Developer Guide

System Overview

A solar charge controller regulates the voltage output from a solar panel in order to ensure that the device will always give max power. Our charge controller uses a buck converter which is controlled by a microcontroller (μC) to regulate the voltage output to 12 volts. The device first charges a 12-volt lead-acid battery, and can then distribute this power to three different types of batteries, as well as to USB devices. It features sensors for input voltage and current and the battery temperature. This information is displayed on an LED screen on the device and is also sent to an app. If the system gets to be over 113° F, the microcontroller will shut off charging. The charge controller also features battery protections to ensure that it does not attempt to charge the lead-acid battery past 12 volts.

Electrical Specifications

Specification	Value
Maximum Supply Voltage	35.2 V
Minimum Supply Voltage	22 V
Maximum Supply Current	4.83 A
Nominal Supply Current	4 A
Operating temperature	90 - 95 ℉

User Guide

The USB interface is set up to be a plug and play system. Users can charge their phones, wireless headphones, calculator, or any other small consumer electronic device with the corresponding USB power delivery cable. The USB port is USB A, thus to charge newer USB-C devices, a USB-A to USB-C will be required. Larger devices such as laptops are not supported, as they require too much power to charge.

Bluetooth Device is ready to transmit as long as the system is on. To connect to the Bluetooth device user must download and install the Bluetooth_Beta app available on the MIT App inventor website (http://ai2.appinventor.mit.edu/#6356250211778560) onto a compatible device. Once downloaded, connect to the Bluetooth module named HC-05. From there, if the system is charging, related data will be transmitted to the phone via Bluetooth and displayed on the app home screen. If no connection is made, all values will read “0.0”. If an error is tripped, a push notification will pop up informing the user that charging has ceased; this notification must be dismissed prior to continuing to the home screen.

Design Artifact Figures

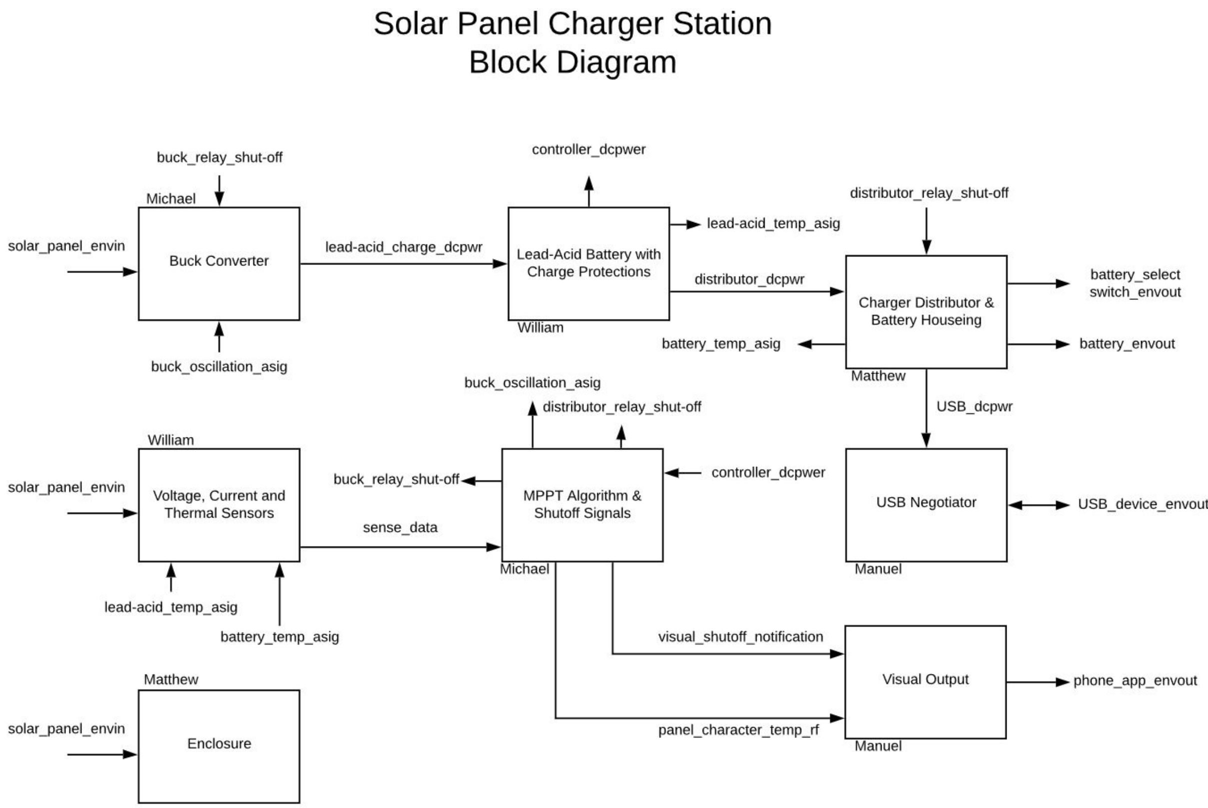


Figure #1: Block diagram of the solar charge controller

The solar charge controller takes input from the solar panel. This is regulated to 12 volts by the buck converter, ensuring the panel will output max power. This voltage then feeds into the lead-acid battery, charging it. The power can then be distributed to one of three types of batteries, or to a USB device. Characteristics such as voltage and current are displayed both on the device and through Bluetooth to an app. The charge controller also has safety features, such as automatic shut-off if the system becomes too hot, and overcharge protection to stop charging the lead-acid battery when it is full.

