



Electric Vehicle Charging System

EE 492: Final Document

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Abstract:

Today more and more vehicles are making the transition from gasoline powered engines to electrically driven motors. The inrush of new electric vehicles on the market has created a demand for

an efficient and convenient way of quickly charging an electric vehicle. This system provides a cost effective solution to these problems. Not only is the system 90% efficient at delivering to power to your vehicle, it also provides a high current solution for electric vehicles with lower battery voltages. This system is convenient by allowing the user to charge their vehicle off any standard electrical outlet in the United States. Although this charger is designed specifically for the Iowa State's multidisciplinary senior design group, the charger provides them with the flexibility to convert their electric vehicle battery system to different voltages and different battery types

Product Description:

The client of this product design is "Paragon INC, requesting the design of a charging station that is capable of charging a range of common battery capacities for their new line of vehicles designed to haul vending stations. The environment in which this product will be used will be in amusement parks and other kinds of fairs. This product is a safe and efficient method of charging a battery quickly and is compatible with a range of battery capacities depending on the consumer's needs. This product can be safely operated as long as the user uses their intuition to follow all safety procedures that are included. This station has other features that are designed for the convenience of the user. Aside from this product's primary purpose, this charging station is capable of informing the user of the battery's state of charge (SOC) remotely from a computer and user is capable of using their Android smart phone to view such information using Bluetooth technology.

System Technical Constraints:

The constraints defining the design of this product include those that affect the rate at which these batteries may be charged, the cost of production, as well as mobility of this product. Some of the technical constraints that is included:

- Rate of Charge must be at maximum 6-8 hours to reach full capacity
- The Charging Station must be designed will all current standards
- Charger maintains battery life for 3-5 years
- State of Charge (SOC) indicator
- Be able to charge Lithium-Ion and Lead Acid Batteries
- Must be able to send user information including estimated time to full charge and the percentage charged on battery to hardware and software user interfaces

System Non-technical Constraints:

This project also requires a number of constraints that are non-technical in nature but are of great importance to the overall success of the project. Each of these constraints is as follows:

- Charger is Safe
- Charger is Reliable
- Easy to use
- May be used for different capacities

Design Standards:

The standards that will be required for the design of this device are those that are currently being used in industry. The industry standards specific to electric vehicle charging stations are those being produced by Society of Automotive Engineers (SAE), IEEE, National Electric Code (NEC).

The National Electric Code NEC has set the current design standards for the system component ratings, protection, ventilation, and functional safety requirements of Electric Vehicles and their charging systems within the United States. An electric vehicle charging system falls within the “Electric Vehicle Supply Equipment” categorization which NEC defines in article 625 as “the conductors, equipment grounding conductors, connectors, devices, power outlets, and all other fittings installed specifically for the purpose of delivering energy from a source into an electric vehicle” (NEC, Article 625 Electric Vehicle Charging System, 2005, Definitions). NEC’s article 625 is the primary standard by which the electric vehicle charging system must comply in order to be installed within the cart and be safely operational.

This charging system design is classified as Level 1. The Level 1 classification specifies permission for the system to plug into a “common grounded 120-volt electrical receptacle (NEMA 5-15R or 5-20R)” (NEC, Article 625 Electric Vehicle Charging System, 2005, p.974). This detail is important for the system’s design because it allows for the charging system to use a common residential wall outlet which is 15 Amps and 120 Volts as a source to supply energy to a vehicle. This allows for the system to conveniently charge at any residential wall source. This classification also specifies that the minimum overcurrent protection rating should be 40 amperes. In general the overcurrent protection rating should be no less than 125 percent of the maximum system load. This means that the minimum rating that all charging system components should be rated at is should abide by this standard.

NEC Basic Charging Station Requirements:

EV Charging Stations:

- Level 1 Classification:
 - A 15-20 amp standard residential wall plug and socket for 120 volt charging.
 - Minimum overcurrent protection rating 15 Amps for 15 Amp source and 20 Amps for a 20 Amp source.
 - General component overcurrent protection rating specified to be 125% of system connected load.
- Cable Sizing must be consistent with overcurrent/ampacity ratings that article 625 specify.
- Supply equipment will have sufficient rating to supply the load consumed.
- Other specifications will include:
 - Equipment must be labeled and listed
 - Connector compliance with SAE standards
 - Ground fault protection

- Diagnostic capability, must be able to prevent batteries from being charged when batteries are damaged or in any unsafe condition
- Connection that is unable to charge when connectors are not engaged.
- No exposed live components or cables.

Battery Charging Profile:

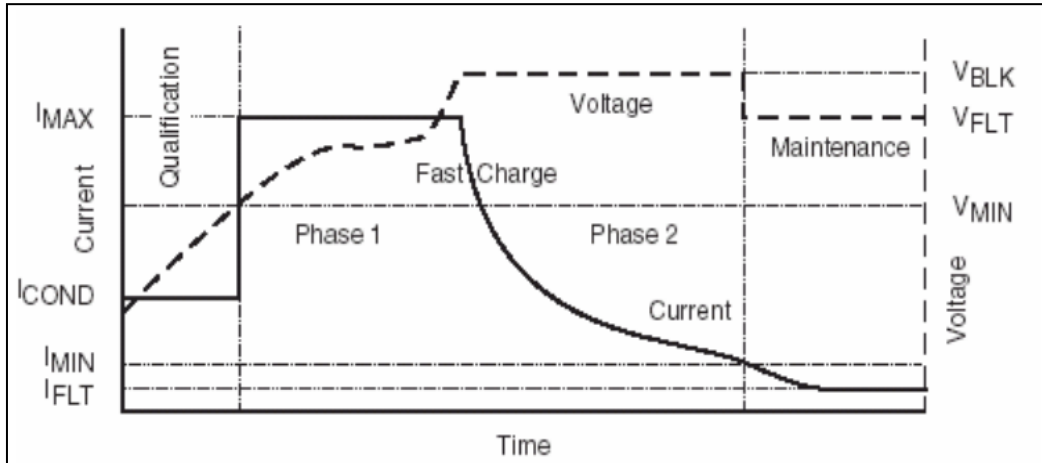


Figure 1: Lithium-ion Charging Profile

The Importance of the Volt-Current Detection

The buck converter uses the volt/current sense to detect the precise amount of voltage and current that needs to go into the batteries. The buck converter charges the batteries using a constant current/constant voltage profile. This means that if the battery is completely drained initially the volt/current sense will first monitor the current and report the value to the Arduino. The Arduino will then continue to take current measurements and increase the Pulse Width Modulation (PWM) duty cycle until the system meets the predefined current level. Once the desired current is met the system will modify its PWM signal to remain at the constant current. While measuring current the system will also measure the voltage to check to see when the system reaches the battery's float voltage.

