminish its purpose and people wouldn't want to make orders through it because of unpractical design.

The dispensing rate should be relatively fast for the convenience of all its users. Consumers shouldn't wait a long time for their drink to be dispensed while keeping them from socializing. The entire process from when the drink is ordered through the phone app until the drink is finally dispensed to the consumer's cup should be as short as possible. One of the main functionalities of drink mixer is to prepare quality drinks in the shortest amount of time, as an incentive for consumers to keep ordering and using Under the Sun Drink Mixer. The users should take less time ordering through the Drink Mixer than making their mixed drinks manually.

The accuracy of the drink specifications should be as closely as possible to the specifications of the user. Sometimes there could be errors in proportions when ordering the drinks, but the ultimate goal is that the ratio of each drink is as accurate as possible for a better and tastier mixed drink. The Drink Mixer will allow the customers to control the ratio of the ingredients in the drink such as 2 parts orange juice/1 part pineapple juice, a portion of an energy drink or even portions, etc. The system will be able to hold up to 8 bottles.

Under the Sun Drink Mixer will mainly be utilized in hot temperatures to maintain hydration among its users. In order to maintain hydration the drinks needs to be kept cold which is why the bottles will be enclosed in a cooler. It will be an old-fashioned way to keep the drinks cold but it will be an effective way than installing a refrigeration system to the apparatus which consumes a lot of energy. The Drink Mixer will be an environmental friendly system and therefore it will not be using a refrigeration system. There will be a wall outlet for those

that want to use the product indoors on those stormy days, as well as a detachable solar panel that can be used outside on a nice sunny day.

When deciding how the drink mixer will be controlled, it was decided that it would be more convenient for all of its users to have their own remote handy. Instead of waiting in queue lines for someone else to finish ordering or using a laptop to make orders, users can just customize their drinks through their phones and the Drink Mixer app will create a unique bar code for the customized drink. The user will then scan this code in the machine and when a cup has been detected, it will dispense the requested drink. That way, users can order the drinks through their phones at any location, the user of a smart phone application will also simplify the creation of complex drinks as well as keeping the manufacturing costs low.

The application will be implemented to be as user friendly as possible with a library of pre- determined drinks and the ingredients associated to each drink type that the user will select.

For those unfortunate and occasionally rainy days in Florida, the option of allowing the system to be plugged in to an outlet will be implemented. In case the system doesn't have enough energy to power and if it's not sunny out, there will be a wall outlet for those who want to use the Drink Mixer indoors on those stormy days. There will be the option to have a detachable solar panel that can be used outside on a nice day next to the pool for a barbeque.

2.4 Tasks and Responsibilities

In order to ensure that the project gets completed in a timely manner and that everyone has the same amount of work, the tasks were divided among the team members according to their areas of interest.

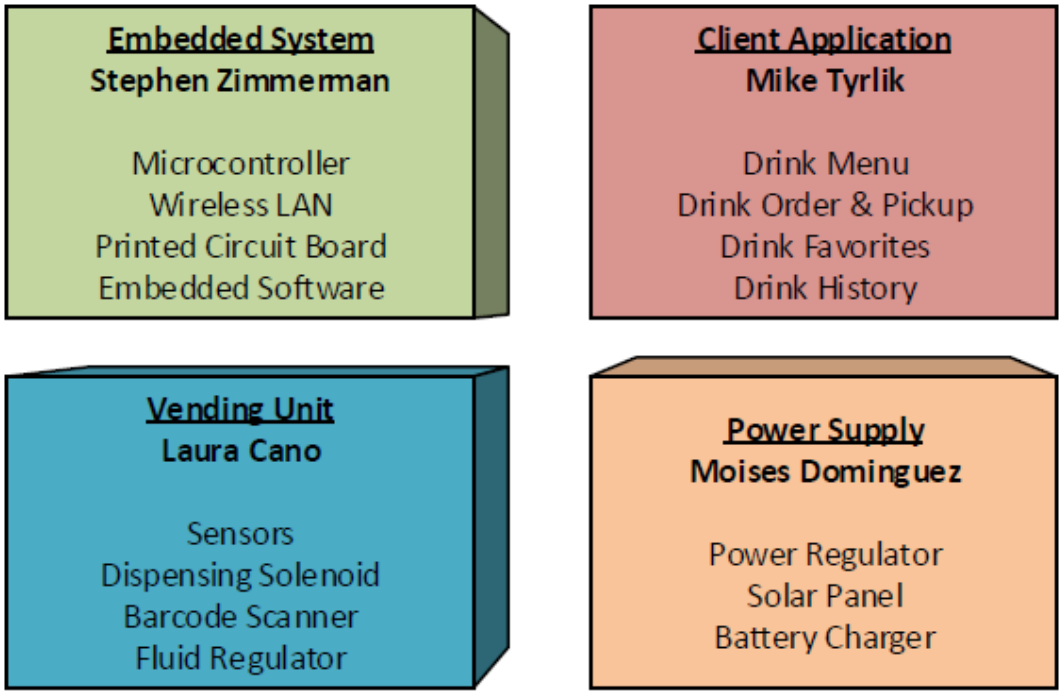


FIGURE 1: BLOCK DIAGRAM

2.5 Milestone Collaboration

In order to monitor the project's progress, various tasks and objectives with due dates will assigned. In this manner, the project will be completed in a timely fashion during the following two semesters. Team members will use these milestones to establish reference points to determine major accomplishments in the development of the product. These milestones will consist of the completion of required research, the attainment of paperwork and documentation, the elapsed time in obtaining the necessary parts, the building phase, the testing phase, and finally the presentation of the final product. The research and work needed for this project based on the inclination and preference of each individual will be distributed while at the same time ensuring that each group member is responsible for equal amount of work.

After research has been completed, the group will start with the building process for the fall semester. The plan is to have a working phone application this summer so the focus can be on building the solar panel in the fall as well as connecting the client application to the system. Also, all parts that are needed for the project will be ordered before the fall semester starts, that way the group could start building as soon as the semester begins in order to advance on the projects and provide plenty of time for testing. The expected duration for each stage of the project for senior design I and II is depicted in the following image which will be used as a guide to effectively track and accomplish the group's goals.

TABLE 1: MILESTONES

Date	Task
3-Jun	Define Project Goals and objectives Area of Interest
10-Jun	Research Similar Projects and solutions Microcontrollers Storage Sensors LCD Screens Power requirements Solar Panel AC Power Converter Network Connections Communication protocols PCB Software
24-Jun	Embedded Software Requirements, all classes, functions, procedures and methods for programming the phone app Class Diagrams Network Connections
1-Jul	Hardware Interface requirements
8-Jul	Power supply Research all components needed to design the solar power supply (regulators)
22-Jul	Design Final schematics of all components connected Hardware diagrams and schematics Software algorithms
29-Jul	Design and order all parts chosen for the final design Micro Controller board Micro Controller chip DC Motor Battery DC Output Wireless/LAN controller Sensors Drink mixer Solar Panel Battery Charger LCD Screen
1-Aug	Programming

	Phone application
1-Aug	Finish Final Documentation
26-Aug	Prepare Initial Presentation
1-Sept	Design Project
5-Sept	Incorporate all components together Solar Panel Drink Mixer Microcontroller LCD Screens
10-Sept	Assembly of Prototype
1-Oct	Test system Software and Hardware connections Charging of solar panel Functionality of app
1-Oct	Observe results
15-Oct	Adjust system if needed Implement upgrades to app Debug and test every case scenario Measure dispensing rate
15-Nov	Prepare presentation

2.6 BUDGET AND FINANCE COLLABORATION

TABLE 2: BUDGET

Item	Price	Quantity	Total
Embedded System			
PCB	$ 60.00	1	$ 60.00
Processor: AM3359	$ 35.00	1	$ 35.00
EEPROM	$ 0.38	1	$ 0.38
512MB DDR RAM	$ 25.00	1	$ 25.00
Wireless LAN Controller	$ 15.00	1	$ 15.00
Power Management System	$ 10.00	1	$ 10.00
USB	$ 7.00	1	$ 7.00
Apple Developer Subscription	$ 100.00	1	$ 100.00
SD Host	$ 5.00	1	
Power Regulator			
Lead Acid Battery 12V	$ 45.00	1	$ 45.00
Solar Panel 30 Watt	$ 120.00	1	$ 120.00
PCB	$ 40.00	1	$ 40.00
Components	$ 50.00	1	$ 50.00
Vending Unit			
LCD Screen	$ 10.00	1	$ 10.00
Barcode Scanner	$ 350.00	1	$ 350.00
IR Proximity Sensor	$ 13.95	1	$ 13.95
Syphon Tubes	$ 9.99	8	$ 79.92
Electronic Solenoid Valve	$ 15.29	8	$ 122.32
CO2 Tank	$ 70.00	1	$ 70.00
PVC Air Line	$ 13.00	8	$ 104.00
Air Regulator with Gauge	$ 5.95	8	$ 47.60
Aluminum Manifold	$ 24.16	1	$ 24.16
Drinks	$ 10.00	8	$ 80.00
Cap Assembly	$ 25.00	1	$ 25.00
			$ 1,434.33

3.0 RESEARCH

3.1 SIMILAR PROJECTS AND SOLUTIONS

3.1.1 SMARTENDER

The Smart Bar USA assists a bartender in producing drinks at an efficient rate. The drinks are made seamless with every ingredient being more accurately measured whereas a bartender would have made the same drink imperfectly with excess on certain ingredients and lack of others. The Smart Bar claims to be the first automatic portable bar in the market and belongs to the family of smart bar. Smartender claims to be portable as it can be easily taken to different rooms but it is easy to transport to different locations due to its size. The Smartender is 58 inches tall and takes up a large amount of space, which wouldn't be optimal for tailgating or BBQs. However, their variety of drinks is very extensive and has many features that are not optimal for a simple drink mixer such as the Under the Sun Drink Mixer. Also, Smartender does not take its orders via a smart phone which is the idea and innovations that will be implemented.

3.1.2 ROBOT BARTENDER

The Robot Bartender takes its orders via a smart phone, which is basically the same concept as the Under the Sun Drink Mixer is trying to incorporate, taking orders via smartphone. However, this robot is way too complex as it involves artificial intelligence and robotic arms which is programmed to graciously slice a lemon, shake a cocktail shaker, pour liquids carefully and so on. The Under the Sun Drink Mixer would take orders through a smart phone and dispense the drink but will not exactly perform all the convoluted functions of the Robot Bartender. Therefore, there weren't many things the Under the Sun Drink Mixer could use from the Robot Bartender in order to improve its functionality or use any of its characteristics.

3.1.3 BAR2D2

BaR2D2 closely reflects the idea behind the Under the Sun Drink Mixer in the sense that there's no elaborated bartender like in Robot Bartender (description above); instead, the drinks are already in plastic bottles and it's pending on the customer to make a selection for a desired drink to be dispensed. Under the Sun Drink Mixer is similar in that case as it will also be using liquid pumps and it can be customized by the user for a desired drink. Under the Sun Drink Mixer will

also be dispensed by a fluid pump just like in BaR2D2; the main difference is that customers using the drink mixer will be using a smartphone application in order to select their desired drinks whereas the BaR2D2 uses a laptop. BaR2D2 uses two compressed air tanks at 100 psi to pressurize 6 ingredient bottles to 5 psi.

3.1.4 Drink-O-Matic Deluxe

This automatic drink mixer was actually inspired by BaR2D2, which was mentioned earlier. But instead, the Drink-O-Matic Deluxe does not use compressed air but uses fluid pumps instead. However, the maker of this model claims that not using compressed air was the biggest flaw in their design as fluid pumps allows venting and there's a significant loss of carbonation; therefore, the compressed air solution with pressure regulation instead of fluid pumps was recommended.

3.1.5 Automated Beverage Dispenser

This project was designed by senior college students from Georgia Tech. It is also controlled by a computer and not by a smart phone application; its purpose is similar to the Under the Sun Drink Mixer in the sense that it efficiently dispenses mixed drinks. The Automated Beverage Dispenser (ABD) focuses on assisting bartenders in being more efficient, rapid, and effective without the need of additional personnel. The Under the Sun Drink Mixer differs with ABD since ABD was only operated by bartenders whereas the drink mixer will be self-operated and anyone with the phone application will be able to use it.

3.1.6 Automatic Drink Mixer

This machine was also designed by senior college students from Rochester Institute of Technology. The main function of the Automatic Drink Mixer is similar to that of all the other projects described above, it's a system that mixes drinks and it is controlled by a computer. All the recipes are added by the user and can hold up to thirty two ingredients, all drinks are customizable. The Under the Sun Drink mixer will only hold up to eight ingredients and will be customizable as well; however, the variety of drinks that can be mixed are more limited that the Automatic Drink Mixer. The creator of Automatic Drink Mixer recommends compressing the pressure valve no greater than 5 psi which would probably be incorporated into the Under the Sun Drink Mixer for best dispensing results.

3.1.7 The Inebriator

This project was not created by college students but by two electronics hobbyists from the UK. It focuses on creating the perfect cocktail without the need of looking up each ingredient and measuring them. It uses 12v electric solenoid

valves in order to dispense the drinks which make it a more complex system than just using plain fluid pumps, the Under the Sun Drink Mixer would focus on using electronic solenoid valves instead of just fluid pumps.

3.1.8 Mix it!

Mix It! is another automatic cocktail machine that can mix up to twenty seven different cocktails and they can be selected by the user using a touch screen. Each drink or cocktail is displayed as a preview in the screen with photo included of what the drink/cocktail looks like. This idea will be incorporated into the Under the Sun Drink Mixer as users will be able to see a preview of their desired drink using the smart phone application.

3.1.9 Conclusion

In conclusion, many things can be learned from the research done on similar projects and solutions. Learning what worked and what did not work when developing an automated drink mixer makes the job a little bit easier when building one from scratch, thus eliminating the trial and error before making it work. Reading reviews on what was successful in similar projects aids in wisely choosing how to build a drink mixer. All of the projects depicted above have the same function which is to mix drinks, however, the user interface and the selection of drinks is what makes each project unique.

Capturing the best feature from each and every drink mixer described above by improving on it would bring the Under the Sun Drink Mixer closer to perfection. One of the things that can be improved upon is the dispensing system; by learning from all of the automated drink mixers out there it was clear that fluid pumps was not the most efficient way to dispense a drink. Therefore, the Under the Sun Drink Mixer will not include fluid pumps but electronic solenoid valves to dispense the final drink.

Something else that could be improved upon is portability. The majority of the drink mixers depicted above claim to be portable because they could be transported from place to place, but cannot be lifted because they are too heavy. One of the purposes of the Under the Sun Drink Mixer is that it has to be able to be lifted and taken outdoors, in the sun, where it can be powered by an array of solar cells.

3.2 Embedded System Research

In the research phase, a very important part of the Under the Sun Drink Mixer was the embedded system (microcontroller and printed circuit board layout) that

was chosen. The task of the embedded system is pretty extensive, so the final design must ensure that the microcontroller and board layout chosen can support the design requirements that are wanted.

Things that are a must for the embedded system is a way to set up a network so that the client application does have a way to communicate with the embedded system, pulse width modulation (PWM) channels for the dispensing solenoids, abilities for LCD screen so that a QR code could be displayed initially for the client application to scan and "capture" the menu list and drink ingredients that are currently in the Under the Sun Drink Mixer, and a low power consumption. The idea of having an operating system on the device was also considered to make some of the functionality of the system a bit easier.

The MSP430 on a printed circuit board , Atmel SAM3X8E ARM Cortex-M3 CPU on a printed circuit board, Broadcom BCM2835 on a printed circuit board and the AM3359 720MHz ARM Cortex-A8 CPU on a printed circuit board were looked into as possible candidates for the design. Reference designs will be looked into to determine the capabilities of current development boards and to get a knowledgeable vision of what these microcontrollers are capable of when paired with a great printed circuit board. The plan is to then use the open source documentation as a reference in creating the printed circuit board that will be implemented into the Under the Sun Drink Mixer. More on this will come later in the "PCB Design" section of this write up.

3.2.1 Texas Instruments MSP430

The first microcontroller option looked into for the design would be making use of a MSP430 microcontroller on a PCB for the Under the Sun Drink Mixer. The MSP430 microcontroller is designed by Texas Instruments and is ultralow power and easy to use.

The MSP430 that was looked into was the MSP430 6 series because it is low power consumption and has integrated USB connectivity as well as an LCD controller. It only required a supplied voltage ranging from 1.8V and 3.6V for operation. This is very achievable with the battery and solar panel design the Under the Sun Drink Mixer will implement. The MSP430 is ultra-low power, draining only $0.1*10^{-6}$ Amps while standby and has a very fast wake-up from standby mode, waking up in less than $5*10^{-6}$ second. In active mode, the MSP430 6 series only draws $165*10^{-6}$ Amps, which is extremely low. The almost instantaneous wake up time is great, because this makes orders virtually real time. It uses 16-bit RISC architecture and has two 16-bit built in timers. The embedded system would incorporate the microcontroller, the abilities for an LCD and the abilities for Wi Fi. As part of the design, the board would have to be

programmed to process a drink order and then control the dispensing solenoid to automatically pour a pre-determined amount of drink ingredients into a drink.

The MSP430 with a PCB would be a very useful design and great because of its low power and low complexity. The disadvantage would however be computing power with only a clock speed of 25MHz. For this reason, other microcontroller options will be looked into.

3.2.2 Atmel SAM3X8E ARM Cortex-M3

The Atmel SAM3X8E ARM Cortex-M3 CPU is a microcontroller that offers 84MHz of processing power and features 512KB of flash memory in two 256KB banks as well as 100KB of SRAM in 64KB and 32KB banks with an additional 4KB as NFC SRAM. The Atmel's peripheral set includes Ethernet, dual Controller Area Networks (CAN), USB MiniHost. The Atmel SAM3X8E ARM Cortex-M3 operates from 1.62V to 3.6V.

As part of the design, the embedded system would have to be programmed to process a drink order and then control dispensing solenoids to automatically pour a pre-determined amount of ingredients into a drink. This system will be tailored to perform the drink making tasks based on the number of drink orders placed. The ability to program in a high level language such as Java or C versus a low level language (assembly) would be sought after in this design. This would allow debugging, code manipulation and overall coding to be much easier.

3.2.2.1 Reference Board

To get an idea of how this microcontroller could be used along with a printed circuit board, a development board was looked into that uses the same microcontroller, the Arduino Due. The great thing about Arduino is that it contains open source design so the board layout could be referenced and components could be added or removed as needed. The Arduino Due board consists of a native USB port and Programming port which could be very useful. This board can be programmed in a high level language such as Java or C which would make programming much easier rather than needing to code in assembly. The Arduino Due has 54 digitial input/output pins, of which 12 can be used as PWM outputs. It also has 12 analog inputs, 4 UARTS (hardware serial ports), and a USB capable connection. The Arduino community also hosts hundreds of different Arduino libraries that can be used for coding purposes.

This microcontroller does have the PWM channels that are needed to allocate the drinks as well as Ethernet capabilities, however, there are some drawbacks of this microcontroller / board layout; its' computing power and memory isn't very high.

Running at only 84MHz and allowing only 512KB of flash memory could put a damper in plans implemented for the Under the Sun Drink Mixer, especially if it was decided that the design would run an operating system such as Linux. For this reason, other microcontroller options were looked into.

3.2.3 Broadcom BCM2835

The next microcontroller option that was considered for the design was the Broadcom BCM2835 system on a chip. The Broadcom BCM2835 includes a low power ARM1176 microcontroller, dual core VideoCore IV co-processor, 1080p Full HD video encode and decode, advanced ISP for up to 20-megapixel cameras, and low power high performance OpenGL-ES VideoCore GPU. The ARM1176 microcontroller produces speeds at a whopping 700MHz with a conservative design and the firmware includes Turbo modes that can get the chip up to 1 GHz. The ARM1176 has broad operating system support, multiple Linux distributions and full internet experience.

To look specifically at what the Broadcom BCM2835 is capable of, being connected to a printed circuit board and in full motion, the Raspberry Pi reference design was looked into.

3.2.3.1 Reference Design

The Raspberry Pi is a credit-card sized computer that is capable of many things your desktop PC can do. It can run different spreadsheets, word processors, games, and even high-definition videos. This computer is developed in the UK by the Raspberry Pi Foundation with the intent for teaching of basic computer science. The design is based around the Broadcom BCM2835 System-on-chip which has an ARM1176JZF-S 700 MHz microcontroller. It also includes the Videocore IV GPU which provides the ability to watch BluRay quality video. The Raspberry Pi offers a 10/100 Ethernet port that enables native network connectivity and also offers 512MB RAM. The Raspberry Pi supports two built-in USB ports, which is enough for a mouse and keyboard, or you can add a USB hub if you need more USB ports. The Raspberry Pi will run off of a 5V power supply @ 700mA. This microcontroller is much more powerful than both the Arduino Due and the MSP430 and will support Linux.

Power consumption of the Raspberry Pi is anywhere from 700mA to 1200mA, and the community suggests using a power supply that can support up to 1A if using USB peripherals or any other add-ons. There are several different add-ons and accessories that can be put onto the Raspberry Pi to expand functionality. For instance, if you want Wi Fi, there is a USB plug in dongle module that allows Wi Fi to be added in the matter of minutes. Also, there is a Raspberry Pi camera

module which allows the ability to add a 5 megapixel camera, which could expand into other solutions for the barcode scanner design that will be implemented into the Under the Sun Drink Mixer.

Using the Raspberry Pi as a reference design for the Under the Sun Drink Mixer shows some of the capabilities of the microcontroller, and it shows how certain peripherals can interface with a board design that will be created for the Under the Sun Drink Mixer.

Even with all of this high end technology and 700MHz of processing power, there are some downfalls to the Raspberry Pi. Unfortunately, the schematics associated with the Raspberry Pi are not open source, so the Raspberry Pi can only be used as a reference design as to what can be considered as good add-ons to a board that could benefit the Under the Sun Drink Mixer, such as USB, Wi Fi capabilities and micro SD card possibilities.

3.2.4 Texas Instruments AM3359 ARM Cortex-A8 CPU

The final microcontroller that was researched for the Under the Sun Drink Mixer was the AM3359 ARM Cortex-A8 by Texas Instruments. This microcontroller is typically used in designs such as vending machines, consumer electronics and the typical building automation tools. This microcontroller is powerful, running at a clock speed of 720MHz and capable of speeds up to 1GHz. The AM3359 has broad operating system support such as Linux, Android and Windows. The AM3359 has a PowerVR SGX530 3D graphics accelerator. The ARM Cortex-A8 microcontroller line also offers 64KB of on-chip L1 cache and 256KB on-chip L2 cache with 128KB of other on-chip memory, and has the ability to support mDDR, DDR2 and DDR3. The AM3359 also offers the abilities for an LCD display, which is useful in the design that will be implemented into the Under the Sun Drink Mixer. It also has support for USB, Ethernet, PWM, I2C and SPI. In case that wasn't enough, the AM3359 also contains the Programmable Real-Time Unit Subsystem (PRUSS), which allows the user to create many different digital resources beyond the native peripherals on the microcontroller. Also, the PRUSS is completely separate from the AM3359, acting as a separate microcontroller, allowing you to run things on the PRU and not bogging down the ARM chip. As far as power consumption is concerned, it takes in between 1.8V and 3.3V to operate.

To look specifically at what the TI AM3359 ARM Cortex-A8 CPU is capable of, a development board on the market that uses this same microcontroller was looked into. The development board that was looked into and referenced was the BeagleBone Black by Texas Instruments.

3.2.4.1 Reference Design

The BeagleBone Black is the newest member of the BeagleBoard family and is a credit-card sized computer. It utilizes an AM3359 ARM Cortex-A8 microcontroller from TI that produces a whopping 1GHz of processing power. The BeagleBone Black makes use of the full capabilities of the AM3359 ARM Cortex-A8 microcontroller, running 512MB of DDR3 RAM and 2GB of onboard flash memory eMMC. The BeagleBone Black also makes use of an Ethernet port, USB port, micro HDMI port and a micro SD port.

The TI AM3359 ARM Cortex-A8 microcontroller offers everything that is needed for the Under the Sun Drink Mixer including a way to set up a network so that the client application would have a way to communicate with the embedded system, PWM channels for the dispensing motors, abilities for an LCD display, micro SD support, USB support, micro HDMI support and enough power to run an operating system so that a webserver can be ran.

The open source BeagleBone Black reference design will be used to create the printed circuit board (PCB) to house the TI AM3359 ARM Cortex-A8 CPU in the design that will be implemented. Components will be added and removed based on needs.

3.3 LCD Displays

Another important aspect of the Under the Sun Drink Mixer is the ability to have an LCD screen. The reason why this is so important is because when the machine is loaded with drink ingredients, it generates a QR code containing access to the webserver which links the client application to all of the menu items and the pre-determined library drink menu, as well as allowing you to order drinks. Several different options for an LCD screen were looked into. The requirements of the LCD screen were that it needs to print a QR code to the screen. Here are a few of the options that were looked into that will be expanded upon:

- Sharp LQ043Y1DX07 4.3 inch LCD
- Elpa S035Q01 3.5 inch TFT Touch LCD Display
- 1.8 inch TFT Color Display

3.3.1 Sharp LQ043Y1DX07 4.3 inch LCD

The first option that was looked into for the Under the Sun Drink Mixer was Sharp's LQ043Y1DX07 LCD. It is a 4.3 inch WVGA 800 X 480 LED Backlight 315 Nits Landscape TFT LCD, and it is actually the same display as the mobile phone HTC Desire HD. The LCD module is controlled by the display driver HX8363A

from Himax. Its input voltage required to power the display is 3.3V. The Under the Sun Drink Mixer design would use the display driver HX8363A and use the receiver chip TFP401 from Texas Instruments which is really just a DVI receiver. Then the display would need a small amount of initializing through a 9-bit SPI interface which could be done using a MSP430. Then, using an EEPROM chip on the board, the Extended Display Identification Data (EDID) would be stored to tell the board what resolution to use to display the information, and the DVI receiver listens for the Transition-minimized Differential Signaling (TMDS) signals and translates those to Parallel RGB signals. This allows the board to communicate and display information to the LCD. The issue with this display is cost and development time. The cost of everything together to get this LCD working would be over $100, for this reason, other LCD options were looked into.

3.3.2 Elpa S035Q01 3.5 inch TFT Touch Display

The next LCD option looked into for the Under the Sun Drink mixer was the Elpa S035Q01 3.5 inch TFT Touch Display. The Elpa display could display resolution of 320 X 240 and is a 4-wire resistive touchscreen. The input power of the Elpa S035Q01 is 3.3V like most other LCD displays. The backlight of this LCD is composed of 6 LED's in series. The Elpa S035Q01 uses the NT39016D as the driver integrated circuit. This integrated circuit uses the 3-wire serial port as a communication interface for all function and parameter settings. However, this LCD option was not available for purchase anywhere so other options were looked into.

3.3.3 1.8 inch TFT Color Display – JD-T18003-T01

The next LCD option looked into for the Under the Sun Drink Mixer was the 1.8 inch TFT Color Display. After figuring out how expensive the Sharp 4.3 inch discussed above was, it was decided to go with a much cheaper option. This 1.8 inch display would be enough to display the QR code that is needed to display without much complexity. It is a 1.8 inch TFT with true TFT color up to 18-bits per pixel, and a resolution of 160 X 128. This LCD is powered with an input voltage of 3.3V and uses the Sitronix ST7735R as the driver. This screen is fast response with video being a possibility if desired and is widely used in the normal mobile phones (non-smartphones). It uses Serial Peripheral Interface Bus (SPI) as its interface, simply taking only four to five digital pins to send pixels to the display. There are two distinct ways that this LCD screen can connect to the embedded system that was researched into. First, the method of using the Programmable Realtime Unit Subsystem (PRU) to send high speed data and code to initialize the display and send the information that is needed such as the QR code was looked into. This method ignores the Linux SPI, frame buffer and GPIO framework. The next method and the method that was decided to be

implemented consisted of using what is already available, such as the Linux SPI, frame buffer, and GPIO subsystems. This display is the one that will be used in the implemented device; it fits the needs of the Under the Sun Drink Mixer device perfectly and doesn't break the bank. This LCD display will be explained in further details later in the design section

3.4 Network Connections

A very important aspect of the Under the Sun Drink Mixer is the network that will connect the client application and the embedded system so that they can communicate back and forth. This is important because the whole idea of the Under the Sun Drink Mixer is to utilize a client application through a mobile device to order drinks, in which a signal must be sent back to the embedded system on the Under the Sun Drink Mixer that will then create the mixed drink for the user. The three options that were looked into for the network connection were:

- Local Area Network (LAN)
- Wireless Local Area Network (WLAN) or Wi Fi
- Wireless Personal Area Network (WPAN) or more specifically, Bluetooth

3.4.1 Local Area Network (LAN)

A local area network connects computers or other network devices over a relatively short distance. Generally, a networked office building, school, or house contains a single Local Area Network. Sometimes, one building contains several small Local Area Networks such as one per room, or a bigger Local Area Network can span a group of nearby buildings. Along with them operating in small areas, Local Area Networks are typically owned by a single person or organization, and often use connectivity technologies such as Ethernet.

For the Under the Sun Drink Mixer, Local Area Networks provide a network that is needed as a connection so that the client application can communicate back with the embedded system to produce the overall result of mixed drinks. However, implemented design for the Under the Sun Drink Mixer will be outdoors, which could cause a problem needing a wired connection, so other options will be explored such as Wi Fi or Bluetooth.

3.4.2 Wireless Local Area Network (WLAN) or Wi Fi

Wireless Local Area Network (WLAN) or more commonly known as Wi Fi is a technology that has become very popular that allows a device to exchange data or connect to the internet wirelessly by utilizing radio waves. The Wireless Local

Area Network is based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards. A device that utilizes Wi Fi can connect to a network resource like the internet using wireless access points. Wireless access points are used to allow wireless devices such as Wi Fi to connect to a wired network. One of the most common uses for access points are hotspots; this is where wireless users can connect to the Internet without worrying about the particular networks that they are connected to for the moment.

For the Under the Sun Drink Mixer, Wireless Local Area Networks seem to work rather well, not having to worry about a wired connection. However, Wi Fi can be less secure than a wired connection such as Ethernet because the intruder doesn't need a physical connection. There are precautions put in place and encryption tools used in Wi Fi including WPA and WPA2 so security is not something that will be a concern.

3.4.3 Wireless Personal Area Network (WPAN)

A wireless personal area network (WPAN) is used to connect devices centered around an individual's workspace wirelessly. A common type of wireless technology used as a Wireless Personal Area Network is Bluetooth. Bluetooth is a wire-replacement communication protocol designed for low power consumption and use with a short range. Bluetooth is commonly known for the wireless control between a mobile phone and a hands-free headset but it also is used in many other applications such as wireless controllers in the Nintendo Wii and Sony PlayStation 3.

Bluetooth and Wi Fi have many similar applications and are used in many of the same devices. Bluetooth and Wi Fi operate on the same radio frequencies, but Wi Fi has a higher power resulting in faster speeds and further range.

For the Under the Sun Drink Mixer, the implemented design will use a Wireless Local Area Network (WLAN). Wi Fi has the best of both worlds, wireless abilities which were needed for an outdoor device as well as a superior distance and speed to Bluetooth. The network connections portion will be discussed in further detail in the design section of this paper.

3.5 Barcode Scanner

A very important aspect of the Under the Sun Drink Mixer is the barcode scanner. The barcode scanner is important in the design because it is what initializes the whole drink processing. The user will initially scan the QR code provided by the Under the Sun Drink Mixer that is displayed on the LCD display with the client application. This will allow the client application access to the

webserver, the drink ingredients and pre-determined library of drinks. The importance of this step is huge, because without initially scanning the QR code provided on the LCD display, the user will not have access to the webserver and thus cannot order any drinks.

Once the user has scanned the QR code and gained access to the webserver, they can begin to order drinks. The user can choose from a pre-determined drink library or customize their own drink using the drink ingredients. After they have chosen or created their drink, the user will then click the "Order Drink" button on the client application. When the user is ready to pick up their drink, they will click the "Pickup Order" button on the client application, which will generate a QR code that can be used to pick up their drink. In order for the user to pick up their drink, they will approach the Under the Sun Drink Mixer and scan the QR code that was generated utilizing the barcode scanner that is embedded into the design, and the barcode scanner will go through its process discussed later in the document.

There were a few requirements that were looked into when choosing a barcode scanner. First, it had to be able to read 2D codes, since a QR code is 2D. Second, it had to have a constant beam, or some sort of automated detection on scanning rather than being a push button because it will be embedded into the Under the Sun Drink Mixer and nobody will be manually pushing a button to scan QR codes. Third, it had to be able to read QR codes on a mobile device, as that is what the client application is on, and that's what is read from. This excludes laser readers, because the white spaces on a LCD display are composed of green, blue and red pixels. Fourth, it has to be able to work day and night. Lastly, it must connect to the embedded system rather easy, preferably by USB. The main issue for barcode scanners that was concerning was price. These 2D barcode scanners are generally very expensive.

There were a few different options discussed and looked into for use in the design:

- Creating a 2D barcode scanner using a pre-existing library and a webcam
- Motorola DS457-HD20009 Fixed Mount 2D Barcode Scanner
- Motorola DS9208-SR4NNU21Z Desktop 1D/2D Barcode Scanner

3.5.1 Creating a 2D Barcode Scanner

The first option that was looked into was creating a 2D Barcode Scanner for the Under the Sun Drink Mixer. This option was looked into because it was going to be very cost effective. There is an existing open source software suite for reading bar codes from sources such as image files and video streams called ZBar. ZBar

has support to read QR codes, so that is exactly what is needed and it is licensed under GNU LGPL 2.1. The prerequisites for this design include an embedded system and support for the following; a USB camera, a USB to serial cable and a micro SD card. There are some pre-built binaries that must be loaded on the host system via the micro SD card and then the application can be built using the open source ZBar sources. This method of utilizing ZBar is very cost effective and will help keep the budget of the design low in the barcode scanner section, but it is very time consuming and finicky with memory corruption issues. For this reason, less time consuming options were looked into.

3.5.2 Motorola DS457-HD20009 Fixed Mount 2D Barcode Scanner

Another barcode scanner option that was looked into for the Under the Sun Drink Mixer was the Motorola DS457-HD20009 Fixed Mount 2D Barcode Scanner. This is an omnidirectional hands-free scanner that can scan any barcode on paper, mobile phones and computer displays. It has the ability to scan 1D code, 2D codes, which includes QR codes, and postal codes. This barcode scanners host interface is USB, which is exactly what was planned to be used for the design. The barcode scanner measures in at 1.15 inches H x 2.3 inches L x 2.44 inches W, which is vital in taking up a small amount of spacing on the overall Under the Sun Drink Mixer. Full omnidirectional scanning eliminates the need to precisely align the QR code and the imager, because of the unique aiming pattern used. This is also able to be used in the bright light during a sunny day in Florida, as well as the ability to work in total darkness. The input power is 5V and it draws a maximum of 450mA. The Motorola DS457-HD20009 Fixed Mount 2D Barcode Scanner offers everything that the Under the Sun Drink Mixer needs; the ability to read QR codes, it is a hands-free device, it can read off of mobile devices, it can scan whether it is sunny out or if it is pitch black out, and it offers USB connectivity. The only issue that with this barcode scanner is the price that comes along with it. It would cost in upwards of one third of the total budget, coming in at $350. For this reason, other options were looked into.

3.5.3 Motorola DS9208-SR4NNU21Z Desktop 1D/2D Barcode Scanner

The next option that was looked into was the Motorola DS9208-SR4NNU21Z Desktop 1D/2D Barcode Scanner. This is an omnidirectional hands-free barcode scanner that can scan in 1D or 2D and can scan barcodes or QR codes from paper, computer displays and mobile devices. It has an input voltage of 5V and draws about 150mA idle and around 230mA when scanning. It is relatively small with dimensions of only 5.5 inches H x 3.2 inches W x 3.1 inches D. The host interface for this barcode scanner is USB, which is exactly what was planned on being

implemented. Full omnidirectional scanning eliminates the need to precisely align the QR code and the imager, because of the unique aiming pattern used. This barcode scanner is immune to natural and artificial ambient light such as sunlight, which is exactly what is needed in the Florida sun, as well having the ability to work in the dark. The Motorola DS9208-SR4NNU21Z Desktop 1D/2D Barcode Scanner also offers everything that the Under the Sun Drink Mixer needs; the ability to read QR codes, it is a hands-free device, it can read off of mobile devices, it can scan whether it is sunny out or if it is pitch black out, and it offers USB connectivity. This barcode scanner is also much cheaper than the previous model that was looked at, the Motorola DS457-HD20009 Fixed Mount 2D Barcode Scanner by about $100. The Motorola DS9208-SR4NNU21Z Barcode Scanner is larger than the Motorola DS457-HD20009, but it is still small enough to work in the system design, so this is what was chosen.

3.6 Storage

For the Under the Sun Drink Mixer, a very important aspect of the design is the storage type that will be used. The embedded system will need storage for the operating system, the webserver running on the embedded system with drink ingredients menu as well as the pre-determined library and MySQL will also be used to store the ordered drinks, the picked up drinks, expiration timers, drink levels, pre-determined drink library and drink ingredients. PHP will be used to access that information stored through MySQL.

3.6.1 Ordered Drinks

To further expand on some of the details that MySQL will store, the database will log all of the ordered drinks and put them into a queue.