Figure #2: Black box model of the solar charge controller

The black box outline of the project shows the input and outputs of the project. The system is designed to take input from the solar panel and output to either battery (Li-ion, NiCad, and NiMH types are all accepted) or to a USB device with or without quick charge capabilities. The system also outputs data both to a LED screen on the device, as well as to a companion app. The incoming voltage and current, the battery temperature, and the charging level are displayed on both of these.

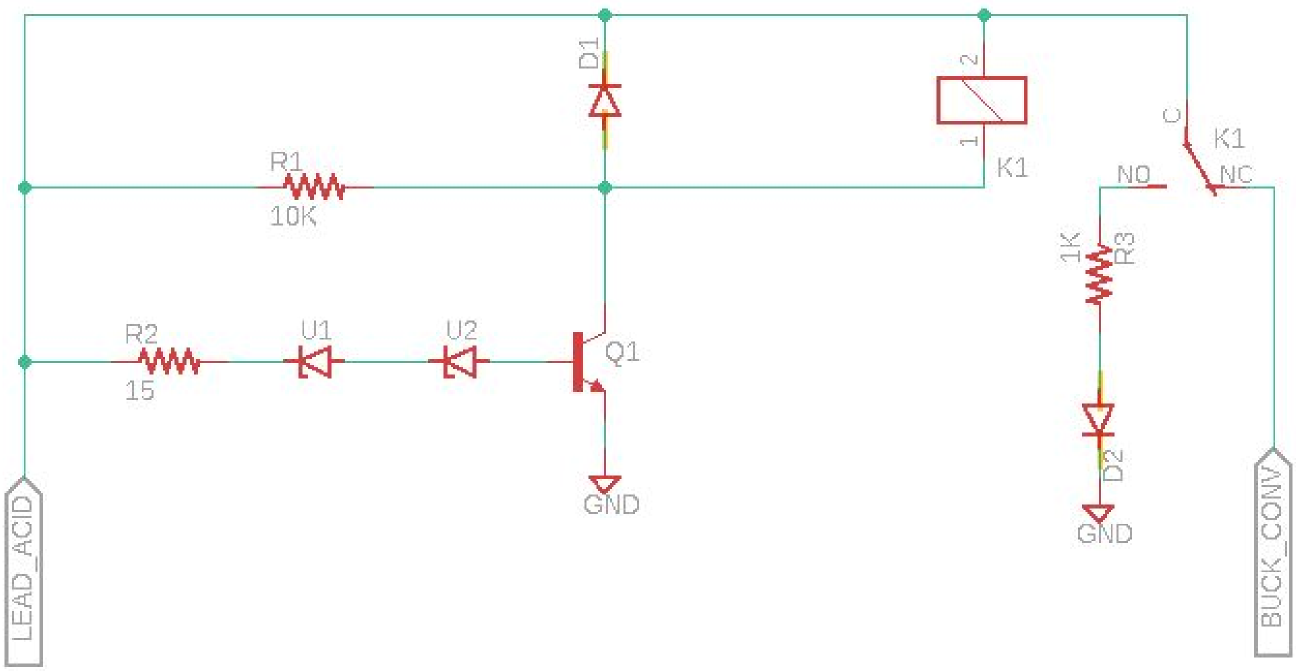


Figure #3: Circuit diagram of the overcharge protector

The overcharge protection circuit ensures that the solar panel will not attempt to charge the lead-acid battery past 12 volts, as this can harm the life of the battery. The circuit uses a transistor that acts as a switch when the voltage of the battery reaches 11.5 volts, (this gives a slight margin of error). When the voltage crosses this threshold, the transistor switches, activating the relay and causing the 12-volt input from the buck converter to be disconnected from the battery.