The float voltage will continued to be measured and the necessary duty cycle changes will take effect to keep the constant voltage in place. While the system maintains this constant voltage the current going into the battery naturally decreases. When the current going into the battery reaches the minimum allowable current going into the battery, the system will shutoff and the charging will be completed. Without an accurate Volt/Current sense the system would not be able to effectively charge the batteries.

System Description & Components:

Charging Circuit Overview:

The charging circuit's input is the source that comes from a residential 120VAC wall source that can be found in any home or commercial industry. The circuit adapts this source to voltage levels that are battery capacity specific using a transformer designed to be able to make use of multiple ratio settings.

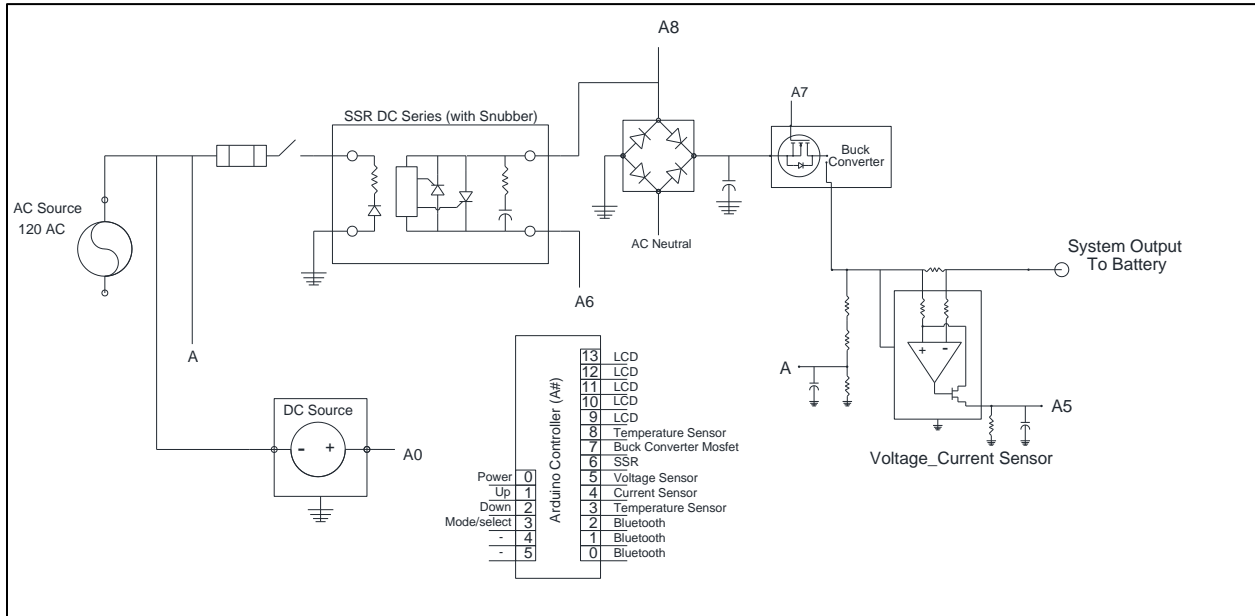


Figure 2: System Wiring Schematic

This system is comprised of a few main components that are used to drive the system operation in conjunction with the microcontroller function. These main components consist of an AC-DC converter, Solid State Relay (SSR), full wave bridge rectifier, Voltage & Current Sensors, Temperature sensors, and a buck converter. Each of these five components is essential to making the system operational and compatible with specific constraints.

AC-DC Converter:

The AC-DC converter is used within the system to act as a source converter to power the Arduino Microcontroller that is used to drive the system. The microcontroller is programmed with specified system logic that modifies how the system operates based on the sensory measurements of the battery state of charge (SOC). On the wiring schematic, this component is representative of the DC Source component due to its actual function within the system.

Full Wave Rectifier:

The full wave rectifier operates as an AC-DC converter for the actual charging circuit. The rectifier inputs the AC waveform and converts to whole of the input, both polarities of the AC waveform to an output of constant polarity (direct current). This is done by using four diodes in a bridge configuration as shown in the figure below.

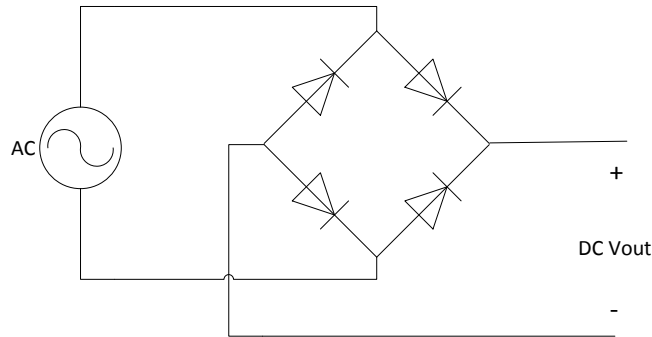


Figure 3: Full Wave Rectifier

Solid State Relay (SSR):

To make a user friendly charging station we need to design a smart charging station. The user should be able to plug in the battery to the charging station and not need to worry about the battery charging for too long, the battery overheating or the battery destroying itself. To do this an implementation of a shut off system so the charging station knows when to shut off when the battery is fully charged. The shut off system being used is a Steady State Relay (SSR). It has the functionality of being a digital switch that uses a small signal to control a large current or voltage. The small signal voltage input can be from 3 volts to 32 volts for the SSR. This will be supplied by the micro-controller. The SSR also has a built in snubber. A snubber is a safety mechanism to make sure the high voltage and current doesn't turn on the SSR when it is not triggered properly. The two figures below represent the SSR being on (Figure 4) and the SSR being off (Figure 5).

