DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Senior Design Project
Class of 2023

Remotely Accessible Portable Solar Charging Evaluation System (RAPSCES)

Fall 2022

Table of Contents

Focus material team will be adding within the coming weeks prior to November Deadline- all to be updated on website as finished

1) More in depth 2D model of design including updated dimensions
    a) In conjunction to the 2D model, a 3D design will also be accessible
2) Standardized wiring
    a) Color coordination
    b) Specific pin coordinates
3) Standardized diagram labeling
    a) Version numbers
    b) Specific labeling and organization
    c) Includes any circuits and separate for research
4) Finalization on foldable solar kid
5) Interface diagrams
6) Auto mode
7) Motor specifications

1. Abstract

Lafayette College's Department of Electrical and Computer Engineering requested the 2023 senior class to design a remotely accessible portable solar charging system for performance and environmental conditions evaluation. The main objective of the proposed system is to collect environmental, directional, and performance data and transmit them wirelessly to a remote computer. The system is composed of solar panels, a 12V battery that serves as a solar charge storage, an inverter to convert 12V DC to 110V AC output voltage, a solar tracking mechanism, wireless data transmission, environmental and performance sensors. The proposed system is required to be portable and terrain proof.

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2. Motivation

Whether you are tailgating at a football game or dealing with a power outage, a generator is a useful tool to grant you electricity when not connected to a power grid. One such generator is the Honda EU2200i portable generator, which has a fuel capacity of 0.95 gallons of unleaded gasoline and a run time of approximately 3.2 hours. Producings 2.2 KW worth of power, it has the capacity to operate a wide range of appliances making it the perfect tool at home, camping, or at the jobsite.

Despite its benefits in supplying power and portability, the Honda EU2200i portable generator's major drawback comes in with its use of fossil fuel which negatively impacts the environment. The proposed system attempts an electrically equivalent or better output with the use of solar panels to power recreational applications and provide a more environmentally friendly alternative.

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3. Design Objectives

3.1. Power

The system should provide a standard AC 110V 60Hz output voltage compatible with a standard residential wall outlet with load capability meeting or exceeding the nominal 20 amps. The system should use an inverter to power convert from 12V DC to 110V AC output.

3.2. Structure

The system must be configured to be portable and accommodate various but reasonable terrain. Should be configured for research into optimizing the charging system under different environmental conditions for recreational application.

3.3. Data collection

The system should acquire environmental, directional, and electrical performance data from the charging system and positioning system by wireless transmission of this data to a remote computer. Measure and display charge controller's input voltage, input current, and output current, battery voltage, inverter input current, and design specific electronics currents.

Environmental factors play a major role in this design so aspects such as temperature, pressure, humidity, and wind should be recorded for user view. Battery temperature should be tracked for safety purposes.

3.4. Solar Tracking

The system should include a panel solar tracking feature that can be set at a fixed angle, or run in a user defined path mode, or a solar feedback tracking mode. The user should have full control of panel orientation, being able to view its relevant rotation and pitch angle during its operation. When the system is in operation relevant solar measurements such as light intensity should be reduced.

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4. Design Metrics

Each unit in the system cannot be heavier than 100lbs. Preliminary research of solar kits found that each solar panel approximately weighs 12lbs, battery weighs 27lbs, charged controller weighs 4lbs, and inverter is about 55lbs. Additionally, the system is required to be portable, which means its size must be minimized. Same solar kits research found that each solar panel is about 40 by 20 inches, battery is 13 by 7 inches, charged controller is about 9 by 7 inches, and inverter is about 19 by 8 inches. Budget for this senior design project should be kept under $5,000.

5. Design Constraints

The system is required to be charged by a 12V battery. It must provide a standard AC 110V 60Hz output voltage with the load compatibility equivalent or exceeding the nominal 20A. Each unit in the system should not exceed 100 lbs total. It is also important that the enclosures of the batteries and inverter are non-conducting. All internal electronics should be powered by the same 12V battery.

6. Relevant Codes and Standards

We plan to use standards set by an International Electrotechnical Commision (IEC Homepage) for installing, testing, and maintaining solar panels. Battery Council International (LINK) has established technical standards for maintaining batteries that we plan to use as a guide. Solar panel and battery warranties are also good standards documents.