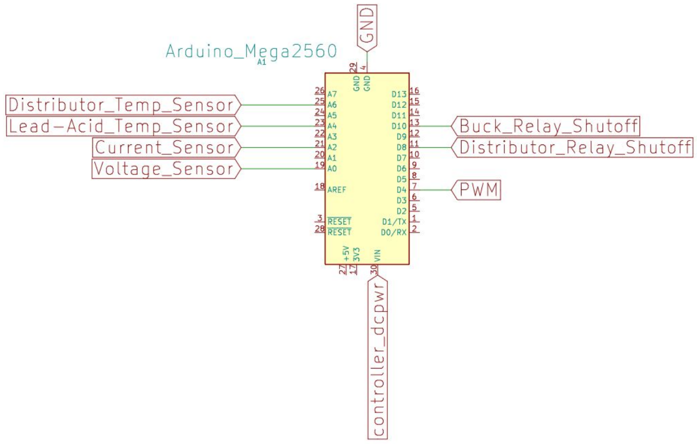


Figure #4: Pin layout of microcontroller

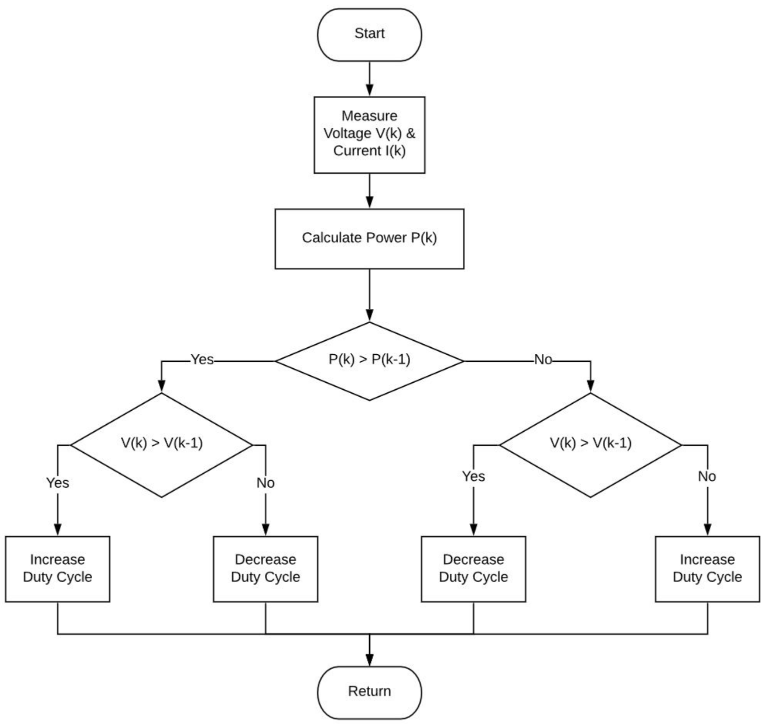


Figure #5: Flow chart for the MPPT algorithm

Figure #4 & #5 show the layout for the Max Power Point Tracking and the shut-off signal block. The block uses a Perturb & observe algorithm commonly used with Solar Panel power systems. The Algorithm will read voltages from the current and voltage sensors on the analog pins of the Arduino (A0 & A2). The voltage of the current sensor pin will be converted to a current value in amperes. The present power of the solar panel will then be calculated and stored. Comparing this value with the previously stored value of the power value, the algorithm will update the duty cycle of the buck converter to make sure the maximum amount of power is being driven through the buck converter and on to the lead-acid battery. The adjusted duty cycle of the PWM signal will then be written to pin D4 on the Arduino.

Pins A4 and A6 of the microcontroller, Figure #4, show voltage input from the temperature sensors within the charge distributor and lead-acid battery blocks. Voltages will be converted to degrees Fahrenheit and compared to the temperature limits set by the engineering requirements (113° F). If the temperature is exceeded, then HIGH signals will be sent to relays throughout the charge station to shut down the system.

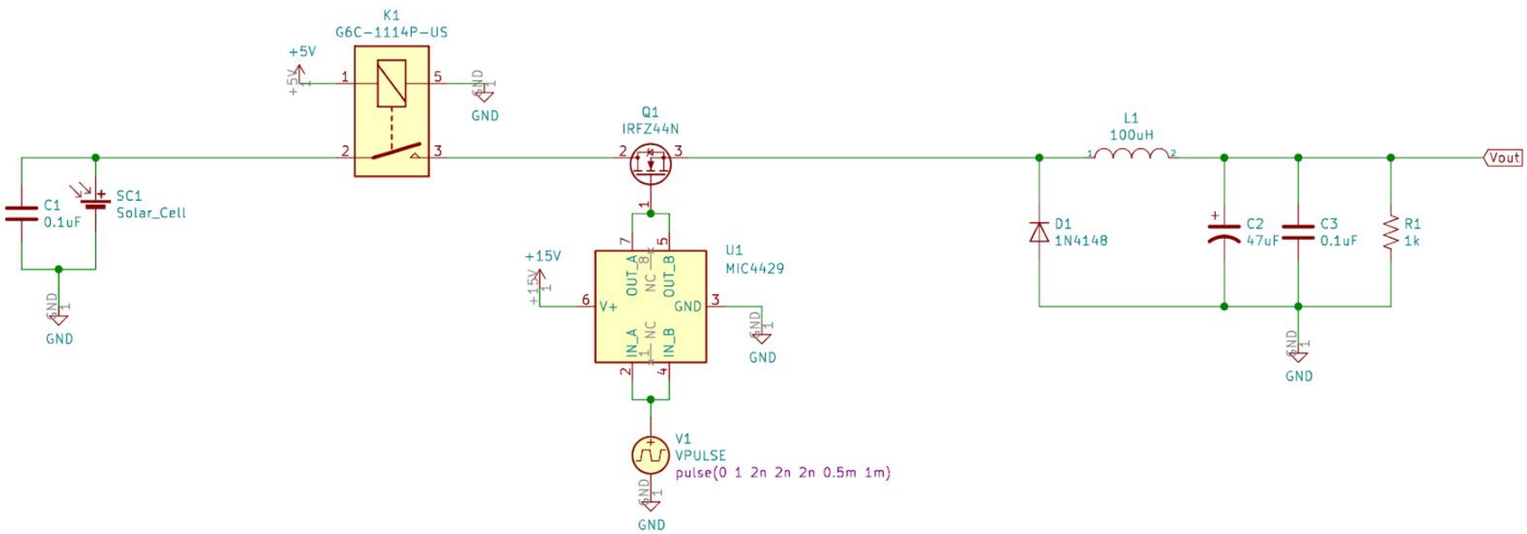


Figure #6: Circuit diagram of the buck converter

The buck converter is a switching power supply that regulates the voltage and current coming from the solar panels. Since the voltage of the solar panel is dependent on lighting conditions, the buck converter is used to keep a constant 12V at its output, which is needed to charge the lead-acid battery. The microcontroller will adjust the duty cycle of the PWM signal used fed to the buck converter. Adjusting the duty cycle makes sure that max power is being output at all times.