3.6.2 Expiration Timers

At the same time it will start a timer to log how long it takes for the user to pick up their drink. The webserver will allow the user five minutes between the order and pick up stage. If the user neglects to go to the “Pick Up” phase within the allotted five minutes, the webserver will drop the order from the queue and the user will no longer be able to pick up their orders. The reason why the expiration timer was added was to ensure that somebody didn’t order many drinks and not pick them up, because each drink that is ordered automatically reserves that amount of drink ingredients. If a user ordered fifty drinks, and doesn’t pick them up, you can see where this could be an issue and that fifty drinks worth of drink ingredients would be reserved. There is not only an expiration timer for the order stage, but also the pick-up stage. If somebody orders a drink, and then clicks the “Pick Up” button and gets issued a QR code, this QR code will be activated for

two minutes for the user to pick their drink up. If this expiration timer expires, the QR code will be removed from the webserver and stripped from the users screen.

3.6.3 Picked Up Drinks

When the user successfully picks up their drink, the webserver will move the drink entry from the “Ordered Drinks” section and move it to the “Picked Up Drinks” section in the database.

3.6.4 Drink Levels

Drink levels is also something that will be stored within the webserver. The database will store the overall amount of a specific drink ingredient is available, and any time a drink is ordered, it will reserve the amount of drink ingredient that the user requests. An example of this, is if the system has 60fl oz. of orange juice and 60fl oz. of pineapple juice and the user orders a mixed drink that contains 4fl oz. of orange juice and 4fl oz. of pineapple juice, the webserver will reserve that amount of drink ingredient to that specific order, and update the “Drink Levels” as well to reflect 56fl oz. of orange juice and 56fl oz. of pineapple juice. Mentioned before, if the user neglects to pick up their drink order in the allotted time, the drink ingredients will be reallocated and the webserver will update the “Drink Levels” to reflect 60fl oz. of orange juice and 60fl oz. of pineapple juice.

3.6.5 Pre-determined Library of Drinks

Also stored by the webserver will be the pre-determined library of drinks. A pre-determined library will be created that the users will have access to once they connect their client application to the webserver via the QR code displayed on the LCD display. There may be multiple pre-determined libraries depending on the current drink ingredients.

3.6.6 Specific Drink Ingredients

The webserver will also contain the specific drink ingredients. The drink ingredients can be updated depending on what was loaded into the Under the Sun Drink Mixer. These updated drink ingredients will reflect into the pre-determined library of drinks, so the user may have multiple pre-determined libraries depending on how many times the Under the Sun Drink Mixer has been updated.

3.6.7 Types of Storage

It was decided that the storage to be used for the Under the Sun Drink Mixer was going to be easy to implement and that wouldn't allow for too many issues, such as size both on the printed circuit board and amount of storage space. Another thing that was taken into consideration is that micro SD cards, USB Flash Drives and External Hard Drives have already been acquired by the group. The four options that were discussed to add to the Under the Sun Drink Mixer were:

- Onboard eMMC
- USB Flash Drive
- SATA Hard Drive
- Micro SD

3.6.7.1 Onboard eMMC

The first storage option chosen for the Under the Sun Drink Mixer was the onboard eMMC. The eMMC is a mass data storage device and communicator. It is nonvolatile memory and draws no power to maintain stored data while delivering high performance.

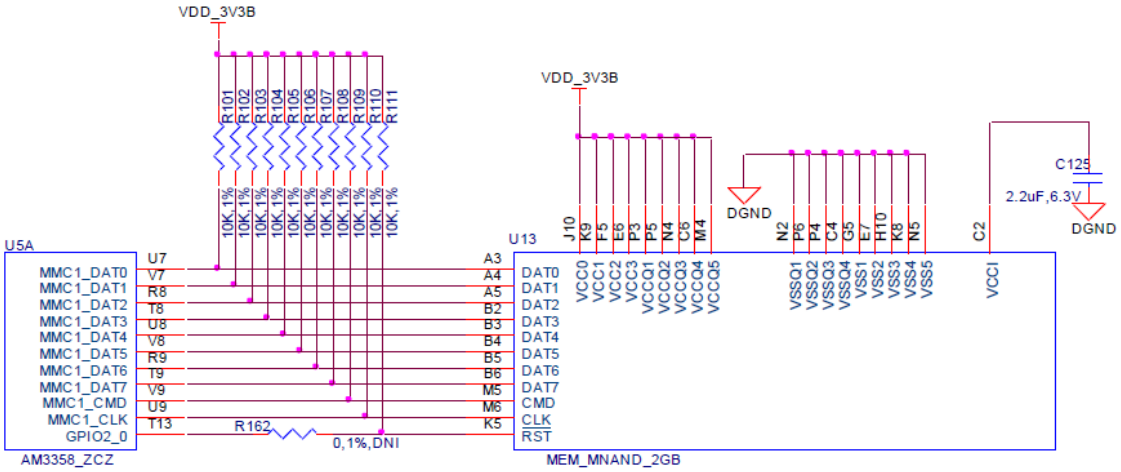


FIGURE 2: EMMC MEMORY DESIGN COURTESY OF TEXAS INSTRUMENTS

This is the design of the eMMC circuitry. This device is connected to the MMC1 port on the microcontroller which relates to boot order. It will first boot from the internal memory storage of eMMC. This schematic is using the same microcontroller layout that was chosen to be implemented in the Under the Sun Drink Mixer, so it will connect in the same way. This device runs at 3.3V and the VCCI is an internal voltage rail to this device. Pullup resistors are also used to increase the rise time on the signals in case there is any capacitance on the board.

The eMMC would work great with this design, but there are other options available that are already acquired, such as a USB Flash drive, micro SD card, or an external hard drive.

3.6.7.2 USB Flash Drive

The next storage option that was looked into for the Under the Sun Drink Mixer was a USB flash drive. A USB flash drive is a storage device that includes flash memory with an integrated Universal Serial Bus (USB) interface. USB flash drives are removable and rewritable, and very small in size; this is why they are extremely useful. USB flash drives have for the most part replaced floppy disks and CD-ROMs as far as when they are used for storage or back-up. A USB flash drive is not technically a drive, as it has no moving parts. A USB flash drive consists of small printed circuit boards carrying a small number of surface-mounted integrated circuits (ICs) and a USB connector. One of these ICs provides an interface between the USB connector and the onboard memory. USB flash drives draw power from the computer via the USB port. There are four parts that are essential to a USB flash drive; a USB connector, a USB mass storage controller, NAND flash memory chips and a crystal oscillator. USB flash drives have grown in amount of memory available significantly, there are typical sizes such as 2GB, 4GB, 8GB and they go all the way up to 1TB in size. USB flash drives are extremely fast, with the capabilities of 480 MB/s which are hypothetical values and not real world values, but USB flash drives are still much faster than micro SD.

This USB flash drive option is very suitable as the storage type for the embedded system that will be designed. The only reason why the USB flash drive was not pursued further is because there are already two items connected to the USB ports; the barcode scanner and the Wi Fi module. For this reason, other options will be looking explored for storage on the Under the Sun Drink Mixer.

3.6.7.3 SATA Hard Drive

The next storage option that was looked into for the Under the Sun Drink Mixer was a SATA Hard Drive. Serial Advanced Technology Attachment (SATA) is a bus interface that connects host bus adapters to mass storage devices. The mass storage device that would be implemented into the design to connect the SATA would be a typical hard drive. This allows for a huge amount of storage, in the hundreds of gigabytes, for very cheap. SATA runs with a native transfer rate of 600 Mbytes/sec, which is faster than the other options looked into for storage. This all seems great; the speed is remarkable and the amount of storage that can be attained for cheap is huge. The problem with SATA is the need to configure the

board that will be used for the Under the Sun Drink Mixer and add a SATA connector to the board layout which makes SATA possible. For this reason, other options were looked into for storage type.

3.6.7.4 Micro SD

The last storage option that was taken into consideration for the Under the Sun Drink Mixer was a micro SD card slot. SD or Secure Digital is a non-volatile memory card format that is used in portable devices like mobile phones, computers and digital cameras. The SD standard was introduced in 1999 as an improvement over MMC that was discussed before. There are three main sizes to SD cards; standard size, mini size, and micro size. Micro SD was looked into more heavily, as micro SD cards are already acquired for use in smart phones that are accessible. In regards to read and write speeds, the SD Association came up with speed ratings split by classes. This information will be shown in the table below.

TABLE 3: SD CARD SPEED CLASS RATING

Class	Minimum Performance
Class 2	2 MByte/sec
Class 4	4 MByte/sec
Class 6	6 MByte/sec
Class 10	10 MByte/sec
UHS Speed Grade 1	10 MByte/sec

These speed class ratings are split even further into suitability for different applications, which is shown in the table below.

TABLE 4: SUITABILITY FOR DIFFERENT APPLICATIONS

Class	Suitability for Applications
Class 2	SD video recording
Class 4	High-definition (HD) to Full HD video recording
Class 6	High-definition (HD) to Full HD video recording
Class 10	Full HD video recording and consecutive recording of HD stills
UHS Speed Grade 1	Real-time broadcasts and large HD video files

The Serial Peripheral Interface Bus (SPI) is mandatory for all SD families, and this bus supports a 3.3V interface. At start up or card insertion, the host device selects the SPI bus by the voltage level present on Pin 1. The power consumption

of micro SD cards vary by models and manufactures, but range anywhere from 20-100mA at a supply voltage of 3.3V.

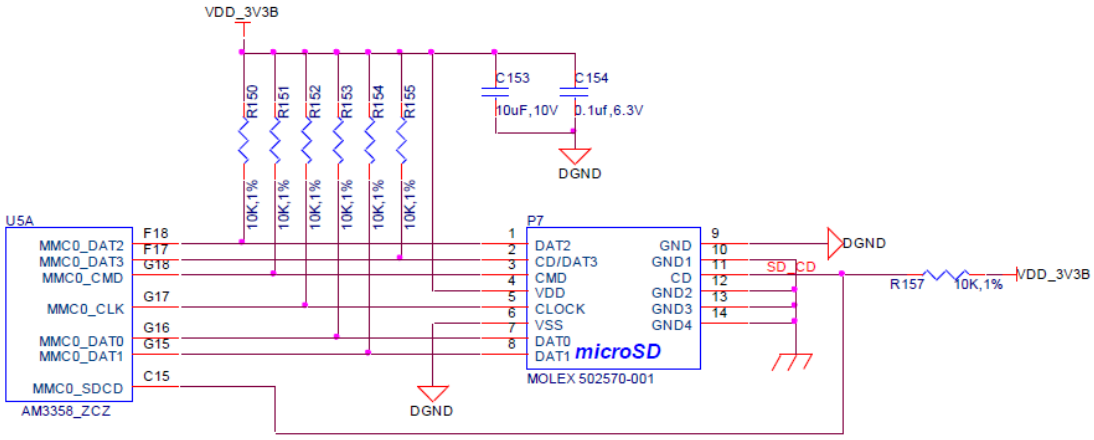


FIGURE 3: MICRO SD CIRCUIT

Shown above is the design of the micro SD circuitry. The signals MMC0_DAT0 through MMC_DAT3 are the data lines for the transfer of data between the microcontroller and the micro SD connector. The signal MMC0_CLK clocks the data in and out of the micro SD card. The MMC0_CMD signal indicates that a command instead of data is being sent. Power is provided from the VDD_3V3B rail and the 10uf capacitor is used for filtering. This schematic is using the same microcontroller layout that was chosen to be implemented into the Under the Sun Drink Mixer, so it will connect in the same way. The micro SD card will work perfectly with the implemented design and it is what will be used as a storage type for the Under the Sun Drink Mixer.

3.7 Power Requirements

3.7.1 Solar Panels

A solar panel is composed of solar cells which are a semiconductor such as silicon. Each cell is doped with an N-type on one side and a P-type on the other. This will produce a certain voltage across it when hit with photons and would allow current to flow in one direction. These cells can then be connected together to create a module. The module is composted of the cells connected in series and in parallel; the series connection dictates the voltage of the module and the parallel connection the amperage. A module is more commonly known as a solar panel. These panels can then be connected to create large arrays. The larger the area of the array of modules, the more electricity will be produced. These modules and arrays produce DC (direct-current) electricity that can then be

connected in both series and parallel to produce any required voltage and current combination.

Right now there are three different types of solar panels. They are monocrystalline Silicon panel, the polycrystalline silicon panel, and thin film. Each type of panel has its own pros and cons and each serves a different purpose depending on the amount of space the panel takes and the expense of the panel.

3.7.1.1Monocrystalline Silicon Solar Cells

These cells are made of monocrystalline silicon (Si), also called single-crystalline silicon, which has the highest-purity of silicon. These cells are made out of silicon ingots, which are shaped cylindrically. Cross sections are then cut to create silicon wafers, which is what gives monocrystalline their smooth uniform finish. Of all the types of panels, the monocrystalline have the highest efficiency rates because of their silicon purity level. The efficiency rates are typically 15-20%. These rates are being pushed even higher to 20.1% and 21.5%. Since the efficiency of a monocrystalline panel is the highest, the panels require less space compared to any other type of panel. Other pros include longest lasting panel and performs better than other types of panels. Like most things that are efficient, the cost is the higher than other similar polycrystalline panels. This is due to the fact that it has the purest silicon content and is the thickest of all the types of panels.

3.7.1.2 Polycrystalline Silicon Solar Cells

In a polycrystalline solar cell the purity of the silicon is less than that of the monocrystalline. This in turn means that the polycrystalline cell is not as efficient as the monocrystalline. The efficiency rate of a polycrystalline cell is usually between 12-16%. Polycrystalline is made by melting pieces of raw silicon and molding them in small rectangular strips. So instead of having a solid crystal of silicon which is cut into wafers, you have many silicon crystals all stuck together. The major benefit to polycrystalline is its low cost to produce. Since it is not as efficient as the monocrystalline, you will need more of them to achieve equal energy requirements. The polycrystalline tends to have a slightly higher heat tolerance then the monocrystalline. Efficiency in a panel tends to go down as the temperature of the panel rises; in this case the polycrystalline is more efficient at higher temperatures then monocrystalline, although the difference is negligible.

3.7.1.3 Thin-Film Solar Cells

Thin-film solar cells are made by depositing one or several thin layers of photovoltaic material one to a substrate. The material that is used determines the

type of thin-film solar cell. The different materials are amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium gallium selenide (CIS/CIGS), and Organic photovoltaic cells (OPC). Thin-film is the most efficient type of solar cell compared to the polycrystalline and the monocrystalline. Its efficiency rate is between 7-13%. This means that the cost of manufacturing is considerably cheaper than the other types. A big advantage that this technology has over the other two is that it is flexible, which opens up many new potential applications. High temperatures and shading have less effect on efficiency with thin-film. There are however drawbacks to this technology, one being the need for wide open spaces. Since thin-film efficiency rate is low, you would need a much bigger area for panels then that of polycrystalline and monocrystalline. So the use of thin-film is not a good alternative to residential areas and city areas. Also, thin-film solar panels do not last as long as monocrystalline or polycrystalline.

3.7.1.4 Conical Solar Panels

Conical Solar Panels are the latest advancement in solar power technology and worth acknowledgement. It is said that is the most efficient solar powered panel configuration. Just like its name implies, it is shaped like a cone with its outside surface layered in PV cells and floats on a magnets. It is then enclosed by an outer cone of made of specialized lenses that concentrate bands of sunlight on the inner PV covered cone. It has been known for a long time that concentrated lensing can dramatically increase electricity. The problem is that the concentration of light focused on one static point continuously produces intense heat that could burn wholes though the PV cell or generate such high temperatures that the PV becomes inefficient. The conical solar panel benefits from this concentration of light produced by its outer bubble lenses by spinning. The cells capture light energy but spin away before thermal energy can transfer. This constant cooling means that the conical solar panel can use less heat-tolerant material than other light-concentrations systems. Another feature that this design benefits from is the shape has less wind sheer then regular flat panels that require structural reinforcements against wind. This new advancement of solar power is of interest to use because it delivers high efficiency for small size. Even though the Under the Sun Drink Mixer will be powered by a regular flat panel, it could be used in its place.

3.7.2 Power Control Circuits

Because a solar panels voltage can swing wildly up and down over a wide range of voltages, a controller is need to increase or decrease the voltage a needed. MPPT charge controllers will be investigated.

3.7.2.1 MPPT Charge Controller

The most efficient way to squeeze every last joule out of your solar panel is to use a Maximum Power Point Tracking controller, or a MPPT controller. This type of tracking should not be confused with mechanical tracking, which use motors to constantly face the solar panel directly at the sun. MPPT uses digital tracking to maximize power. Unlike a PWM controller, that holds the panel voltage at your battery voltage and losing that extra power, the MPPT provides another function that can account for this. It uses a DC voltage converter that converts the voltage of the panels to that required by the batteries, with practically no loss of power. This means that this smart controller can keep the panel voltage at their maximum power point, while supplying the voltage requirements of the battery.

A MPPT controller is basically made up of a DC/DC converter that is controlled by an integrated microcontroller. The microcontroller will sense the battery voltage and adjust the DC/DC converter to provide maximum power point. The DC/DC converter can be composed of one or two different topologies: a buck converter, a boost converter, or a buck-boost converter. This project will investigate these topologies below. Figure 5 shows a schematic of a MPPT controller with a buck and boost mode converter.

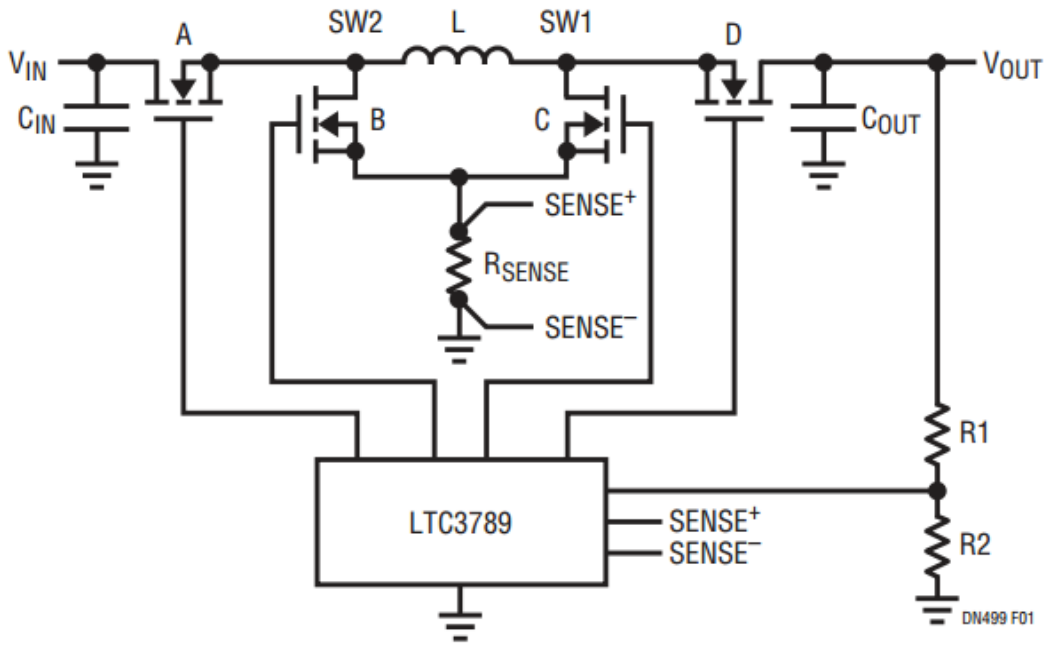


FIGURE 4: SWITCH BUCK-BOOST CONVERTER

3.7.2.1.1 BUCK CONVERTER

A buck converter is a DC/DC that steps down the voltage to a direct current load. It provides a steady output voltage under varying load conditions while maintaining heat, which leads to high efficiency. This circuit uses the basic topology seen in Figure 8 below.

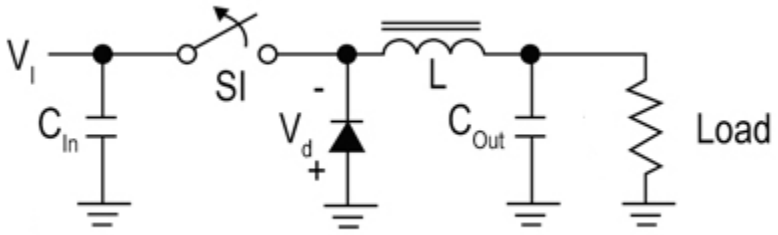


FIGURE 5: BUCK CONVERTER

Buck converters are used to decrease the DC voltage while still maintaining no power loss. It accomplishes this by utilizing the electrical inertia inherent to the inductor. When the switch turns ON, the input voltage is applied across the inductor. This will cause current to be stored in the inductor in the form of a magnetic field. When the switch is turned OFF, the inductor discharges and current flows through it. Before it is fully discharged, the switch is turn ON and the inductor charges back up again. Because of inductor output voltage ripple, due to the switching, a capacitor is used the smooth the output. This output voltage ripple is calculated in the equation below.

$$\Delta V_0 = L\frac{di}{dt}$$

Because the inductor never reaches zero current, the system is assumed to be loss less. This means that the input power and the output power are equal. Therefore, the duty cycle can be found for a given input voltage and a required output voltage. The voltage relationship becomes $V_{out} = DV_{in}$, where D is the duty cycle. This also means that the input and output current average is $I_{in} = DI_{out}$.

This circuit can also be made by switching the diode with another switch. This second switch will be OFF when the first is ON. When the first switch is OFF the second will be ON. The alternation of ON and OFF will cause the same effect as a diode, but will increase efficiency by not having to overcome the built in potential

of the diode. The two switch buck converter will be ideal for MPPT charge controlling, since this project is trying to maximize power efficiency.

3.7.2.1.2 BOOST CONVERTER

Like the buck converter, the boost converter is a DC/DC converter but steps the voltage up to a direct current load. This is one of the most effective ways to step up the voltage while having no energy loss.

The basic topology of the boost converter can be seen below in Figure 9.

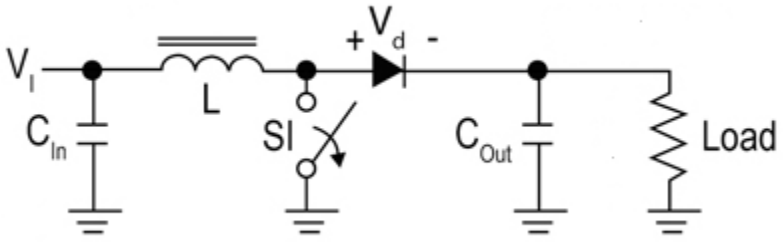


FIGURE 6: BOOST CONVERTER

The boost converter works by adding the converter voltage to the input supply voltage. First the switch is ON, it allows current to flow through the inductor which is charging it up. Once the inductor is charged, according to the duty cycle, the switch turns OFF. The inductor produces the necessary electromotive force to overcome the capacitor voltage. The result is a step up DC/DC conversion. The input and output voltage can be repressed in equation below.

$$V_{out} = \frac{V_{in}}{1 - D}$$

Duty cycles for the boost converter could be as high as 93%, due to the fact that it takes a longer time to charge the inductor compared to its discharge time. This circuit can be used when the input voltage from the panel drops below the necessary charge voltage for the battery. Like the buck converter, the boost converter can replace the diode with another switch that will alternate OFF and ON.

3.7.2.1.3 BUCK-BOOST CONVERTER

The buck-boost converter is a combination of the buck topology and the boost topology. If you take the buck circuit and crop it at the inductor, then take the boost circuit and crop it at the inductor, then combined the two topologies the

buck-boost converter is created. Figure 8 below shows a circuit representation of a four switch buck-boost converter.

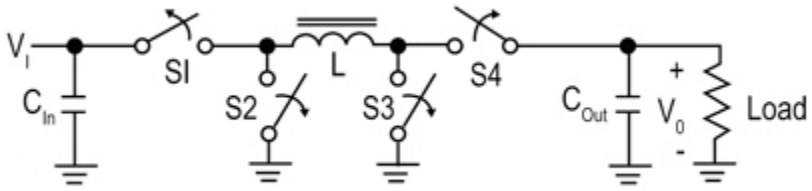


FIGURE 7: BUCK-BOOST CONVERTER

The buck-boost converter can both step up and step down the input voltage. If the input supply voltage is greater than the necessary output voltage, the circuit will be in buck mode. In buck mode, a switch 4 is always ON and switch 3 is always closed. The other switches will alternate switching according to the duty cycle. You will also notice that if switch 4 is short and switch 3 is open, it is the same topology as the buck converter. If the input voltage is smaller than the necessary output voltage, then boost mode is needed. In boost mode, switch 1 is always ON and switch 2 is always OFF. As you can see, if switch 1 is short and switch 2 is open then boost topology is made.

The four switch buck-boost converter will be an ideal choice as a DC/DC converter for this project. Because the output of the panel can vary over a wide range of voltages, a DC/DC converter that can both step the voltage up and down is needed. This DC/DC switch converter can then be integrated with a micro controller to controller when it needs boost or buck mode and what duty cycle is needed for maximum efficiency.

3.7.3 MICROCONTROLLER (MPPT)

Because of the varying input voltage from the solar panel, a microcontroller is needed to continuously check the input voltage of the solar panel and compare it to a reference voltage. It then must take the error of the two voltages and decide whether to it need to be in buck mode or boost mode. Any microcontroller can be used for such a task but it would turn out to be complicated do to the programing and algorithms that would be needed.

3.7.3.1 SM72442 (MAXIMUM POWER POINT TRACKING CONTROLLER)

This project will be investigating Texas Instruments SM72442 maximum power point tracking controller for photovoltaic solar panels. A circuit diagram and typical application can be seen below in Figure 9.

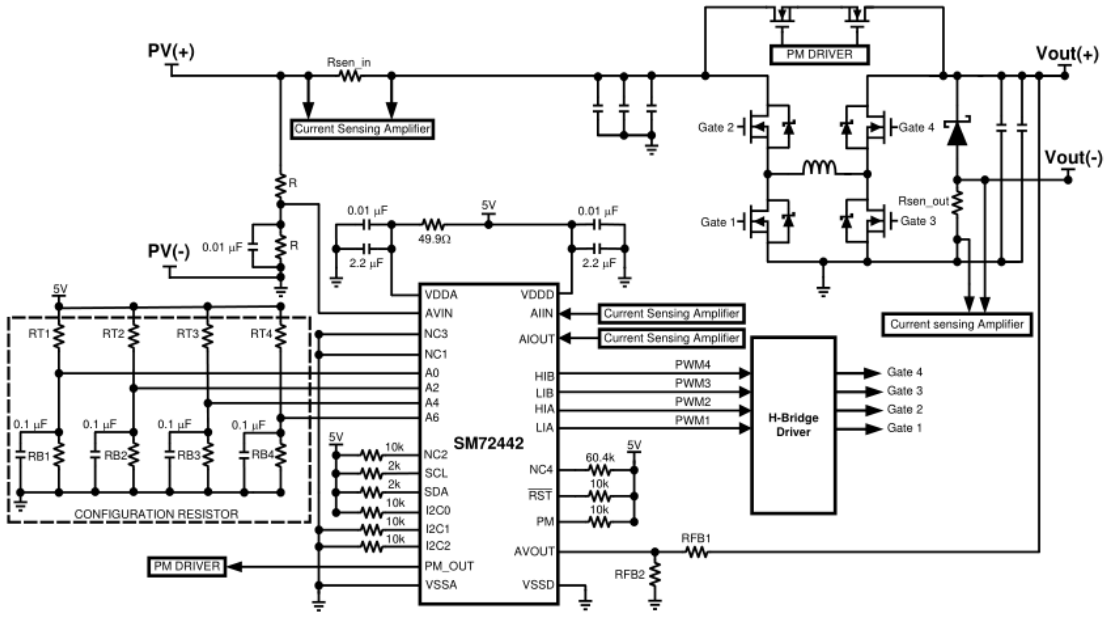


FIGURE 8: SM72442 SAMPLE SCHEMATIC

This controller is meant to control four PWM gate driver signals for a four switch buck-boost converter. The SM72442 also comes with a panel mode feature that allows the panel to be directly connected to the output of the DC/DC converter. In order to control the switches, a driver is needed. It is recommended that the SM72295, which is a photovoltaic full bridge driver, is used to drive the switch gates. It also features an 8-channel, 12-bit A/D converter that sense input and output voltages and currents, as well as board configuration.

This chip is programmed with a maximum power point tracking algorithm that monitors the input current and voltage and controls the PWM duty cycle to maximize energy from the solar panel. The SM72442 has fast convergence of maximum power point; it typically occurs within 10ms. This enables the controller to maintain optimum performance under fast changing conditions. The transition between buck, boost, and panel mode are smoothed and advanced digital PWM techniques are employed to increase effective PWM resolution. Output voltage and current limiting functionality are integrated into digital logic. The controller is capable of handling both shorted and no-load conditions and will recover smoothly from both.

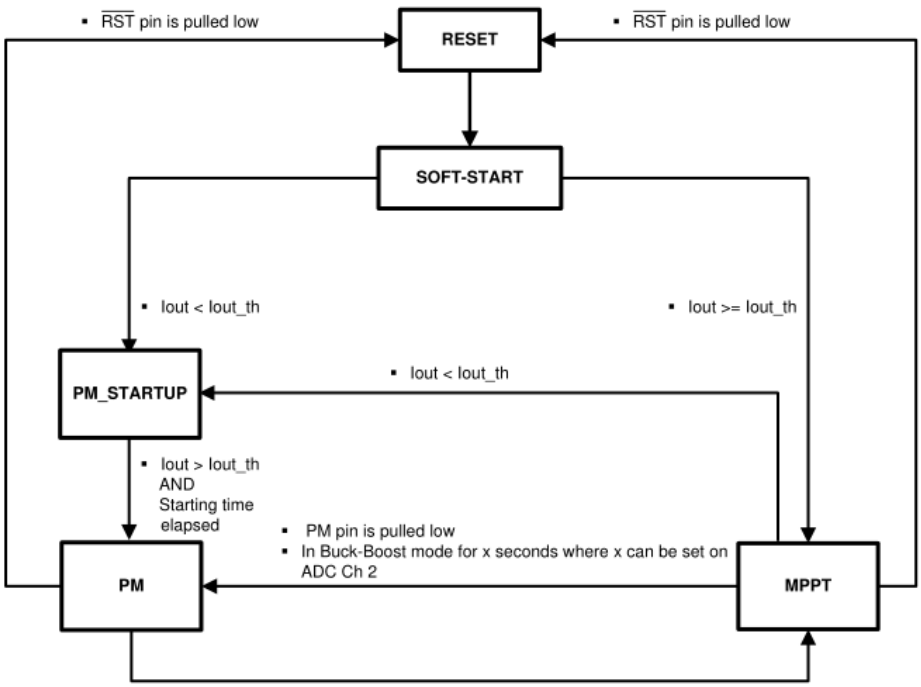


FIGURE 9: HIGH LEVEL STATE DIAGRAM FOR STARTUP

The above diagram shows the different states of the controller when starting up. The soft start feature will ramp up the output voltage for a fixed time. If now output current id detected during soft-start time, the chip will then be in panel mode. A counter will start once the minimum output current threshold is met. During that time, any variation on the output power will not cause the chip to enter MPPT mode. Once that time has passed, a certain power level variation at the output will engage the chip in MPPT mode. If the output current exceeded the current threshold set at A/D channel during soft-start, the chip will then engage in MPPT mode.

3.7.3.2 Communication with SM72442

The SM72442 can be configured through its I2C interface. Using the I2C pins, the SM72442 can control the duty cycle of the PWM signal. It can also control the input and output voltages and current offset through I2C on register 4. There are other control registers that can be used. Below in Table 5, 6, 7, 8, and 9 are the registers that are available and there use. These registers will be important for programming the SM72442.

TABLE 5: REG0 REGISTER DESCRIPTION

Bits	Field	Reset Value	R/W	Bit Field Description
55:40	RSVD	16'h0	R	Reserved for future use.
39:30	ADC6	10'h0	R	Analog Channel 6 (slew rate detection time constant, see adc config worksheet)
29:20	ADC4	10'h0	R	Analog Channel 4 (iout_max: maximum allowed output current)
19:10	ADC2	10'h0	R	Analog Channel 2 (operating mode, see adc_config worksheet)
9:0	ADC0	10'h0	R	Analog Channel 0 (vout_max: maximum allowed output voltage)

TABLE 6: REG1 REGISTER DESCRIPTION

Bits	Field	Reset Value	R/W	Bit Field Description
55:41	RSVD	15'h0	R	Reserved for future use.
40	mppt_ok	1'h0	R	Internal mppt_start signal (test only)
39:30	Vout	10'h0	R	Voltage out
29:20	Iout	10'h0	R	Current out
19:10	Vin	10'h0	R	Voltage in
9:0	Iin	10'h0	R	Current in

TABLE 7: REG3 REGISTER DESCRIPTION

Bits	Field	Reset Value	R/W	Bit Field Description
55:47	RSVD	9'd0	R/W	Reserved
46	overide_adcprog	1'b0	R/W	When set to 1'b1,the below overide registers used instead of ADC
45	RSVD	1'b0	R/W	Reserved
44:43	RSVD	2'b01	R/W	Reserved
42	power_thr_sel	1'b0	R/W	Register override alternative for ADC2[9] when reg3[46] is set (1/2^^5 or 1/2^^6)
41:40	bb_in_ptmode_sel	2'd0	R/W	Register override alternative for ADC2[8:7] when reg3[46] is set (5%,10%,25% or 50%)
39:30	iout_max	10'd1023	R/W	Register override alternative when reg3[46] is set for maximum current threshold instead of ADC ch4
29:20	vout_max	10'd1023	R/W	Register override alternative when reg3[46] is set for maximum voltage threshold instead of ADC ch0
19:17	tdoff	3'h3	R/W	Dead time Off Time
16:14	tdon	3'h3	R/W	Dead time On time
13:5	dc_open	9'hFF	R/W	Open loop duty cycle (test only)
4	pass_through_sel	1'b0	R/W	Overrides PM pin 28 and use reg3[3]
3	pass_through_manual	1'b0	R/W	Control Panel Mode when pass_through_sel bit is 1'b1
2	bb_reset	1'b0	R/W	Soft reset
1	clk_oe_manual	1'b0	R/W	Enable the PLL clock to appear on pin 5
0	Open Loop operation	1'b0	R/W	Open Loop operation (MPPT disabled, receives duty cycle command from reg 3b13:5); set to 1 and then assert & deassert bb_reset to put the device in openloop (test only)

TABLE 8: REG4 REGISTER DESCRIPTION

Bits	Field	Reset Value	R/W	Bit Field Description
55:32	RSVD	24'd0	R/W	Reserved
31:24	Vout offset	8'h0	R/W	Voltage out offset
23:16	Iout offset	8'h0	R/W	Current out offset
15:8	Vin offset	8'h0	R/W	Voltage in offset
7:0	Iin offset	8'h0	R/W	Current in offset

TABLE 9: REG5 REGISTER DESCRIPTION

Bits	Field	Reset Value	R/W	Bit Field Description
55:40	RSVD	15'd0	R/W	Reserved
39:30	iin_hi_th	10'd40	R/W	Current in high threshold for start
29:20	iin_lo_th	10'd24	R/W	Current in low threshold for start
19:10	iout_hi_th	10'd40	R/W	Current out high threshold for start
9:0	iout_lo_th	10'd24	R/W	Current out low threshold for start

This documentation will refer the SM72442 application note to see how to communicate with the chip.

The data registers in the SM72442 are selected by the Command Register. The Command Register is offset from the base address 0xE0. Each data register in the SM72442 falls into one of two types of user accessibility:

- Read only (reg0, reg1)
- Write/Read same address (reg3, reg4, reg5)

There are 7 bytes in each register, and data must be read and written in blacks of 7 bytes. Figure 11 depicts the ordering of the bytes transmitted in each frame and the bits with each byte. In the read sequence depicted by Figure 11 the data bytes are transmitted in frames 5 through 11, starting from the LSByte, DATA1, and ending with MSByte, DATA7. In the write sequence depicted in Figure 11, the data bytes are transmitted in frames 4 through 11. Only the 100 kHz data rate is supported.