7. Concepts applied from other classes

- Soldering
- DC-to-DC step-down conversion (circuit design)
- Power distribution
  - -Low power design for sensing and transmission circuits
- Writing skills for project proposals, users' manual, etc.
- Group work from various lab classes
- GUI creation
- Microcontroller programming

8. Concepts we need to learn

- Safety procedures and precautions associated with high power systems
  - Focus on battery safety
  - The proper way to test high power systems
- PCB (Printed Circuit Board) Design
- Arduino
  - -Wifi
    - -Arduino Dashboard
  - -Interfacing between Arduinos
    - -SPI
    - -I2C
  - -GPIO
    - -Sensor interfacing
- ADC
- Arduino GFX Library
- Adafruit touchscreen Library
- Component procurement
- 3D modeling/printing
- 2D modeling for communications with machine shop
- Solar panel axis movement

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9. Runtime comparison between Solar Generator and Honda Generator

The preliminary proposal should include runtime comparison studies of the solar charging solution versus the Honda generator based on load and agreed upon reasonable operating assumptions.

Honda Generator Specifications:

- 3.2 hours of runtime at 15 amps(rated load)
- 8.1 hours at 25% rated load

While we have not decided on a kit yet, most kits we've researched come with a single, or multiple, 100aH batteries.

Ideally we would select the solar kit with two 100 aH batteries as this gives us flexibility in terms of placing objects in the final product while fulfilling the output specifications as well.

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10. Preliminary Operation Manual

The Operation Manual will include a quick start guide, a more detailed set up guide, some quick solutions to common problems, and resources for if there are bigger issues, along with the technical specifications that a user could be interested in.

The quick start guide will start off the Operation Manual, coming right after the table of contents and any title pages. It will consist of mostly easy to understand graphics that will demonstrate the minimum amount of work necessary to start using the solar panel battery assembly. It will not include information on collecting data, rather it will focus on assembly and end with where to plug things in with some brief safety notes.

After the quick start guide, there will be a much more detailed explanation of each step for set up as well as a guide to how to use the data collection feature. It will also give more information on what each step of the set up actually accomplishes. From this point, there will be references to the quick fix guide for any problems that might arise from set up. That way if you are stuck on a specific step in the set up process, you can quickly and easily find more information on what may be causing the problem.

The start guide will naturally lead into a more detailed description of how to use the GUI and further enhance the experience of the user. This part of the Operation Manual will outline how to use the GUI as well as how to use the Dashboard online and how to collect data if that is something the user is interested in.

Following the description of the GUI and the Dashboard, there will be a section on quick fixes to common problems. This section will include details on how to stay safe while troubleshooting and how to fix anything we find to be common problems during our design and building process. This will allow users to solve problems on their own rather than having to pay someone else to do it down the road.

If they have a problem that cannot be fixed on their own, the Operation Manual will lead into a section with information on how to get support for the solar kit we choose to use, as well as the solar panel itself. This section will be similar to an owner's manual in a car referring to the dealership for larger issues. This allows users a source for further information since we will not be around as a company to be that support.

This will be followed by technical specifications for both the finished product and various components of the device. That way if a user needs to replace a part for any reason and they want to use the original components, they can do so, but if they want to choose a different version, they will know what specifications to look for to ensure they are safe in their choice for a replacement part.

Throughout the guide there will be information on how to stay safe during operation and appropriate uses of the device. Safety will be important with use just as it is in the building process and we would not want any customer to get hurt while using our product. By emphasizing safety to the user throughout, we will hopefully be able to encourage any user to remain safe while operating our product.

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11. GUI

11.1 How to operate it

The solar generator will be operated through a touchscreen with a user interface. The user interface home page contain a WiFi icon that lead users to the WiFi connection setup page, a STATS icon that lead users to the sensor monitor page, a AUTO button to enable/disable the autonomous sunlight tracking mode, and a SLEEP button to put the central control unit to sleep and turn off the touchscreen display.

WIFI List page displays the available WiFi detected by the IoT WiFi module. To connect to a WiFi on the current list, click on the WiFi you wish to connect to. The two arrow buttons allow users to display other available WiFi if the IoT unit detected more than 3 WiFi sources. The house button leads users to the home page. The WiFi button is by default on, the WiFi module will be turned off if it is set to off.

The Sensor List page displays the data from sensors. The two arrow buttons allow users to monitor data from other sensors other than the current 5 sensors displayed.The house button leads users to the home page. The record button is by default off If the generator is connected to WiFi, the generator will start sending data to the remote server when the record button is turned on and will stop recording when it is turned off.