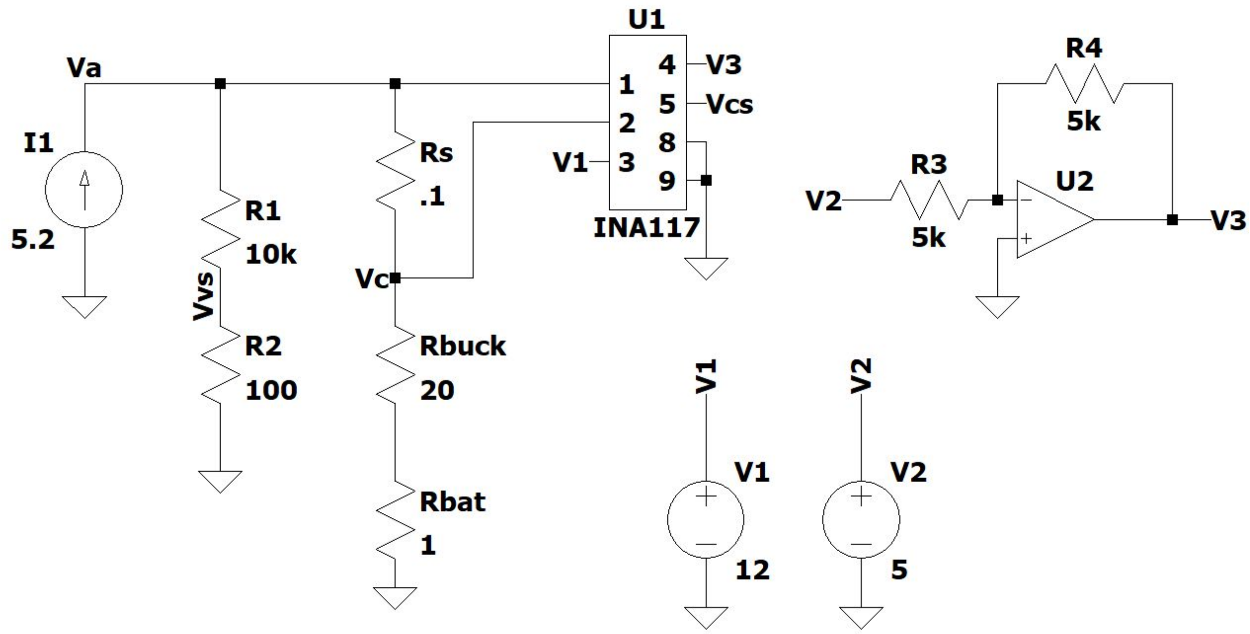


Figure #7: Circuit diagram for current and voltage sensors

This circuit measures both the current and voltage from the solar panel. The voltage measurement is done through a high resistance voltage divider to minimize power loss. The current is measured using an integrated circuit, which is powered from the lead-acid battery, removing the need for external powering.