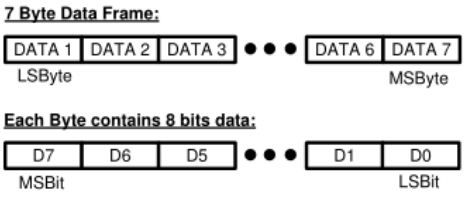


FIGURE 10: ENDIANNESS DIAGRAM

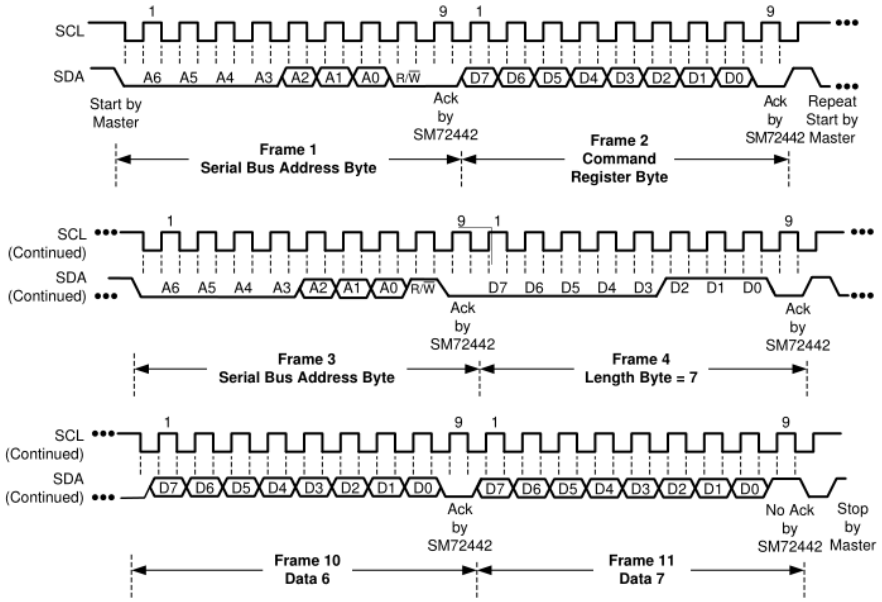


FIGURE 11: READ SEQUENCE

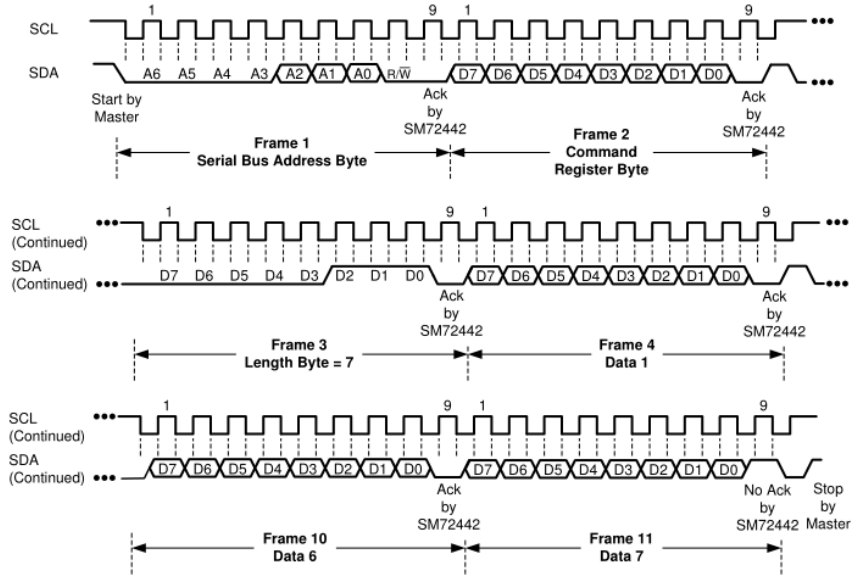


FIGURE 12: I2C WRITE SEQUENCE

3.7.3.1 SM72295 (Photovoltaic Full Bridge Driver)

The purpose of the SM72295 is to drive 4 discrete N type MOSFET's in a full bridge configuration. The drivers have integrated high speed bootstrap diodes and provide 3 amps of peak current for fast efficient switching. A diagram containing a typical application is in Figure 14 below.

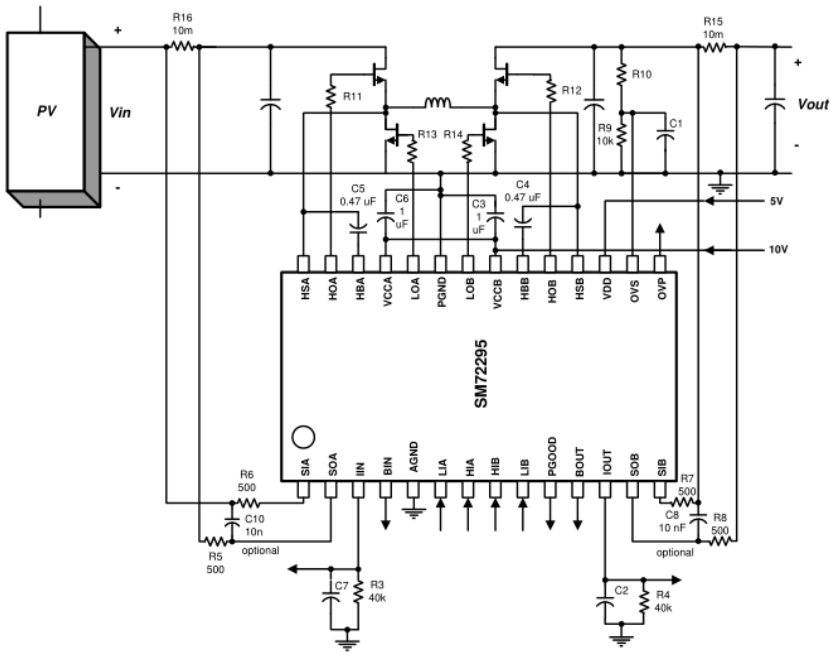


FIGURE 13: SM72295 SAMPLE APPLICATION

This chip also features two transconductance amplifiers with externally programmable gain and filtering to remove ripple current to provide average current information to the control circuit. If low impedance interface to an A/D converter is needed, the current sense amplifiers have buffered outputs available. An externally programmable input over voltage comparator is also included to shut down all outputs. Under voltage lockout with a PGOOD indicator prevents the drivers form operating if VCC is too low.

3.7.4.3 SM72482 (Panel Mode Driver)

The SM72442 has an optional pin for panel mode. Panel mode is a mode that directly connects the panel to the battier bank. This can only work if the open voltage of the solar panel is the proper charge voltage for the battery. Most solar panel under 50 watts has an open voltage of about 17 to 18 volts. They are specifically made to be 17 to 18 volts so it can easily charge a 12 volt battery. Panel mode could add even more efficient to the MPPT controller design by reducing heat and switch power dissipation. A diagram of the use of the SM72482 is seen in Figure 15 below.

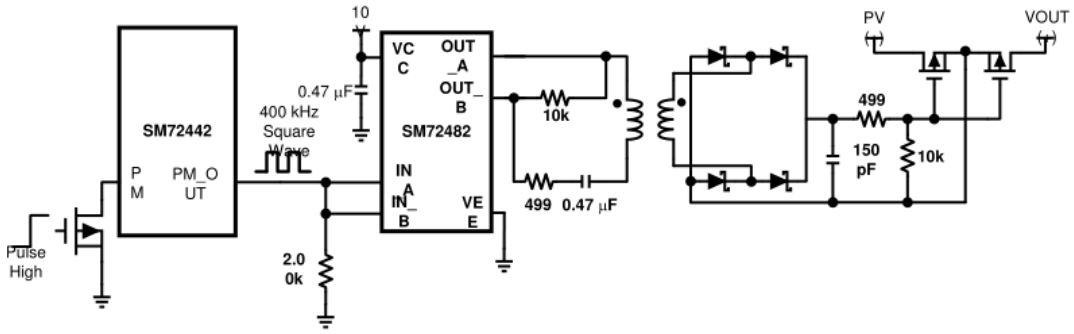


FIGURE 14: SM72482 IN PANEL MODE APPLICATION

If Figure 15, you can see how to switches are hooked up to the panel mod driver. Also, notice that when the two switches are ON, the panel current bypasses the DC optimizer circuit and goes directly to the output. The SM72482 dual gate driver will be ideal for this purpose. It replaces industry standard gate drivers with improved peak output current and efficiency. Each output driver stage includes MOS and bipolar transistors operating in parallel that together sink more than 5 amps peak from capacitive loads. Combining the unique characteristics of MOS and bipolar devices reduces drive current variation with voltage and temperature. Under-voltage lockout protection is also provided. The drivers can be operated in parallel with inputs and outputs connected to double the drive current capability.

3.7.4.4 SM72240 (5-Pin Microprocessor Reset)

The SM72240 is a chip that controls a microprocessor supervisory circuit. It monitors the power supplies in a microprocessors and digital systems. It provides a reset to the microprocessor during power-up, power-down, and brown-out conditions, and manual reset. Figure 16 shows a typical application circuit.

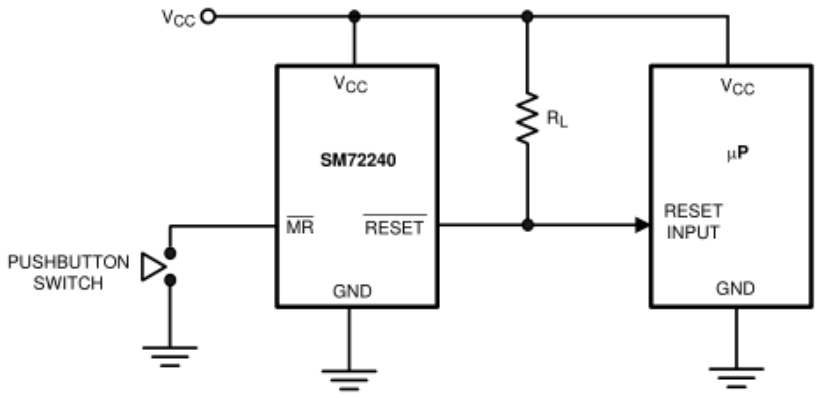


FIGURE 15: SM72240 SAMPLE APPLICATION

This chip has an active-low open-drain “reset” output. The SM72240 is suitable for monitoring 5 volts. With a low supply current of only 6 micro amps, and is ideal for use in portable equipment. This chip will be used to reset the SM72442 when whenever needed.

3.7.4.5 SM72485 (Buck Switching Regulator)

For the 10 volt regulator, this project will investigate the SM72485 as appose to a 10 volt voltage regulator. There are many benefits to using the SM72485 chip as stated in the TI SM72485 application note.

> “The SM72485 is a step down switching regulator that has all the functions needed to implement a low cost, efficient, buck bias regulator. It will be used to maintain a constant 10 volt power supply to power the drivers for gate switching. This regulator design is based on a control scheme using an ON time inversely proportional to the input voltage. This will allow the operating frequency to remain constant. The scheme requires no loop compensation.” [2]

An application circuit can be seen in Figure 17 below.

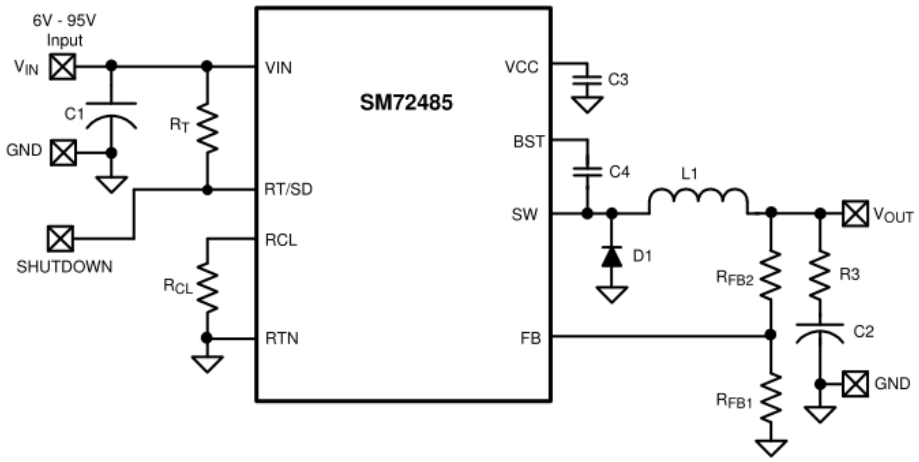


FIGURE 16: SM72485 SAMPLE APPLICATION

To further investigate the SM72485, the control circuit overview in the application notes was referenced.

> “The SM72485 controls the output voltage by a Buck DC-DC regulator that uses a control scheme in which the ON time is inversely proportional to the input voltage. A comparator is used to control the ON time, while an

output voltage feedback is compared to an internal reference voltage. If the feedback voltage is below the reference the buck switch is turned ON for a fixed time that is determined by the line voltage and a resistor. It will then switch OFF for a minimum time of 300ns. If the feedback is still below the reference at the end of the OFF time, it will turn ON again for a fixed time. This process will continue until regulation is achieved." [2]

This chip is idle for stepping down large voltages efficiently. This application will not require such a huge voltage regulation, but rather, concerned more about efficiency. With a 10 volt voltage regulator, the voltage regulator loses a lot of energy to heat, which is undesirable for this applications purpose.

3.7.4 Battery

In order to store the power from the solar panel, the project will require the need to choose a battery that will meet all power requirements. The battery will need to be able to run six 12 volt 1.6 amp DC motors that will be used to pump the liquid for the Under the Sun Drink Mixer. It must also power the projects microcontroller and all necessary divers and modules. Let's investigate four types of rechargeable batteries and weight out the pros and cons to see which will be ideal for this project.

3.7.4.1 Nickel Cadmium

Nickel Cadmium batteries have been around for over 100 years. It uses a nickel oxide in the positive electrode or the cathode, a cadmium compound as the negative electrode or anode, and potassium hydroxide solution as the electrolyte. Like most rechargeable batteries it converts chemical energy into electrical energy upon discharging and converts electrical energy into chemical energy during charging. The Nickel Cadmium battery is compiled of rolled up layers of nickel with cadmium between the layers. The most common battery sizes go range from AAA to D.

One of the advantages of using Nickel Cadmium batteries is it can be recharged several times. It is also very robust; it performs well in cold temperatures and is very resistant to overcharging. However, there is a problem with Nickel Cadmium batteries called the "memory effect". The "memory effect" is when your battery "thinks" that it is fully charged but isn't. This can happen if you continuously recharge your battery when it is not fully discharged. To prevent this from happening, you would have to discharge the battery completely and then charge it back up to its full capacity. Another disadvantage of the Nickel Cadmium battery is that they are very toxic to the environment.

3.7.4.2 Nickel Metal Hydride

The Nickel Metal Hydride battery is an alkaline storage battery due to the use of potassium hydroxide as the electrolyte. Like the Nickel Cadmium battery, the positive electrode of the Nickel Metal Hydride is nickel hydroxide, but instead of using Cadmium as the negative electrode it uses a hydrogen-absorbing alloy instead. Because Cadmium is the reason for the "memory effect" the Nickel Metal Hydride battery will not suffer from this effect. The Nickel Metal Hydride battery have about three times more capacity than that of a Nickel Cadmium battery, they also have a higher energy density then Nickel Cadmium which means it can power for longer periods of time. Some other advantages of this battery is a wide range of temperature that it could operate, it has a flat discharge characteristic, and rapid charge. Because there is no Cadmium in this battery, it is a much safer battery to dispose of. One of the disadvantages of Nickel Metal Hydride battery is that it outputs lower current then a Cadmium battery would. It also has a high self-discharge rate, which means it cannot be stored for long periods of time.

3.7.4.3 Lithium-ion

Today, lithium-ion batteries are used to power many electronic devices and for powering electric cars. This is because lithium is the lightest of all metals, has the greatest electrochemical potential and provides the largest energy density for weight. Because of safety problems, due to the instability of lithium when it is charged, of lithium metal a non-metallic lithium-ion is used. This allows for safe recharge of the battery. The energy density of lithium-ion is typically twice that of the standard nickel-cadmium. It also has the highest cell voltage of 3.6 volts. Lithium-ion is a low maintenance battery, an advantage that most other chemistries do not have. There is no memory and no scheduled cycling is required to prolong the battery's life. In addition, the self-discharge is less than half compared to nickel-cadmium; making lithium-ion well suited form modern fuel gauge applications. Lithium-ion cells cause little harm to the environment when disposed of.

Despite all of the advantages, lithium-ion has its drawbacks. It is fragile and requires protection circuit to maintain safe operation. This circuit is built into the battery pack and limits the peak voltage or each cell during charge preventing the cell voltage from dropping to low on discharge. The biggest disadvantage of lithium-ion batteries is aging. Lithium-ion batteries will lose their charge density after many charge and discharges.

3.7.5.4 Lead-acid

Lead-acid battery technology has been around since the 19th century and remains the technology of choice for automotive applications because of their robustness and low cost. Lead-acid batteries are composed of a lead-dioxide cathode, a sponge metallic lead anode and a sulfuric acid solution as the electrolyte. Due to the heavy metal elements in these batteries, it makes them the heaviest of all batteries and improper disposal can be hazardous to the environment. Lead acid batteries charge by the lead sulfate and water are electro-chemically converted to lead, lead oxide and sulfuric acid by an external charging source. During discharge the positive plate and negative plate react with the electrolyte of sulfuric acid to create lead sulfate, water and energy. Along with its low cost and robustness, the lead acid battery is also tolerant to overcharging, low internal impedance, can deliver very high currents, and can be left on float charge for prolonged periods of time. For the project, a prolong float charge is necessary for charging from a solar panel.

3.8 Sensors

Deciding which type of sensor to incorporate to the device was a complex task as many factors played an important role when choosing the right sensor. Many elements needed be taken into consideration such as the sensor's weight, price, accountability, requirements, etc. The sensor needs to be light and inexpensive as well as compatible with the microprocessor. There are also a huge variety and types of sensors in the market to choose from, research on all the different types of sensors and its functionalities had to be done in order to choose the correct one and the most appropriate to use with the Under the Sun Drink Mixer. Below are some of the sensors that came to mind when choosing the right sensor, the pros and cons of each one, and why the chosen sensor is the most appropriate one to this project.

3.8.1 Type of Sensors

From the huge variety of sensors in the market, the one below were considered because it matched the requirements more closely according to the specified needs. All the various types of sensors such as: temperature sensors, chemical sensors, environmental sensors, thermal sensors, optical sensors, density sensors, fluid viscosity sensors, water sensor, hydrogen sensor, flow sensor, gas sensor, etc. were automatically discarded for obvious reasons as they were far off from the purpose of this project.

3.8.1.1 Position Sensors

Position sensors can simply detect the presence of absence of an object which is ideally what it needs to be accomplished. The sensor should detect the presence of a cup before it starts dispensing. However, these types of sensors could be more complex as it also measures linear or angular positions in reference to a fixed point and it also provides other unrelated information such as time measurements, speed, velocity, and acceleration. All of these extra things can also be calculated from such sensors, and to the purpose of this project, it is unnecessary.

3.8.1.2 Capacitive Displacement Sensor

These types of sensors measure the position or change of position of any object as well as measuring thickness or density of such object. Again, way too complex for the purpose of the project but one of the reasons these sensors were appealing at first is because they are non-contact devices which is essentially what it was needed. Meaning an object, a cup in this case, could be detected without the need to be directly touched.

3.8.1.3 Touch Sensor

These type of sensors need to be touched so it can send a signal. These types of sensors bring other issues to the table that need to be taken into consideration, like the weight of the object and how light or heavy would it need to be in order to be sensed. It is not in the best interest of the users to have to press the sensor firmly because the cup is not being sensed on its own. If the object is not sensed, the Under the Sun Drink Mixer will not start dispensing.

3.8.1.4 Light sensors

Light sensors seemed to be appropriate since they would send a signal if it's completely dark, putting a cup on top of the sensor would trigger that signal. A positive aspect of using this sensor is that it will have fewer margins of errors since it will be triggered only if it detects complete darkness. Since all the circumstances had to be taken into consideration, using a light sensor at night would trigger the sensor because it is dark. This does not serve the purposes of having an efficient sensor that would be reliable. The light sensor was taken into consideration because it gives the minimal margin of error during daylight; if there was no issue for its use during night, it would have been the ideal sensor. The possibility of fixing this issue was contemplated; for instance, adding an LED light to illuminate the sensor at all times would allow the sensor to work correctly in the evenings as well. However, this was an extra step and due to the limited

time and resources, the group has decided to opt for a simpler and more efficient method to detect a cup.

3.8.1.5 Infrared Proximity Sensor

An infrared sensor closely matched the requirements as it would detect the cup without any of the downfalls from the other sensors described above. However, the IR sensor has to be short range since the space provided for the cup will be about 8 inches and the sensor should not detect the other side of the cup slot in the absence of the cup. The particular sensor that will be used for this project is the *Infrared Proximity Sensor Short Range*; this sensor has an analog output that varies from 3.1V at 3cm (1.18in) to 0.3V at 30cm (3.94in) so it will be ideal for the purpose of the project as the red solo cup slot will be placed about 2 inches away from the sensor so it can be detected.

There's a possibility that the sensor might not function correctly if direct sunlight is received into the detector surface or if an LED light is directed at it. There are cases that the distance cannot be measured exactly if light is received from the sensor. Therefore, the sensor will be placed in a spot where direct sunlight will not reach and not be affected by it.

The drink mixer itself might have an LED light on just to illuminate the section when it's dark in order to guide its users when placing their cup, scanning their code, etc. In such cases, the light will not be placed directly above the sensor or near it where it could affect its performance.

3.8.2 Connecting IR proximity sensor

The sensor is recommended to be connected by a by-pass capacitor of 10µF or more between Vcc and GND. The output will be connected to one of the analog input pins on the embedded system, two of the wires on the sensor are for power and the third wire is the actual output signal.

Figure 5 below shows how the IR sensor that will be used in the implemented design of the Under the Sun Drink Mixer will connect to the Texas Instruments AM3359 microcontroller.

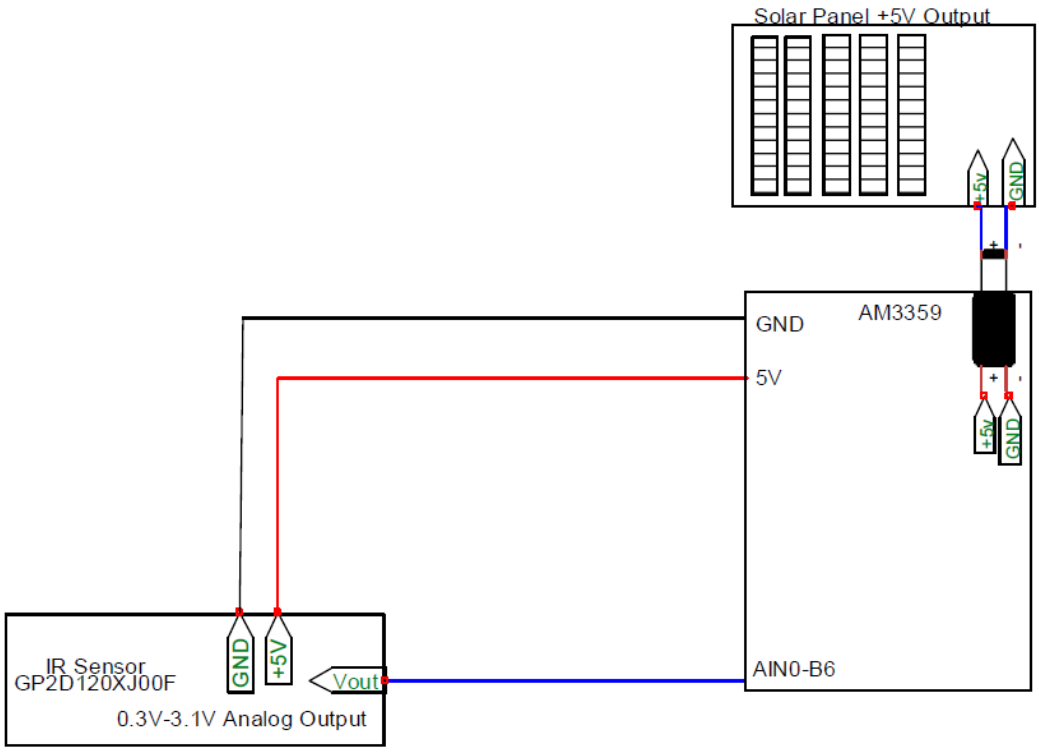


FIGURE 17: CONNECTING IR PROXIMITY SENSOR

3. 9 FLUID PUMPS

While investigating and researching similar projects, the pumps were a common ground for error since carbonated drinks would cause bad pump performance by allowing venting and loss of carbonation. From the variety of ingredients that will be incorporated into the drink mixer, carbonated drinks will be one of them and therefore this issue should be avoided.

DC Motors were also considered for this project since they are reliable; however, these motors are particularly used in systems where neither size nor speed is an issue. In the case of the Under the Sun Drink Mixer, speed is an issue as the drinks should be dispensed the quickest possible rate; ensuring users get more drinks. Therefore, opting for compressed air pumps seemed like the best option. Compressed air pumps would ensure that carbonated drinks have their CO_2 when being delivered to the customer.

The entire vending unit will include eight 12 volt electronic solenoid valves which will dispense the ingredients, such as liquors or mixers. The eight electronic valves control how much liquid comes out of the syphon tube and into the customer's cup. All the eight bottles will be about a liter each (32 ounces) and will have a standard neck like a plastic coke bottle. The CO_2 tank will have enough

volume to fully displace all the contents in the ingredients and the regulator will be charged to about 80 psi, the individual ingredient bottles will have pressure reduced to 5 psi using the regulator to reduce air leaks. The Tygon PVC tubing will be used to connect everything on the low pressure side, and the PVC air line will be used for everything on the high pressure. To facilitate the connections, a push-to-connect fitting will be used to thread into the valves and the Tygon tubing plugs into this fitting. In order to distribute all eight air lines into the ingredient bottles, aluminum manifold from McMaster.com will be used. The entire Drink Mixer will be of aluminum material forming a 15x15x15 box. Finally, the tops of the bottles have the air nipples and will be purchased from lazydrinker.com.

This would conclude the assembly of the pump system. All the parts will be acquired from different sources such as: amazon.com, lazydrinker.com, and McMaster.com.

4.0 Aesthetic Design – Vending Machine Design

The Under the Sun Drink Mixer will be designed mainly for outdoor activities such as BBQ, tailgating, camping, etc. Therefore, its design need to be easy to transport and carried around. The Under the Sun Drink Mixer will have wheels attached as well as a handle for easy carrying and transporting. There will be in total 8 plastic bottles with ingredients placed securely in circular slots inside the drink mixer; there will be ice surrounding the circular slots in order to maintain the ingredients cool at all times. The tank will be charged at around 80 psi and then using a regulator, the pressure will be reduced to 5 psi per ingredient bottle. To make connections easy, push-to-connect fittings (purchased from McMaster Carr) will be used.

On the outside, there will be a slot for the customers to place their cup as well as an LED screen to display which drink is being dispensed at the time. Customers will have to scan the given code from their phones so the Drink Mixer knows which drink is being requested. Once the code is scanned, it will wait for a cup to be detected before dispensing; there will be an infrared sensor next to the cup slot that will detect the presence of a cup.

After the drink mixer has scanned code and the cup has been detected, then the customer will obtain the desired drink and the machine will be available for the next order.

4.1 Vending Machine Design

Picture below shows front view of the Under the Sun Drink Mixer; scanner is shown on the right where the code should be scanned. The IR sensor (not shown below) will be placed on the left side of the dispenser section and will be able to detect any object placed on that slot up to 8in wide which is the length of the entire cup slot, that way the sensor won't detect the other side of the wall of the dispenser section.

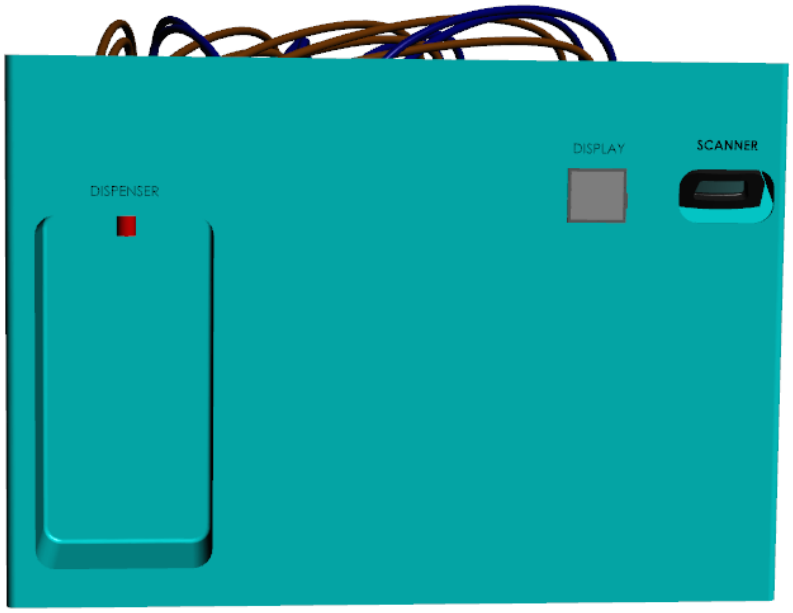


FIGURE 18: FRONT VIEW

The picture below shows a top view of the Drink Mixer, the area surrounding the plastic bottles will be covered in ice to ensure the ingredients are kept cool at all times. There will also be a plug on the bottom to allow melted ice to drain.

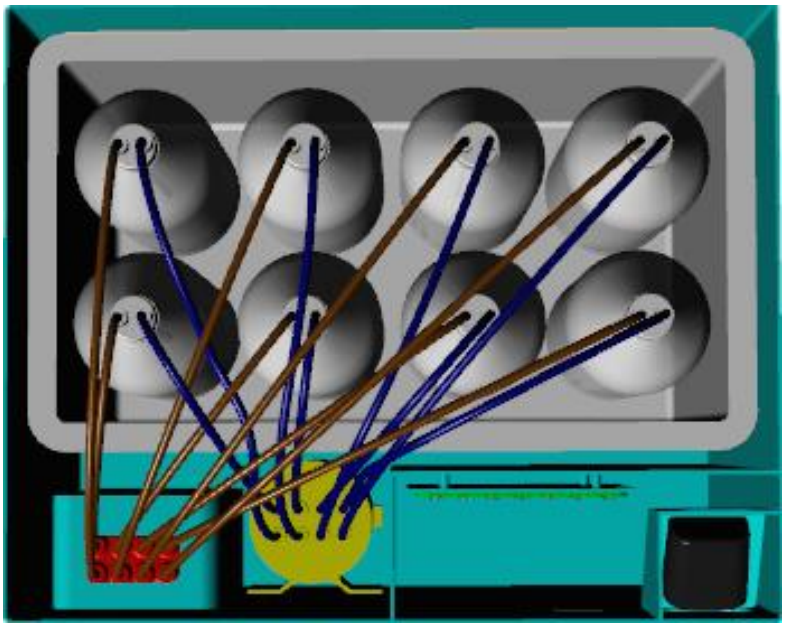


FIGURE 19: TOP VIEW

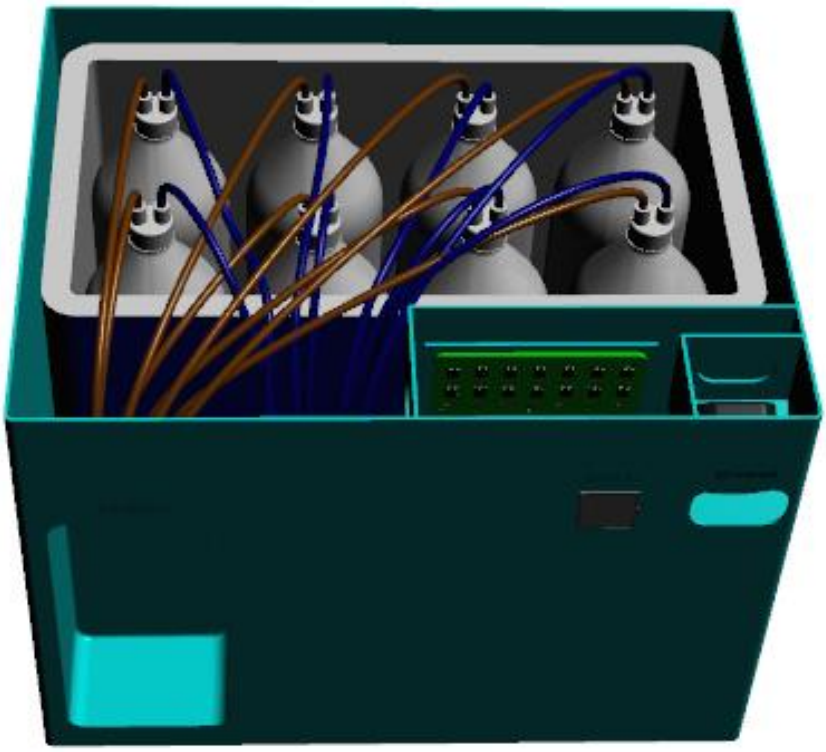


FIGURE 20: DRINK MIXER VIEW

5.0 EMBEDDED SOFTWARE

The Under the Sun Drink Mixer will have several pieces of software that are onboard to manage and fulfill the requirements set below.

5.1 REQUIREMENTS

The embedded software for the drink machine will be responsible for a couple of different functions. The first function that it will be responsible for will be controlling the dispensing of drinks. This will control the dispensing of fluid from the nozzles. The second function the embedded software will be responsible for will be the management of drink pick up and drink reservation. When a user orders a drink, the client application will contact the server and verify that there is a sufficient amount of all needed ingredients for the drink before allowing the user to order it. The server will then be required to keep the contents of that drink available for a defined period of time so the user will have time to come retrieve it. The third purpose of the embedded software will be to give the client application a menu of drinks that can be made using the liquids in the machine. The fourth purpose of the embedded software will be to keep information for the owner about usage of the dispensing machine. Some things that the embedded software will keep track of are: who ordered the drink, what drink was ordered, how much beverage is left in each dispenser, what time was it ordered, what time was it picked up, and who ordered it.

5.1.1 CONFIGURATION

The machine will need to be programmable and configurable through the client application. Programming will consist of both first time setup as well as adjusting settings that have already been defined. Almost all of the settings that are defined during the initial setup will be user configurable through the client application at a later time. To configure the machine at a later time, the user will need to present sufficient and valid credentials through the application to enter the application settings screen.

5.1.2 DISPENSING SLOTS

The dispensing slots are one of the primary components of the embedded system. The dispensing slots will need to be able to have assignable names to each slot. During the configuration process of the dispensing slots, the user will be allowed to disable the use of some dispensing slots if they are not required. The dispensing slots can all hold variable amounts of liquid, and this size should be

configurable through the use of the client application. The dispensing slots will not be allowed to be reassigned by the user, only renamed.

5.1.3 Drink Menu

After the assignment of the dispensing slots, the machine's default drink menu will be created by the user. This list will consist of recommended drinks that the machine is capable of making. If the user does not want to create a menu of recommended drinks, they can choose to skip the configuration of this feature.

5.1.4 Network Configuration

The user will also be required to configure the network preferences for the embedded system. The network setup will include two different parts. The first part of configuration will be to assign the network information to the wireless card. The network information required is the network settings that the client applications will use to contact the machine during its normal use. The user will have be required to choose how client applications will connect to the machine. The user will have the option to use the internal Wi-Fi card to be used as a Wi-Fi access point to allow users to connect directly to the embedded system or for the card to be used as a Wi-Fi client to connect to the user's WLAN network. The need for both modes of operation is based upon the nature of the Under the Sun Drink Mixer. The need for both of these settings will be discussed further in section 7.3.

If the user chooses to connect the Under the Sun Drink Mixer to the internet using a wireless access point, they will be required to choose the SSID, security information, and the IP address scheme that they will be using. The Under the Sun Drink Mixer will allow the user to use DHCP or Static IP addresses and will allow the user to use a statically assigned DNS server if they choose. If the user chooses to configure the machine using the Wireless Access Point method, the users' settings will be greatly limited. In this case, the user will only be allowed to configure the SSID that will be broadcast out for client applications to connect to and the IP address of the machine. The user will not be permitted to change the DNS servers for they will not be needed in this mode.

5.1.5 Login Credentials

Upon completion of the network settings, the user will be required to create a unique username and password. This username and password will be used to regulate who will be able to configure the settings of the Under the Sun Drink Mixer. The username will be saved in the machine and a hash of the password will also be saved. The machine shall be capable of storing multiple password in the user database. There will be only two types of users: anonymous users and

elevated users. Anonymous users shall only be permitted to view settings and order drinks whereas the elevated users shall be allowed to edit settings and order drinks. There will not be any access levels within the elevated users.

5.1.6 First Time Programming

For the first time the user powers on the Under the Sun Drink Mixer it will not a configuration in it and it will therefore not have network connectivity. In this instance, the onboard display will present the user will a pairing QR code that will be scanned by the user. The client application will then enter the first time programming wizard where the user will be required to configure the network settings and create a username and password. Once that has been completed, the client application will present the user with a QR code which will be scanned by the Under the Sun Drink Mixer. The QR code will contain the vital machine information the user just filled in and the Under the Sun Drink Mixer will apply the settings it just received and restart any appropriate services. The Client application will now exit the first time configuration wizard and will instead be presented with the pairing wizard. The pairing wizard is a method for the client application to receive the appropriate settings required to sustain communication between the Client Application and the Under the Sun Drink Mixer. By Prompting the user to go through the pairing procedure, it can be verified that the settings given to the machine are valid and it also allows for an opportunity to simply the programming by encouraging the reuse of various sections of code and to limit the number of possible states the client application can be in.

At this point once the user pairs with the Under the Sun Drink Mixer, the user will be prompted to login with the username and password previously created. Once again, although this process seems repetitive, it will be used to verify the settings passed to the machine are valid. The user will then be presented to the settings screen where any other setting may be changed. This configuration view will now be accessible anytime the user would like to make a system change through the use of the client application.

A machine reset sequence will be included. The reset procedure will entail removing the micro SD card in which the machine boots from and reinstalling the embedded software stack onto it. The alternative to a complete reinstall is a re-initialization of the configuration files that are stored within the micro SD card. Although this method is somewhat low level and cumbersome, it was determined that it would suffice due to the low number of units being produced. All drink related modifications to the machine will occur over a secure HTTP connection between the application and the machine. The machine will keep a plain text version of the username, and a salted hash of the password. The application will have the ability to save the username, however there will be no provisions to save

a password. Provisions will be put into place to allow the user to change the username and password of the machine. Shown below is a simplified diagram of the embedded software's booting procedure and how it can transition from one phase to the next.