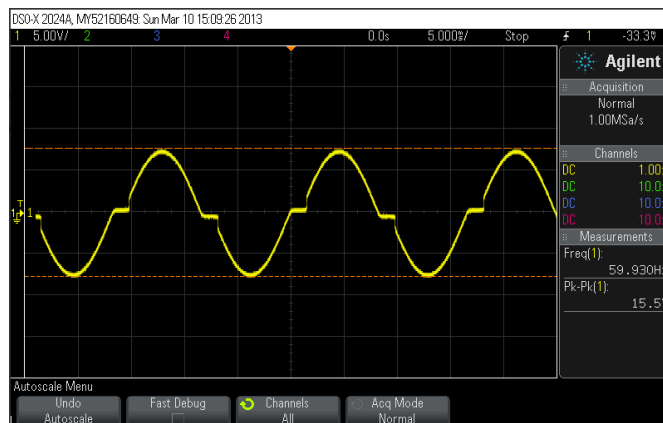


Figure 4: SSR in "on" State

In the above figure, the peak to peak voltage is 15.5 volts. In the figure below the peak to peak voltage is 860m volts. This is the SSR in the "off" state.

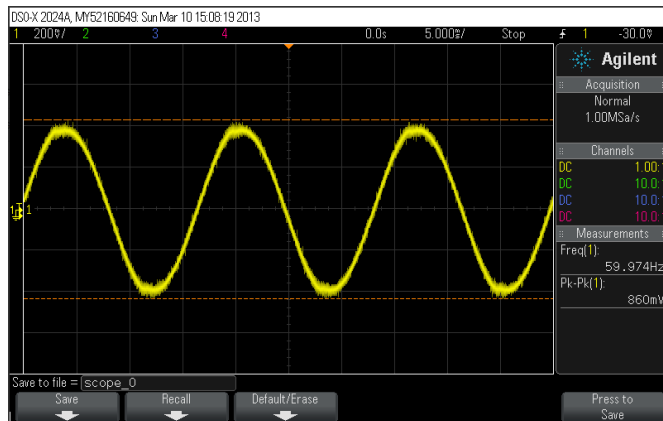


Figure 5: SSR in “off” State

Buck Converter with Gate Driver:

Buck converter

In the design of this charging station, a buck converter is used to bring the rectified AC voltage to lower DC voltage. In a very simple step-down converter, one could use a linear regulator, but they waste energy in the form of heat. With this charger, the buck converter was the better choice. Buck converters are more efficient, up to 95% in some cases, and for the system to convert to multiple voltages. For this system there were four different voltages the user can choose from for the battery. With the buck converter, the user will be able to choose between 12V, 24V, 36V, and 48V. Once chosen, the Arduino processor will allow the buck converter to convert the DC signal to the chosen output voltage. The figure below gives a schematic of what the buck converter looks like.

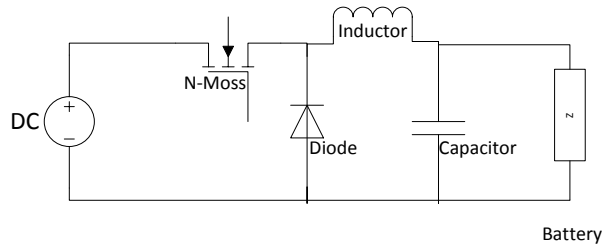


Figure 6: Buck Converter

To convert the input voltage to the lower output voltage, the buck converter’s main component is an N-MOS transistor and in this case a power MOSFET. These MOSFETs are rated for high voltage as well as high current. The voltage going into the MOSFET is considered the drain. The output voltage from the MOSFET is the source and in the middle is a gate. Not getting into semiconductor devices, this is simply a switch and when the voltage at the gate reaches a certain level the gate turns “on” and allows the current to flow through the switch and to the rest of the components. To lower the input voltage, this switch can be switched on and off at different intervals. This creates a duty cycle where in one “duty cycle” a percentage of the switch is on and the other part is off. For example in a 40% duty cycle, the switch is in the “on” mode 40% of one cycle. This creates an output voltage of 60% of what the input voltage is.

A big part of this is the inductor and how it changes current through reluctance. Starting with the switch in the “off” position, the current in the circuit is zero. When the switch is first closed, the

current will begin to increase, but the inductor doesn't want the current to change from zero, so it resists the increase by dropping voltage. Over time, the inductor allows the current to increase slowly by decreasing the voltage it drops and therefore increasing the net voltage as seen by the load. When the switch is then opened, the voltage source will be removed from the circuit, the current will then try to drop. The inductor will try to resist this drop by reversing the direction of its voltage, in turn acting like a voltage source. If the switch is opened or closed before the inductor has fully charged, or discharged then there will always be a voltage drop across the inductor, so the net voltage seen by the load will always be less than the input voltage source but not a zero voltage. This creates a ripple current and a ripple voltage, where the current and voltage are increasing and decreasing in a specific time interval. The figure below shows what a ripple current/voltage is.

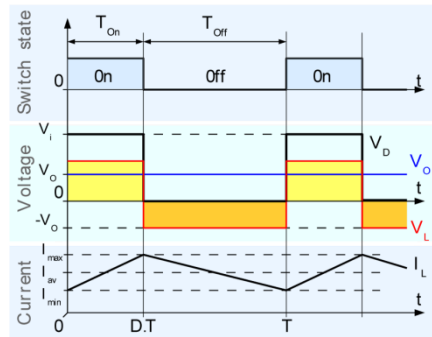


Figure 7: Buck Converter Wave Forms

With this ripple comes an issue with charging. In a constant voltage/constant current charger, this ripple can decrease the overall life of the battery. With most batteries including lithium ion batteries, there is a minimum tolerance the battery can take from this ripple. This is where the capacitor helps. The capacitor will help by discharging when the switch is off and the current is decreasing in the inductor. This keeps the ripple from decreasing greatly before the switch is on. With a big enough capacitor, the battery sees very little ripple and is not affected. Below is a figure of capacitance vs. ripple.

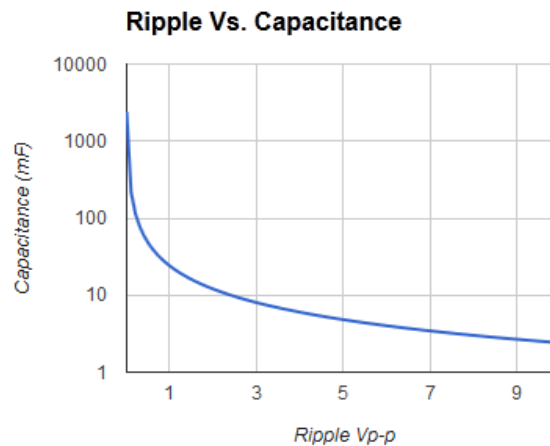


Figure 8: Ripple vs. Capacitance

In this ripple vs. capacitance curve, the lower the ripple value, from 9 down to 1, the greater the capacitance is needed to smooth out the ripple, from 1 to 10000.