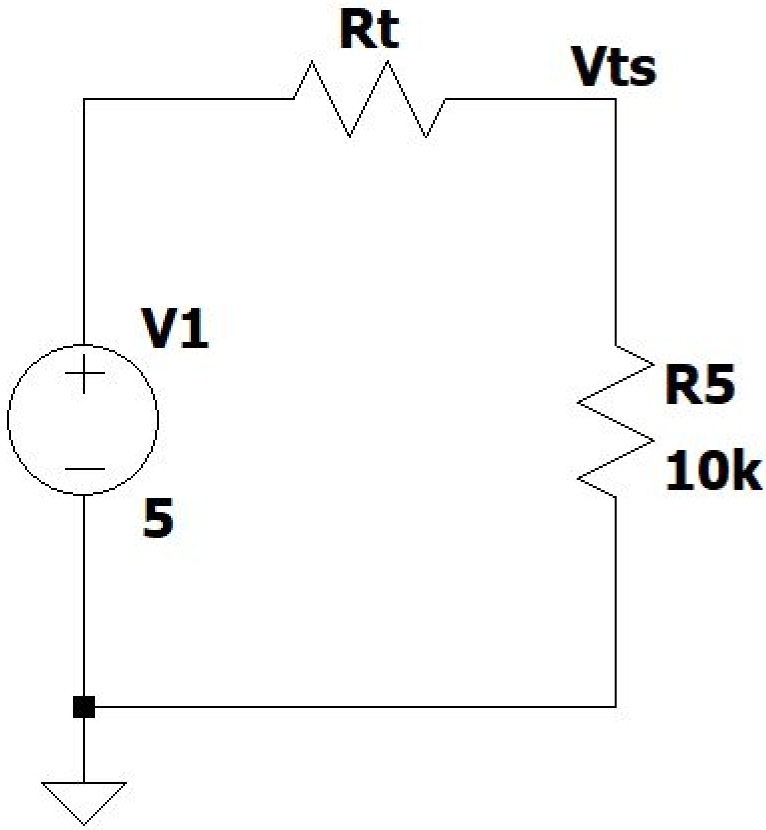


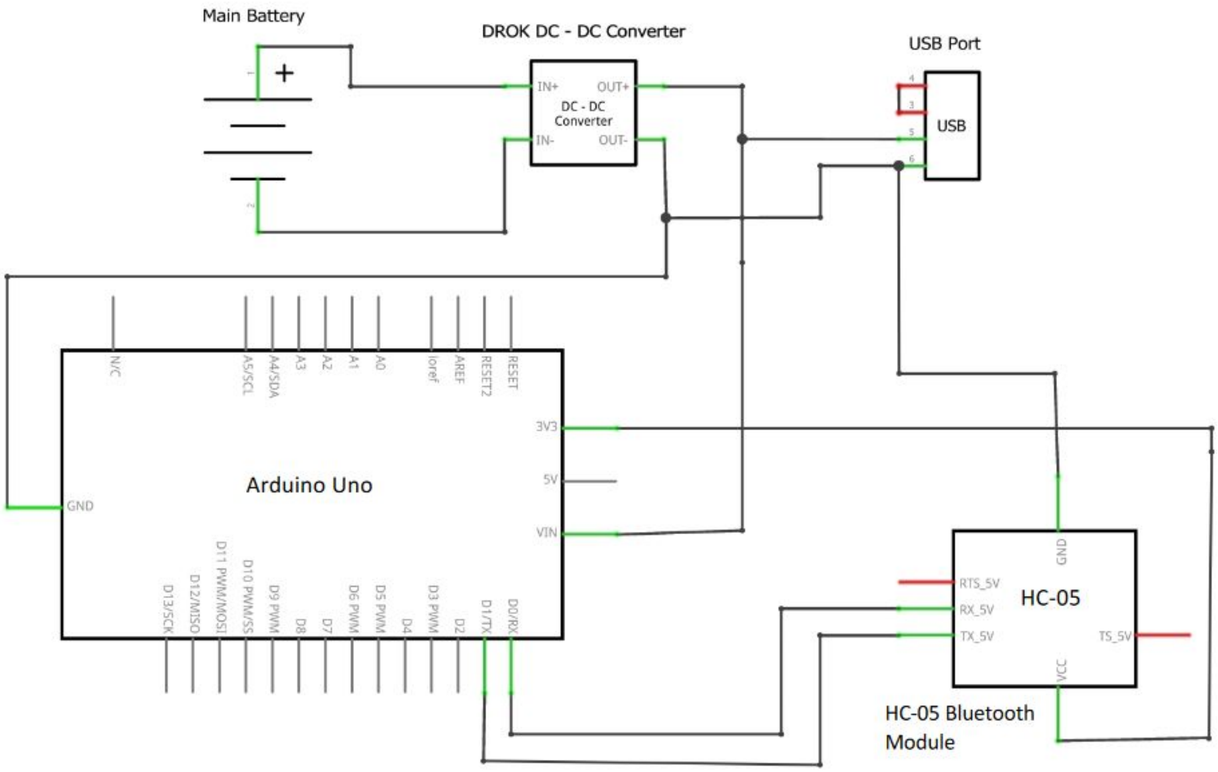
Figure #8: Temperature measurement circuit

The thermal measurement is done with a thermistor and is powered from a stepped down rail of the lead-acid battery. The voltage across the thermistor is measured by the microcontroller, which converts it into a usable measurement of temperature. This system is integral to the safety of the system as if the reading is too high, the microcontroller will issue a shut-off signal to the whole system, preventing it from being damaged or possibly catching fire.

Figure #9: 3D model of the system enclosure

The enclosure includes a basic computer fan powered from the 12V rail on the charge distributor PCB, this will keep the main transistor for Ni-MH and Ni-CAD batteries cool as well as providing ventilation for the other electronic components. The box will include a lid (not shown for demonstration purposes) as well as connectors mounted to the square holes shown in the side of the enclosure.

Bluetooth Module Schematic



*Bluetooth block and USB interface block are intertwined in the final product, so their schematics and BOMs are identical

Figure #10: USB and Bluetooth interface schematic

The USB power interface is integrated with the Bluetooth module as both the Arduino and the USB port source their Vin from the buck converter that is being used to step down the voltage from the main Lead Acid battery. The USB port has the communications pins connected, which indicates to a charging device that this is just a charging port, not one used for communication, and it is allowed to draw the amperage it needs. This works in our system because the amperage and voltage required to charge a small consumer electronics are well within the specifications of our system, so our system can go without the need for confirming voltage and current draws from devices before allowing them to charge as some charging devices do.

The Bluetooth module is being powered by 3.3 V coming from the Arduino UNO. The Arduino monitors the sensors throughout or system, incoming and outgoing voltage and currents, total charging time elapsed, and calculates outgoing power as well. This data is transmitted via Bluetooth and is refreshed every 250ms, to ensure the system provides a user with up to date information, without conflicting with the clock speed of the android application on the user’s phone. The HC-05 Bluetooth module has a range of 33 ft.