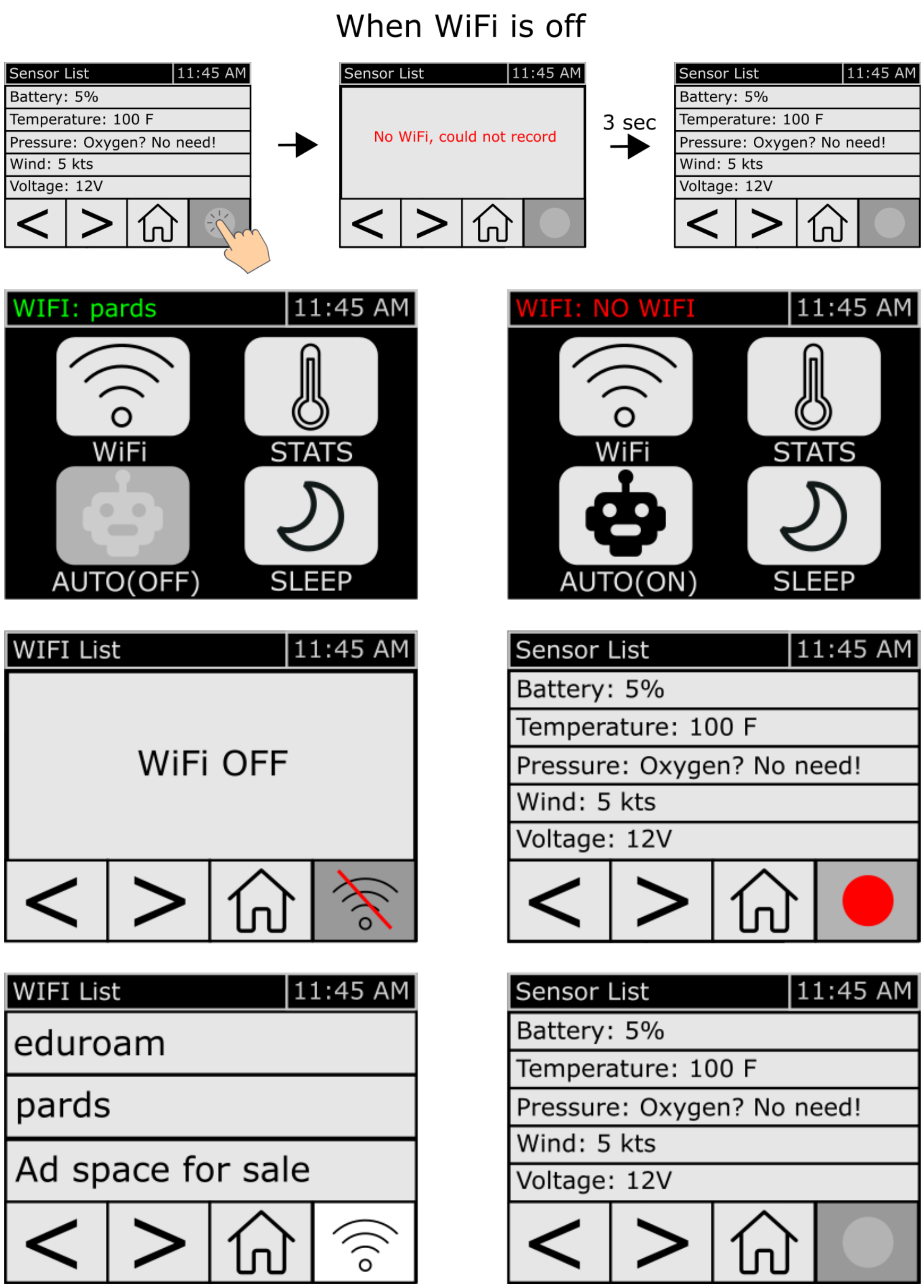

*Figure (1): A diagram showing the different screens a user will be presented with while operating the GUI.

11.2 Features

Main menu displays the basic information about the system, including options to open the statistics window, entering sleep mode, and opening a list of wifi options nearby. Furthermore, there is another option to put the system in autonomous mode, in which the system will adjust the solar panels by itself.

The arrows at the bottom will simply cycle through the windows, and the home button will return the user to the main dashboard.