Buck Converter Testing:

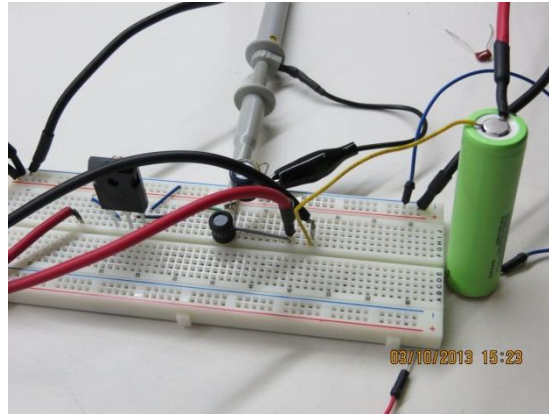


Figure 9: Small Scale Testing

To fully understand how this was working, a small scale test was performed to see how well the MOSFET worked with its other components. The first test performed worked. The MOSFET was bucking the input voltage and was charging the small battery that was hooked up to it. Figure 9, above, shows the small scale buck converter test with the battery. Below are images of the small scale tests of ripple voltage (Figure 10) and the bucked output voltage (Figure 11).

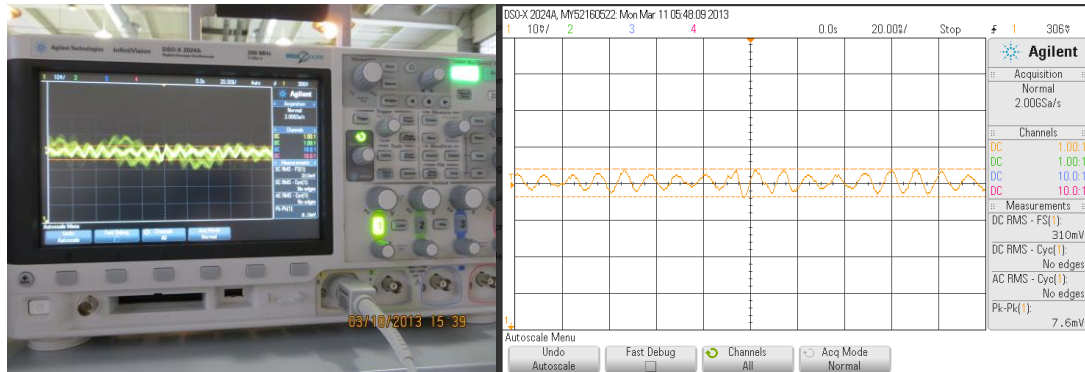


Figure 10: Voltage Ripple

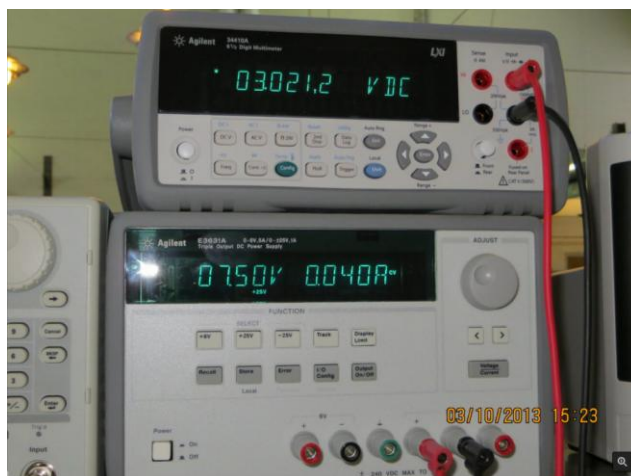


Figure 11: Voltage Output

One of the issues that arose was the different outputs that were received during tests. The calculations that were performed showed that with a 40% duty cycle, the output voltage should be 60% of what the input voltage is. In the tests this was not the case. The tests proved that it was close but not exact. Further research is needed to solve this problem. For the charger this is not a problem because just decreasing the duty cycle % as well as feedback from the current/voltage sense will give the correct voltage to the battery. Figure 12 (below) shows the differences in the actual test performed.

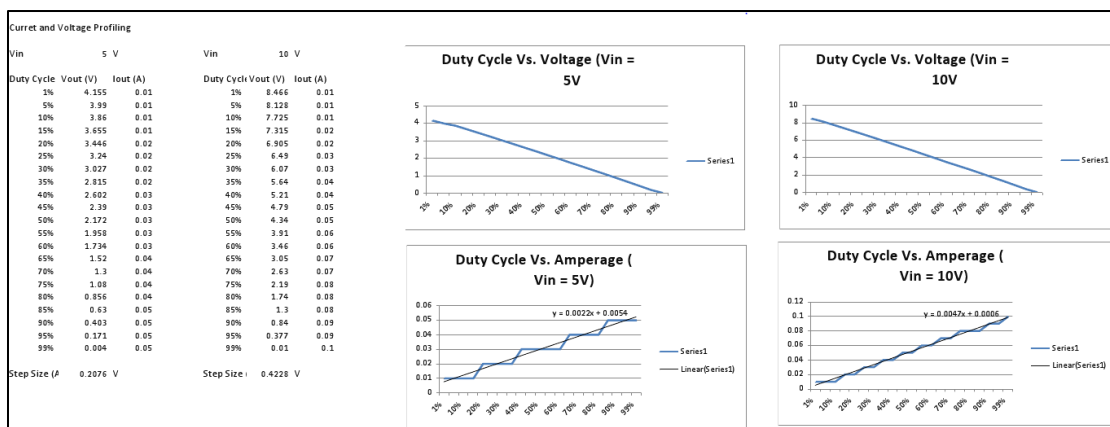


Figure 12: Duty Cycle Tests

Other issues that arose when the multiple tests were performed were scaling issues. What happened was, when there was more voltage applied to the input on the mosfet, the mosfet quit working and did not buck the input voltage. The solution was in how the mosfet works. In semiconductor devices like mosfets, the gate voltage or the voltage at the switch must be higher than the input voltage. This was found out with further testing and researching that the gate voltage needs to be about 10 to 15 volts higher than the input voltage. To further solve this was to introduce a gate driver circuit to keep the gate voltage higher than the input voltage during the “on” time of the duty cycle.