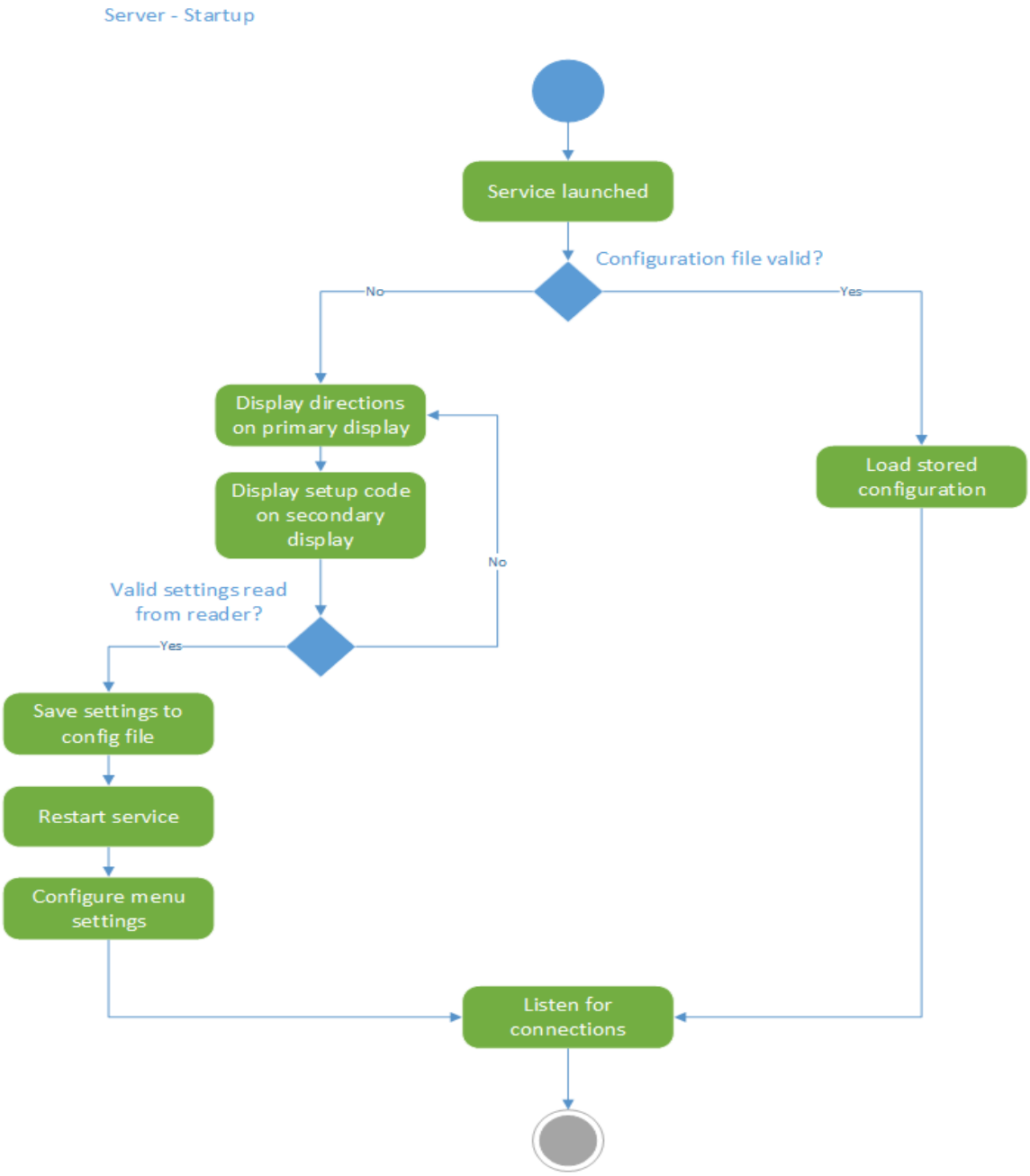


FIGURE 21: SERVER STARTUP

5.2 Embedded Software Platform

5.2.1 Internal to Machine

This concept would make the Under the Sun Drink Mixer self-sustaining. Everything from the vending controller to the order management to the history tracking would be done on an embedded machine within the vending unit. This would allow the machine to run without any external needs other than power and an internet connection. This method would require that each user would be required to connect their client application directly to the machine. This would increase the complexity of each machine individually; however it could eliminate the dependency on other outside systems.

5.2.2 External to Machine

This concept would make the vending machine be dependent on another server to handle the ordering, programming, and record keeping tasks. The vending machine would only be a dispenser of the drinks and a relay of pickup codes. The embedded software would only be responsible for connecting to the primary server and sending information back and receiving control commands. This method was quickly ruled out as reasonable for it creates a dependency that the machine should not have.

5.2.3 Operating System

The use of an operating system was considered as a foundation for the embedded applications run within the drink dispensing machine. An operating system would allow us to put focus on the completion of the features that need to be incorporated into the server system to complete the objectives. The operating system provides a foundation of software for managing multiple transactions between users, network communications, database tasks and record keeping, hardware control, and multiple options for programming languages. The operating system also allows for the software to be multithreaded and easily scalable if need be. There are several versions of operating system that could be used. Both open source variants and closed source variants are available. The two versions primarily under consideration are Linux and Windows Embedded. Windows Embedded was quickly ruled out due to its cost of acquisition and limited software and hardware support. Linux was then considered and was ultimately determined to be the best fit for the embedded software due to its open source nature having a price of free and its large knowledge base of information that is easily accessible. It was also found that the hardware support for Linux is fairly extensive, especially with Texas Instruments products.

5.2.4 Simple Control Loop

A simple control loop was initially considered because of its ability to control the hardware at a very low and granular level. The simple control loop would also require less raw processing power and would consume less electrical power. There were a variety of large issues that were determined would be an obstacle to accomplish the software goals that would be required if a simple control loop was chosen. With just a simple control loop, the validity of network connections, I/O, and all aspects of the hardware ourselves would need to be handled and maintained. It felt that this would be unreasonable and unnecessary when there is the ability to rely on an operating system to complete such tasks.

5.3 Programming Languages

Several programming languages were considered based upon the design requirements of the Under the Sun Drink Mixer. There were several options for the embedded portions of the software that were compatible with both Linux and Windows. A couple of the programming languages that were under consideration are discussed below.

5.3.1 C

The C programming language is a language that is compatible with both Linux and Windows. It is a language that a majority of the programmers on our development team are already familiar with which gave a large push for it. C is a procedural language that is somewhat low level. It provides provisions for direct access to memory. C is a compliable language which is light weight and efficient on resources. C is capable of handling the creation of multithreaded applications as well as the ability to create network sockets with other applications; however these functions are dependent on the operating system it is running on making the code somewhat importable.

5.3.2 PHP

PHP is a server side scripting language. PHP has syntax similar to C which made it desirable to our development team for a majority of our development team is familiar with C. PHP has the ability to connect to SQL databases as well as connect to sockets, start local processes and it is capable of creating web pages to return to clients.

5.3.3 C++

C++ is a language that is compatible with both the Linux and Windows operating systems. With the introduction of C++11, it is capable of natively creating network sockets and handling the creation of multithreaded applications, thus

making the code portable from one operating system to the next. C++ is also an Object Oriented language which can be beneficial.

6.0 Client Software

6.1 Client Platforms

There are many different programming languages along with many different frameworks available to choose from, each with its pros and cons.

6.1.1 Android

Android is an open source operating system designed for mobile touchscreen devices. The primary programming language used by android is a customized version of Java. Android currently has the largest market share of smartphone platforms with approximately 52% [4]. This makes for an appealing platform to initially use, however due to android's large variety and fragmented software base, this appeal is somewhat lost. Android has no added cost to run and deploy applications to users.

6.1.2 iOS

iOS is a closed source operating system designed for mobile touchscreen devices. The primary programming language used by iOS is a customized version of Objective-C. As in the case of android, this makes for an appealing platform to use. iOS is also appealing due to the significantly less amount of variety and platform fragmentation. iOS costs one hundred dollars per year to develop and distribute applications to users.

6.1.3 Windows Phone 8

Windows Phone 8 is a closed source mobile operating system designed for mobile touchscreen devices. There are several programming languages that can be used with Windows Phone 8 including C#, Visual Basic, or C++. At the time of this writing a developer promotion was available and Windows Phone 8 cost nineteen dollars to distribute applications to users.

6.1.4 HTML

HTML is an open standard to display content within a web browser. Web browsers are available on almost every internet connected device which would allow the Under the Sun Drink Mixer to be accessible to a large majority of

people. An inherent problem with such widespread access would be the need to support the various standards of HTML interpretations and ensure that the web pages would function properly on the majority of platforms which would require a large undertaking.

6.1.5 Desktop Application

Desktop and laptop operating systems are common to almost everybody, however due to their stationary nature this did not seem to be applicable to the type of environment thatare looking to cater to.

6.1.6 Chosen Platform

The platform that was chosen to be used for the client software application was iOS. This decision was made with the bases that portions of the development team have used a variety of the proposed platforms and iOS was considered to be the most feature filled platform for our requirements. The iOS application will also be using some form of HTML to access information that is stored on a webserver and to send commands to a webserver.

6.2. Software Requirements

The primary method of the user interfacing with the drink machine will be through the use of a smart phone application. The application will support two types of users, machine administrators and general users. General users will be able to order, create, pickup and track drinks. Administrators will be able to view machine drink levels, change network settings, and configure the default drink menu available to users.

6.2.1 Ordering

Users will be able to view a menu of pre-determined drinks created by the administrator of the machine. Once the user selects a drink they are interested in, they will be shown the amount of each ingredient in the drink. If they would like to change the amounts of any ingredient, they will be allowed to do so. When a drink is customized, the original drink recipe will not be overwritten. Instead, a new menu item will be created and the user will then be allowed to customize the contents and name of the drink. The user will be able to customize a drink for multiple predetermined drink sizes and will be able to choose between ounces and parts when determining ingredient quantities. If the recipe for the drink is identical to the recipe of another drink, the user's customized drink will be discarded and they will be brought to the equivalent menu item. For each drink in the menu, the user will have the opportunity to mark a drink as a favorite. If the

machine is out of any ingredient for a drink, the user will not be allowed to order the drink at that time.

Below is a diagram showing a high level layout of the procedure that will be used while customizing a specific drink. The various decisions and an overview of the available actions are given.

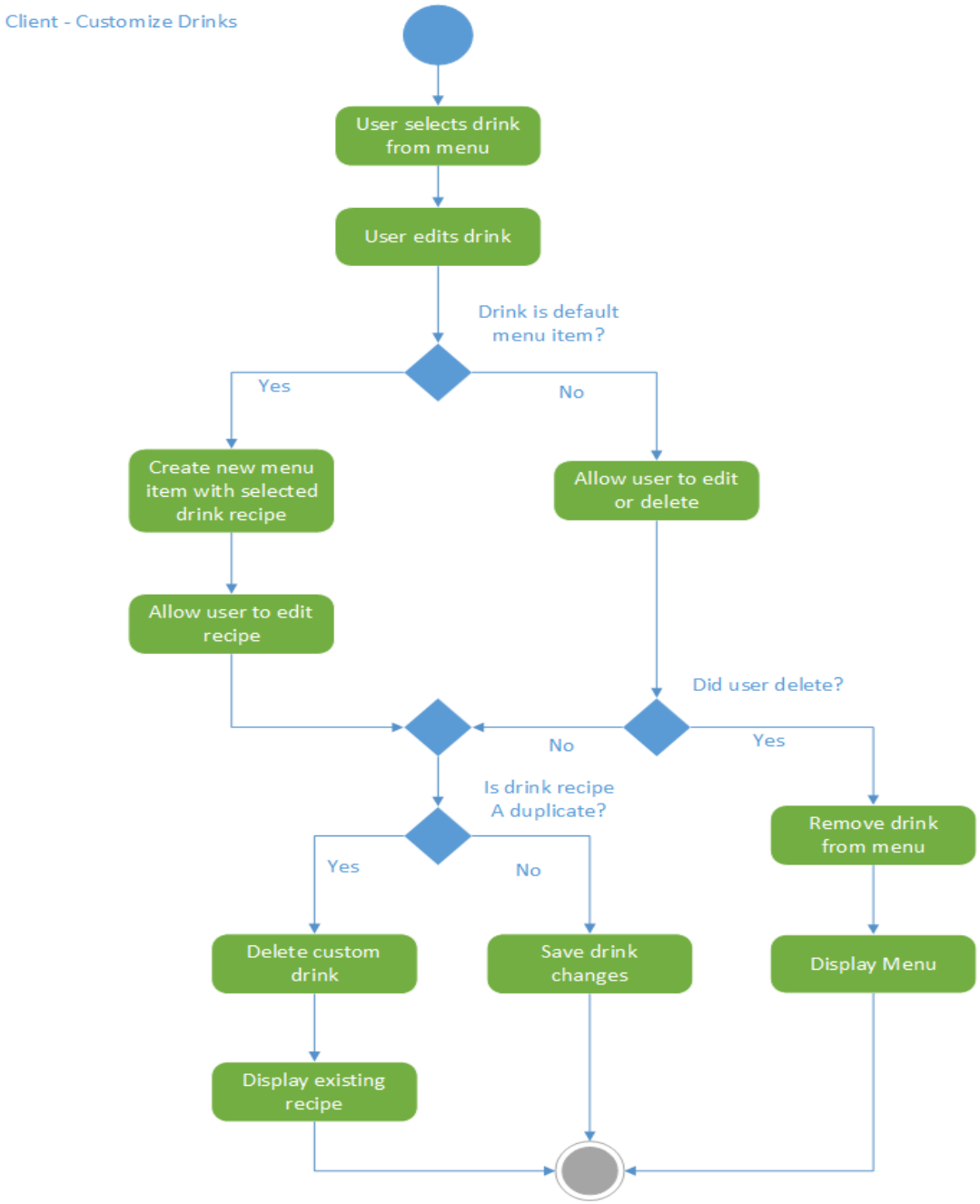


FIGURE 22: CLIENT APPLICATION DRINKS CUSTOMIZATION

When a user selects a drink and attempts to order it, there are several steps involved in the actual ordering process. The first objective that needs to be completed by the client application is to verify that the ingredients needed for the drink are still in stock. This is accomplished by querying the Under the Sun Drink Mixer in which the Client Application is paired with and attempting to place an order. If the ingredients are in stock, the Under the Sun Drink Mixer will create the reservation for a limited amount of time for the user of the client application to pick up the drink. The drink that was ordered is now added to the pickup section of the client application as well as the history section of the client application. A badge on the pickup tab will then be updated to show that there is a new activity waiting for attention.

In the case that the Under the Sun Drink Mixer is out of ingredients or has reserved all of the ingredients for other drinks, a reservation failed message will be sent back to the client application alerting it of the situation. At this point, the client application will also force itself to update the ingredient list and disable any drinks that do not have sufficient ingredients to be created. A flow diagram is shown below of the ordering requirements.

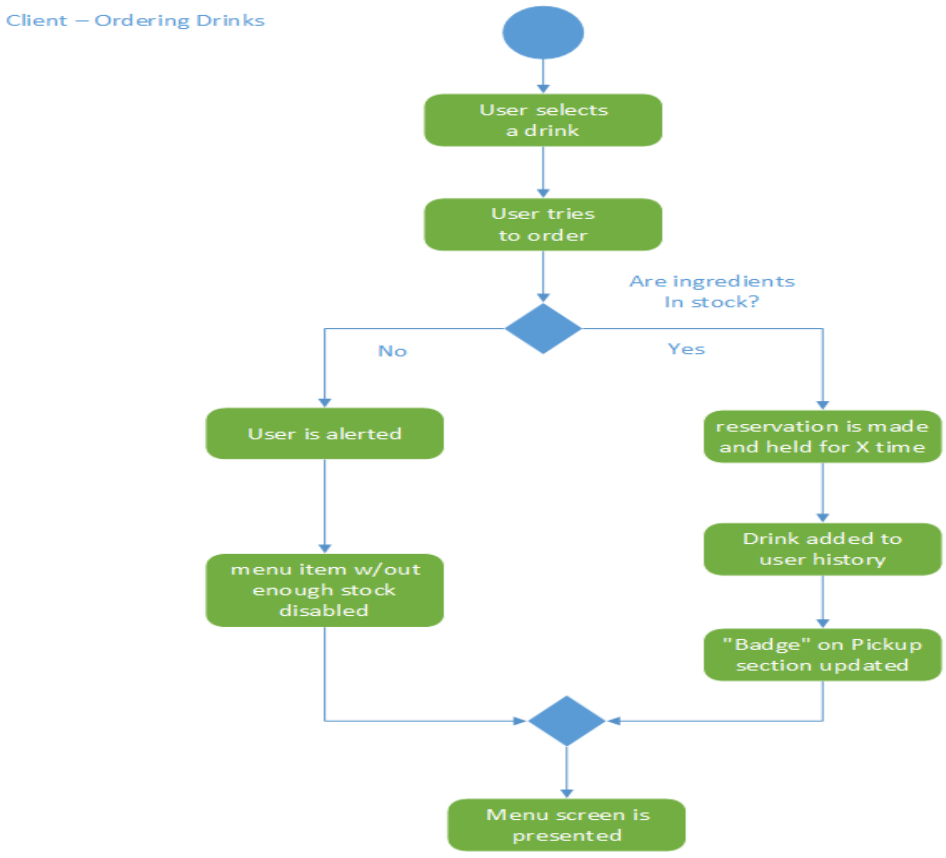


FIGURE 23: CLIENT APPLICATION DRINK ORDERING

6.2.1.1 User Interface

The user interface is designed to be intuitive and easy to use. The process of finding a drink and then quickly knowing the ingredients of the drink is paramount to the overall design of the application. The manner in which this will be accomplished is through the use of graphics and consistent layouts.

The user will be presented with the drinks in the menu in a graphical form. The drink menu's items will be displayed in such a way that will permit the user of the application to scroll through the various drinks. When the user stops scrolling, the application will stop on a drink. This drink is will be the currently selected drink. Once the drink is selected, the table of ingredients that is on the screen will be updated and will tell the user which ingredients are in the drink. If the user finds those proportions of drinks favorable, they can order the drink immediately with the "Order Drink" button.

If they find that the ingredients are close to the desired proportions but not quite there, the user can press the "Tweak" button where they will be presented with a collection of actions that can be taken with the drink. Such actions include adding to favorites, deleting the drink if it a custom creation, sharing the drink with others, or editing the drink. If the user decides to edit the drink by pressing the "edit" gear, they will make changes to the ingredients by the use of a slider bar for each ingredient. When they are done they will have to option to cancel or to save there creation. An example of the proposed interface is below for the viewing, "Tweaking", and the editing perspectives of the ordering Screen.

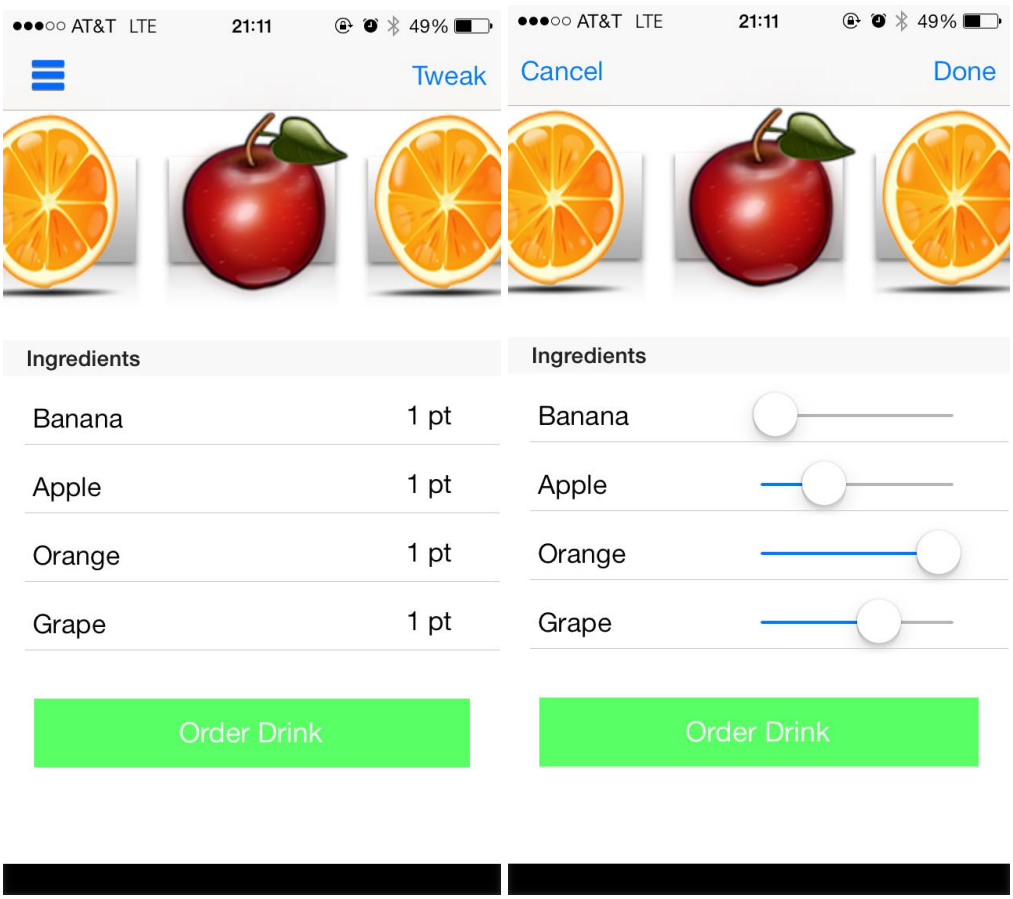


FIGURE 24: CLIENT APPLICATION MENU BROWSING

The "Tweak" area of the menu section also provides the user with other options that can be taken. This is where the user will go to add the currently selected drink to their favorites list. This action is provided by the button with the heart shape below. If the current drink is not yet in the favorites, the icon will be hollow as it is below. If the drink is already in the user's favorites list, then the heart will be filled and colorized.

In addition to adding the drink to favorites, the user will also be permitted to remove the drink from the menu if it is a customized drink that they have created. If the user chooses to remove a custom creation from the menu, it will also remove the drink from the favorites list if it is considered a favorite. The deletion of a custom drink will not however remove the drink from the history list. This action will be completed by using the trash can icon in the "Tweak" menu. If the drink is not a custom creation, the icon will still persist; however it will be grayed out and inoperable.

The user will also be able to share the drink with others through various methods. This will be accomplished by activating the button with the person

communicating on it. This button will bring a prompt to the foreground that can be used to share the drink with people through various methods such as email, text, Facebook, and Twitter. This prompt is not shown below.

FIGURE 25: CLIENT APPLICATION TWEAK MENU EXPANDED

6.2.2 Ordering History

The application will also keep a list of drinks that were ordered by the user. This information will be accessible through the history section of the client application. The drink history will be able to be viewed in three forms: the date the drink was ordered, the name of the drink, and number of times the drink was ordered. Similar information will be displayed to the user as the menu however the user will not be able to edit any information in the history tab. Although the user cannot edit any values, the user will be able to clear the history as they please. All information that is displayed in this section is only kept on the client application and is not transmitted to or from any of the Under the Sun Drink Mixer machines. The ordering history section of the client application will also allow the user to view a machine history. The machine history will allow the user to see which machines they have used, as well as providing a quick method to quickly change between machines. The machines will be identified internally with a non-configurable ID with the user only being capable of modifying the machines displayed name.

6.2.2.1 User Interface

The user interface for the ordering history portion of the client application follows similar guidelines as the menu interface. The history interface should be simple to navigate and primarily graphical. The various drinks that have been ordered will be provided in a list view that can be sorted based upon the machine in which the drink was ordered, the date, and also by the number of times the drink has been ordered. If more details about any of the drinks is needed, the user can click on the drink and a page that looks similar to the menu view will appear and allow them to view the drink details as well as order the drink again. From the drink details page the user will be able to share the drink through various methods. A proposed list view and detail view is shown below. The table view showing the list of drinks and the sorting selections is shown on the left. The detailed drink view and selectable actions are shown on the right.

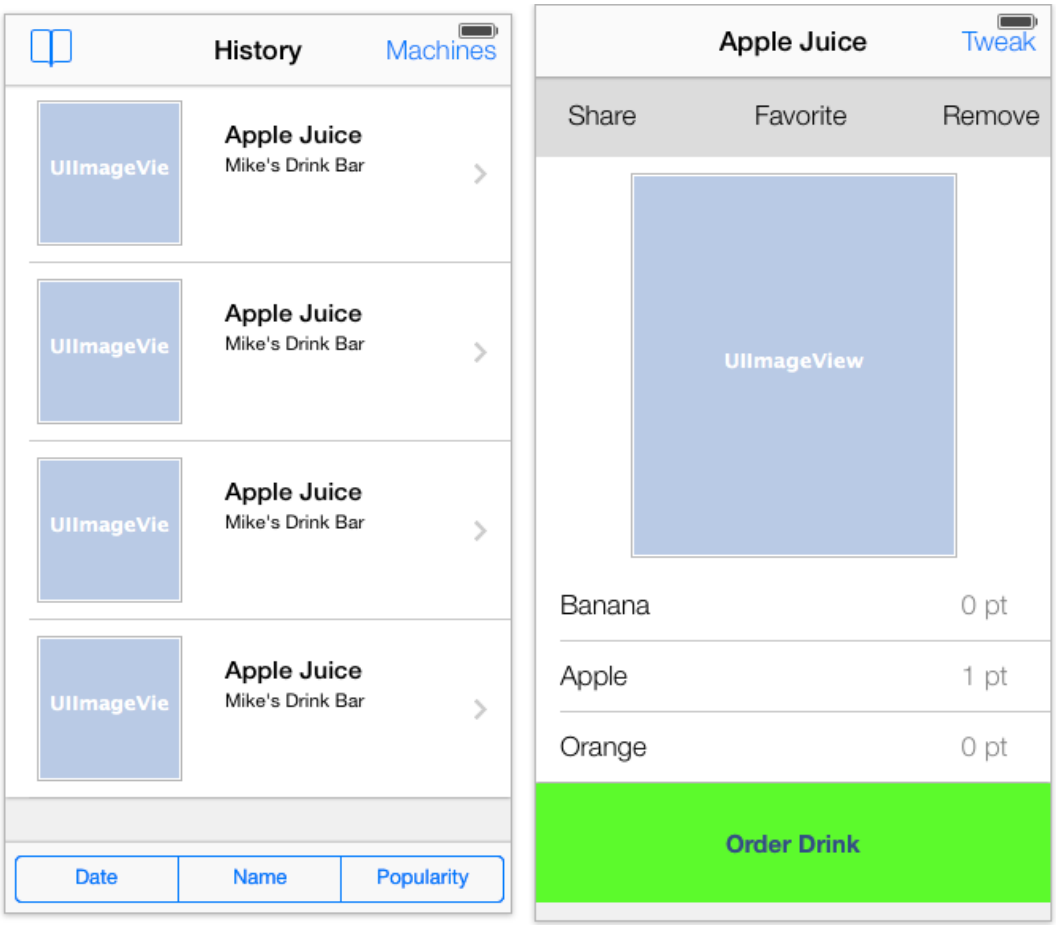


FIGURE 26: CLIENT APPLICATION HISTORY AND DETAIL VIEW

6.2.3 Drink Favorites

The application will have the ability to access the user's favorites. The drinks in this section are selected by the user to have a quick way of accessing their favorite drinks. This section will have the ability to hold both custom drinks as well as drinks that were predefined by a machine they connected to. The view in the favorite drinks will stay in the application no matter what machine the user is connected to. If the machine doesn't have the necessary ingredients to make the drink, the ordering ability will be disabled for the drink.

6.2.3.1 User Interface

The user interface for this section follows similar requirements to the drink menu interface. The interface should be easy to understand quickly and should be intuitive to the user. The interface should be primarily graphical and should provide the user with a fast way of finding and removing drinks that they had found to be to their liking. The Under the Sun Drink Mixer does not obtain any information within the Favorites section and all information is stored directly within the client application. The Favorites view shares the same resemblance to the history view; however it does not have any provisions for sorting the drinks as the history view does. The favorites drinks will be presented in a list type view and if the user chooses to view more detail about the drink or would like to order the drink, they will be able to select the drink and be brought to a detailed view where they can remove it from there favorites, share the drink, or order the drink. Below is a proposed layout of the table view, which is displayed on the left, and the detailed view which is displayed on the right.

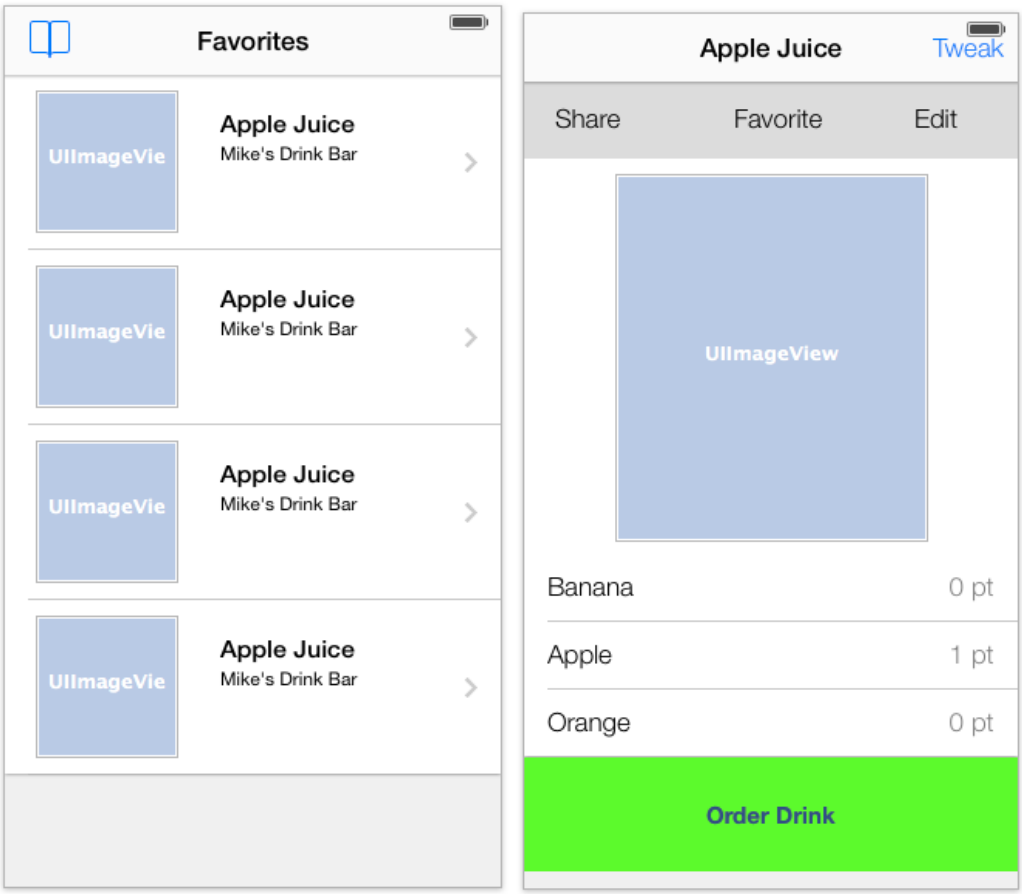


FIGURE 27: CLIENT APPLICATION FAVORITES VIEW

6.2.4 PICK UP

The application will give the user the ability to pick up a drink that has been ordered from the machine. To do this, the user will pick the drink they ordered out of a list of ordered drinks. They will then select “Pick Up” in which they will be presented with a barcode. The use will then be required to go to the machine and scan the barcode. The machine will then instruct them on how to get the drink dispensed. Once the drink is dispensed, the drink will be removed from the “Pick Up” view and will now show in the history section as being picked up. If the user waits too long before picking up the drink, the drink will be moved to the history with a message telling the user that there drink order expired due to waiting too long to pick up their drink.

When the user selects the pickup option within the application a QR code will appear on the screen along with instructions and the user will be required to scan the QR code at the machine to redeem the drink they are trying to pick up. This ensures that the user is actually at the machine and will be the correct person receiving the dispensed drink. When the QR code is displayed on the screen, the

client application will contact the server and maintain a connection with the machine until either the user cancels the pickup process or the pickup process is complete. In the case of the latter, when the barcode is scanned, the machine will communicate to the application through the previously established network connection and the client application will close the barcode presentation screen as well as take care of any other adding the drink to the user's history and removing it from the users pick up area.

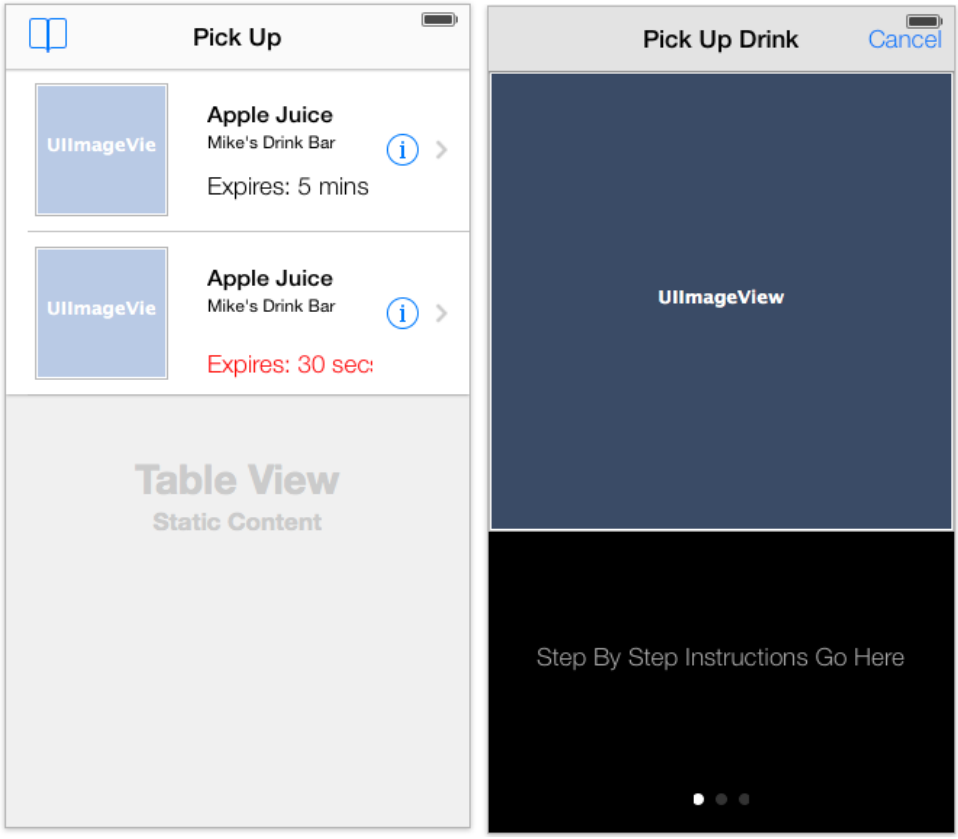


FIGURE 28: CLIENT APPLICATION PICK UP WINDOWS

6.2.5 SETTINGS

The settings view will hold information for both the users of the machine and the elevated users of the machine. All users will be able to use this section to change the machine in which they are communicating with, along with general preferences. This will also be where any credits, legal information, and application information will be kept. If you are an elevated user of the machine, you will be able to "elevate" yourself with a username and password combination that will grant you access to the machine settings. The machine settings will allow you to view the fill level of the ingredient tanks. The elevated level will also be the location that the predefined menu items can be edited.

The settings area of the client application will contain all of the various settings that the machine will require to run correctly. All items that are listed in the settings view will be configured during the first time setup of the machine. Any setting that is changed in the settings view will take effect once the associated "Save" button is selected. Any change that is being made will be able to be canceled before it is made.

Shown below is an implementation of the settings screen. For each section that is listed, the user can select the section and receive detailed information and make changes to the selected area.

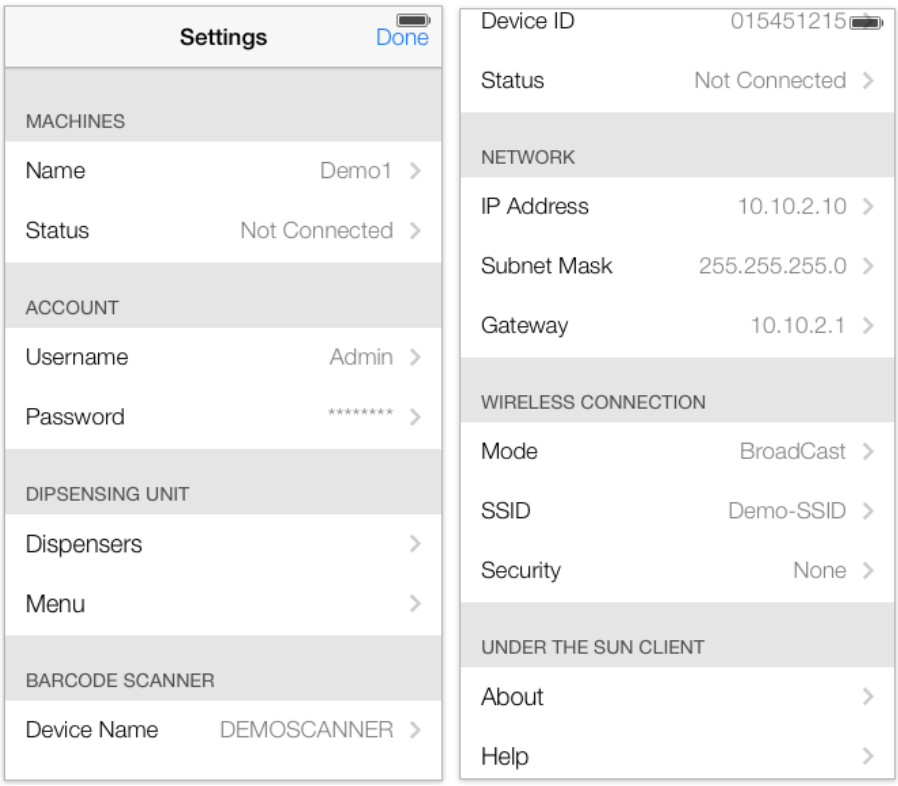


FIGURE 29: CLIENT APPLICATION SETTINGS VIEW

6.2.5.1 MACHINES

Under this section of the settings menu, the user will be able to configure the machine that they are currently connected to as well as see the current connection status. If the user has elevated privileges, they will be able to select the name field and change the name of the machine.