The touchscreen will utilize the AdaFruit libraries in order to display and operate. We plan to implement a “sleep mode”, in which the backlit part of the touchscreen will be disabled in an effort to save power. Furthermore, the touchscreen will maintain one process to recognize a user tap so someone can wake the system up.

11. 3. Dashboard

The dashboard is an GUI interface accessible on a computer which will display the sensor data. We will be using the built in arduino dashboard for this feature as this easily interfaces the data as it is an arduino product.

The software is called the Arduino IOT Cloud. This service allows you to connect to the software as a “thing”. Once connected, there are many options for how to access and display data. Once we have an arduino, we will be able to connect it to the cloud and we will be able to store sensor data here and export it as JSON/CSV compatible.

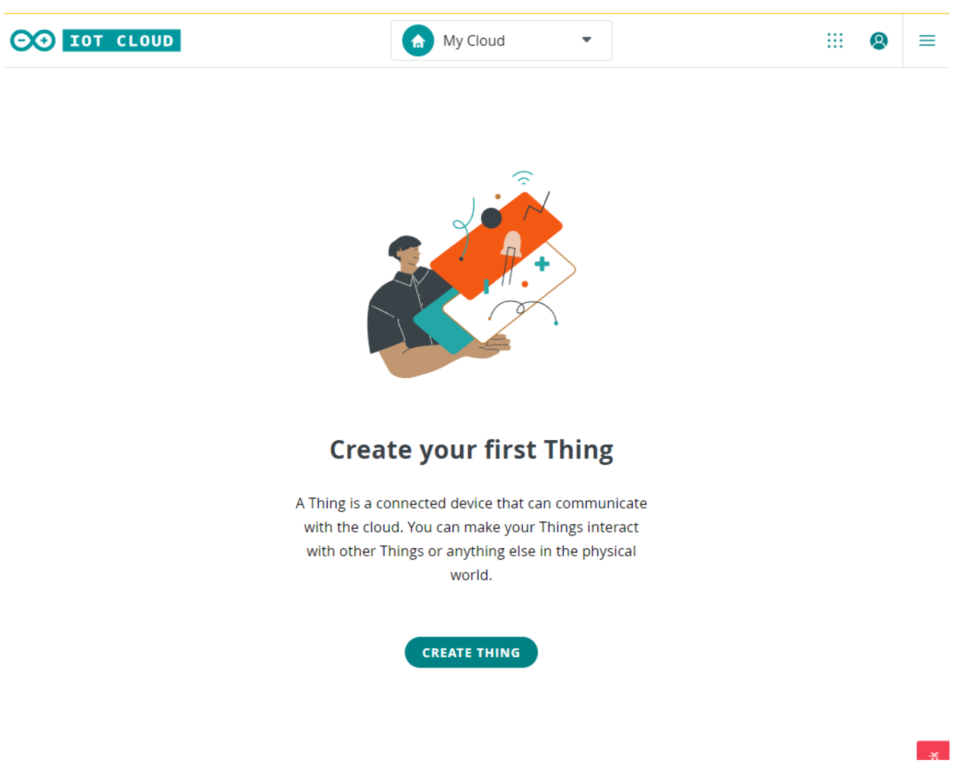

*Figure (2): An image showing the main menu of the Arduino IOT Dashboard.

11.4. Tracking Schedule

As shown in Figure (2), one of the menus will include an option to record data over a certain interval. Once enabled, the system will run on a clock to record sensor data at a specific time and it will label the data with that time as well.

In order to accomplish this task, the system will run on a local clock. By doing this, we will be able to track the time so that the time on the power generator is consistent with the actual time.

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12. Preliminary Safety Analysis

12.1 Battery Precautions

Batteries are "always on", in that their terminals are always energized. Thus, steps should always be taken to prevent accidental shorts. When in storage, keep terminals covered. We should use a very low gauge wire to connect the battery leads directly to a breaker which is also capable of handling the high current pulled from the battery. The breaker should remain off unless in use. Completely cover the leads in a non-conductive jacket from the battery itself to the breaker, including the lug nuts. Additionally, make efforts to prevent the breaker from accidentally being shut.

Furthermore, batteries are made from strong acid and alkaline materials. A spill can prove dangerous, thus it may be worthwhile to purchase or make a battery spill kit and become familiar with using it. If damaged, report it immediately. Finally, ensure that the battery itself is properly grounded.