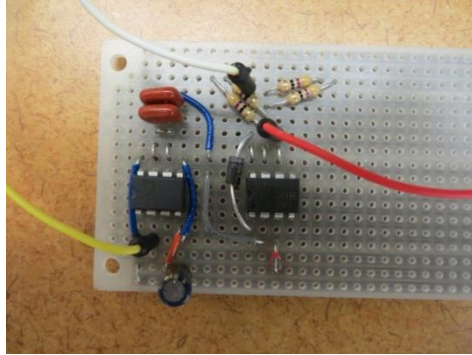


Figure 13: Gate Driver Circuit

The gate or switch on the MOSFET gets the duty cycle signal from the Arduino processor based on the inputs from the user. This duty cycle or Pulse Width Modulation (PWM) signal is generated by the Arduino with varying duty cycles. This PWM signal varies from an on voltage of 5V and an off voltage of 0V. The PWM signal is amplified by a Low-side MOSFET gate driver that amplifies the PWM signal to an on voltage that is equal to the high rail of the MOSFET gate driver. In this circuit (Figure 13, above), a MIC4420 was used to amplify the PWM signal to an on voltage of 12V. This step is necessary to meet the minimum requirement for the input of the next component. The amplified PWM signal out of the MIC4420 is then fed into an IR2117. The IR2117 is a high-side NMOS gate driver (a.k.a. bootstrap amplifier) that ensures that the voltage at the gate of the NMOS device is always greater than the voltage of the input of the MOSFET. This is necessary to keep the NMOS device in saturation region when turning on the device. The output of the IR2117 provides the appropriate PWM signal to drive the gate of the buck converter MOSFET. Below is a figure of the buck converter with its gate amplifier.

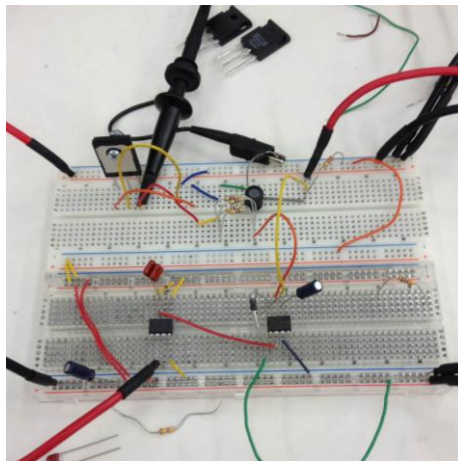


Figure 14: Buck Converter with Gate Driver

With the gate amplifier added to the circuit, the voltage at the gate will always be greater than the input voltage. This has helped in further testing resulting in better output voltages and currents.

Voltage and Current Sensor:

The sensor is a small voltage and current sense PCB from attopilot. The DC current is determined by measuring a voltage drop across a pair of parallel 1 mOhm shunt resistors, and then converted to a final analog voltage output by the TI INA-169. Voltage sense is accomplished by scaling to 5V ADC range by a precision resistor divider. In our design the sensor is connected to Analog pins A2 and A3. The ADC takes the data from the sensor and calculates the actual values. These values are then used for control purposes.

Features:

- 51.8V Max
- 89.4A Max
- Very low zero current offset
- Analog output scaled for 3.3V ADC
- Self-Powered

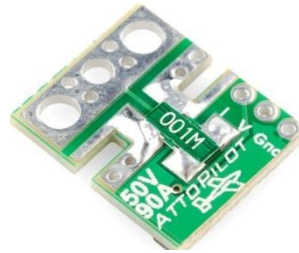


Figure 15: Volt-Current Sensor

Temperature Sensors:

The temperature sensors have been installed within the system as a safety mechanism both for the electrical components as well as the user. There is one temperature sensor that is being utilized within the system. This sensor is placed near the Arduino microcontroller and its function is to detect the ambient temperature within the casing and communicates the temperature readings to the microcontroller. If the sensors detect the ambient temperature that exceeds 90 degrees Celsius, the microcontroller will shut off the system to ensure each of the components are not damaged. The system components are rated to maintain proper functionality up to 100 degrees Celsius. The controller is programmed to turn off at 90 degrees to ensure that the system will not be damaged during operation. The temperature specifications are written below:

The DS18B20 is the latest temperature sensor from Dallas. It is a 1-Wire digital temperature sensor from Maxim IC. It reports degrees C with 9 to 12-bit precision, -55C to 125C (+/-0.5C). Each sensor has a unique 64-Bit Serial number etched into it - allows for a huge number of sensors to be used on one data bus. This temperature sensor in our design is connected to pin 13 of the Arduino and works with the 1-Wire library.

Features:

- Unique 1-Wire® interface requires only one port pin for communication
- Each device has a unique 64-bit serial code stored in an onboard ROM
- Multidrop capability simplifies distributed temperature sensing applications
- Requires no external components
- Can be powered from data line. Power supply range is 3.0V to 5.5V
- Measures temperatures from -55°C to +125°C (-67°F to +257°F)
- ±0.5°C accuracy from -10°C to +85°C
- Thermometer resolution is user-selectable from 9 to 12 bits
- Converts temperature to 12-bit digital word in 750ms (max.)
- User-definable nonvolatile (NV) alarm settings
- Alarm search command identifies and addresses devices whose temperature is outside of programmed limits (temperature alarm condition)

- Applications include thermostatic controls, industrial systems, consumer products, thermometers, or any thermally sensitive system

Arduino Programmed Microcontroller:

The Arduino programmed microcontroller is the logic behind all system operations. The microcontroller takes receives input from the DC microcontroller source in order to maintain system operations. The Arduino Microcontroller is used to interface between the hardware and software interfaces as well as to maintain all logic functions behind the charging process. It is used to control all logic within the pulse width modulation control of the buck converter by reading the battery voltages and currents to change how the battery is charging based on the given Lithium-ion profile. The Arduino is also used to calculated and make any system changes for protection such as reading temperature, vottage, and current to determine when the system needs to be shut down for safety reasons. The process map which states the system operation logic is located in Appendix A.