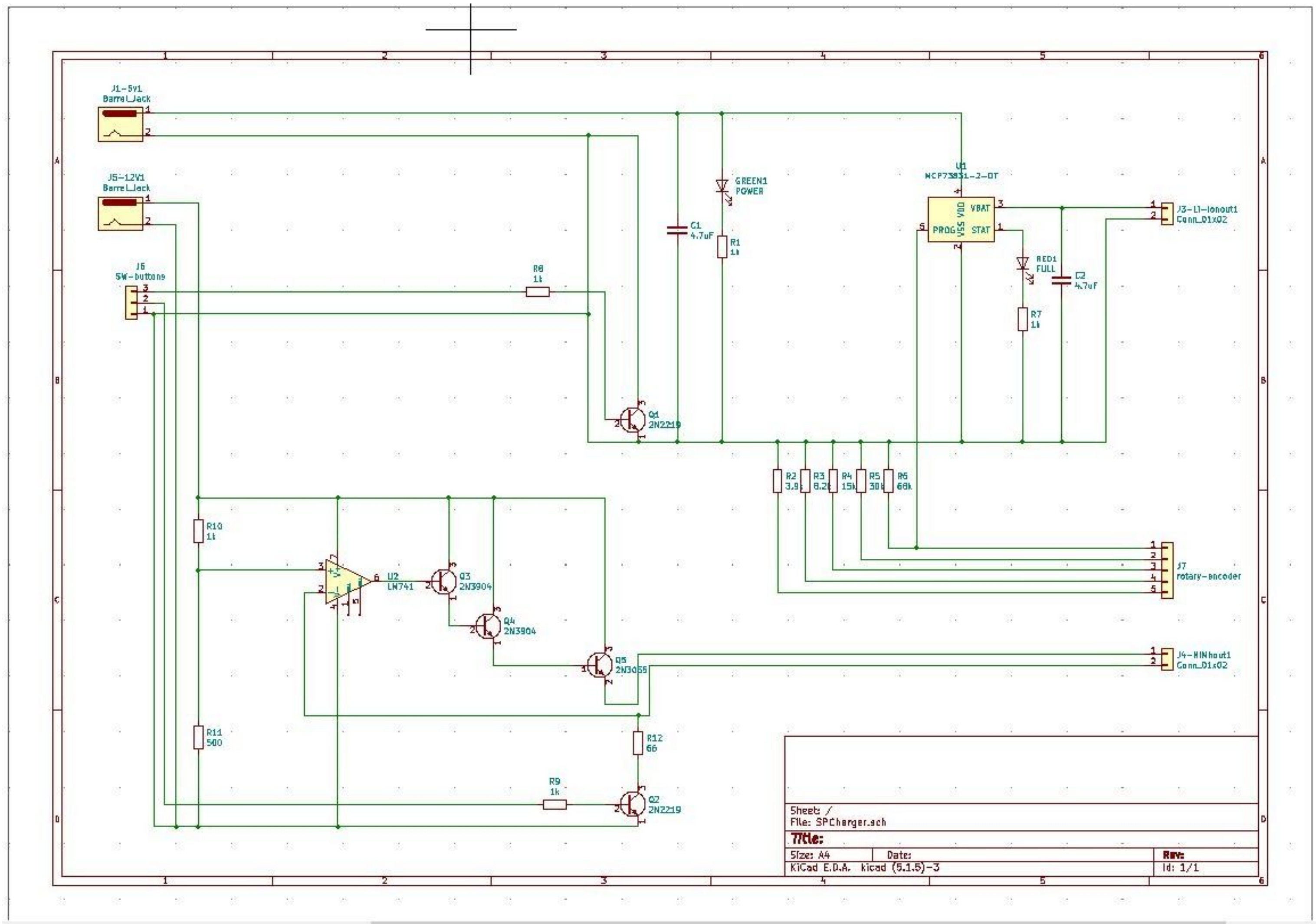


Figure #11: Charge distributor schematic

The charge distributor takers in a constant voltage from the buck converter and outputs a constant current source for Ni-CAD and Ni-MH batteries, as well as an optimum charging curve for Li-ion batteries This circuit is mounted inside the enclosure with wires leading to mc4 connectors, mounted to the enclosure for a waterproof connection.

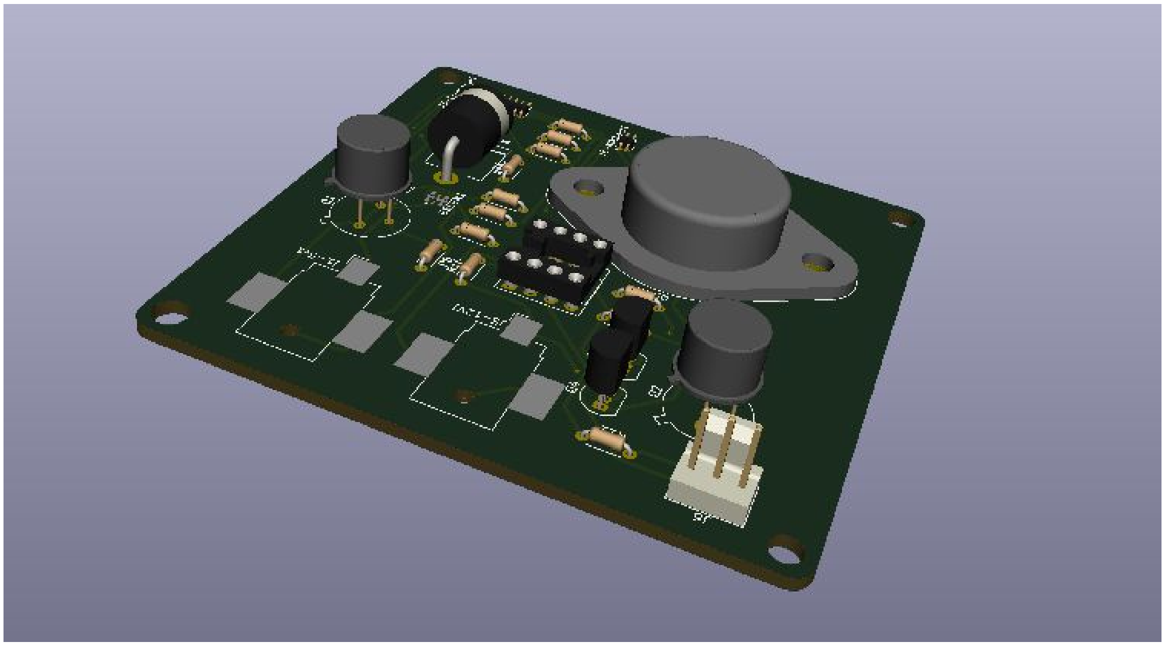


Figure #12: 3D model of charge distributor PCB

This shows a 3D model of the charge distributor, which was necessary to generate so the enclosure could be designed around it. The large transistor on the upper right of the board is the main transistor that current flows through to provide charging for Ni-MH and Ni-Cad batteries. The holes on the corners are so the board can be mounted in the enclosure.