12.2. Weight Concerns

This system will likely weigh in excess of 100lbs. Steps must be taken to ensure both that each individual assembly will weigh no more than 100lbs, and that these assemblies will be ergonomic.

12.3. General Safety Concerns

Common sense safety practices should be followed while working on this project such as wearing closed toed shoes, safety glasses when necessary, and tying back long hair.

13. Estimated Cost

13.1. Preliminary Bill of Materials:

Ckt	Qty	Description	Manufacturer	Vendor	Weight	Dimensions	Vendor P/N	Unit Price	Datasheet	Ext Price
BME280	2	Temperature, H	BosTech	Adafruit	1.7g	25.5 x 17.6 x 4.6	5046	$19.95	https://www.bosc	$39.90
BME680	2	Temperature, H	BosTech	Adafruit	1.7g	25.2 x 18.0 x 4.6	2652	$14.95	https://www.bosc	$29.90
Non-Invasive Curi	1	Ammemeter	Echun Electronic	Sparkfun	60g	25.5 x 26.0 x 40.	SEN-11005	$10.95	http://cdn.sparkfu	$10.95
ZMPT101B AC V	1	Transformer	Qingxian Zeming	Amazon		19.2 x 16.7 x 18.6 mm		$6.42	https://5nrorwxhr	$6.42
Anemometer for	1	Wind meter	Davis Instrument	Davis Instrument	1332g	381 x 38 x 457 m	6410	$185.00	https://cdn.shopi	$185.00
MIKROE Compa	2	Compass	MIKROE	Sparkfun		1.59 x 1.59 x 0.5	SEN-18781	$11.95	https://cdn.spark	$23.90
ESPS8266	2	SoC								$0.00
Solar Kit	1	Integrated Solar I	Various	Various	TBD	TBD	TBD	$2,100.00	TBD	$2,100.00
Arduino Pro Mini	3	Main Controller	Arduino	Sparkfun		17.8 x 33.0 mm	DEV-11113	$10.95	https://docs.ardu	$32.85
Arduino Nano RF	5	Secondary Contr	Arduino	Arduino	6g	18 x 45 mm	ABX00052	$29.40	https://docs.ardu	$147.00
Arduino MKR100	5	Secondary Contr	Arduino	Arduino	32g	51.6 x 25 mm	ABX00004	$44.60	https://docs.ardu	$223.00
Arduino Nano 33	5	Secondary Contr	Arduino	Arduino	5g	18 x 45 mm	ABX00027	$24.00	https://docs.ardu	$120.00
										$0.00
Framing, Casing,	1	All parts for the fi	Various	Various	TBD	TBD	Various	$1,000.00	Various	$1,000.00
Other Incedentals	1	All parts not yet	Various	Various	TBD	TBD	Various	$1,000.00	Various	$1,000.00

*Figure (3): Preliminary BOM

This is a very preliminary BOM for the project. Many items are not yet covered because they have not been selected or even considered. The total price based off of the current BOM is $4918.92; we should round up to $5000 to account for the cost of our labor (jk). In general, I would expect the number to end below the $5000 label for a few reasons. Firstly, we have not selected the primary and secondary Arduinos yet, and they are all on the BOM; furthermore, we are asking for multiple copies of many sensors to give a buffer incase of mishap and allow for parallel work.

14. Preliminary figures and Designs

14.1. Mechanical design

Below are four AutoCad drawings representing the preliminary design of the physical system. The four drawings include the Structural Base, *Figure (4), the Solar Panel Frame, *Figure(5), a Side View of the Structural Base, *Figure(6), and an Interior View of the Structural Base, *Figure(7). All drawings are not to scale and are subject to change as we finalize specific components to be used in final design.

Structural Base, *Figure (4)- The preliminary design of the Structural Base will act as a structure to hold all necessary components within. This includes sensors, microcontrollers, and solar kid components. It will move like a wheelbarrow with one handle, two wheels, and one handle. On the front side will reside the touch screen display containing the GUI. On the sides there will be vents allowing air circulation for an interior fan for temperature cooling of the battery. The top of the base will consist of a connecting rod to the frame and motors for the solar panel.

Solar Panel Frame, *Figure(5)- Will be attached to the connecting rod of Structural Base that the user will be easily able to slide in the foldable solar panel.

Side View of the Structural Base, *Figure(6)- On the side of the Structural Base will be some sort of storage compartment where users can store foldable solar panels when not in use.