6.2.5.2 Account

The account section is used for users with elevated privileges to manage their account name as well as change their password. The machine is capable of holding multiple usernames and password, and this interface provides a way for the user to modify their user credentials.

6.2.5.3 Dispensing Unit

The dispensing unit section provides an area for machine administrators to configure the various dispensing ports of the machine. The users will be able to assign names for the various dispensing ports as well as reset the filled status of the bottles supplying the dispensers. The users will be able to go here after refilling a bottle and notify the machine of their actions.

The dispensing unit section will also provide a location for the machine administrators to modify the menu that is given to users when they connect to the machine. The administrators will be able to come to this area and add, remove, or modify the menu. They will follow a similar pattern as normal users do when ordering, with the ability to add, remove, and of course customize proportions with a slider bar. The administrators will also be able to specify a cup size for a give drink at this screen.

6.2.5.4 Barcode Scanner

The barcode scanner section provides administrators with a location to select the barcode scanning device that the machine is currently configured to use. When the administrator enters the “Device Name” section, they will be able to view a list of USB HID devices that were found on the machine that could be used by the software. This feature allows the user to customize the barcode scanner that they use with their Under the Sun Drink Mixer. The Device ID and Status update accordingly based on the device chosen and its current system status.

6.2.5.5 Network

The network system provides administrators with the availability to customize the IP address, subnet mask, and IP gateway of the machine. The user will also be able to enter DNS servers and select the type of IP address that will be received. These values will include DHCP or Static. Although IP address type and DNS servers are not shown in the preliminary design above, they will be user configurable options in the final product.

6.2.5.6 Wireless Connection

The wireless connection area provides the administrator of the machine to select the network connection type. The machine will be configurable to connect to a wireless local area network or if an existing network is not available it will be able to create its own wireless network and allow users to directly connect to the machine. These settings as well as the wireless SSID and network security based settings will be displayed here and will be configurable to the administrator.

6.2.5.7 Under the Sun Client

Within this section will be included a brief but thorough description of the various components of the application that will give both users and administrators guidance. Within this section link to rate the application in Apple's App Store will be provided.

6.2.5.8 Legal

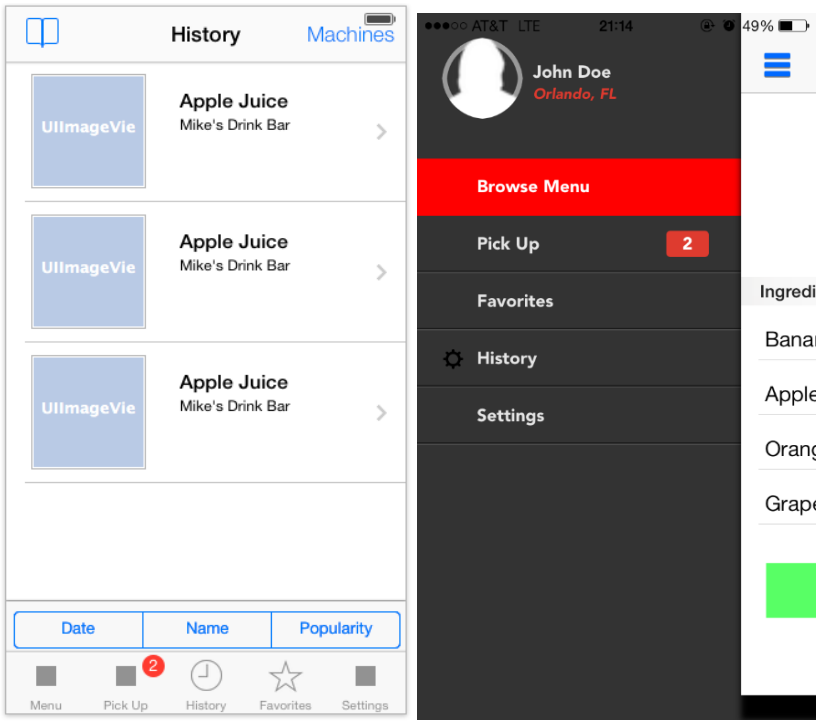
Within the legal section of settings will be the credits to the programmers who wrote the application as well as a list of any libraries used for the creation of the both the client application as well as the Under the Sun Drink Mixer's embedded systems.

6.2.6 Application View Switching

Due to the nature of the client application, some sort of tabbed interface is required. There are several different methods and ways of accomplishing this look and feel by using both native user interface elements provided by the platform and by third party libraries. The various methods that could be employed are tabs along the bottom or a sliding tab bar. The tab bar along the bottom consumed a large amount of room from the screen and complicated the various information that was being displayed within the view. As seen below, the bottom bar clutters the display and shrinks the amount of viewable area on the display.

The second method that was looked into was a sliding menu that is hidden when not needed. This capability is available through many different libraries; however the screen shot below is shown using the open source library GHSidebar. This method of switching views allows for all of the same features as the default system tabs but provides them in a way that allows for more room for the primary content to be displayed. As seen below, both implementations allow for the use of icons and titles to describe the currently selected view. Both the system tab bar and the custom tab bar allow for the use of badges to be displayed over a

particular section to indicate that there is new information available within the section for the user to interact with.



6.2.7 Miscellaneous

In the case that a user connects to a new drink machine with the client application, any custom drinks that were created that are in saved in the history, favorites and menu section of the application will be retained. If the new machine that the user is connecting to does not have any of the correct ingredients to create the drink order, the user will not be able to order them even though they will still be able to view and edit the custom drink.

6.3 EMBEDDED SOFTWARE COMPONENTS

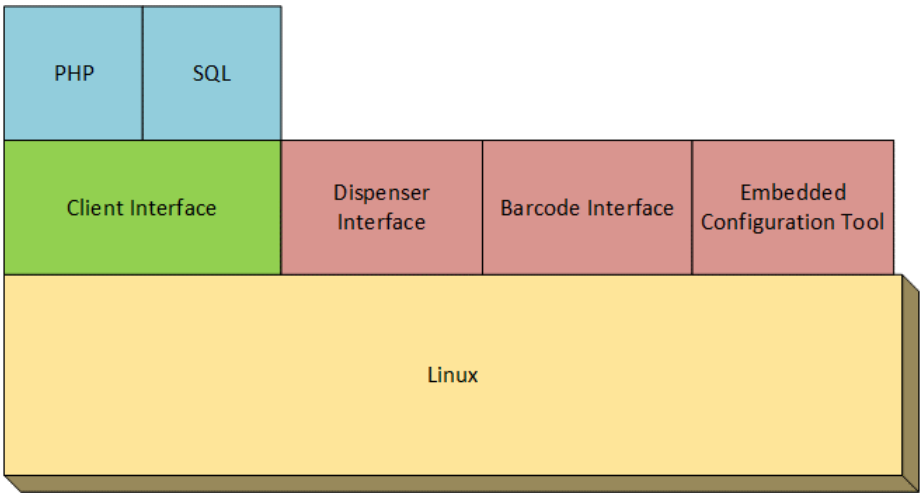


FIGURE 30: EMBEDDED SOFTWARE DESIGN

The embedded system will consist of a collection of different software applications to manage the various tasks that the embedded system will handle. The four primary components that will be created are a client interface, a barcode interface, a drink dispensing interface, and an embedded configuration utility. The client interface is a web server that is running on the embedded system that will accept connections from the client applications that will be running on mobile devices. The client interface will be the primary communication interface for the client applications and will update them with any required information. The client interface will be the coordinator and receiver of all commands that the client applications send to the embedded system. The client application will also be the primary method of programming the configuration of the various components of the embedded system.

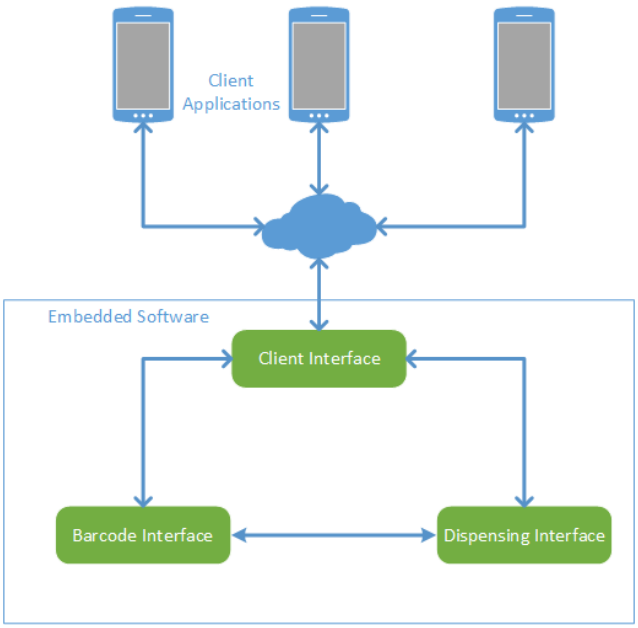


FIGURE 31: INTERFACE COMMUNICATION

6.3.1 BARCODE INTERFACE

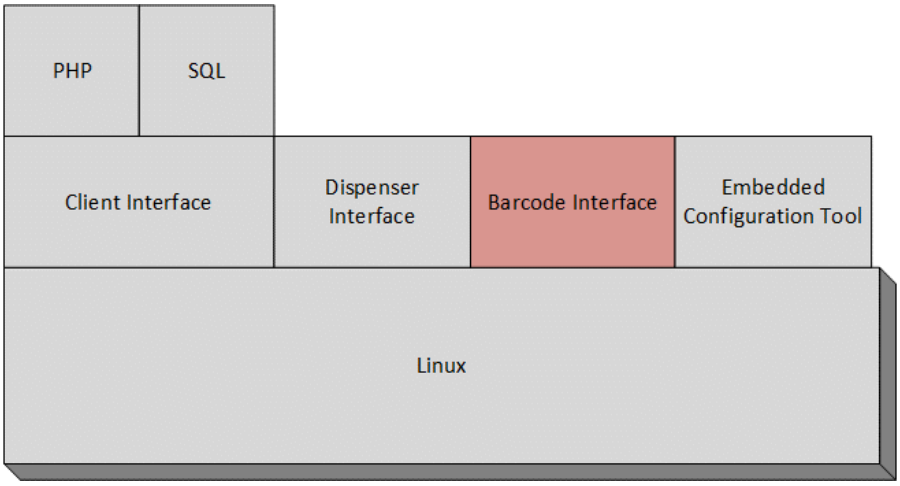


FIGURE 32: BARCODE INTERFACE

6.3.1.1 OVERVIEW

The barcode interface is the piece of software that coordinates the reading of barcode scanning with the client interface. It does the job of waiting for barcodes to be scanned, and upon a successful scanning of a barcode, it will handle the dataflow of the information contained in the newly acquired barcode. The barcode interface will interact directly with the barcode scanning device as well as the client interface and the Dispensing Interface. The barcode interface will

communicate with the client interface and the Dispensing Interface through the use of BSD sockets. The socket was chosen as a communication protocol for their ease of setup and their ability to sustain two way communications.

The barcode interface will accept incoming socket connections from the various client interface instances and will keep the socket connected until either a pickup timeout is reached or until the barcode that the corresponding client interface is waiting on arrives from the barcode scanner. In the latter case of an incoming barcode, the barcode interface will alert the client interface that the barcode is scanned and at that time, the client interface can continue as normal. The barcode interface will then disconnect the socket and remove the reference to the socket that was being stored by the Barcode Interface. When the Drink Dispensing Interface is busy, it will inform the Barcode Reading Interface of its

The barcode interface will be a multithreaded Linux service that will begin at startup and will be managed by the Linux system manager. It will have the ability to read from either a USB barcode scanner or a serial attached barcode scanner. This will be configurable through the embedded system settings that will exist on the client application. Because the Barcode Interface will be managed by the Linux system manager, it will be started on system startup and it will be properly halted at system shutdown.

6.3.1.2 Barcode Reader Communication

The barcode interface will employ the use of the open source HIDAPI library to communicate and interact with the USB barcode scanner. This library allows the barcode interface to communicate with registered USB devices that use the Human Interface Device (HID) protocol to interact with the operating system and for the barcode interface to easily interact with the USB HID barcode scanner that will be used. In order to keep the availability of using a variety of different barcode scanners, the Barcode Interface will be user configurable to select which USB barcode scanner device the interface will monitor. In order for the user to be able to select which device to use, the Barcode Interface will be capable of populating a list of the USBHID devices that it finds, and it will be able to return the list to the Client Interface when requested to be displayed by the client application.

6.3.1.3 Startup

Upon the initial startup of the Barcode Interface by the Linux system manager the service will attempt to open and read its configuration file. The configuration file location will be hard coded into the system service. If at any point along the

startup process the service encounters any problems, it will fall back into its initial configuration mode. When the configuration file is present and valid the Barcode Interface will then proceed to load and begin to startup into its normal running status. At this point, the Barcode Interface will create a listener that will be used by the client interface to communicate with. Upon the successful creation of the Client Interface listener, the Barcode Interface will then create another separate listener that will be used exclusively by the Dispensing Interface.

In the event that the Barcode Interface does not have a valid configuration file, it will call upon the embedded configuration utility for some assistance. The embedded configuration utility will display a special QR code onto the LCD display that will allow a Client Application to enter programming mode.

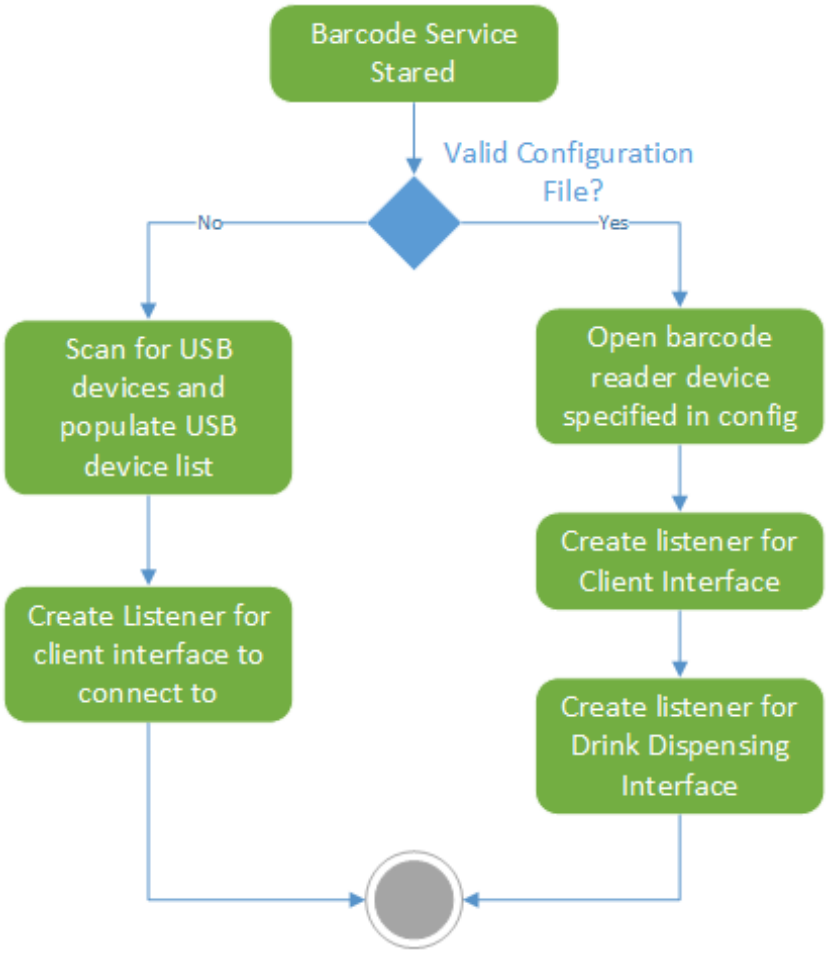


FIGURE 33: BARCODE INTERFACE STARTUP PROCEDURE

6.4 Drink Dispensing Interface

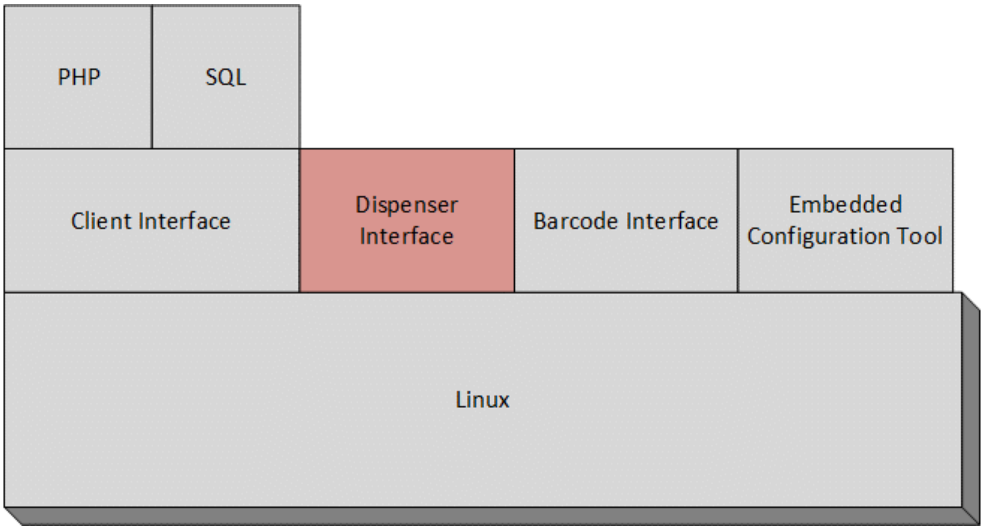


FIGURE 34: DISPENSER INTERFACE

6.4.1 Overview

The drink dispensing interface is a piece of software that coordinates and handles the dispensing efforts for the embedded system. It will communicate to the various instances of the web server that is communicating with the client applications, and will also communicate with the Barcode Interface. The primary method for communication with other components will be through the use of BSD sockets.

The Drink Dispensing Interface will be in charge of multiple objectives. The first objective the Drink Dispensing Interface will be in charge of is the control of the drink dispensing values. These valves will be opened and closed at the appropriate times by the Drink Dispensing Interface to dispense the proper amounts of liquid ingredients that is required for a drink. The Drink Dispensing Interface will not queue any requests, but instead it will inform any callers that it is already busy dispensing and at that point it will disconnect from the caller. It will be the responsibility of the caller to try again later. Although this case should not happen because the Barcode Interface will block any incoming scans while the dispenser is busy dispensing, this is still being included to ensure there are no inconsistent states within the software.

The major difference between the drink dispensing interface and the barcode interface is that the barcode interface maintains the connection of multiple sockets, whereas the drink dispensing interface will only keep one connection alive. The drink dispensing interface will continue to accept new connections, however it will notify the sender that it is busy dealing with somebody else. This

will also communicate with the barcode interface and drink dispensing interface directly on the server.

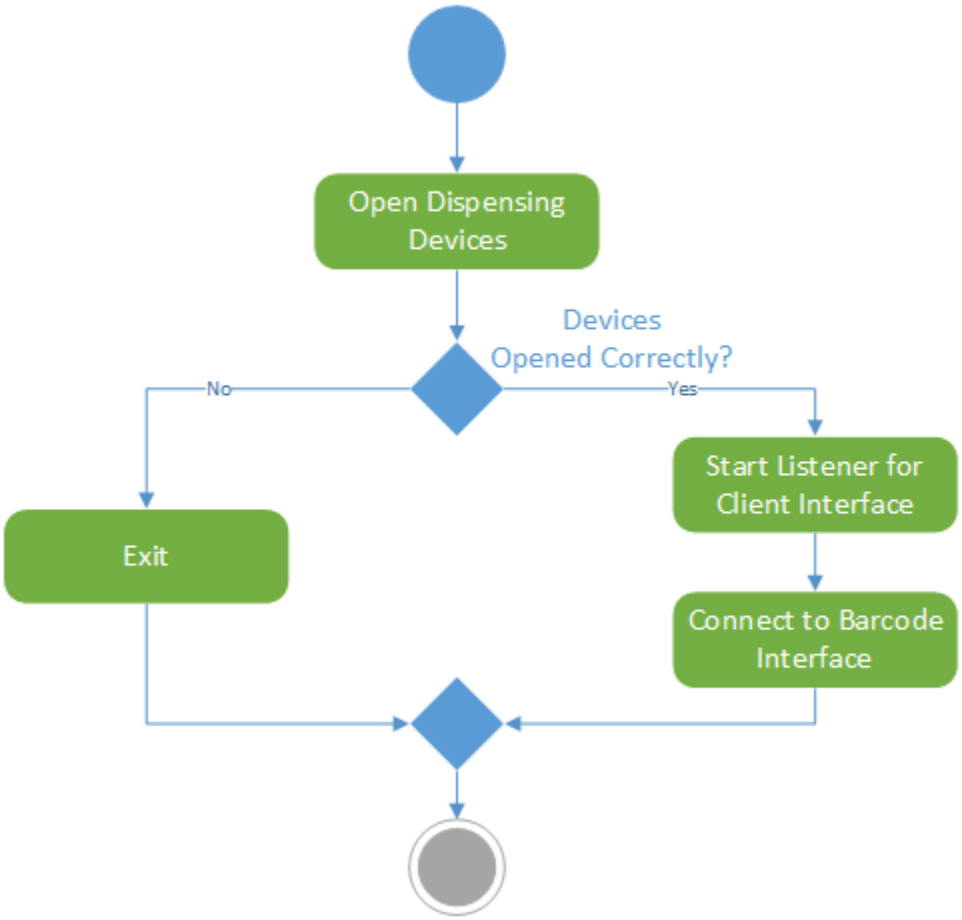


FIGURE 35: DRINK DISPENSING INTERFACE STARTUP PROCEDURE

6.5 Embedded Configuration Tool

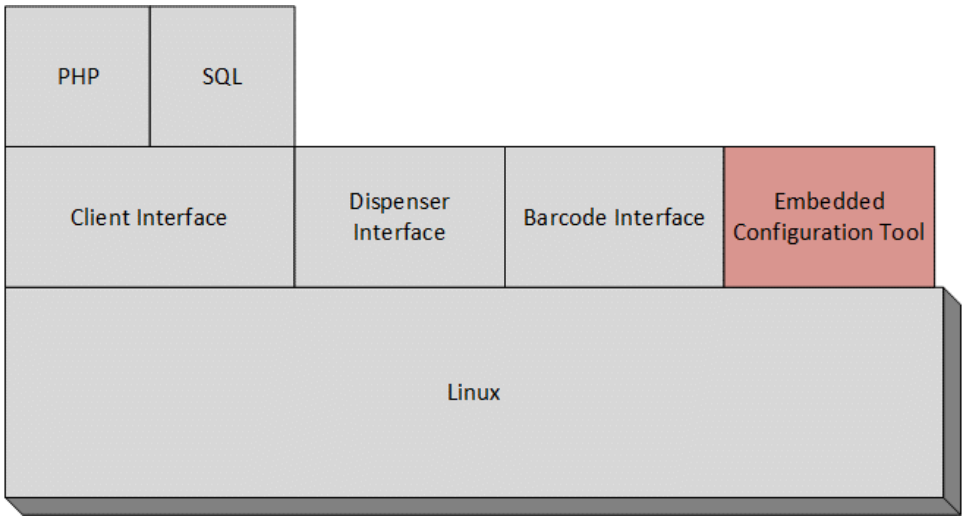


FIGURE 36: EMBEDDED CONFIGURATION TOOL

The embedded configuration tool will be a go to solution for several of the interfaces of the embedded system. The embedded configuration tool will be a service like many of the other interfaces within the system will be, but will not require any configuration. Rather, the embedded configuration tool will be a self-contained tool that can be used by the various interfaces when they are not all configured or if they are configured incorrectly. The primary role of the embedded configuration tool will be to edit configuration files that are required by the various interfaces and to coordinate the changing of any of the configuration files. This tool will also have many secondary roles.

6.5.1 Barcode Interface Configuration

In the event that the barcode interface is not configured correctly or when the initial configuration wizard has not been run, the role of the barcode interface changes drastically. Under these circumstances, the barcode interface does not need to listen for any requests sent from the client interface because the embedded system may not have network connectivity at this point. Rather, the barcode interface will need to listen for a system configuration barcode. A system configuration barcode is a special barcode format that is used during configuration to send settings to the embedded system from the client application when network connectivity is not yet established. When the barcode interface is in programming mode and a system configuration barcode is received, the barcode interface will give the embedded configuration tool the new data. In this role the embedded configuration tool will make the appropriate configuration

changes with the newly received data and will restart any system services who received modifications to their configurations.

6.5.2 Drink Dispensing Interface Configuration

The embedded configuration tool is also responsible for the coordination and setup of the Drink Dispensing Interface. The drink dispensing interface needs to be aware of the dispensing devices it is to communicate with, and which dispensing device corresponds to which drink slot. This configuration is managed by the embedded configuration tool, although parts of the configuration, such as the modification of the dispensing device to the internal slot number will not be user configurable through the client application, the settings still needs to be adjusted without recompiling and reinstalling the system service. For this reason is the responsibility of the configuration given to the embedded system configuration tool.

6.5.3 Client Interface Configuration

The embedded configuration tool is responsible for making system changes when an administrator makes a change to the system when using a client application through a network connection. The client interface will communicate the requested changes to the embedded configuration tool which will be the application that is actually making the change. The client interface will accept information from the client application; however it will forward the appropriate changes to the embedded configuration tool.

6.5.4 Synchronization Display

The embedded configuration tool will also be responsible for displaying the correct QR code onto the display. This code will be responsible for the synchronizing of client applications to the embedded system as well as sending the client application into programming mode. If any of the configurations of the various software interfaces are out of order, the embedded configuration tool will update the display to show the special setup code. If all of the system's interfaces are in the proper order then the display will show the normal synchronization code.

6.5.5 Barcode Generation

The synchronization display will require the use of some type of barcode. The barcode that was determined to be most suitable for our use was the QR Code. The QR code is capable of encoding and decoding standard text that can be retrieved by our client application. The QR code is also a prevalently used symbol allowing users to maximize the recognition and intuition of the use of the Under the Sun Drink Mixer.

6.6 Client Interface

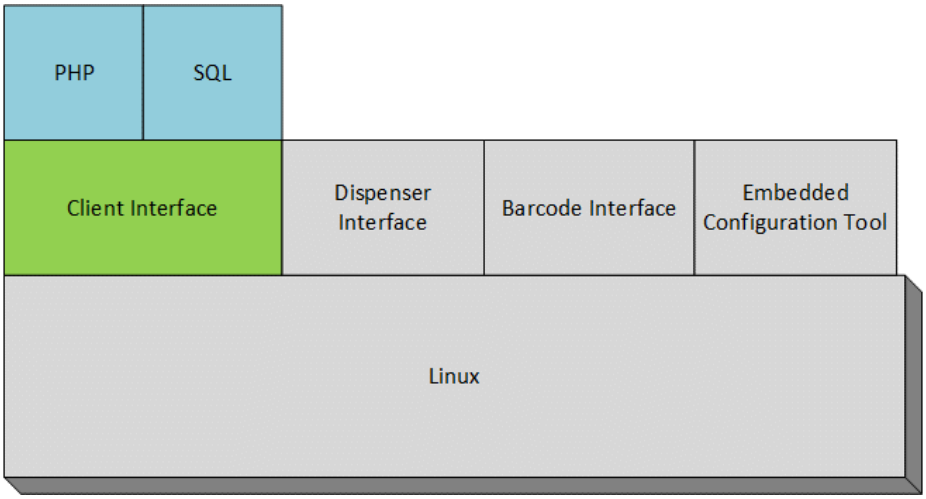


FIGURE 37: CLIENT INTERFACE

6.6.1 Overview

The first task that the Client Interface will handle will be the connection of the client application to the embedded system. This will be handled on the embedded system using a web server that is compatible with the Linux operating system and is capable of running PHP and MySQL. The web server will provide the ability for multiple client applications to communicate with the embedded system at the same time. This will allow users to service multiple different types of requests from multiple different client devices running the client application while not needing to worry about writing a multithreaded web server service. The use of PHP was determined to be a correct fit for our web server scripting language interface because of its syntax is similar to that of C and it provides all of the features that will be required by our embedded system.

6.6.2 Retrieve Menu

The client interface will provide several different services that the client application will depend on. The first service provided by the client interface is the transfer of the menu that was created by the machine administrator. This menu will be a JSON formatted file that contains a list of the drink items, their ingredients, and an image that can be used to represent the drink. This page of the client interface will be a statically supplied page and thus not use or require any PHP scripting within in it. Any changes that are to be made to the menu will be configured by the Embedded Configuration Tool. The format of the data that is returned can be viewed in Appendix D

6.6.3 Ingredient Status

While the user is using the client application, they are given feedback with regards to the drinks that are in stock and the drinks that are out of stock. In order for the application to determine the availability of a drink, the client application needs to know an approximate level of the ingredients. This portion of the Client Interface is a dynamically scripted page that will send the current drink level counters to the client application. The ingredients will be formatted using JSON. The ingredient levels will be stored using within the SQL database that will reside on the embedded system. The values will be queried using the MySQL plugin for PHP. No information will need to be sent to this page from the client application for the page will be querying all of the ingredients every time it is launched.

6.6.4 Create Reservation

Once the user decides on a drink that they would like to have they are required to reserve it before the drink can be dispensed. This portion of the Client interface is used to reserve a drink. The client application will need to submit the ingredient identifiers that it requires as well as the corresponding ingredient amounts. To identify the client application and for the client interface to be able to discriminate between two client applications, a UUID will be created in each application. This UUID will be required when ordering to present some form of distinguishable identity between two client applications. This UUID will be used to ensure that a user does not reserve an infinite amount of drinks. The create reservation page will query the database and ensure that the drink ingredients are in stock before creating a reservation ID. If all is successful, the client application will receive a reservation ID and a reservation expiration time. If the creation of the drink reservation fails, the client application will receive a reservation ID and expiration time of negative one (-1).

6.6.5 Check Reservation

Upon a successful reservation, a client application will have a reservation ID number as well as an expiration time. If too long of a time has elapsed since the drink reservation was created, the user will no longer be able to pick up their drink. This web form is used to verify that the reservation is still valid before attempting to pick up a drink order. This script will receive the Client Application's UUID and Drink Reservation ID and will query the order database. If the drink time is still within the pickup margins, the client application will be notified of the success. If the pickup time has expired, then the record will be removed from the SQL database and the Client Application will be notified.

6.6.6 Pickup Reservation

The job of this web form is to go through the sequence to get a drink dispensed. This is the most complicated portion of the application for it involves the interaction of every system to accomplish the required task. This web form will be responsible for a multitude of things. The first thing that Pickup Reservation is responsible for is acquiring the drink reservation ID and forwarding it to the Barcode Interface. The web form will then be required to wait for the Barcode Interface to report back that the barcode was scanned successfully. Once the barcode is scanned, this web form will notify the client application that the scan was successful and then open communication with the Drink Dispensing Interface. The web form will pass the required amounts of ingredients that need to be dispensed. Pickup Reservation will then wait until the Dispensing Interface replies back that everything is completed. At this time, the Pickup Reservation script will modify the SQL records that the transaction was completed. Once the logs have been updated, the Client Application is notified of the successfully completed process. The connection with the Client Application will then be closed.

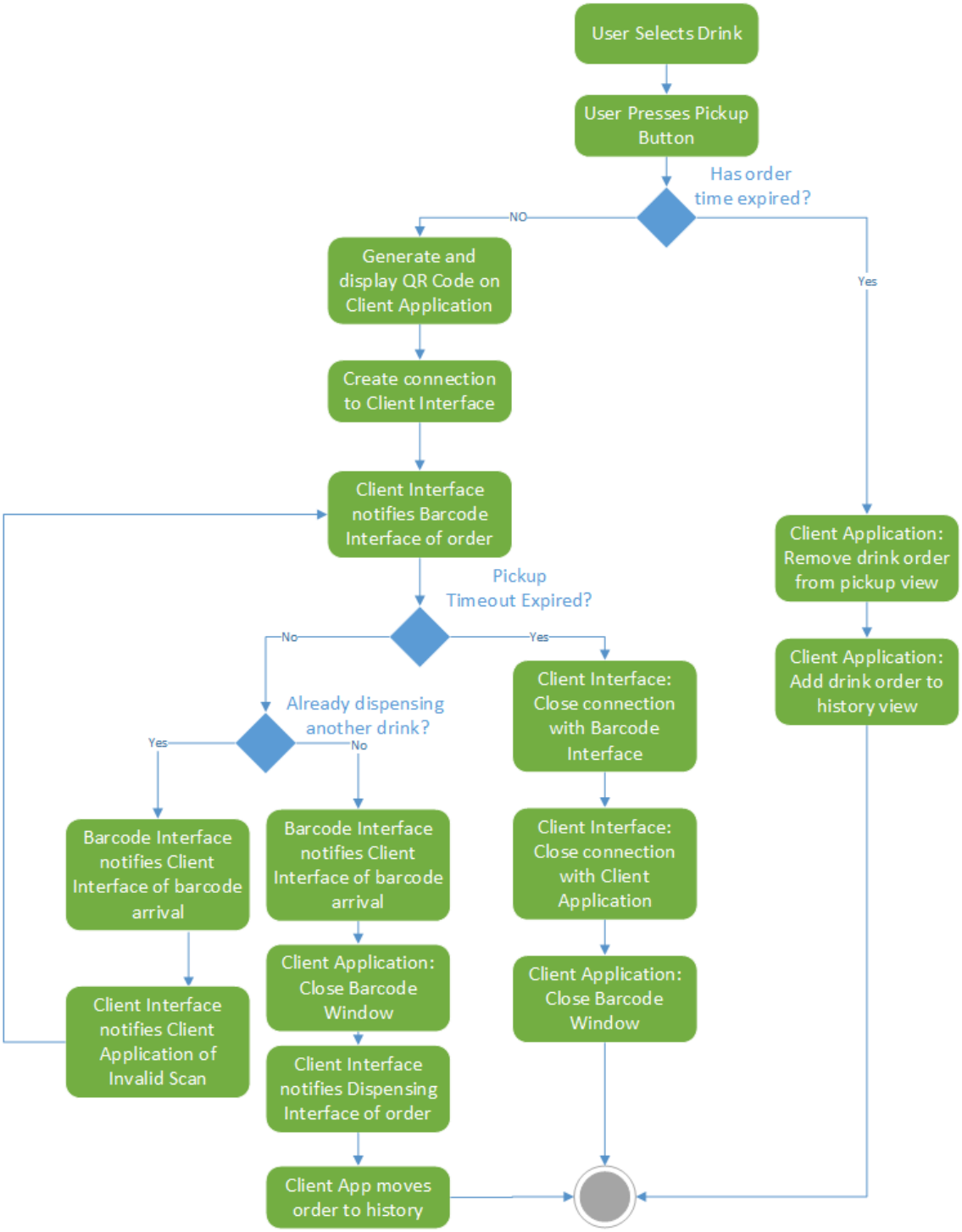


FIGURE 38: DRINK PICK-UP PROCEDURE

6.6.7 Get Settings

When the client application wants to configure the settings of the Under the Sun Drink Mixer, they will access the settings area. When the settings area is brought to the screen, it will need to retrieve the settings from the client interface. The "getSettings" script will be responsible for retrieving the current configuration from the embedded configuration tool. It will then be responsible for converting the data into the appropriate JSON data to return to the client application. The client application will then display the information accordingly to the user. No information will be required to be sent to the client interface for this information to be returned.

6.6.8 Unlock Settings

The "UnlockSettings" script will be responsible for authenticating a user's credentials to allow them to enter a mode within the client application to edit the configuration. This script will require the user's username and a password. The client application will send the password to the client interface which will hash and salt the password to compare to the stored password. If the authentication is successful the client application will allow the user to edit settings and the

6.6.9 Update Settings

After entering the settings view of the client application and retrieving the Under the Sun Drink Mixer's current settings using the "getSettings" script, by default the user will be able to view the settings, however they will not be able to modify any of the settings. If the settigns have been unlocked using the "UnlockSettings" as shown below, the user will be permitted to save the settings back to the embedded system. When this is done, the "updateSettings" script will be used by the client application. The update settings script will send the changes that the user has made to the embedded configuration tool to apply the settings to the appropriate location.

7.0 Hardware

7.1 Embedded System Design

As mentioned before in the research section, the embedded system is a very important aspect of the Under the Sun Drink Mixer. The embedded system will be handling numerous different requests and giving out numerous commands through signals. Also, everything is run off of the embedded system to make this design possible.

The Under the Sun Drink Mixer will be composed of three main parts that will be elaborated on:

- The Embedded System
- The Client Application
- The Power Supply

7.1.1 The Embedded System

The embedded system (microcontroller and printed circuit board) for the implemented design is very extensive; within the embedded system a webserver will be ran that will contain a database and access to that database via PHP. The embedded system is also responsible for containing peripherals that are necessary for the implemented design, such as a barcode scanner, dispensing motors, sensors and an LCD display, as well as communicating with the peripherals.