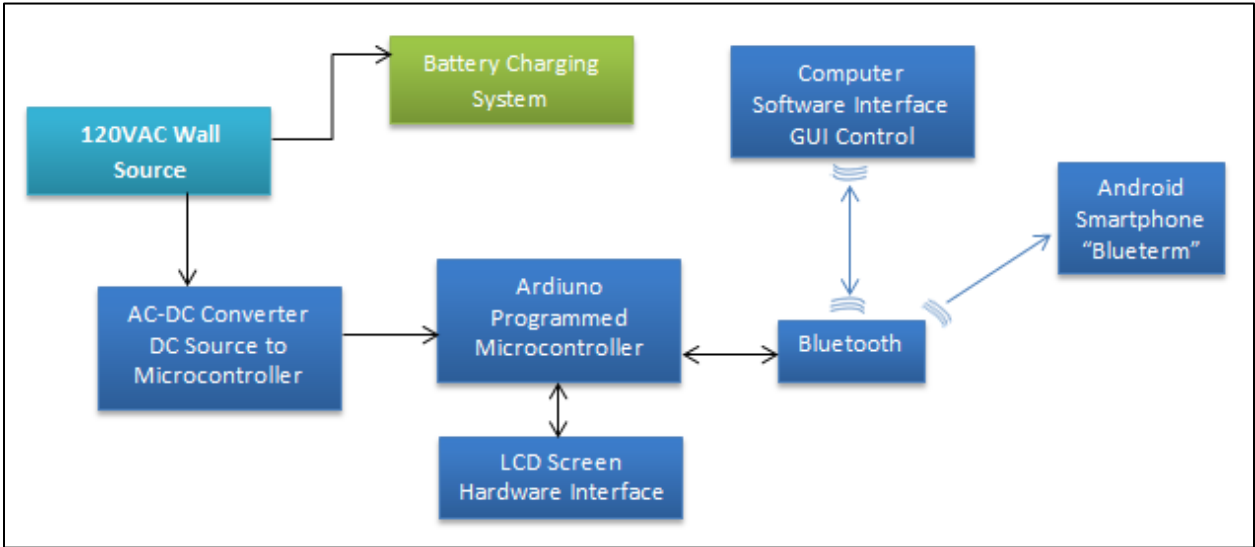


Figure 16: Microcontroller Operational Diagram

System User Interface:

User Interface Specification:

To make this product more user friendly a remote user interface and a hardware user interface were created.

Hardware specification:

The hardware interface consists of a 16x2 LCD screen, with four buttons for user navigation and control. Users may use the navigation buttons to select battery type and voltage levels. The control button

allows the user to start charging at any instance. Each button is connected to analog pins of a microcontroller and uses a minimum bounce time to allow smooth selection of battery type and voltage level. Once the battery type and voltage level have been selected, a Voltage & Current sensor reads the voltage and current levels on the battery selected. The estimated time of charging and percentage charge on the battery is then calculated by the microcontroller and displayed on the LCD.

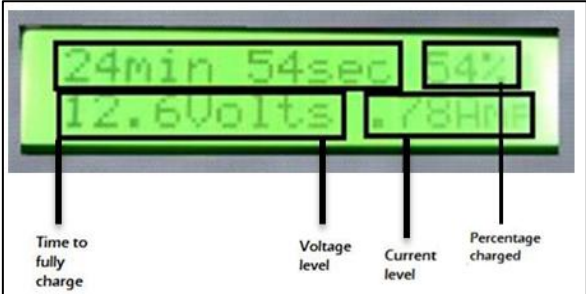


Figure 17: LCD Screen Interface

Software Specification:

The software interface shown below was developed using windows form application in Microsoft Visual Studio. The Graphical User interface (GUI) is designed to be used on a computer using any windows operating system. The development of the GUI allows the user to remotely access information such as estimated time of charge or percent charged on the battery. Given such information user can decided to turn off the charging by using "TURN OFF" tab on the GUI. Bluetooth silver-mate from Sparkfun is being used to send information to remote devices. Additionally the user can also download a free application named "Blueterm" on any Android based smartphone. The application can only be used to access the battery information but does not offer any control actions.

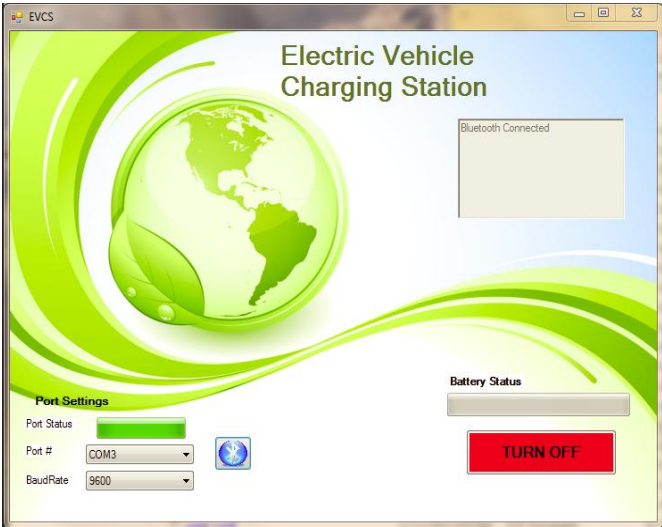


Figure 18: User Software Interface Screenshot

Testing, Modeling and Simulation Specification:

Due to the high voltage and current requirements of this system, it was unable to modeled using conventional circuit analysis tools such as PSPICE or ModelSIM. There were no libraries available within these software packages to be able to model our design and simulate it using a computer. Instead the wiring schematic was modeled using AutoCAD and was representative of the circuit. To simulate how this system operates, the system testing was broken up into three categories. These categories consisted of small scale testing, medium scale testing, and large scale testing with the rated votages and currents. In this testing process the full system was tested, each component including casing were tested in their appropriate subcategory.

Project Enclosure:

Phase 1

In phase one of the design of the casing, it was an off car or stationary charging station. It was to be mounted to the side of a wall of a garage or house to be used when the user was parked and done operating. Our charging circuit needed to have the ability to operate in numerous weather conditions as well as be protected. For this the plan on the design of the case was made of a light weight sheet metal that will be able to weather the elements. Also the need to make sure the moisture and humidity did not short the circuit. Part of the design was to use a cooling fan mounted inside the casing and a filter to stop moisture from getting inside. The dimensions of this casing were 13 inches wide, 8.5 inches tall and 19 inches long. Below is a 3D conceptual computer aided design of the casing.