PCB Information

Buck converter:

Size: 1.4 in x 1.6 in

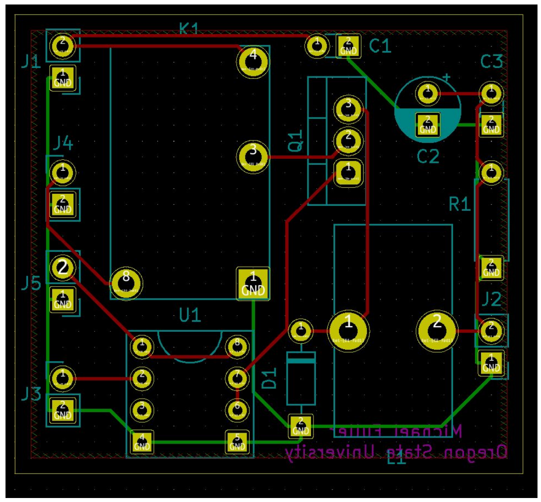


Figure #13: Buck converter PCB layout

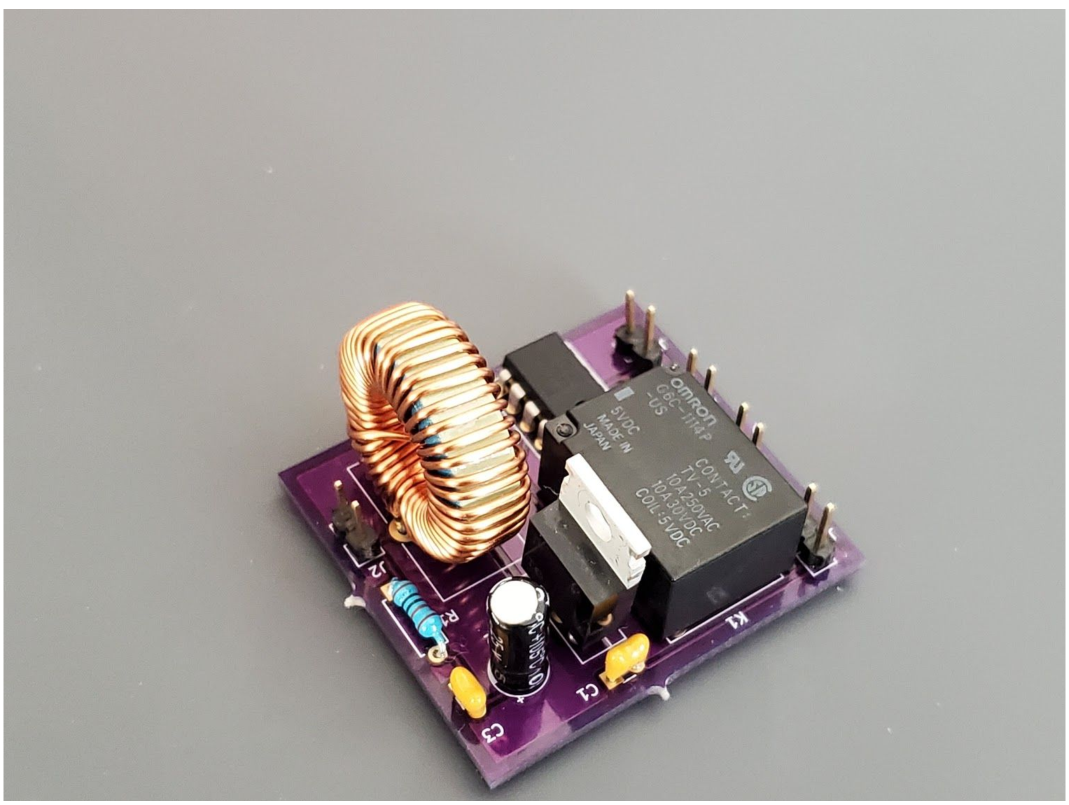


Figure #14:Picture of buck converter PCB

Overcharge protection:

Size: 4.38 in x 7.14 in

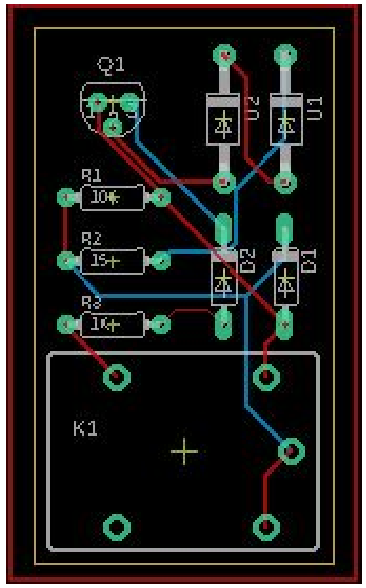


Figure #15: Overcharge protection PCB layout

Charge distributor:

Size: 2.75 in x 2.87 in

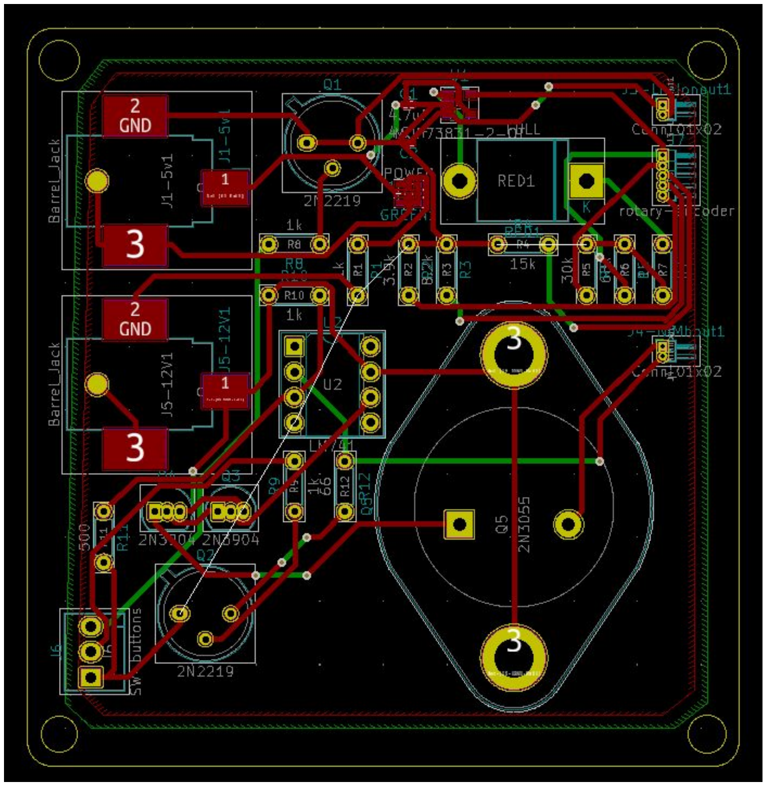


Figure #16: Charge distributor PCB layout

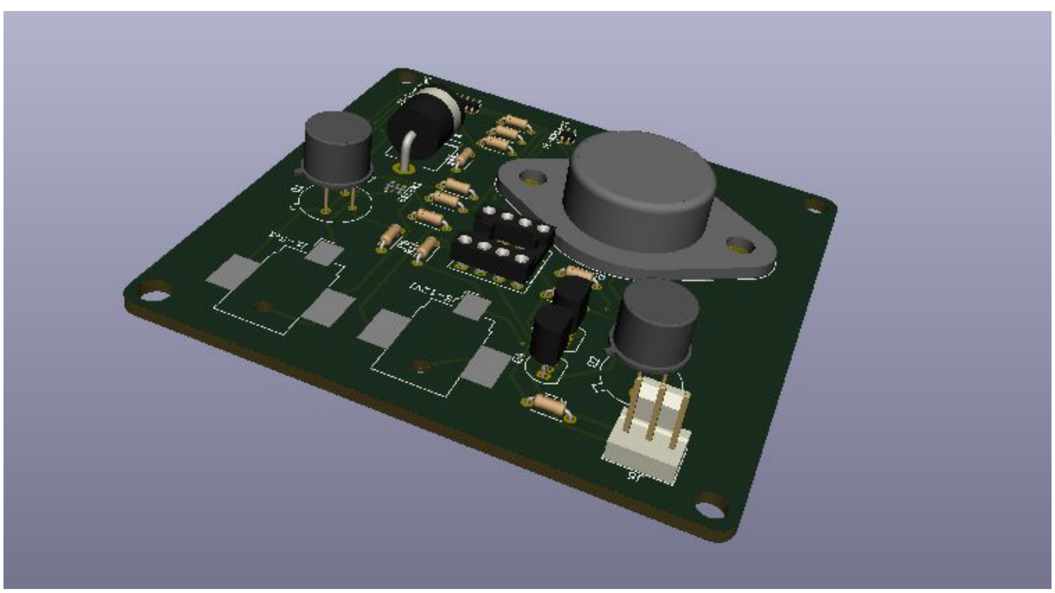


Figure #17: 3D model of charge distributor PCB layout

Part Information

Description	Value	Quantity	Part Number
Resistor	15 Ohms	1	N/A
Resistor	10k Ohms	2	N/A
Resistor	1k Ohms	8	N/A
Resistor	100 Ohms	1	N/A
Resistor	0.1 Ohms	1	N/A
Resistor	5k Ohms	2	N/A
Resistor	500 Ohms	2	N/A
Resistor	66 Ohms	1	N/A
Resistor	3.9k Ohms	1	N/A
Vertical Toroid Magnetic Inductor	100 uH	1	N/A
Polarized Capacitor	47 uF	3	N/A
Ceramic Capacitor	0.1 uF	2	N/A
Thermistor	N/A	1	NTCLE100E3-103
LED	N/A	4	N/A
Zener Diode	7.5 V	1	1N4737
Zener Diode	3.3 V	1	1N4728
Switching Diode	100V	1	1N4148
Inverting Opamp	N/A	1	UA741CP
Op-amp	N/A	1	LM741
5V Relay	N/A	1	G6C-1114P-US-DC5
5V Relay	N/A	1	JQC-3FF-S-Z-5V
BJT	N/A	1	2N3904
Mosfet	N/A	1	IRFZ44NLPBF
Transistor	N/A	2	2N2219

Transistor		2	2N3904
Transistor		1	2N3055
Arduino MEGA2560	N/A	1	N/A
Arduino Uno	N/A	1	N/A
Gate Driver	N/A	1	MIC4429ZN
Current Sensor	N/A	1	INA 117
Rotary encoder		1	KY-040
USB Port	N/A	1	
Bluetooth Module	N/A	1	HC-05
Drok DC-DC Converter	N/A	1	
Li-ion charger	N/A	1	MCP73831