7.1.2 The Client Application

The client application for the design is also pretty extensive; this is where the users will order their drinks and by clicking the “Pick Up Drink” button, the user will be able to interface with the Under the Sun Drink Mixer and pick up their ordered drink.

7.1.3 The Power Supply

The power supply’s responsibility is to supply power to the Under the Sun Drink Mixer and allow it to function. Also, the power supply is responsible for regulating the power going through each part of the embedded system so that it doesn’t overload the system.

7.1.4 Overall View

Above was given brief descriptions on the responsibilities of each of the three main parts of the Under the Sun Drink Mixer; the embedded system, the client application and the power supply. Now, here is a more in depth description of how the implemented design will function.

When the Under the Sun Drink Mixer first goes online, it will need to be hardcoded via the webserver to determine what drink ingredients are in the machine and to what dispensing motor each drink corresponds to. This is also the time in which the pre-determined library will be created based on the drink ingredients in the machine. Once this is completed, a QR code will be generated containing access to the webserver. When the user wants to communicate with the Under the Sun Drink Mixer, they will scan the QR code into the client

application, this will give the client application access to the webserver, making a connection allowing the client application and the webserver to communicate back and forth. After the QR code is scanned into the client application, the user will have access to the webservers menu of drink ingredients as well as the pre-determined library to choose from. The user can then either pick a pre-determined drink from the library, or customize their own drink using the drink ingredients. When the user is finished picking out the drink that they want, they will click the “Order Drink” button. When the “Order Drink” button is pressed, it will send that order to the webserver and the webserver will store that ordered drink into the MySQL database, it will also reserve the amount of drink ingredients the user selected and begin the five minute expiration timer in which the user will get alerted about. The expiration timer is used to be sure that when somebody orders a drink, they also pick up the drink. The reason why this is important is because when a user orders a drink, that amount of drink ingredient is reserved; if that user does not pick up that drink, that drink ingredient is still considered reserved. The five minute expiration timer was put in place so that after five minutes, the MySQL database will throw out that order and reallot the drink ingredients.

When the user is ready to pick up their drink, they will click the “Pick Up Drink” button on the client application, this will also send a signal to the webserver telling it that somebody is ready to pick up a drink. The webserver will generate a QR code corresponding to that drink order, and send that QR code to the client application. At the same time, the webserver will update the MySQL database and push that drink order from Ordered to Pick Up stage, and start the two minute expiration timer. This is the same general idea of the five minute expiration timer before. Now it is time for the user to pick up their drink, they will walk up to the Under the Sun Drink Mixer, locate the barcode scanner, and scan their QR code. The QR code will link up to the specified drink order, and the webserver will now move the drink order from Pick Up stage to History stage, the webserver will also send a signal back to the client application and move the ordered drink to the History tab on the client application. Now that the embedded system has received the drink order and corresponding QR code, it will check with the sensors to be sure a cup is being sensed, and once a cup is sensed it will send a signal to the specified dispensing motors to tell them how long to stay open for and the drink will be poured.

If the expiration time expires during either the “Order Drink” stage or the “Pick Up Drink” stage, the corresponding order and/or QR code will be deleted, and the webserver will send a signal back to the client application informing the user that their drink order has expired, and they must order again.

At this time the user will enjoy a nicely poured drink, without realizing all of the back work that went on to make that drink possible. In the users' eyes, he ordered the drink, clicked pick up, scanned the QR code, and received his/her drink.

7.2 LCD Design

Like discussed earlier in the research section, the LCD display was a very important part of the Under the Sun Drink Mixer as it will be displaying a QR code that makes the entire system function. The QR code contains access to the webserver which supplies the client application with the drink ingredient menu as well as access to the pre-determined drink library. This QR code is also what allows the user the ability to order drinks from the Under the Sun Drink Mixer by gaining access to the web server. The 1.8 inch TFT Color Display (JD-T18003-T01) will be implemented into the Under the Sun Drink Mixer to display the QR code. The reasons that this LCD screen was chosen over the others was simple, it was much more cost effective, readily available and not as difficult to set up. This LCD screen uses the Sitronix ST7735R as the driver. This chip allows you the capability of connecting directly to a microcontroller and uses the Serial Peripheral Interface (SPI) which is a very simple approach. This allows display information to be stored in the on-chip display RAM, and then it can perform RAM read or write operations to display your information or add new information, in the Under the Sun Drink Mixer's case, the QR code.

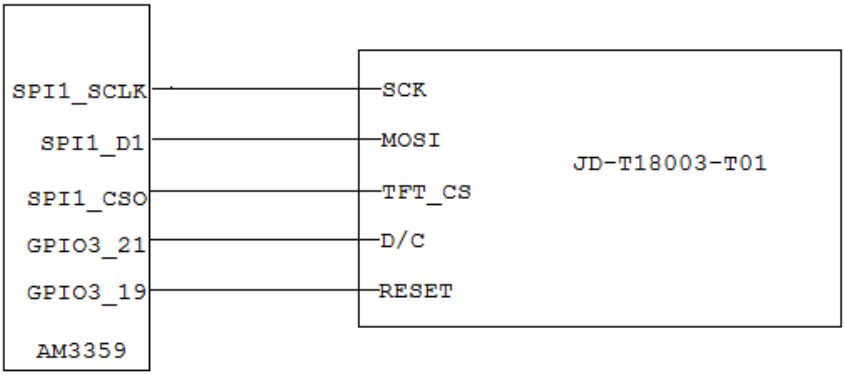


FIGURE 39: LCD DISPLAY INTEGRATION

Figure 39 shows how the 1.8 inch TFT Color Display (JD-T18003-T01) will be implemented with the embedded system. The LCD display will be connected to the embedded system by the use of a Flexible Printed Circuit (FPC) Connector. There are three SPI signals that are output only and the out-of-band Reset and Data/Command (D/C) signals which are driven by two GPIOs. It is a pretty simple interface. D/C is an out-of-band signal that drives the SPI bus transfers to either the internal RAM or the internal register file. From there, the SPI device

will be registered which is a pretty simple procedure. This is where the driver signals will be converted to the unique Linux GPIO values. The ST7735 reset signal will then be converted from the input that is on the GPIO3_19 pin to a unique Linux GPIO value and the D/C command signal from GPIO3_21 to a unique Linux GPIO value. Traditional frame buffer drivers rely on video memory which directly drives the display; however, SPI cannot directly expose the internal display controller memory to userspace. The work around for this is using the frame buffer deferred I/O, which allows an indirect connection. This allows the design to successfully integrate the 1.8 inch TFT Color Display (JD-T18003-T01) with the embedded system and use it to display the QR code that is needed.

7.3 Network Connections Design

As discussed in the Network Connections Research, for the Under the Sun Drink Mixer, a Wireless Local Area Network (WLAN) will be implemented. Wi Fi was chosen because it allows the implemented device to operate outdoors as intended without a large amount of Ethernet cable and it has greater distance and faster speeds than Bluetooth. The Wi Fi adapter that will be implemented into the design is the Realtek RTL8192CU chipset wireless dongle that connects by USB 2.0 port.

The Realtek RTL8192CU chipset allows for 802.11b/g/n specifications. For the implemented design, the 802.11n standard will be used. 802.11n works in both the 2.4 GHz and the 5 GHz frequency bands so it is compatible with the 802.11a, 802.11b and 802.11g. The 802.11n is capable of speeds up to 600 Mbps, and this is accomplished by the use of multiple-input multiple-output communication techniques and 40 MHz channels added to the physical layer, and frame aggregation to the MAC layer. Multiple-input multiple-output (MIMO) utilizes multiple antennas, which improve distance, reliability and speed. There can be up to four data streams sent simultaneously using 20 MHz or 40 MHz channels, which provides the theoretical maximum data rate of 600 Mbps. This is the most popular 802.11 standard available at the moment. (SITE MYSELF FROM MY WIRELESS PAPER)

Unfortunately, this isn't a straight plug and play USB dongle because the mainlined kernel driver for the adaptor's chipset (rtlwifi) does not work well, but the setup isn't incredibly difficult. The Realtek RTL8192 driver first needs to be built, then the Realtek RTL8192 driver must be ran and the old rtlwifi drivers must be blacklisted as they do not work. From there the Access Point (AP) will be configured, Wi Fi will then be enabled, allowing you to encrypt the passphrase and reboot and Wi Fi is set up.

7.4 BARCODE SCANNER DESIGN

As discussed before in the research section, the barcode scanner is a very important aspect of the Under the Sun Drink Mixer design. The barcode scanner is important in the overall design because it is what initializes the whole drink processing. The user will initially scan the QR code provided by the Under the Sun Drink Mixer that is displayed on the LCD display with the client application. This will allow the client application access to the webserver, the drink ingredients and pre-determined library of drinks. The importance of this step is huge, because without initially scanning the QR code provided on the LCD display, the user will not have access to the webserver and thus cannot order any drinks.

Once the user has scanned the QR code and gained access to the webserver, they can begin to order drinks. The user can choose from a pre-determined drink library or customize their own drink using the drink ingredients. After they have chosen or created their drink, the user will then click the “Order Drink” button on the client application. When the user is ready to pick up their drink, they will click the “Pick up Order” button on the client application, which will generate a QR code that they can use to pick up their drink. In order for the user to pick up their drink, they will approach the Under the Sun Drink Mixer and scan the QR code that was generated utilizing the barcode scanner that is embedded into the implemented design, and the barcode scanner will go through it’s process discussed later in the document.

The barcode scanner that was implemented into the design was the Motorola DS9208-SR4NNU21Z Desktop 1D/2D Barcode Scanner. This barcode scanner offers everything that the Under the Sun Drink Mixer needs; the ability to read QR codes, it is a hands-free device, it can read off of mobile devices, it can scan whether it is sunny out or if it is pitch black out, and it offers USB connectivity. The way that it will be implemented into the design is by USB port.

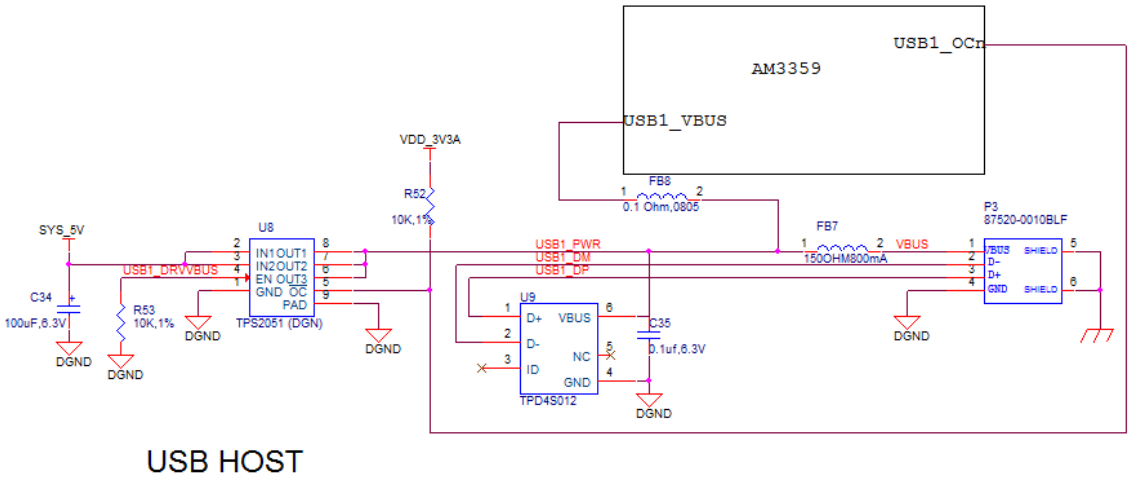


FIGURE 40: USB HOST

The printed circuit board created will be equipped with a USB host interface accessible from a USB Type A female connector. The USB1_VBUS signal is used by the microcontroller to detect that a 5V power supply is present on the connector. USB1_OCn is used to detect if the current gets to high across the connector, in which the microcontroller can tell the U8 switch to turn off the power to the connector.

7.5 Storage Design

As discussed earlier in the research section, the storage is a very important aspect of the Under the Sun Drink Mixer. The embedded system will need storage for the operating system, the webserver running on the embedded system with drink ingredients menu as well as the pre-determined library and MySQL will also be used in the design to store the ordered drinks, the picked up drinks, expiration timers, drink levels, pre-determined drink library and drink ingredients. PHP will be used to access that information stored through MySQL.

If you need a recap on specifically what each detail that MySQL stores refers to, go back to the “Storage Research” portion of this paper, it is all discussed there in detail.

As discussed in the research portion, micro SD was the chosen storage device used in the Under the Sun Drink Mixer. The reason that micro SD was chosen versus the other types of storage devices that were researched was because it accomplished everything that was needed for the implemented design, it was a component that was already readily available and there wasn’t a significant amount of work that needed to be done to add that ability to the printed circuit board (PCB) used in the implemented design.

The micro SD will be used to boot Ubuntu from and the micro SD will also store all of the information for the webserver including MySQL.

7.6 Printed Circuit Board Design

A very important aspect of the Under the Sun Drink Mixer was the printed circuit board (PCB) design. The printed circuit board is what houses the microcontroller and allows the microcontroller to reach its full capabilities and even expand those capabilities. Besides housing the microcontroller, it also connects many different components using conductive pathways.

The microcontroller that was implemented into the Under the Sun Drink Mixer design was the Texas Instruments AM3359 ARM Cortex-A8. The development board that stumbled across that supports the use of the Texas Instruments AM3359 was the BeagleBone Black. This development board really suited all of the needs and then some when it came to specifications that were initially wanted for the Under the Sun Drink Mixer. The BeagleBone Black supports Ethernet so there is a way to communicate from the client application to the embedded system, pulse-width modulation (PWM) for the dispensing motors, abilities for an LCD display, micro SD support, micro HDMI support, 2GB of onboard storage and plenty of power to run an operating system so that a webserver to host a MySQL database could be set up. This was going to be the reference design used, and thing would be added or removed depending how necessary they were to the design.

Throughout the duration of the semester, the printed circuit board design has constantly changed as new designs have been researched and new approaches have been looked into. The goal was to keep the cost of the printed circuit board design low, while still being able to perform all necessary tasks; that meant a lot of scrapping unnecessary components. The original plan was to keep the 2GB onboard storage and run the operating system and webserver on that, and then scrap the micro SD card from the board, but then it was realized that it would probably be a better decision to do it the opposite way, keep the micro SD card and scrap the onboard storage, as it is a fixed 2GB and 8GB micro SD's were already an accessible part. The decision was made, the 2GB onboard storage was scrapped from the design and the micro SD would be used as the storage type.

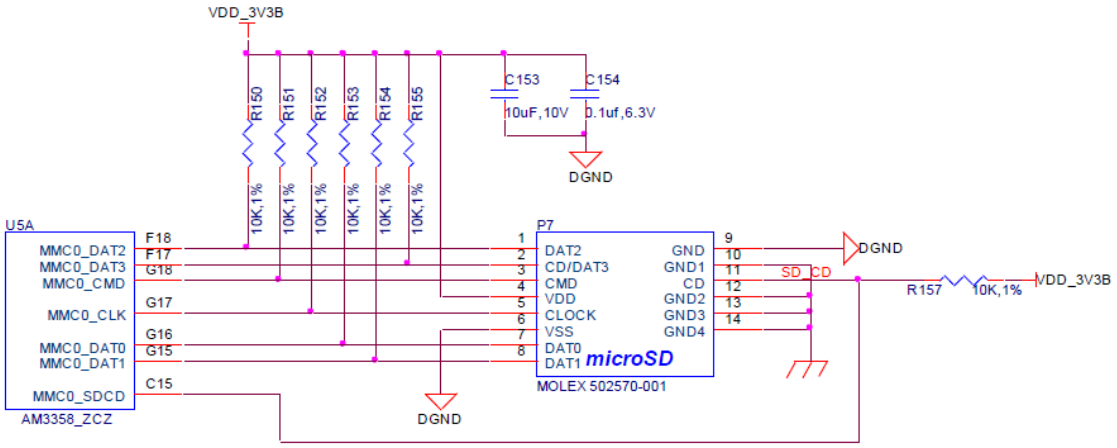


FIGURE 41: MICRO SD DESIGN

Shown above is the design of the micro SD circuitry. The signals MMC0_DAT0 through MMC_DAT3 are the data lines for the transfer of data between the microcontroller and the micro SD connector. The signal MMC0_CLK clocks the data in and out of the micro SD card. The MMC0_CMD signal indicates that a command instead of data is being sent. Power is provided from the VDD_3V3B rail and the 10uf capacitor is used for filtering.

Next thing that had to be decided on was the Ethernet/LAN option. Was it necessary? A requirement for the design was a way to communicate back and forth between the client application and the webserver, but wired certainly wasn't the solution because the design was based outdoors. One would need to haul long Ethernet cables everywhere they went if they decided to use this option. The decision made for the design instead looked into wireless capabilities such as Wi Fi. A Wi Fi adapter was found for the design that would be great. It was a wireless dongle that connects straight into the USB 2.0 port and provides 802.11n with relatively easy setup. As a cause of this, USB was needed in the design. Below is the design of the USB port that will be used in the printed circuit board design.

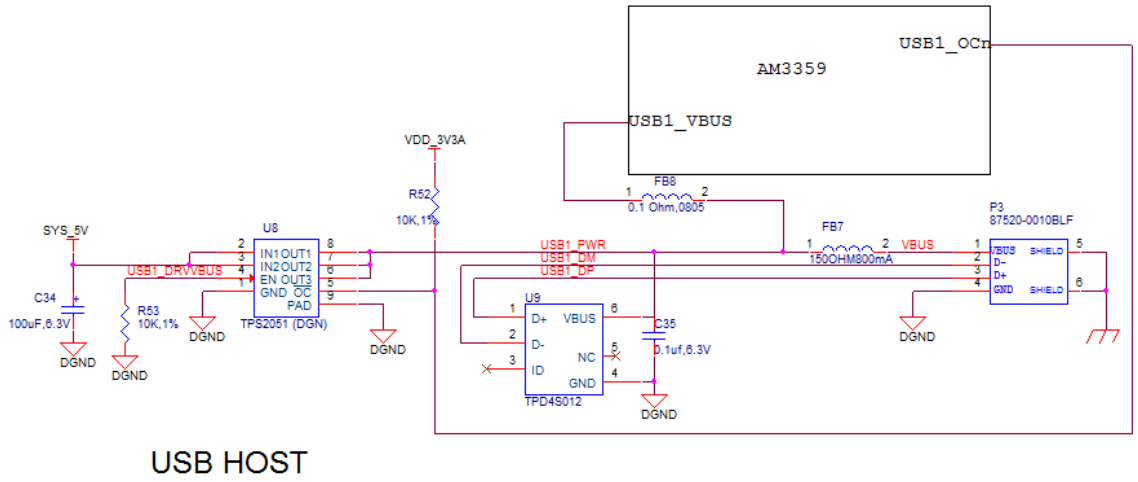


FIGURE 42: USB HOST

The printed circuit board created will be equipped with a USB host interface accessible from a USB Type A female connector. The USB1_VBUS signal is used by the microcontroller to detect that a 5V power supply is present on the connector. USB1_OCn is used to detect if the current gets to high across the connector, in which the microcontroller can tell the U8 switch to turn off the power to the connector.

Next thing that was considered in the reference design was the expansion headers. These things were not needed as they were used for connecting capes and other devices to that would not be used, this was an easy decision to scrap.

It was also decided that it would be a good decision to edit the boot configuration on the board. The standard way the reference design booted up, was by first booting from the onboard storage. If it was necessary to boot from micro SD card, there was a “Boot from micro SD” button that had to be held down on boot up to tell the board to boot from micro SD. However, with the removal of the onboard storage, this would be a problem having to hold down the button each and every time the board was booted. The way around this hassle was looking into the configuration and seeing the order; the board first tries booting from onboard storage, and then it moves to micro SD, and then to USB. Removing the “Boot from micro SD” button would cause the microcontroller to search for the onboard storage, not find it, and then boot from micro SD automatically. This was the

design that will be implemented in the Under the Sun Drink Mixer.

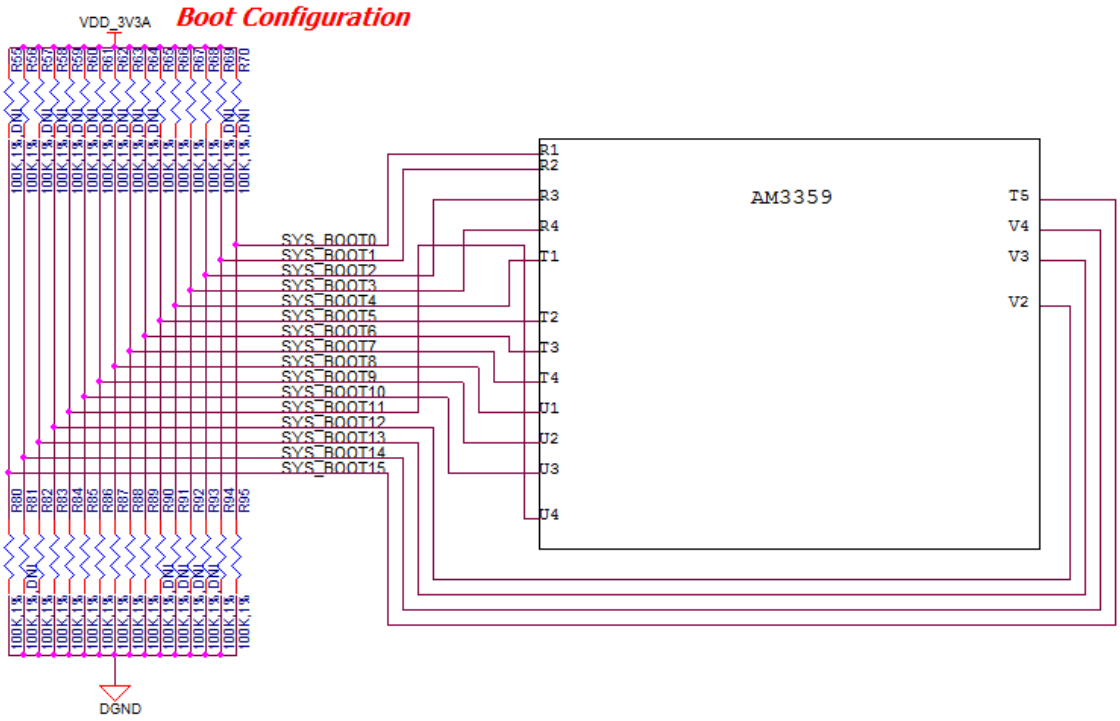


FIGURE 43: BOOT CONFIGURATION

This is how the boot configuration will connect to the microcontroller. These pins that the boot configuration is connected to are multi-purpose pins meaning they can be used for many different things from PRU to LCD/HDMI and GPIO's.

The next decision that was made regarded the LCD display, how would the LCD display be interfaced with the printed circuit board, would it use HDMI, serial, another method? It was decided to connect the LCD display serially by using the Serial Peripheral Interface (SPI).

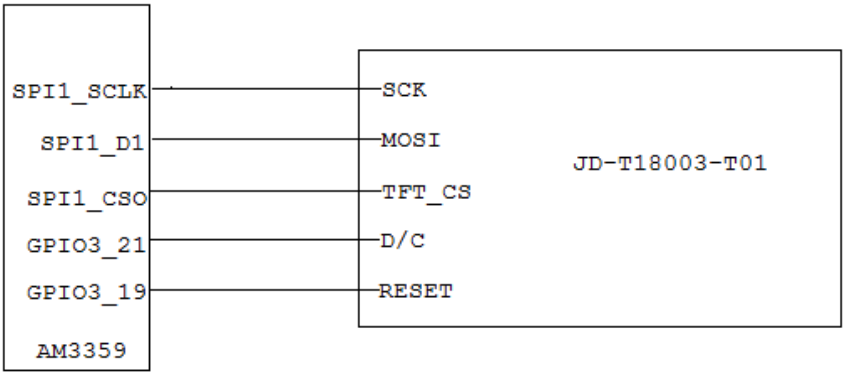


FIGURE 44: LCD DISPLAY INTEGRATION

The schematic above shows how the 1.8 inch TFT Color Display (JD-T18003-T01) will be connected to the embedded system. The design will use a Flexible Printed Circuit (FPC) connector to connect the LCD display. There are three SPI signals that are output only and the out-of-band Reset and Data/Command (D/C) signals which are driven by two GPIOs.

For this reason, HDMI wasn't entirely necessary for the design platform once it is set up, but the decision was made to leave it in there to make the startup design possible. The HDMI framer and mini HDMI port will be included so that the initial setup of the webserver on the embedded system will be possible.

The onboard HDMI framer converts LCD signals and audio signals to drive an HDMI monitor utilizing the TDA19988 HDMI Framer. The TDA19988 is a HDMI transmitter.

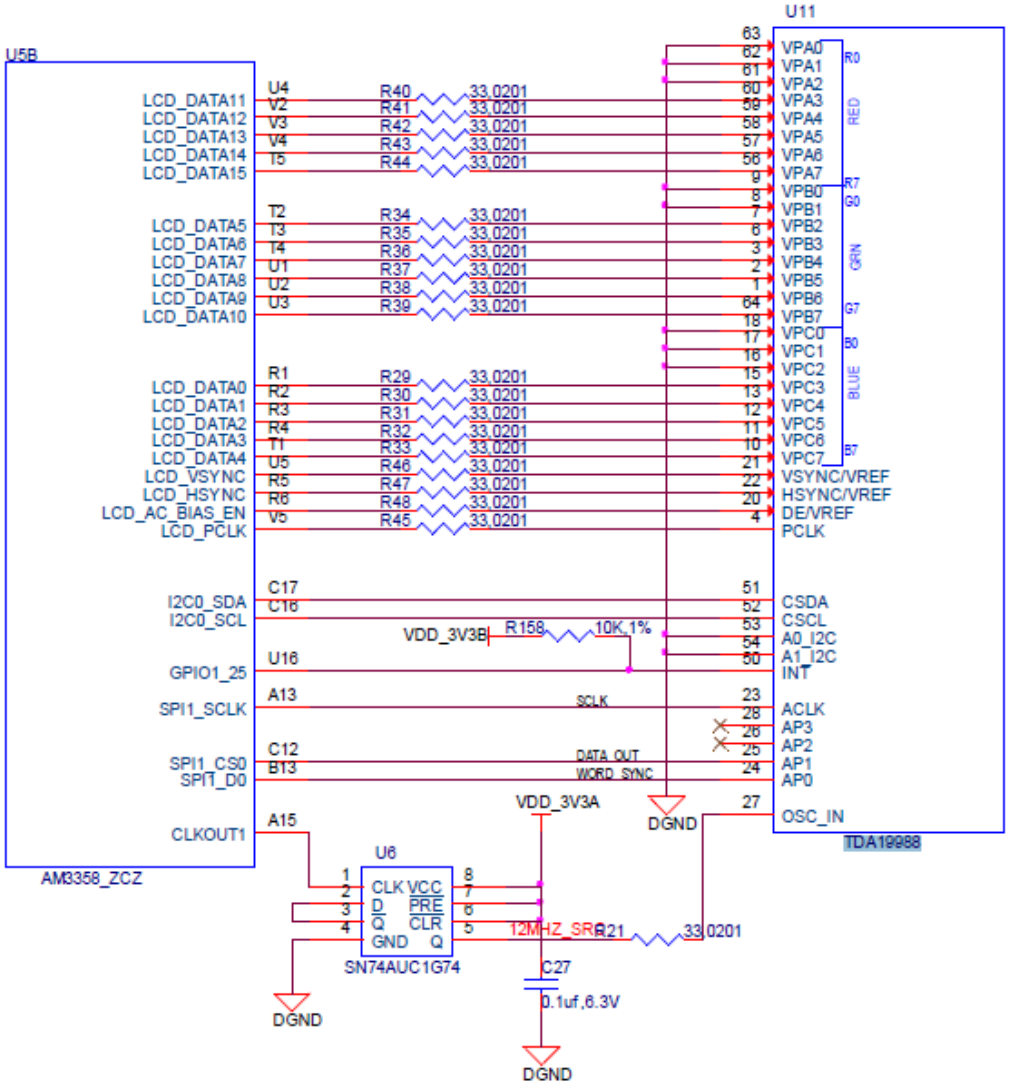


FIGURE 45HDMI FRAMER PROCESSOR INTERFACE

The schematic above shows the connections between the microcontroller and the HDMI framer. 16 bits of display data are used to drive the framer and the unused bits are tied low.

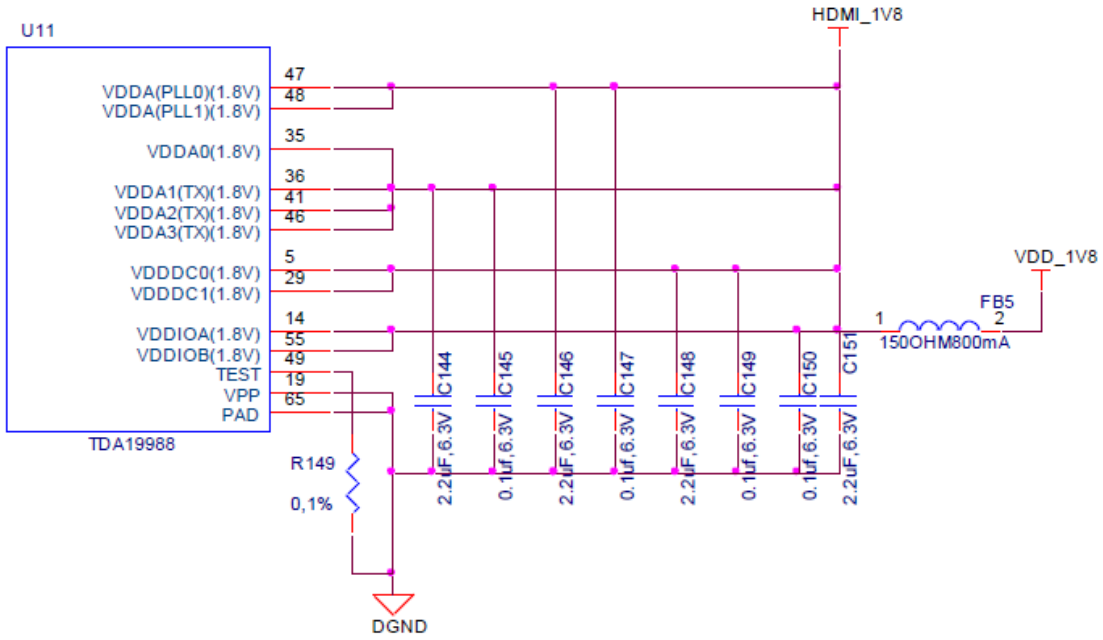


FIGURE 46: HDMI POWER CONNECTIONS

The schematic above shows the power connections to the TDA19988 HDMI framer. The voltage rails for this device are all 1.8V and a filter is provided to minimize noise from the 1.8V rail getting into the device. The interfaces between the processor and the HDMI framer are all 3.3V tolerant which allows direct connection.

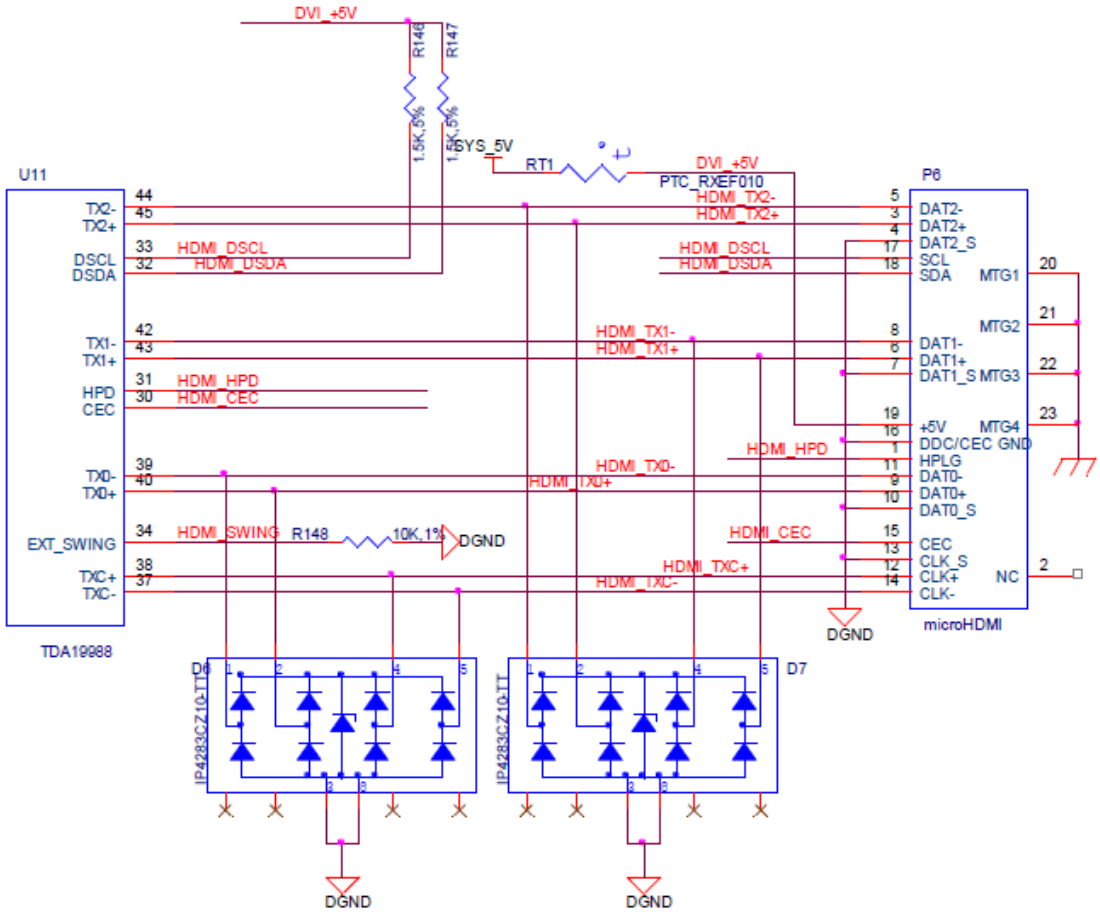


FIGURE 47: HDMI FRAMER AND CONNECTOR

This schematic shows the design of the HDMI Framer and how it connects to the connector. This HDMI interface uses the micro HDMI connection, and D6 and D7 are Electrostatic Discharge protection devices.

The next part of the Under the Sun Drink Mixer design that was needed to implement into the printed circuit board was the barcode scanner. The great thing about the barcode scanner that was chosen is that it is very easy to implement, it is literally a plug n play via USB port. The USB port was discussed earlier in regards to the Wi Fi that will also be implemented. For this reason, a USB hub will be used so that both the barcode scanner and the Wi Fi dongle can be used.

The Under the Sun Drink Mixer board design will also incorporate 512MB of DDR3L RAM. RAM is important because it allows access to stored data in any random order versus a hard drive having to search because the way that a hard drive saves is in a pre-determined order, this makes access times to be very inconsistent based on what you are searching for is physically located on the hard drive.

What's the sense in having all of these goodies without having a device to manage the power that is going to different areas of the board? This is where the TPS65217C power management device comes into play. The TPS65217C device is a single chip power management IC (PMIC) that contains a linear dual-input power path, three step down converters and four low dropout regulators. The printed circuit board is supplied power by a 5VDC adapter, and then three 2.25MHz step down converters provide the core voltage, microcontroller, and memory voltage for the printed circuit board.

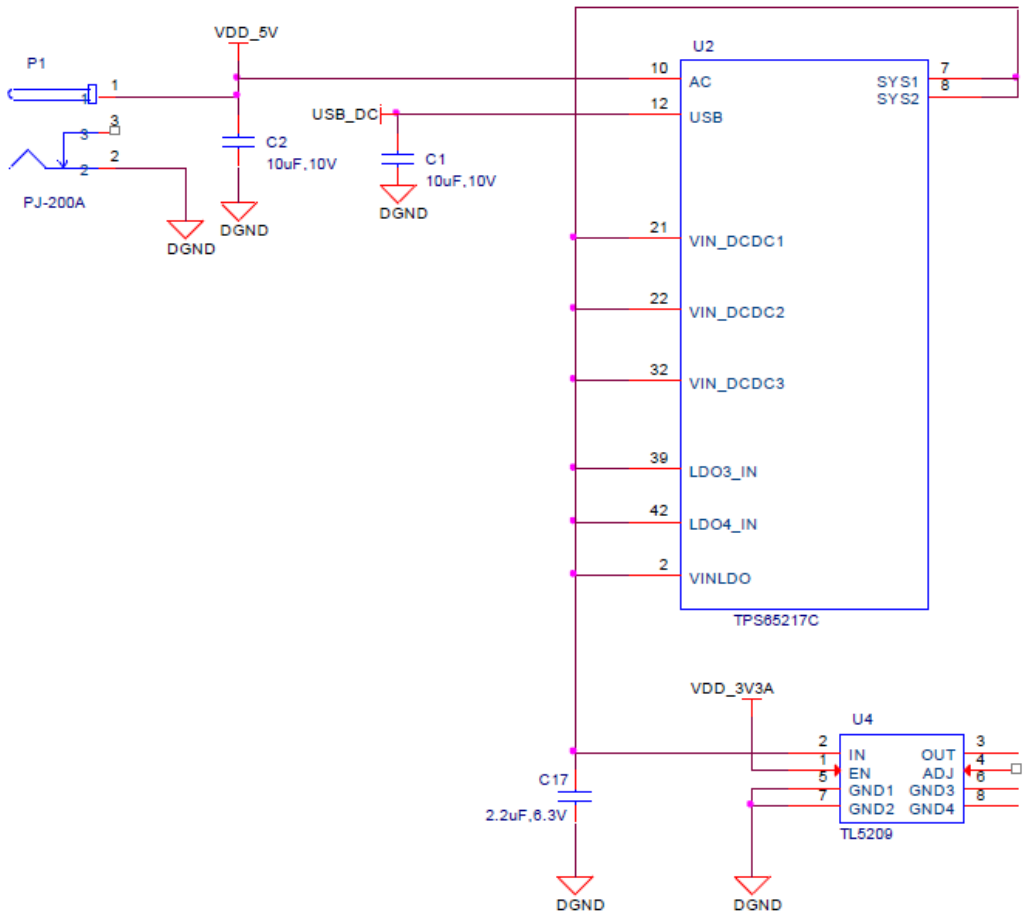


FIGURE 48: TPS65217 DC CONNECTION

The schematic above shows how the 5VDC supply is connected to the printed circuit board to supply power to it.