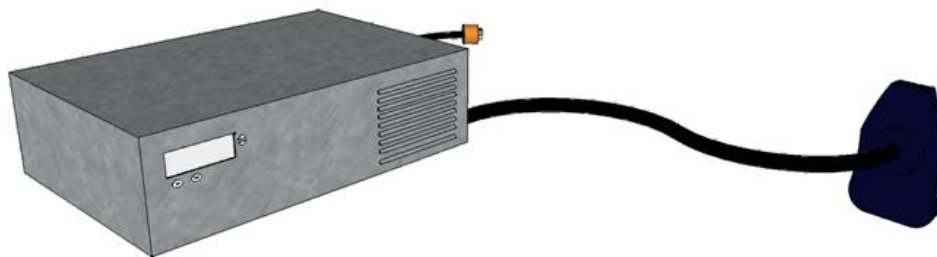


Figure 19: Charging Station Casing

Phase 2

In phase two of the design, the charger was decided to be an on board system with the same capabilities with charging, but with changes with the design of the casing. First, the LCD screen and the buttons are actually going to be located on the dashboard of the electric car. Second, the casing itself, is smaller with dimensions being 6 inches wide, 6.5 inches tall and 13 inches long. Third, the casing did not need to be weather tight because it is being mounted on the underside of the seat inside of the car. And fourth, with the projected heat dissipation of about 100 watts, venting and heat sinks were sufficient enough to not need a fan. Below is the completed casing.

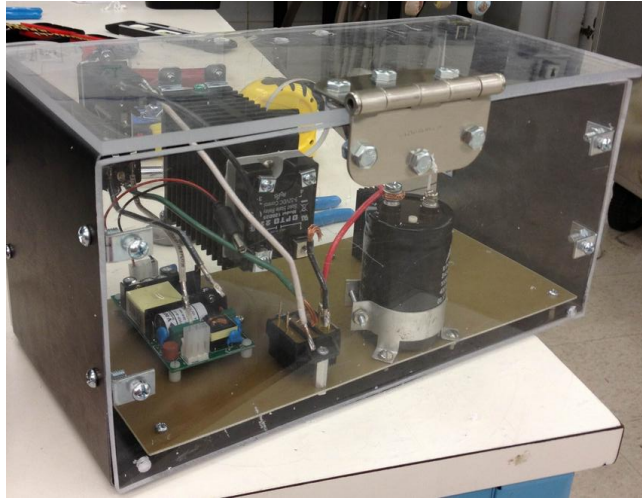


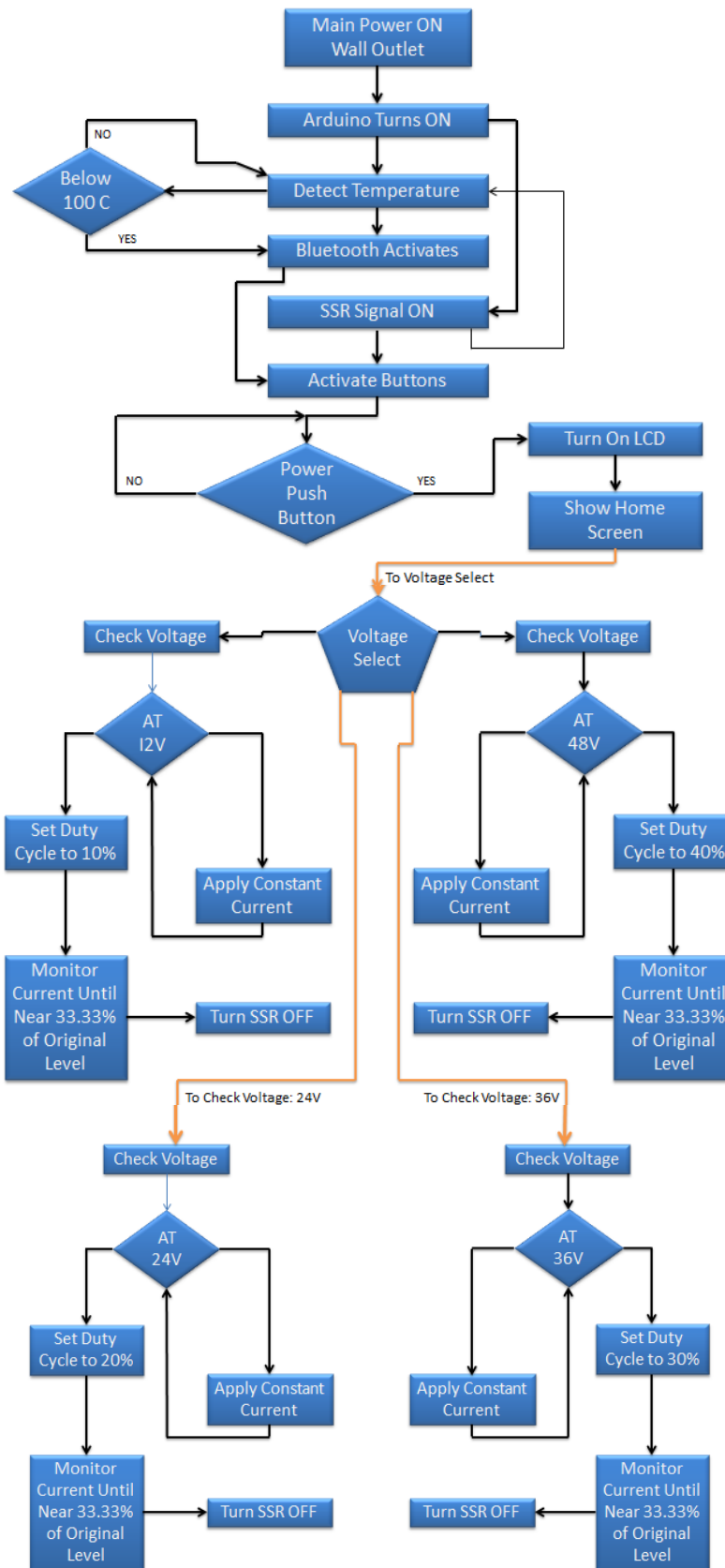
Figure 20: Completed Casing

Improvement Suggestions and Reasoning:

- Reduce/Replace Arduino.
 - Currently the Arduino Uno device being used is very large and requires a large power supply to operate. Switching out the Arduino Uno with the smaller Arduino Nano will reduce the amount of space taken inside of the device. Another option would be to replace the Arduino Uno with an embedded chipset; this would be another space saving option.
- Replace/Remove Bluetooth Device.
 - Although having a Bluetooth device was a design requirement for our project, it would be more feasible to have the system operate over a wifi network or completely remove the system. Since Bluetooth is limited to a range of 30 feet it becomes an inconvenience for the user to always be within 30 feet of the charger in order to read the state of charge. Since 30 feet is close enough to the charger to walk to the vehicle and check the state of charge, it would be more convenient to extend the range.
- Embed all components.
 - Using components that come in Small-outline integrated circuit (SOIC) packages and embedding all of the components in place of the Dual-Inline Packages is another space saving measure that could be implemented.
- Replace Solid-State Relay with TRIAC controlled system.

- Another option for embedding versus receiving the individual component is to replace the Solid-State Relay (SSR) with a TRIAC shutoff system. Since the SSR and heat sink requires the most space in the charging casing, this would once again reduce the amount of space.
- Design and fabricate a custom casing with ventilation.
 - Designing a custom casing would better protect our system from damage and protect users from accessing the component contained within the casing. The custom casing could also be used to selectively place ventilation in areas with the greatest heat dissipation. This would improve the longevity of our system.

Appendix



User Guide for Multi-Voltage Battery Charging System

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User Guide Contents

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Warnings:

*****Potential risk of shock or battery explosion which could result in death*****

WARNING — RISK OF EXPLOSIVE GASES

- Working in vicinity of a lead-acid battery is dangerous. Batteries generate explosive gases during normal battery operation. For this reason, it is of utmost importance that each time before using your charger, you read this manual and follow the instructions exactly.
- To reduce risk of battery explosion, follow these instructions and those published by the battery manufacturer and the manufacturer of any equipment you intend to use in vicinity of the battery.
- Use charger to charge only Lead-Acid batteries.
- Make sure vehicle is turned off while charging batteries.
- Do not expose charger to moisture and operate in area free of moisture.
- Do not use and an attachment not rated for charger. Doing so may result in a risk of fire, electric shock, or injury to persons.
- To reduce risk of damage to electric plug and cord, pull plug rather than cord when disconnecting charger.
- Do not use an extension cord unless absolutely necessary. Use of an improper extension cord could result in a risk of fire and electric shock. If extension cord must be used, make sure:
 - That pins on plug of extension cord are the same number, size, and shape as those of plug on charger
- Do not operate charger with damaged cord or plug. Replace the cord or plug immediately.
- Remove all jewelry when hooking up cables or working on charging station.
- Do not disassemble charger unless you are qualified to do so; take it to a qualified service person when service or repair is required. Incorrect reassembly may result in a risk of fire, electric shock, or injury to persons
- To reduce risk of electric shock, unplug the charger from outlet before attempting any maintenance or cleaning. Turning off the charger will not reduce this risk
- Monitor battery charger daily when using it to maintain battery for extended periods

Basic Configuration:

1. If charging station is mounted on vehicle and already hooked up to batteries to charge skip this step.

After taking off all metallic objects connect charging cables to battery terminals.

- a. Connect Red colored cable to the positive terminal of the battery.
 - b. Connect Black colored cable end to the negative terminal of the battery.
2. Make sure the power switch on the back side of the charging station is in the off/open position (O).



3. Plug the female end of the three prong cable into the male receiver on the charging station.
4. Plug the male end of the cable into the 110 V AC three prong wall outlet (If using an extension cord it needs to be rated for 15 Amps)
5. After the system is plugged in turn the power switch to the on/closed position (-).
6. Once the system is plugged in and turned on all, interaction will be through the LCD and push button interface

Push Buttons:

Push Buttons enable the user to choose the type and specific voltage. There are four push buttons: ON/OFF, Mode, Up and Down (As seen in figure 1 below).

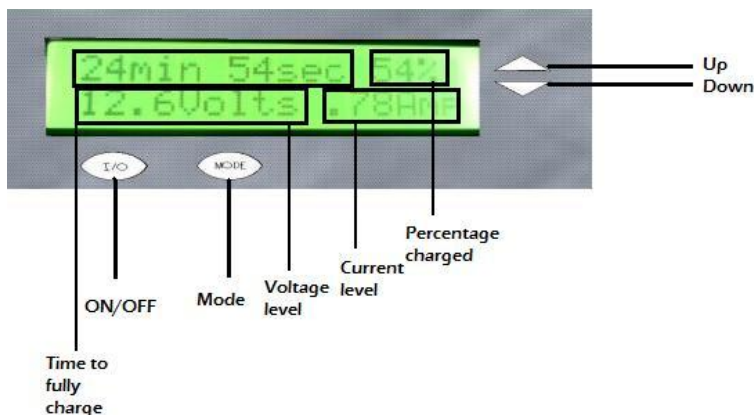
1. Use the ON/OFF button to turn the charging system off.
Always start in off mode until battery type and voltage level have been selected
2. Press the Mode button to choose the type of battery.
3. Use the Up/Down arrows to choose between Lithium ion or Lead Acid.
4. Press Mode to choose the voltage rating.
5. Use the Up/Down arrows to choose between voltage ratings (12V, 24V or 36V).
6. Press the Mode and the charger is ready
7. Use the ON/OFF button to turn the charging system on.

Physical User Interface:

The 16×2 LCD screen acts as a user interface that is mounted on the charger itself. The LCD is used when setting up the battery type and rating. Also shows the estimated time to fully charge, percentage charge, voltage level and current level. Once the charger is operating, the LCD will show two lines of readings.

First Line: Estimated time to fully charge and percentage charge on the battery.

Second Line: Voltage and current levels.



(Figure 1)

Graphical User Interface:

Download BlueTerm in any smart phone to connect to the Bluetooth built in the charger. One smart phone can be connected at a time. Voltage and Current can be read using the BlueTerm application on the smart phone. The readings change instantaneously to ensure accuracy. The GUI is only for monitoring the charging status and the user cannot make changes or operate the charging station using it.

Approximate Range: 10 Meters.



(Figure 2)