The microcontroller interacts with the TPS65217C using different signals. I2CO is a control interface between the microcontroller and the TPS65217C that allows the microcontroller to control the registers inside of the TPS65217C for voltage scaling or switching of the input rails.

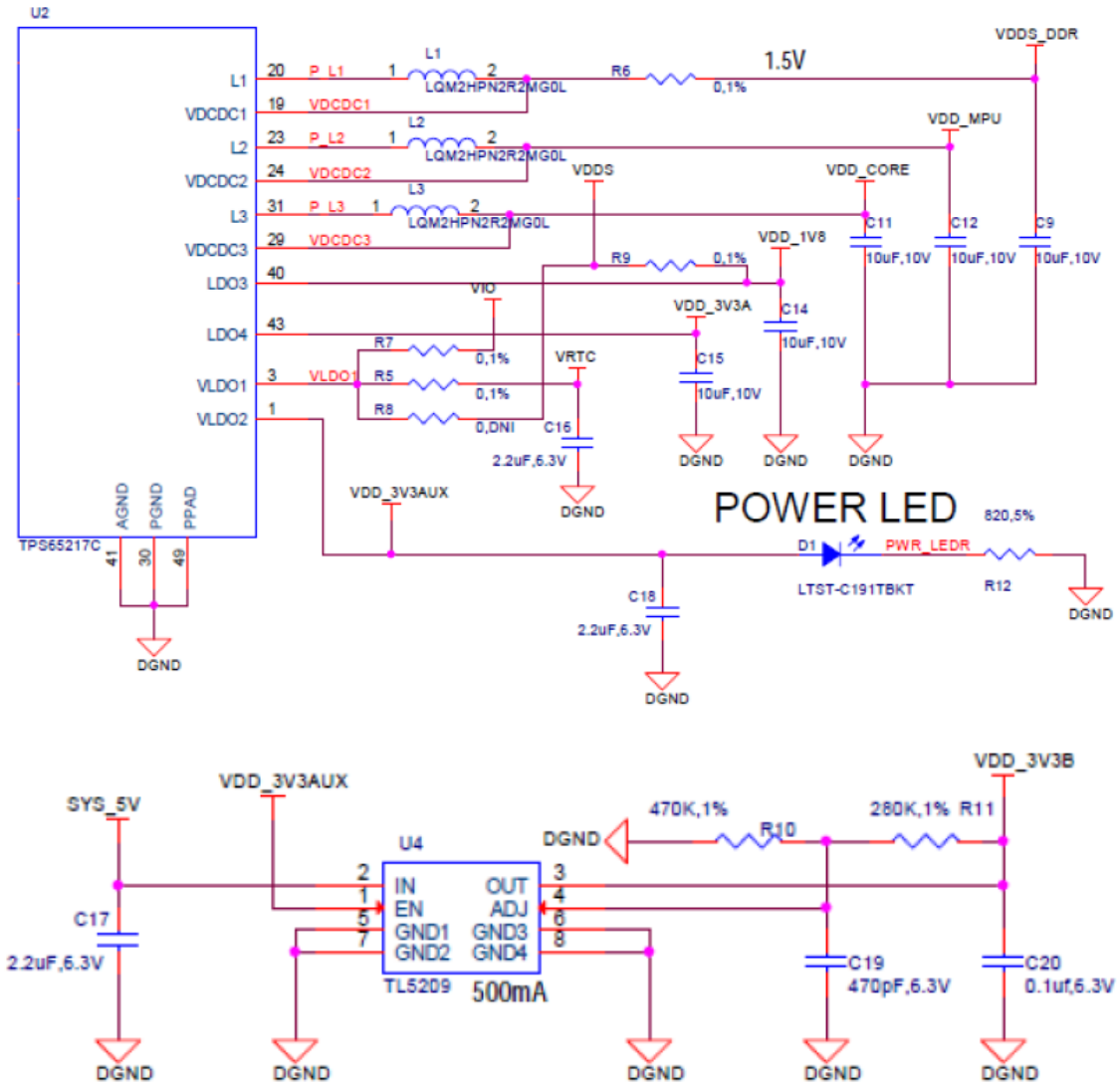


FIGURE 49: POWER RAILS

The schematics above show the connections of each of the power rails of the TPS65217C. The VRTC rail will be looked into first; it is a 1.8V rail that is first to come up during the power sequence. It provides power to the RTC domain of the microcontroller as well as the I/O rail of the TPS65217C. It delivers a maximum of 250mA. Next is the VDD_3V3A rail which is supplied by the TPS65217C and provides 3.3V for the microcontroller rails and provides up to 400mA. Because the current supplied by the VDD_3V3A rail isn't sufficient enough to power all of the 3.3V rails throughout the board, a second LDO is supplied, the TL5209A shown in the second schematic. This LDO supplies power to the VDD_3V3B rail and is powered up right after the VDD_3V3A rail. Next is the VDD_1V8 rail which can deliver upwards of 400mA and it sources power to all the 1.8V rails on

the microcontroller and HDMI framer. The VDD_CORE rail connects only to the microcontroller and can deliver up to 1.2A at 1.1V. The DDR rail supplies the DDR3L RAM rails with 1.5V and can deliver up to 1.2A.

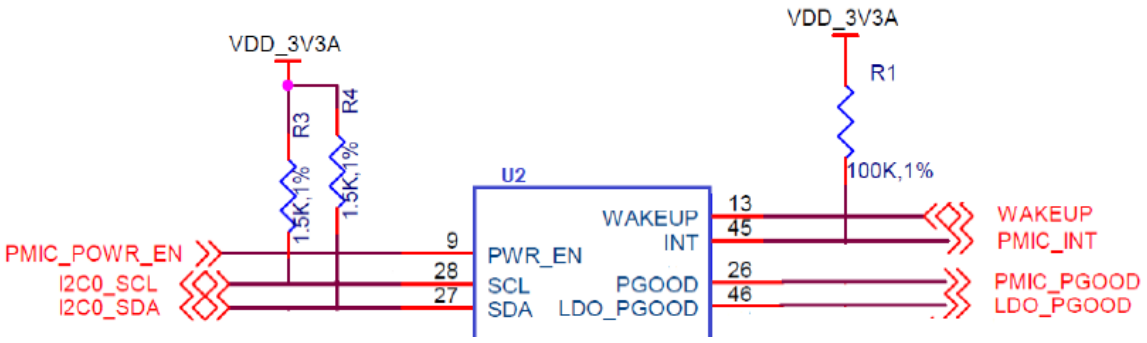


FIGURE 50: INTERFACE BETWEEN TPS65217C AND THE AM3359

This schematic shows two interfaces between the microcontroller and the TPS65217C used as control after the power up sequence is done. The first is the I2C0 bus which allows the microcontroller to turn on and off power rails and allows the microcontroller to set the voltage levels of each regulator to support things such as voltage scaling. The second is an interrupt, which allows the TPS65217C to alert the microcontroller when there is an event.

For the Printed Circuit Board Design section of this document, only certain parts were shown that were important to the Under the Sun Drink Mixer design. There is much more than went into the PCB design that was not shown. The main important components were covered.

7.7 Power Requirements

7.7.1 Solar Panel

For this project, a 30 watt polycrystalline silicon solar panel will be used to charge the battery. This panel was chosen because of its efficiency at lower coast then the mono-crystalline. The mono-crystalline would have been ideal for this type of application because it is the most efficient type of panel, but the cost is slightly higher than polycrystalline. Thin film was ruled out right away because of its inefficiencies for small areas. This project will use the SLP030-12 high efficiency multicrystalline PV module from Solarland. A 30 watt solar module will be ideal for charging the battery since a lead acid battery has a low maximum charge current. Also, the dimensions of the 30 watt module will be 21.5 x 20.5 inches, making it compact enough to fit on top of the machine. The electrical characteristics of this panel can be seen in Table 10.

TABLE 10: SOLARLAND SLP030-12 ELECTRICAL CHARACTERISTICS

Electrical Characteristics	SLP030-12
Maximum power	30W
Voltage at max power	17.4V
Current at max power	1.72A
Open-circuit voltage	21.5V
Open-circuit current	1.89A
Temperature coefficient of power	-(.5±.05)%/°C
Operating temperature	-40°C to 85°C
Power tolerance	+10%/-5%

The current at maximum power is 1.72 amps. This means that the maximum amount of current that can be pulled from the panel is 1.72 amps at 17.4 volts, which is the voltage at maximum power. When the battery is discharged to about 50%, the MPPT controller will go into a rapid charge where it will drop the voltage from the panel output and deliver higher current the battery. When the battery reaches a certain voltage, in this case around no higher than 12 volts, it will then step down the current. A .250 tab will be used to connect the solar module to the MPPT controller PV input.

7.7.2 MPPT CONTROLLER

7.7.2.1 CHARGING PROFILE

This project will be using a lead acid charging profile for the design of the charge system. Figure 51 shows a graph of the charging profile. If the battery voltage is very low, a slow charge current is applied until the voltage reaches a threshold voltage V_T. The full charge current is then applied until full charge is detected on the voltage of the battery. It will then switch into a floating charge and will maintain the battery voltage at a fixed threshold. At full charge voltage the current is drop to zero, as floating voltage reaches a fixed battery threshold the current will gradually rise to a slow charge current. If the available power is lower than the power required to achieve voltage or current regulation, the system will automatically go into MPPT mode.

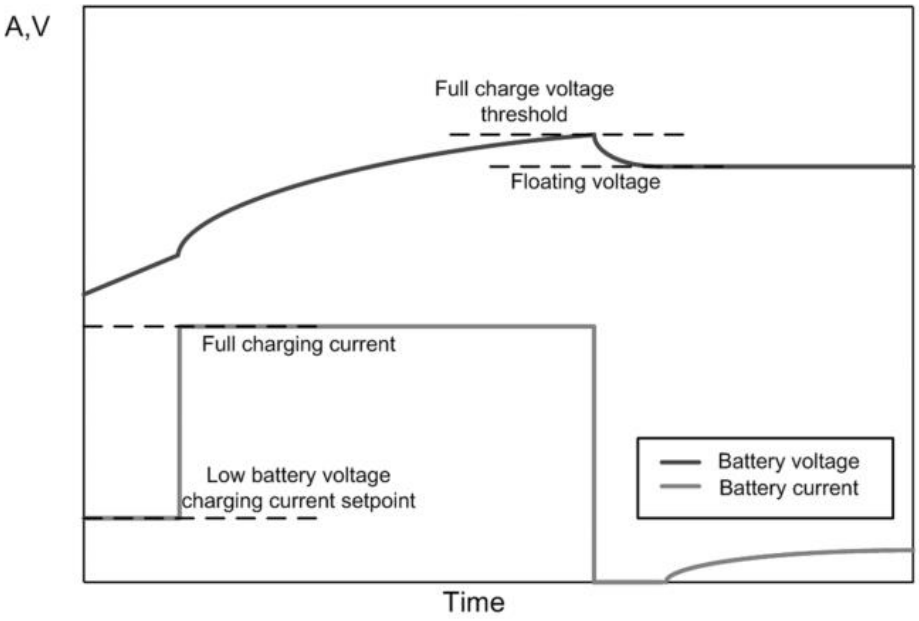


FIGURE 51: LEAD-ACID CHARGING PROFILE

7.7.2.2 Features of Design

The requirements and features for this charge system are given below.

- Will need to charge a 12V lead acid batter
- The input voltage range from the PV will be between 5V and 17.2V Vmp
- The maximum input current will be 1.72 amps
- An MPPT algorithm for optimizing photovoltaic application
- Up to 2.14 amp charging current
- Protection from reverse current
- Trickle charge and fast charge modes
- Up to 98 percent converter efficiency
- 14.2V max charge voltage, 13.5V floating voltage
- Output voltage set-pints can be reprogrammed

7.7.2.3 10 Volt Power Supply

A 10 volt power supply rail is required to properly bias the gate driver (SM72295). This project will be using the SM72485 application notes to choose design specifications and component selection. The schematic for the 10 volt power supply is seen in Figure 52. The steps below will be used to configure the SM73485.

- Input voltage range: 5V to 30V
- Output voltage range: 10V
- Load current: 100mA to 150mA

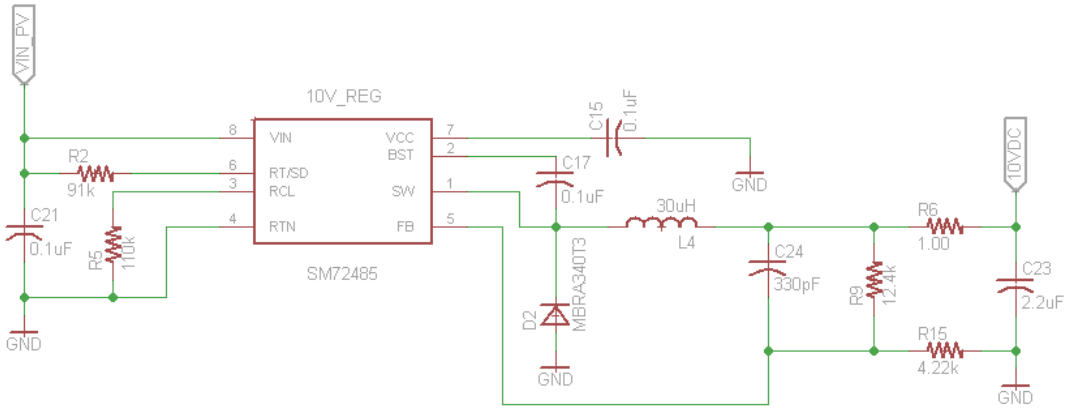


FIGURE 52: EAGLE CAD SCHEMATIC OF 10 VOLT POWER SUPPLY

7.7.2.3.1 CALCULATIONS AND COMPONENT SELECTIONS

The output voltage is programmed by two external resistors R9 and R15 in the Figure 52. The regulation point can be calculated equation below.

$$V_{out} = 2.5 \times \frac{R15 + R9}{R15}$$

V_{out} is equal to 10 volts and by choosing R15 to be 4.22kΩ, next R9 can be found which comes out to be 12.4KΩ. Other values could have been used as long as a 3:1 ratio is maintained between the resistors.

The recommended operation frequency rage for the SM72485 is 50 kHz to 1.1 MHz. the maximum allowed frequency is based on a minimum on-time of 400 ns. It can be calculated by equation below.

$$F_{MAX} = \frac{V_{OUT}}{V_{INMAX} \times 400ns}$$

Where V_{INMAX} is equal to 30 volts. F_{MAX} is found to be about 833 kHz. Once the maximum frequency is fond, the resistor R2 can be calculated. It comes out to be R2 ≈ 86kΩ, the closest resistor value is 91kΩ, therefore R2 = 91 kΩ.

7.7.2.3.1.1 INDUCTOR SELECTION

For choosing the inductor, it must consider the output ripple current amplitude. The choice of the inductor will be dependent on the minimum and maximum load currents. The maximum ripple current will occur at maximum input voltage. Equation below will be used to calculate the inductor value.

$$L4 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{I_{OR} \times F_S \times V_{IN}}$$

Where I_{OR} is the maximum ripple current in the inductor. The maximum output current cannot exceed 200 mA, and therefore is 200 mA. From the equation you will find that L4 ≈ 26.67 µH to be the minimum inductor value. The next closest value is 27 µH, but for good safety measure a 30 µH will be used. Using a 30 µH, the maximum output current will be 177.8 mA, which falls into the appropriate range.

7.7.2.3.1.2 RESISTOR AND CAPACITOR SELECTION

Using the application notes of the SM72485, this project can find an appropriate resistor and capacitor values needed to construct the 10V regulator.

> "R5: When current limit is detected, the minimum off-time set by this resistor must be greater than the maximum normal off-time, which occurs at maximum input voltage. Using equation below, the minimum on-time is 476 ns, yielding a maximum off-time to 3.8 µs. Due to the 25% tolerance on the on-time, the off-time tolerance is also 25%, yielding a maximum off-time to 4.73 µs. allowing for the response time of the current limit detection circuit increases the maximum off-time of 5.1 µs. This is increased an additional 25% to 6.4 µs to allow for the tolerance of equation below. Using Equation below, R5 can be calculated." [2]

$$T_{ON} = \frac{(1.385 \times 10^{-10} \times R5)}{V_{IN}}$$

$$T_{OFF} = \frac{10^{-5}}{(0.285 + (V_{FB}/6.35 \times 10^{-6} \times R5))}$$

V_{FB} is equal to 2.5 volts. Next R5 is calculated to R5 = 103.1 kΩ. A standard value 110 kΩ will be used. The application note allow gives equations on finding proper capacitor values.

C21: This capacitor's purpose is to supply most of the switch current during the on-time, and limit the voltage ripple at the input voltage, on the assumption that the voltage source feeding the input voltage has an output impedance greater

than zero. At maximum load current, when the buck switch turns on, the current into pin 8 will suddenly increase to the lower peak of the output current waveform, ramp up to peak value, then drop to zero at turn-off. The average input current during its on-time is the load current (150 mA). For a worst case calculation, C1 must supply this average load current during the maximum on-time. To keep the input voltage ripple to less than 2 volts. Equation below calculates C1.

$$C1 = \frac{I_{LOAD} \times T_{ON}}{\Delta V} = 0.268\ \mu F$$

> "Quality ceramic capacitors in this value have a low ESR which adds only a few millivolts to the ripple. This is the capacitance which is dominant in this case. To allow for the capacitor's tolerance, temperature effects, and voltage effects, a 1.0 µF will be used." [2]

All other capacitors are constant values; they remain the same under all design conditions.

7.7.2.4 DC/DC Converter

This project will be utilizing a step up/step down four switch converter to transfer power from the PV panel to the battery. This DC/DC converter has 4 different modes that it can operate in in order to achieve maximum charge performance. An important feature of this DC/DC topology is the bypass panel mode that is controlled by two MOSFET switches. For design procedures and component selection, TI's Power Circuit Design for SolarMagic was referenced. Figure 53 below shows the topology of the DC/DC converter.

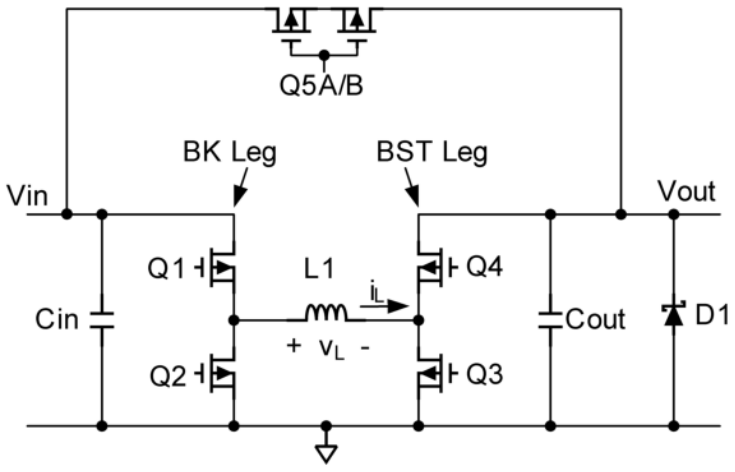


FIGURE 53: DC/DC CONVERTER WITH PM

Using Power Circuit Design application notes as a reference, this documentation will go over the operation principles and power converter design. This DC/DC converter will be utilized along with the SM72442 micro-controller to dynamically determine the optimal mode of buck, boost, or panel mode. The advantage of panel mode is that when the output voltage and the input voltage are within 2%, it will jump into panel mode and directly connect the output of the PV panel to the battery for almost lossless energy. The panel mode can be enabled by opening the dual switch Q5 in Figure 53. The panel mode is a way to replace a buck-boost mode that would require more tedious programing.

For buck and boost modes, the power circuit design application notes explains the operating principles of both modes.

> "When the panel mode is not the optimal condition, the MPPT/PM (SM72442) controller will turn-off PM switches and engage the DC/DC converter for maximum power tracking. In a conventional buck-boost converter, witching of the diagonal switches is synchronized. Namely, Q1 and Q3 are turned on and off at the same time. So are Q2 and Q4. In this application, the switching sequence of the four switches in Figure 53 is different from the conventional buck-boost converter. This converter has three operation modes: the buck-only mode (BK), the boost-only mode (BST) and the panel mode (PM). Based on real time assessment of the operation conditions, the MPPT/PM controller dynamically determines an optimal mode to operate the converter in order to track the maximum power point of the PV panel." [3]

The MPPT/PM controller will run in buck mode when the mpp voltage of the PV panel is lower than 98%, given by equation below. Figure 54 below shows the buck mode equivalent circuit where Q1 and Q2 are switching, while Q3 is OFF and Q4 is ON.

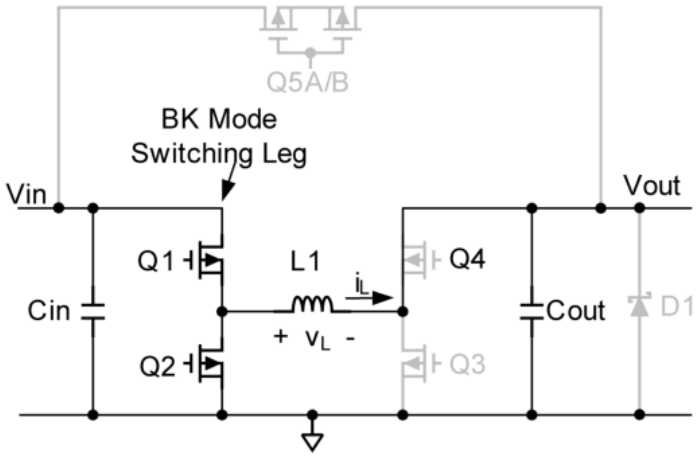


FIGURE 54: BUCK MODE EQUIVALENT CIRCUIT

When the PV panels mpp voltage is greater than 102% of the output voltage given by equation below, then the controller will run the DC/DC converter in boost mode. Figure 55 below shows the equivalent circuit of the boost mode. In this mode only Q3 and Q4 are switching, while Q2 remains OFF and Q1 stays ON.

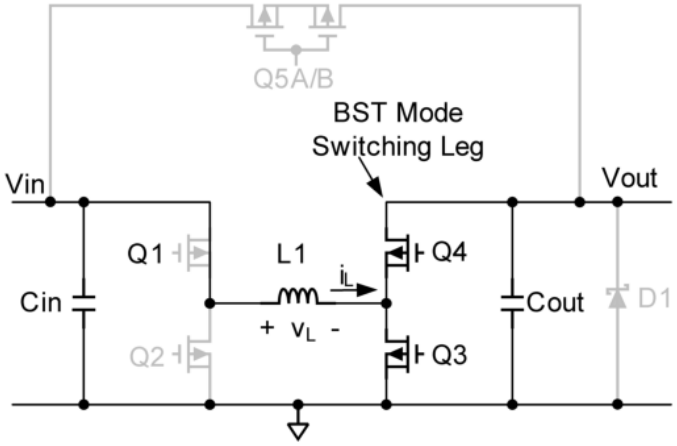


FIGURE 55: BOOST MODE EQUIVALENT CIRCUIT

7.7.2.4.1 BUCK MODE

In buck mode switches Q1 and Q2 are switched ON and OFF complementary to each other. The voltage across the inductor is equal to $V_{in} - V_{out}$ when Q1 is ON. When Q1 is OFF, the inductor voltage is $-V_{out}$. In steady state, the inductor's volt-second product must be balanced each switching cycle. Equation below is given.

$$(V_{in} - V_{out}) \times D + (-V_{out}) \times (1 - D) = 0$$

D is equal to the duty cycle of the switch Q1. The equation that governs the duty cycle in buck mode is given by equation below. Also, the key waveforms of the converter when it is in buck mode are given in Figure 56. The Key Waveform is important, as it shows the inductor voltage and current as the gates switch ON and OFF.

$$D_{buck} = \frac{V_{out}}{V_{mpp}}$$

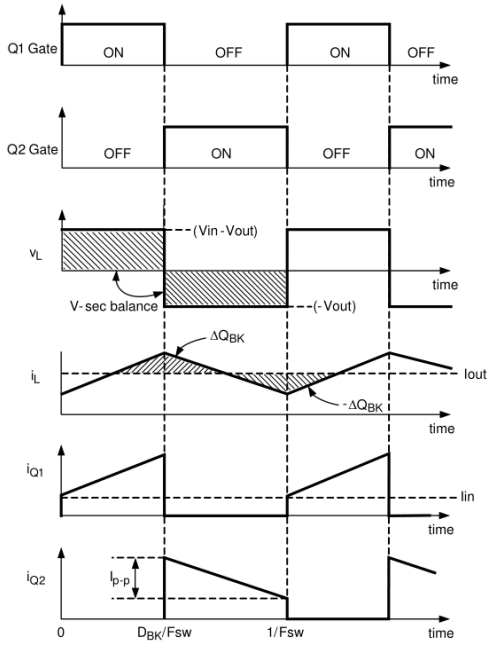


FIGURE 56: BUCK-ONLY K WAVEFORM

7.7.2.4.2 BOOST MODE

In boost mode, the switches Q3 and Q4 are switched complementary of each other. The voltage across the inductor will be equal to V_{in} when Q3 is ON. When Q3 is OFF, the inductor voltage is $(V_{in} - V_{out})$. The steady state inductor volt-second product for the boost configuration is given by the equation below.

$$(V_{in} \times D) + (V_{in} - V_{out}) \times (1 - D) = 0$$

D is the duty cycle in boost mode for gate Q3. The equation for the duty cycle in boost mode is given below. Also, the boost-only key waveforms are given below in Figure 57.

$$D_{boost} = \frac{V_{out} - V_{mpp}}{V_{out}}$$

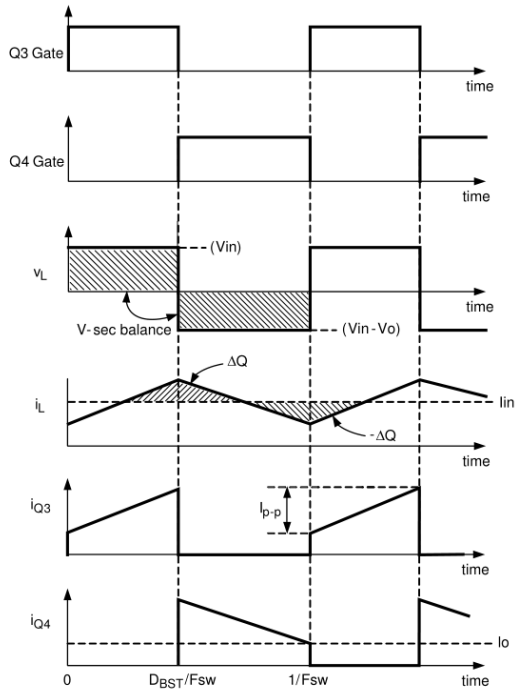


FIGURE 57: BOOST-ONLY KEY WAVEFORMS

7.7.2.4.3 POWER CONVERTER COMPONENT SELECTION

The first step for selecting components for the power converter is to know the PV panels' electrical characteristics. The characteristics are as follows:

PV panels maximum power level

$$P_{max} = 30\ watts$$

Minimum and Maximum PV panel open circuit voltages

$$Vmpp_{min} = 5V, Vmpp_{max} = 21.5V$$

PV panel maximum short circuit current

$$Isc_{max} = 1.89\ amps$$

Minimum and Maximum PV panel MPP current

$$Impp_{min} = P_{max}/Vmpp_{max} = 1.79\ amps$$

$$Impp_{max} = P_{max}/Vmpp_{min} = 7.7\ amps$$

These parameters define the power circuit's input specifications.

The following additional parameters that will be needed before selection components:

Maximum output voltage

$$Vout_{max} = 21.5V$$

Minimum buck down voltage at full power can be determined by the following equation: $Iout_{max}$ is the current limited by the maximum output current. In this application the output current will be limited to two amps.

$$Vout_{min} = P_{max}/Iout_{max} = 13V$$

Maximum peak-to-peak input ripple voltages

$$\Delta Vin_{p-p} = 1.1V$$

Maximum peak-to-peak output ripple voltage

$$\Delta Vout_{p-p} = .75V$$

Witching frequency controlled by MPPT controller. This project will be using the SM7242 that has a nominal switching frequency of 200 kHz with a ±10% tolerance.

$$F_{sw} = 200\ kHz$$

$$Fsw_{min} = 180\ kHz$$

$$Fsw_{max} = 220\ kHz$$

7.7.2.4.3.1 Duty Cycle

The next step is to find the buck and boost duty cycles under worst operation conditions. There are two cases to consider when finding the worst case converter duty cycles.

The minimum buck duty cycle that relates maximum input voltage step down ratio from the input to the output

The maximum boost duty cycle that corresponds to the maximum voltage step up ratio from the input to the output, both at maximum

Equations below will find these worst case duty cycles

$$D_{buck\_min} = \frac{Vout_{min}}{Vmpp_{max}} = 77\%$$

$$D_{boost\_max} = \frac{Vout_{max} - Vmpp_{min}}{Vout_{max}} = 81\%$$

Inductor, Input Capacitor, and Output Capacitor

For selecting the inductor and capacitors, there is a correlation between the two that can be followed from Power Circuit Design application notes.

> "In buck mode the inductor teams up with the output capacitor to fulfill an output L-C filter, and in boost mode it works with the input capacitor to fulfill an input L-C filter. Because both the inductor and capacitors affect the filter performance, selection of the inductor L1, input capacitor Cin and output capacitor Cout are correlated. Selection trade-offs between the values of inductor and capacitors are normally required." [3]

Equation below can be solved to find the maximum inductor ripple current. According to good design practice, the inductor ripple current should be 30% of the maximum DC current, or the peak-to-peak ripple be 60% of the maximum DC current. Equation below will be solved for the minimum inductor value to satisfy the design specifications.

$$I_{p-p\_max} = \begin{cases} \frac{Vout_{min}}{L1} \times \frac{1 - D_{buck\_min}}{Fsw_{min}} = .83\ A \\ \frac{Vmpp_{min}}{L1} \times \frac{D_{boost\_max}}{Fsw_{min}} = .95\ A \end{cases}$$

$$\begin{cases} L1 \geq \frac{Vout_{min}^2}{0.6 \times P_{max}} \times \frac{1 - D_{buck\_min}}{Fsw_{min}} \rightarrow L1 \geq 12\ \mu H \\ L1 \geq \frac{V_{mpp}^2}{0.6 \times P_{max}} \times \frac{D_{boost\_max}}{Fsw_{min}} \rightarrow L1 \geq 3.8 \mu H \end{cases}$$

From equation above, an inductor of 12µH is the minimum inductor size for this design. For good measure a 20µH inductor will be used. Using a 20µH inductor will ensure that the ripple current will stay below 60% of the peak-to-peak maximum DC current.

For choosing the input and output capacitors, this project will need to consider the worst case parameters obtained previously. You can obtain the minimum filter capacitance required to meet the ripple limits. The equations below define the values of the capacitors.

$$C_{out} \geq \frac{(Vmpp_{max} - Vout_{min}) \times Vout_{min}}{8 \times Fsw_{min}^2 \times L \times Vmpp_{max} \times \Delta Vin_{p-p}} \rightarrow C_{out} \geq 2.8\ \mu F$$

$$C_{in} \geq \frac{(Vout_{max} - Vmpp_{min})}{8 \times Fsw_{min}^2 \times L1 \times \Delta Vout_{p-p}} \rightarrow C_{in} \geq 4.5\ \mu F$$

For the input and the output capacitor, you want to use capacitors that are no smaller than 5 µF. To ensure that the capacitors will properly filter for this design, this project will require choosing an input and outputting capacitors to be 12 µF. Figure 58 show a schematic of the DC to DC converter draw in EAGLE CAD.

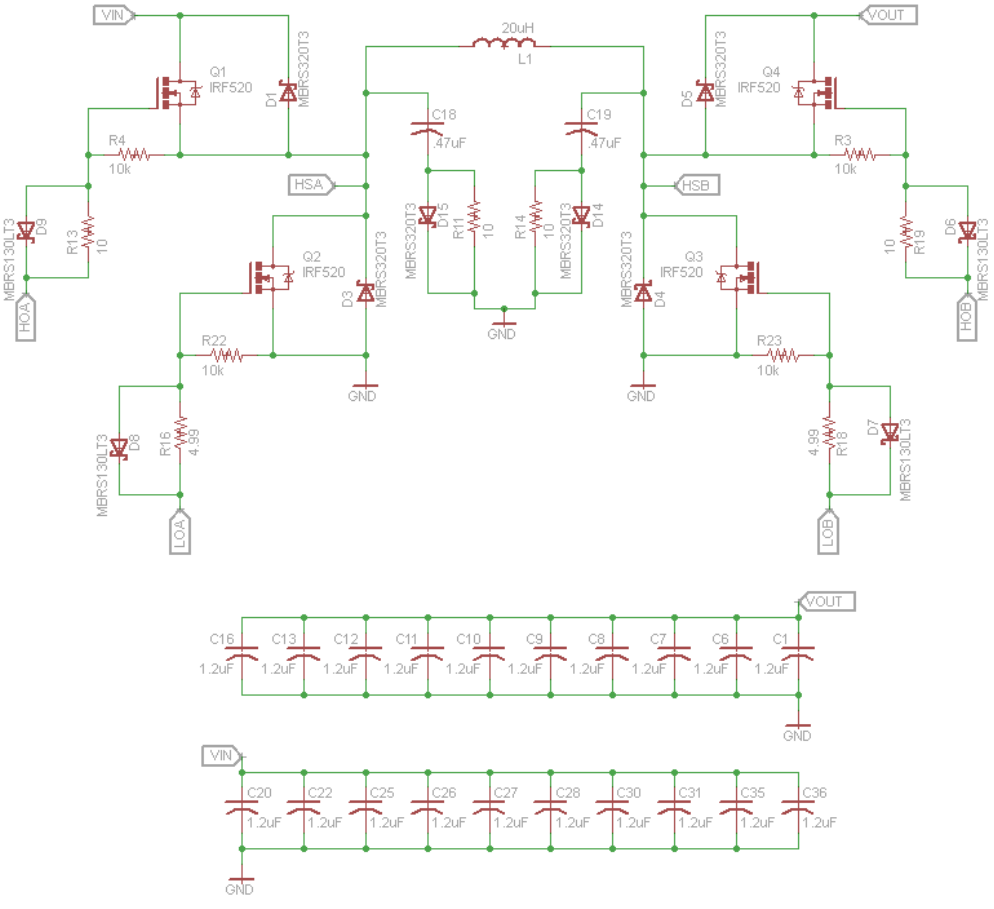


FIGURE 58: EAGLE CAD SCHEMATIC OF DC/DC CONVERTER

7.7.2.4.4 DC/DC Converter Summary

This DC/DC in Figure 58 will be integrated with the SM72442 MPPT chip and the SM72295 photovoltaic full bridge driver to switch the gates Q1, Q2, Q3, and Q4. Also, the PM switch will be integrated on the input voltage Vin and output voltage V_{out}. There will also be a bypass diode on the out voltage to prevent current from flowing back into the system.

7.7.2.5 Communicating with the SM72442

The SM72442 will be in charge of multiple tasks such as output current regulation, voltage regulation, and maximum power point tracking. The SM72442 application notes will be used to configure settings as well as how to communicate with it. To communicate with the SM72442, I2C will be used.

7.7.2.5.1 Output Current Regulation

Current regulation will be enforced using the voltage divider if Figure 59 below. This current setting can be switched to a high current setting and a low current setting that is controlled by the microcontroller. At the AVOUT pin (pin 17) on the SM72442, is set to high impedance the high current limit is set high. If it is set to 0V, the current limit is low.

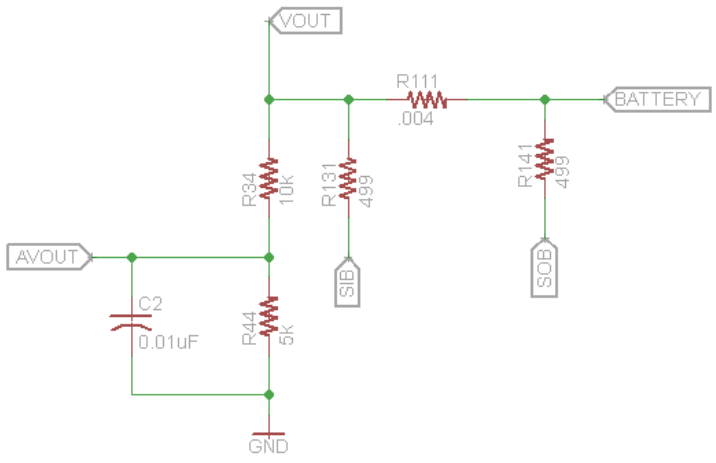


FIGURE 59: VOLTAGE DIVIDER FOR OUTPUT CURRENT REGULATION AND OUTPUT CURRENT SENSING

7.7.2.5.2 Voltage Regulation

Voltage regulation is done internally of the SM72442. The output voltage set point can be altered by I2C communication. Interface by setting the register 0x03 bits 20:29 to the required voltage set pint and bit 46 to 1. The initial output voltage setting is set through pin A0 using 5 volts or 0 volts. It will also reset the SM72442 and cause the DC/DC converter to stop if the output voltage increases beyond the values set by output voltage divider in Figure 59 above. When the RESET sees an increase over 5 volts, the SM72442 will be reset. Figure 60 below shows a diagram of the reset circuit.

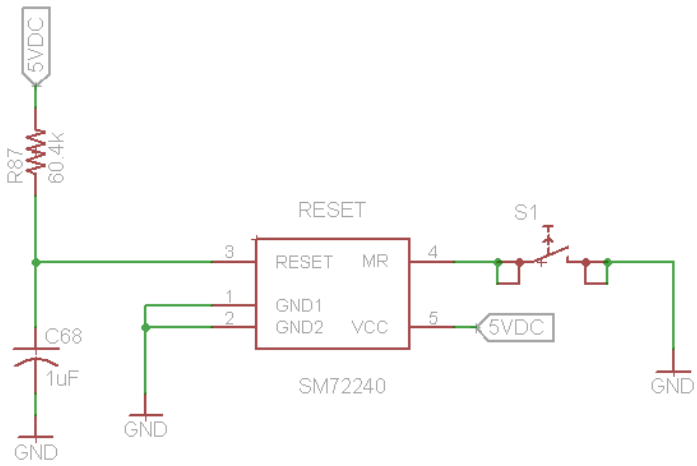


FIGURE 60: EAGLE SCHEMATIC OF RESET CIRCUIT

7.7.2.5.3 MPPT

The maximum power point tracking will be performed on the SM72442 chip. It will implement what is called a "Perturb and Observe" algorithm method. Regardless of the panels characteristics the maximum power point tracking algorithm will extract maximum power from the solar panel and send it to the battery for charging.

The startup of the MPPT process begins with the PV and batter voltages being verified for proper connection and values. If the voltages of those values are within a specific range, the SM72442 enables the charge by releasing the RESET line of the chip.

A safety feature that the SM72442 has is it is programmed by default to stop charging the battery if the output is above 14.5 volts or below 8 volts. Figure 61 shows a flow chart of how this operation works.

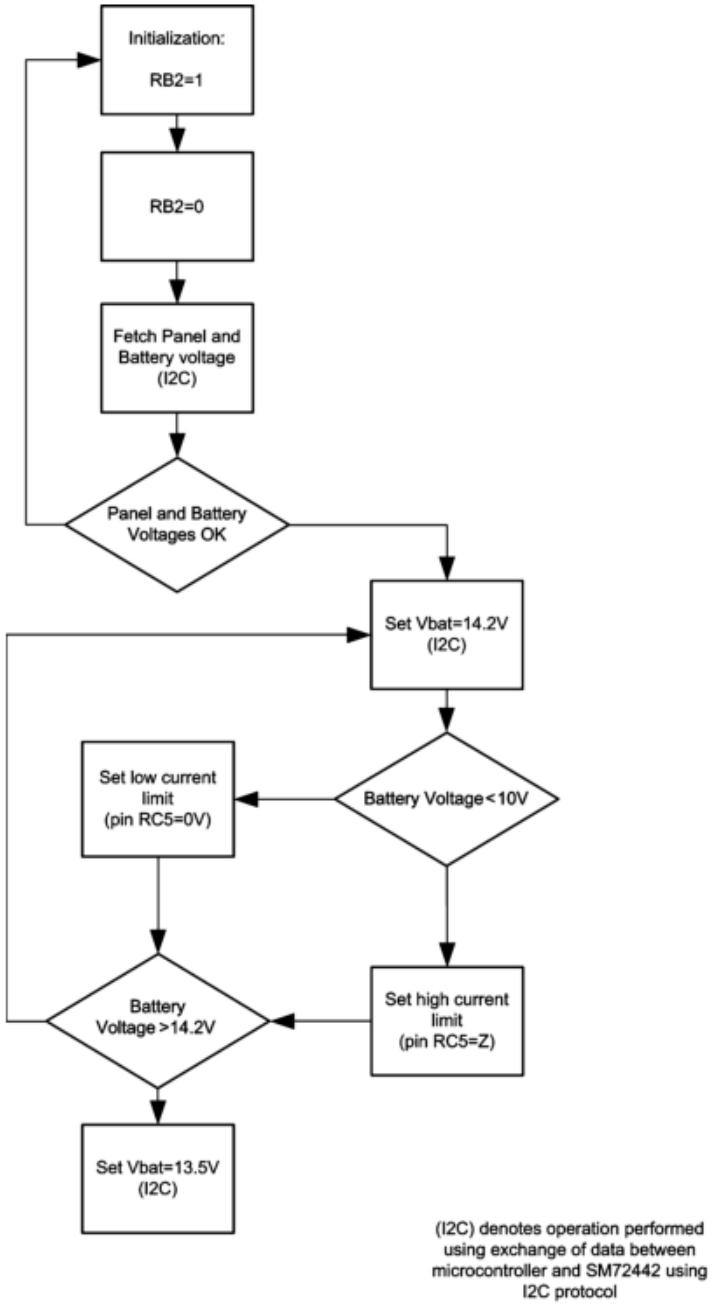


FIGURE 61: OPERATIONAL FLOWCHART

The flow chart below in Figure 62 shows the code programed into the SM72442. The check_lead_acid function issues a value depending on the state of the battery

as detected by the voltage. The main function uses this value to issue the proper action. The other functions in the program are essentially I2Cdriver functions and low level port setup functions.

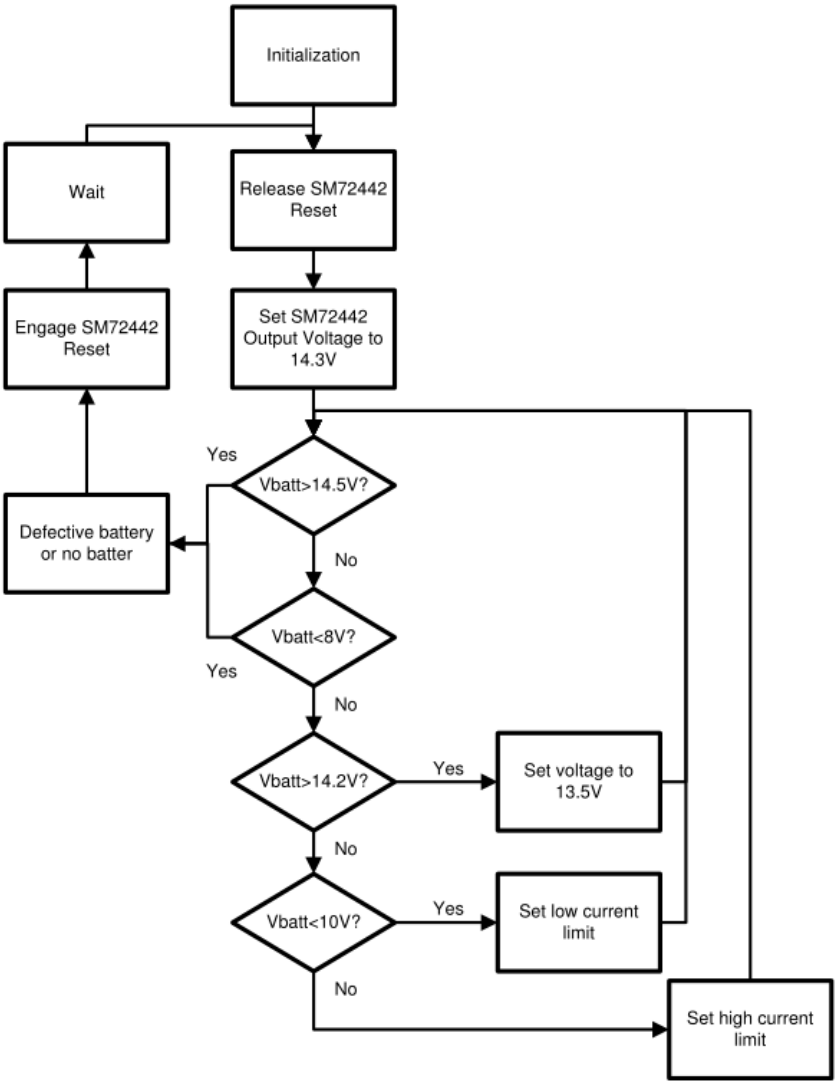


FIGURE 62: SM72442 CODE FLOWCHART

The SM72442 is preprogrammed with specific functions for maximum power point tracking. A list of the function and a description is given below.

- Function: check_lead_acid()
    - This function senses the battery voltage through the A/D converter on the SM72442. The A/D conversion is needed because the current limiting circuit in the hardware acts on the voltage sensing line of

the microcontroller. When the system is running in high current mode, the voltage sensed by the microcontroller is not the battery voltage.

- Function: Main()
    - The Main function calls the Init function which initializes the variables and the registers. The program then enters an infinite while loop in which the values of the sensed voltages and current are recovered from the SM72442 through I2C. the next function called is the check_lead_acid an returns the value of the voltage of the battery.
- Function: get_i2c_data()
    - This function reads the sampled voltage of pins 19, 15, 21, and 17 of the SM72442. The data is fetched through I2C channel. The function updates the global variable “outval” which is an array of unsigned 16 bit integers.
- Function: send_i2c_command
    - Sends an I2C communication string. Each byte sent is stored in the global array “I2C_butter”. The argument number indicates how many bytes from the buffer will be sent.
- Function: Set_Voutmax()
    - This will read the maximum output voltage and send it to proper I2C command to the SM72442 to regulate the voltage.
- Funciton: Check_low_current()
    - This function is called by the Man and controls the startup and forces the duty cycle of the converter up if the current becomes close to zero.

The overall summarization of the structure of the program is seen in Figure 63 below.

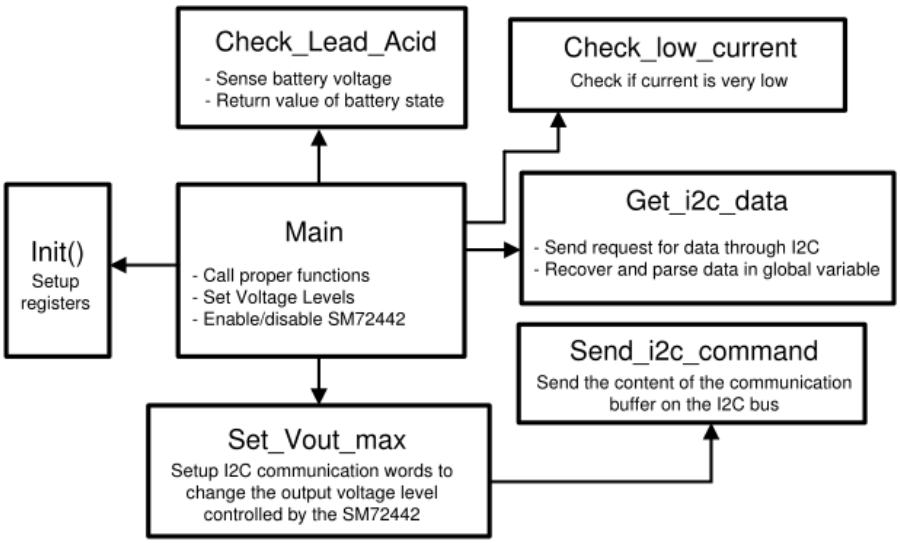


FIGURE 63: MICROCONTROLLER CODE BLOCK DIAGRAM

7.7.3 POWER SYSTEM SUMMARY

A 30 watt solar panel will be used to harvest energy to charge the battery the solar panel will be connected to the DC/DC converter on a PCB. The PCB will include the 10 volt power regulator, the DC/DC converter, the RESET circuit, the Panel Mode circuit, the gate divers, and the SM72442 microcontroller to create the MPPT controller for the panel. The output of the DC/DC converter will be attached to the batter for charging. When the MPPT controller is not charging the battering, a Shockley diode will be put in place to prevent the back flow of current into the system.

8.0 TEST PLAN

8.1 HARDWARE/SOFTWARE INTERFACE TESTING

	Pass	Fail
Code is detected		
Code is scanned		
Drink is dispensed		
Appropriate amount of drink is dispensed		
LED screen status is updated		
Status of order is updated on phone		

8.2 SOFTWARE TESTING

	Pass	Fail
Barcode cannot be scanned while drink is being dispensed		
Drink reservation expires after 5 minutes and becomes invalid		
Barcode interface can sustain multiple client interface connections		
Drink dispenser interface refuses new connections while dispensing a drink		
Drink history is maintained in Client application after new machine is connected		
Drink interface successfully opens and closes solenoids		
Barcode interface can read HID devices and output to client interface		
Barcode interface can bind only to specified HID device		
Client interface can successfully distribute menu to client applications		
Embedded configuration tool updates LCD display based on IP address		
Embedded configuration tool can update barcode interface hid ID		
Client application displays ingredients from retrieved menu file		
Embedded configuration tool can restart		

interfaces after configuration changes		
SQL database flushes expired and completed up orders		
Ensure QR code generation conforms to communication protocol		
Ensure client interface		

8.3 HARDWARE TESTING

Battery	**Pass**	**Fail**
Maintain at least 12 volt charge for 24 hour with on load after one charge cycle (8 hours)		
Solar Panel	**Pass**	**Fail**
Consistently output 17 volts in direct sunlight		
MPPT Controller	**Pass**	**Fail**
Buck down a maximum voltage of 20 volts		
Boost up a minimum voltage of 5 volts		
Enter panel mode when input voltage is 12 V		
Reset when output current reaches maximum of 1 amp		
Reset when output voltage exceeds 14.3 volts		
Enter flow charge when battery reaches 95% charge		

9.0 DESIGN SUMMARY

The power system will be composed of the solar module, the MPPT controller, and the battery. A 30 watt solar panel will be used to charge a 12 volt lead acid battery using a maximum power point tracking power controller. The MPPT controller uses a 4 switch buck-boost DC/DC conversation topology for maximum charge efficiency. The SolarMagic chip set will be used to control the DC/DC converter. The SM72442 microcontroller will be responsible for input voltage sensing, output voltage sensing, output current sensing, buck mode, boost mode, and panel mode.

The SM72442 will sense the output voltage and the input voltage then compare the two. If the input voltage is higher than the required output voltage, the system will go into buck mode which steps the voltage down. When the input voltage is lower than the output voltage, the system will go into boost mode which steps the voltage up. When the input voltage is within ±2% of the output voltage, maximum power point tracking is no longer required and the system will go into panel mode for almost no energy loss. In panel mode, the DC/DC converter is bypassed and the solar panel is directly connected to the battery. To drive the gates in the DC/DC converter and panel mode the SolarMagic chips SM72295 and the SM72482 will be used. To produce the 10 volts needed to power the drivers, the SolarMagic SM72485 buck switch regulator will be used. A 5 volt regulator will then be connected to the 10 volt output to power the microcontroller. If the output current of voltage becomes too high or too low, the reset circuit will kick in and restart the whole system, which will be controlled by the SM72240.

When the Under the Sun Drink Mixer first goes online, the embedded software will need to be configured by an administrator via the webserver to determine what drink ingredients are in the machine and which dispensing solenoid each drink corresponds to. This is also the time in which the pre-determined library will be created based on the drink ingredients in the machine. Once this information is entered, a QR code will be generated and displayed on the onboard LCD containing access to the webserver. When a user wants to access the features of the Under the Sun Drink Mixer, they will scan the QR code using the client application, which will give the client application access to the webserver. This connection will allow the client application and the webserver to communicate with each other. After the QR code is scanned into the client application, the user will have access to the webserver's menu of pre-determined drink recipes. The user can then either pick a pre-determined drink from the library, or create their

own drink recipe using the drink ingredients. When the user is finished selecting or creating the drink that they desire, they will be able to order the drink for pickup. When the drink is ordered, it will send a reservation request to the webserver and the webserver will store that ordered drink into the MySQL database. The drink reservation will reserve the appropriate amount of drink ingredients the user selected for a minimum of five minutes, after which time the reservation will expire. This expiration will ensure that when somebody orders a drink, they also pick up the drink. The expiration time is important because when a user orders a drink, that amount of drink ingredient is reserved; if that user does not pick up that drink, that drink ingredient is still considered reserved thus preventing other users from ordering drinks with the same ingredients. The five minute expiration timer was put in place so that after five minutes, the MySQL database will throw out that order and reallocate the drink ingredients.

When the user is ready to pick up their order, they will be able to do so through the client application. This will send a signal to the webserver telling it that somebody is ready to pick up a drink. The webserver will generate a QR code corresponding to that drink order, and send that QR code to the client application. At the same time, the webserver will update the MySQL database and push that drink order from Ordered to Pick Up stage, and start the two minute expiration timer. This is the same general idea of the five minute expiration timer before, preventing users from retaining reservation codes that are never picked up. If the expiration time expires during either the “Order Drink” stage or the “Pick Up Drink” stage, the corresponding order and QR code will be deleted. The webserver will send a signal back to the client application informing the user that their drink order has expired, and they must order again.

When the user goes to pick up their drink, they will walk up to the Under the Sun Drink Mixer, locate the barcode scanner, and scan their QR code. The QR code will link up to the specified drink order, and the webserver will now move the drink order from Pick Up stage to History stage within the database. The webserver will also send a signal back to the client application to notify it that the drink has been picked up. This will move the ordered drink from the orders tab to the history tab on the client application.

Now that the embedded system has received the drink order and corresponding QR code, it will check with the sensors to be sure a cup is in place. Once a cup is sensed, a signal will be sent to the specified dispensing solenoids to tell them how long to stay open for. The drink will now be poured for the user to enjoy. In the users’ eyes, the drink was only ordered and picked up, concealing all of the intricacy actually involved.

APPENDIX A: WORKS CITED

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APPENDIX B: IMAGE PERMISSION

Texas Instruments

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Regards,
Samantha Brown
TI Customer Support
Americas Customer Support Center
512-434-1560

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Gerald Coley <gerald@beagleboard.org>
Sun 7/28/2013 10:09 AM

mark as unread

Yes you can, just make sure you give proper reference.

Gerald

REPLY REPLY ALL FORWARD ...

zimmerman
Sun 7/28/2013 7:58 AM
Sent Items

mark as unread

To: Coley, Gerald <g-coley1@ti.com>; gerald@beagleboard.org;

Good morning Gerald,

I am currently working on a Senior Design project at the University of Central Florida and was wondering if I could use any and all information from the existing BBB Reference Manual including pictures, schematics and information in my research. Of course I will be citing my sources directly to TI.

Thank you.

First Name: Moises
Last Name: Dominguez
Email Address: moises.dominguez1988@gmail.com
Telephone: 7863875735
Fax: 3054694596
Company/Organization: UCF
Position/Title:
Department:
Address 1: 3229 new mexico ct
Address 2:
City: orlando
State: fl
Postal Code: 32826
Country: United States
Application: student
Distributor:
Product Type:
Estimated Annual Usage: 1
Questions/Comments: Hello, I am a student at the University of Central Florida and I am currently working on a MPPT controller design project. I was wondering if I could have permission to use figures and information from the 4 switch buck boost converter, that uses the LTC3789, in my report. thank you Moises Dominguez

Linear Technology

[Prefix: Mr.]
[First Name: Moises]
[Last Name: Dominguez]
[Job Title:]
[Company: UCF]
[Email: moises.dominguez1988@gmail.com]
[Phone: 7863875735]
[FAX: 3054694596]
[Country: USA]
[Address1: 3229 new mexico ct]
[Address2:]
[City: orlando]
[State: FL]
[Postal Code: 32826]
[Part# or Description: 11]
[Category: General Information]
[Application: Security]
[Design Stage: New design]
[Estimated Annual Production: 11 units]
[Production Date: 11]

[Problem:
Hello, I am a student at the University of Central Florida and I am currently working on an MPPT controller design. I contacted a TI rep. a couple of days ago asking for permission to use figures, tables, and information from SolarMagic Application notes in my report. Specifically the SM72442, SM72295, SM72240, SM72482, SM72442, SNOSB76B Application Report, and the SLVA535A. An email was sent back to me with a link to the Copyrights page, but I need to include and email from a TI rep. that grants me permission and include it in my report. Proper referencing and citation of all figures and information will be included in my report. Thank you Moises Dominguez]

APPENDIX C: BILL OF MATERIALS

Designator	Description	Manufacturer	Part Number	Qty
U1	Flash-Based, 8-bit CMOS Microcontroller, 2K Program Memory, 128 bytes data memory, 25 I/O pins, 28-Pin SOIC	Microchip Technology	PIC16F722-E/SS	1
C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12,C13,C14, C16, C20, C25, C27, C28, C30, C36, C42, C44, C45, C47, C48 C53, C55, C57, C67, C70, C72	Ceramic, X7R, 50V, 10%	MuRata	C3225X7R1H225k	32
C15, C17, C22, C26, C32, C49, C50, C51, C52, C65	Ceramic, X7R, 25V, 10%	MuRata	CRM188R71JAT2A	10
C18, C19	Ceramic, C0G/NP0, 100V, 5%	AVX	08051A471JAT2A	2
C21	Ceramic, X7R, 100V, 10%	Taiyo Yuden	HMK212B7104KG-T	1
C23, C33, C34, C38	Ceramic, X7R, 16V, 10%	Taiyo Yuden	EMK212B7225KG-T	4
C24	Ceramic, X7R, 50V, 10%	MuRata	GRM188R71H331KA01D	1
C29, C37, C39, C59	Ceramic, X7R, 100V, 20%	AVX	06031C103MAT2A	4

C31, C35, C40	Ceramic, X7R, 16V, 10%	Taiyo Yuden	EMK212B7105KGT	3
C46, C54	Ceramic, X7R, 16V, 10%	AVX	0805YC474KAT2A	2
C58, C60, C61, C62, C66, C69	Ceramic, C0G/NP0, 100V, 5%	TDK	C1608C0G1A102J	6
C73	Ceramic, C0G/NP0, 50V, 5%	TDK	C1608C0G1H151	1
C88	CAP, CERM, 0.1Uf, 25V 5%	AVX	06033C104JAT2A	1
C100, C102	CAP, CERM, 1000pF, 100V, 10%	TDK	C1608X8R2A102K	2
C101	CAP, CERM, 0.1uF, 16V, 5%	AVX	0603YC104JAT2A	1
D2, D7, D9, D12, D13, D14, D15	Vr=100V, Io=1A, Vf=.77V	Diodes Inc.	DFLS1100-7	7
D3, D4, D5, D6	Vr=30V, Io=1A, Vf=.47V	ON Semiconductor	MBR130T1G	4
D100, D101	Vr=30V, Io=.2A, Vf=.65V	Diodes Inc.	BAT54-7-F	2
L4	Shielded Drum Core, .56A, .907Ohm	Coiltronics	DR74-221-R	1
Q1, Q2, Q3, Q4	40A, 53nC, rDS @ 4.5V	International Rectifier	IRF3205ZPBF	4
Q7, Q8, Q9	.26A, .81nC, rDS @ 4.5V	Diodes Inc.	2N7002ET1G	3
R1, R10	1%, 2W	Stackpole	CSNL 2 0.004 1% R	2
R2, R54	1%, .125W	Vishay-Dale	CRCW0805178Kfkea	2

R3, R4, R22, R23, R30, R36, R42, R43, R45, R72, R100, R101, R102, R105, R106, R111, R119, R120, R121, R300, R400	1%, .1W	Vishay-Dale	CRCW060310k0FKEA	21
R5	1%, .1W	Vishay-Dale	CRCW0603124Kfkea	1
R6	1%, .125W	Vishay-Dale	CRCW08051R00FNEA	1
R7, R13	1%, .25W	Vishay-Dale	CRCW120619k6FKEA	2
R8, R12, R24, R34	1%, .1W	Vishay-Dale	CRCW0603499RFKEA	4
R9	1%, .1W	Vishay-Dale	CRCW060312k4FKEA	1
R11, R14	1%, 1W	Vishay-Dale	CRCW121810R0FKEK	2
R15	1%, .1W	Vishay-Dale	CRCW0603k22FKEA	1
R17	1%, .1W	Panasonic	ERJ-3RQFR33V	1
R18, R19	RES, 10Ohm, 5%, .125W	Vishay-Dale	CRCW080510R0JNEA	2
R20, R29, R31, R47, R48	1%, .1W, RES, 2kOhm	Vishay-Dale	CRCW06032k00FKEA	5
R21	1%, .1W	Vishay-Dale	CRCW060349R9FKEA	1
R25, R35, R37, R44	5%, .1W	Vishay-Dale	CRCW06030000Z0EA	4
R26, R56, R87, R116	1%, .1W	Vishay-Dale	CRCW06030k4FKEA	4
R71, R73	1%, .1W	Vishay-Dale	CRCW060319K1FKEA	2
R32, R33	RES, 4.99Ohm, 1%, .125W	Vishay-Dale	CRCW08054R99FNEA	2
R38	1%, .1W	Vishay-Dale	CRCW060331k6FKEA	1

R39	RES, 1MOhm, 1%, .1W	Vishay-Dale	CRCW060331M00FKEA	1
R40	1%, .1W	Vishay-Dale	CRCW0603150Kfkea	1
R41	RES, 45.3kOhm, 1%, .1W	Vishay-Dale	CRCW060345K3FKEA	1
R51, R52	RES, 12.4kOhm, 1%, .25W	Vishay-Dale	CRCW120612K4FKEA	2
R53, R103	RES, 4.02kOhm, 1%, .1W	Vishay-Dale	CRCW0603K02FKEA	2
R104	RES, 24.9kOhm, 1%, .1W	Vishay-Dale	CRCW06034K9FKEA	1
R107, R108	RES, 270kOhm, 1%, .1W	Yageo America	RC0603FR-07270KL	2
R112	RES, 51.1kOhm, 1%, .1W	Yageo America	RC0603FR-07340KL	1
R113, R117	RES, 22kOhm, 1%, .1W	Yageo America	RC0603FR-07100KL	2
R118	RES, 105kOhm, 1%, .1W	Vishay-Dale	CRCW0603511KFKEA	1
U1	150Ma, 100V Step-Down Switching Regulator	Texas Instruments	SM72485	1
U2	Series of Adjustable Micropower Voltage Regulators	Texas Instruments	SM72238	1

U3	Driver	Texas Instruments	SM72295	1
U4	Digital Contrller	Texas Instruments	SM72442	1
U5	5-Pin Microprocessor Reset Circuits	Texas Instruments	SM72240	1
U6	Driver	Texas Instruments	SM72482	1

Qty	Reference	Description	Manufacture	Part Number
24	C1,C2,C4,C7,C8,C9,C10,C11,C12,C13,C14,C15,C39,C40,C55,C62,C77,C95,C96,C118,C122,C126,C133,C153	CAP CER 10UF 10V Y5V 0805	TDK	C2012Y5V1A106Z
6	C24,C89,C90,C91,C104,C134	CAP CER 1UF 6.3V 10% X5R 0402	AVX	JMK105BJ105KV-F
8	C16,C17,C18,C125,C144,C146,C148,C151	CAP CER 2.2UF 6.3V 10% X5R 0402	TDK	C1005X5R0J225K
2	C19,C136	CAP CER 470PF 50V 10% X7R 0402	Yageo	CC0402KRX7R9BB471
100	C3,C20,C27,C28,C29,C30,C31,C33,C35,C36,C37,C38,C41,C42,C43,C44,C45,C46,C47,C48,C49,C50,C51,C52,C53,C54,C56,C57,C58,C59,C60,C61,C63,C64,C65,C66,C67,C68,C69,C70,C71,C72,C73,C74,C75,C76,C78,C79,C80,C81,C82,C83,C84,C85,C86,C87,C88,C92,C93,C94,C97,C98,C99,C100,C101,C102,C103,C105,C106,C107,C108,C109,C110,C111,C112,C113,C114,C115,C116,C117,C119,	CAP CER 0.1UF 6.3V 10% X5R 0402	TDK	C1005X5R0J104K

	C120,C121,C124,C127,C128,C129,C130,C131,C132,C135,C145,C147,C149,C150,C152,C154,C155,C158,C159			
4	C21,C22,C25,C26	CAP CER 18PF 50V C0G 5% 0402	TDK	C1005C0G1H180J
2	C32,C123	CAP_CER_0.001UF_16V_X7R_0402	Yageo	CC0402KRX7R7BB102
1	C34	Aluminum Electrolytic Capacitors - SMD 100uF 6.3V 85C	Cornell Dublier	AVE107M06D16T-F
1	C141	CAP CER 0.022UF 10V 10% X7R 0402	Tayo Yuden	LMK105B7223KV-F
2	C142,C143	CAP CER 30PF 50V 5% NP0 0402	TDK	C1005C0G1H300J
5	D1,D2,D3,D4,D5	LED BLUE CLEAR THIN 0603 SMD	Lite-On	LTST-C191TBKT
2	D6,D7	DIODE ESD PROT HDMI TSSOP-10	NXP	IP4283CZ10-TT,118
1	D8	DIODE SCHOTTKY 40V 120MA SOD-323	NXP	RB751V40,115
5	FB1,FB2,FB3,FB4,FB5	Ferrite Bead 150 Ohm	Steward	LI0805H151R-10

		800mA		
2	S1,S2	SWITCH TACTILE SPST-NO 0.05A 32V	C&K	KMR231GLFS
2	Q1,Q2	TRANS NPN/NPN W/RES 50V SMINI6	Panasonic	DMC564040R
1	RT1	POLYSWITCH RXE SERIES 0.10A HOLD	Polyswitch	RXEF010
3	L1,L2,L3	INDUCTOR 2.2UH 20% 1300MA 1008	Murata	LQM2HPN2R2MG0L
1	J1	CONN HEADER 6POS, VERTICAL, .100 STR TIN	FCI	68000-406HLF
1	P1	CONN POWER JACK 2.1MM	CUI	PJ-002A
1	P4	CONN RCPT USB MINI B R/A SMD	Hirose	UX60SC-MB-5ST(80)
1	P3	CONN RCPT USB TYPE A R/A PCB	FCI	87520-0010BLF
1	P7	Connector SD/MMC	ALPS	SCHA5B0200
1	P6	HDMI / Displayport / DVI Connectors MICRO HDMI RCPT SMT DIP+ SMT LEG TYPE D	FCI	10118241-001RLF
6	R23,R24,R25,R26,R163,R164	RES 4.75K OHM 1/16W 1% 0402 SMD	Stackpole	RMCF0402FT4K75
1	R144	RES 12.1K OHM 1/16W 1% 0402 SMD	Yageo	RC0402FR-0712K1L
1	R136	RES .10 OHM 1/8W 5% 0805	CTS	73L3R10J
9	R3,R4,R119,R146,R147,R97,R112,R113,R114	RES 1.50K OHM 1/16W 1% 0402 SMD	Yageo	RC0402FR-071K5L

2	R130,R132	RES 470 OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ471X
21	R1,R56,R65, R66,R67,R68, R76,R77, R78,R79,R80,R82,R83,R84,R85,R86, R87,R88,R89,R94,R95,	Resistor 100Kohm 1/16W 1% 0402	Stackpole	RMCF0402FT100K
11	R75,R125,R126,R127,R128,R129,R131, R133,R134,R138,R139	RES 100 OHM 1/16W 5% 0402 SMD	Yageo	RC0402JR-07100RL
1	R143	RES 10.0 OHM 1/16W 1% 0402 SMD	Yageo	RC0402FR-0710RL
17	R5,R6,R7,R8,R19,R20,R27,R49,R50,R51,R137,R142,R160,R161,R149,R159,R162	Resistor Zero ohm Jumper 0402	Yageo	RC0402JR-070RL
34	R14,R52,R53,R54,R96,R98,R100,R101, R102,R103,R104,R105,R106,R107,R108,R109,R110, R111,R115,R116,R117,R118,R135,R145,R148,R150,R151,R152,R153,R154,R155,R156,R157,R158	Resistor 10Kohm 1/16W 5% 0402	Rohm	MCR01MZPJ103
1	R17	Resistor 1Mohm 1/16W 1% 0402	Stackpole	RMCF0402FT1M00
5	R22,R120,R121,R122,R123	RES 49.9 OHM 1/16W 1% 0402 SMD	Yageo	RC0402FR-0749R9L
5	R12,R71,R72, R73,R74	RES 820 OHM 1/16W 5% 0402 SMD	Yageo	RC0402JR-07820RL

1	R11	RES TF 1/16W 280K OHM 1% 0402	Stackpole	RMCF0402FT280K
1	R99	RES 240 OHM 1/16W 1% 0402 SMD	Yageo	RC0402FR-07240RL
1	R10	RES 470K OHM 1/16W 1% 0402 SMD	Yageo	RC0402FR-07470KL
1	R166	RES 27K OHM 1/16W 1% 0402 SMD	Yageo	RC0402FR-0727KL
24	R18,R21,R28,R29,R30,R31,R32,R33,R34,R35,R36,R37,R38,R39,R40,R41,R42,R43,R44,R45,R46,R47,R48,R167	RES 33 OHM 1/16W 5% 0402 SMD	Yageo	RC0402JR-0733RL
1	U2	Integrated Power Management Unit	TI	TPS65217C
1	U5	SubArctic Cortex A8 Processor,720Hz	TI	XAM3359ZCZ
2	U9,U10	IC 4CH ESD SOLUTION W/CLAMP 6SON	TI	TPD4S012DRYR
1	U4	IC LDO VOLT REG 500MA 8-SOIC	TI	TL5209DR
1	U8	IC 1.5A PWR DIST SWITCH 8-SOIC	TI	TPS2051BDGN
1	U6	IC SGL POS EDG TRIG D F-F SM8	TI	SN74LVC1G74DCTR
1	U15	IC BUFF/DVR TRI-ST DL 8VSSOP	TI	SN74LVC2G241
1	U3	IC INVERTER SINGLE 1INPUT SC705	TI	SN74LVC1G06DCK
1	U12	DDR3 Memory 512Mb,256Mx1	Micron	MT41K256M16HA-125:E

		6		
1	U7	IC EEPROM 32KBIT 400KHZ SOT23-5	MicroChip	24LC32AT-I/OT
1	U11	IC HDMI INTERFACE HVQFN64	NXP	TDA19988BHN/C 1,551
1	Y1	CRYSTAL 32.768KHZ 12.5PF SMD	Citizen	CM200C-32.768KAZF-UT
1	Y3	CRYSTAL 25.000 MHZ 18PF SMD	TXC	7A-25.000MAAJ-T
			ILS	ILCX03-25.000000M-TBA
			CTS	445C33D25M00000
1	Y2	CRYSTAL 24.000 MHZ 18PF SMD	TXC	7A-24.000MAAJ-T
			ILS	ILCX03-24.000000M-TBA
			CTS	445C33D24M00000
1	Y4	Oscillator, 24.576MHZ, 3.3V	Abracom	ASDMB-24.576MHZ-LC-T
		Oscillator, 24.576MHZ, 3.3V	ILSI	ISM95-3161BH-24.576
		Oscillator, 24.576MHZ, 3.3V	ECS	ECS-2033-24.576-B

APPENDIX D: SAMPLE CODE

MENU FORMAT

```
{
    "Menu":[
        {
            "ID": "xxxxx",
            "Description": "",
            "CupSizes": [
                "5",
                "10"
            ],
            "Ingred1": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred2": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred3": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred4": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred5": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred6": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            }
        },
        {
            "ID": "xxxxx",
            "Description": "",
            "CupSizes": [
                "5",
                "10"
            ],
            "Ingred1": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred2": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred3": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred4": {
                "ID": "xxxx",
                "Description": "xxxx",
                "Amount": "xxxx"
            },
            "Ingred5": {
                "ID": "xxxx",
```

SETTINGS FORMAT


```
{
   "machineName":"Group 4's Mixer",
   "username":"admin",
   "Ingredients":[
      {
         "ID":"xxxx",
         "Description":"xxxx",
         "Amount":"xxxx"
      },
      {
         "ID":"xxxx",
         "Description":"xxxx",
         "Amount":"xxxx"
      },
      {
         "ID":"xxxx",
         "Description":"xxxx",
         "Amount":"xxxx"
      },
      {
         "ID":"xxxx",
         "Description":"xxxx",
         "Amount":"xxxx"
      },
      {
         "ID":"xxxx",
         "Description":"xxxx",
         "Amount":"xxxx"
      },
      {
         "ID":"xxxx",
         "Description":"xxxx",
         "Amount":"xxxx"
      }
   ],
   "BarcodeScanner":{
      "name":"",
      "ID":"",
      "connStatus":"Connected"
   },
   "Network":{
      "IP":"",
      "mask":"",
      "gateway":"",
      "DNS1":"",
      "DNS2":""
   },
   "Wireless":{
      "Mode":"1",
      "SSID":"DemoSSID",
      "securityType":"2",
      "Passphrase":""
   },
   "softVersions":{
      "ClientInt":"0.0.0",
      "BarcodeInt":"0.0.0",
      "DispenseInt":"0.0.0",
      "EConfTool":"0.0.0"
   }
}
```