Interior View of the Structural Base, *Figure(7)- Within the structural base will be all electrical components. It will be ventilated and cooled by a fan to allow for temperature cooling so no components overheat while in use.

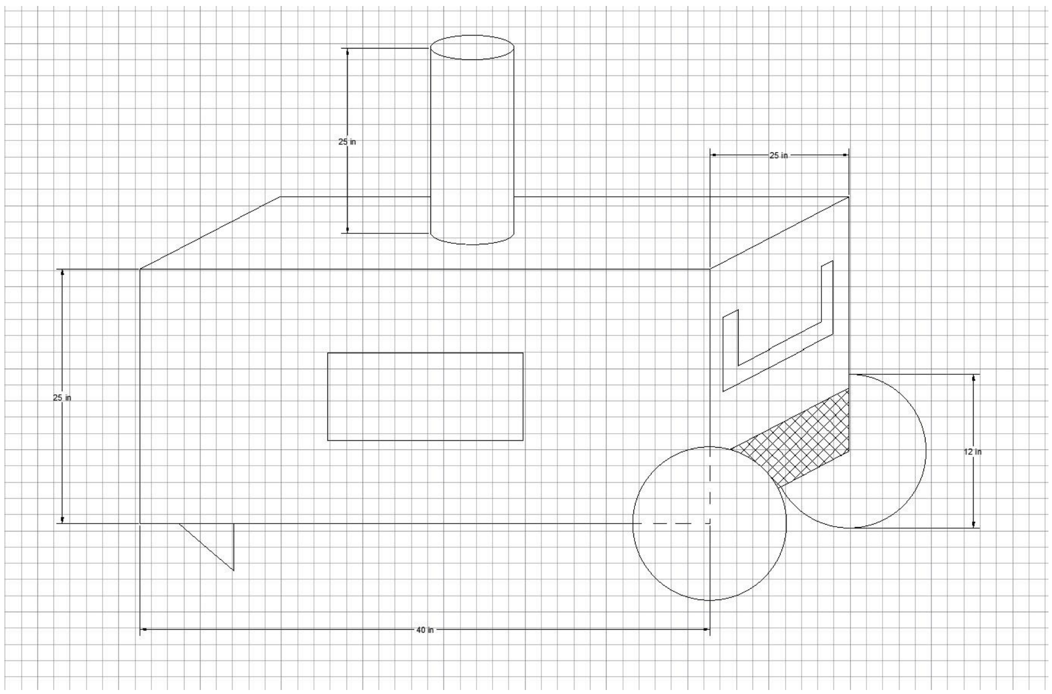

*Figure (4): Structural Base

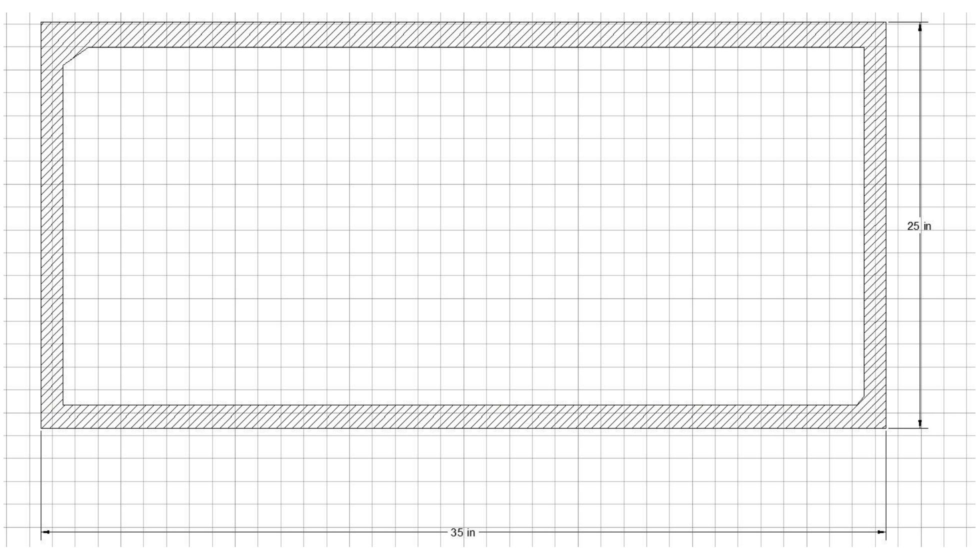

*Figure (5): Solar Panel Frame

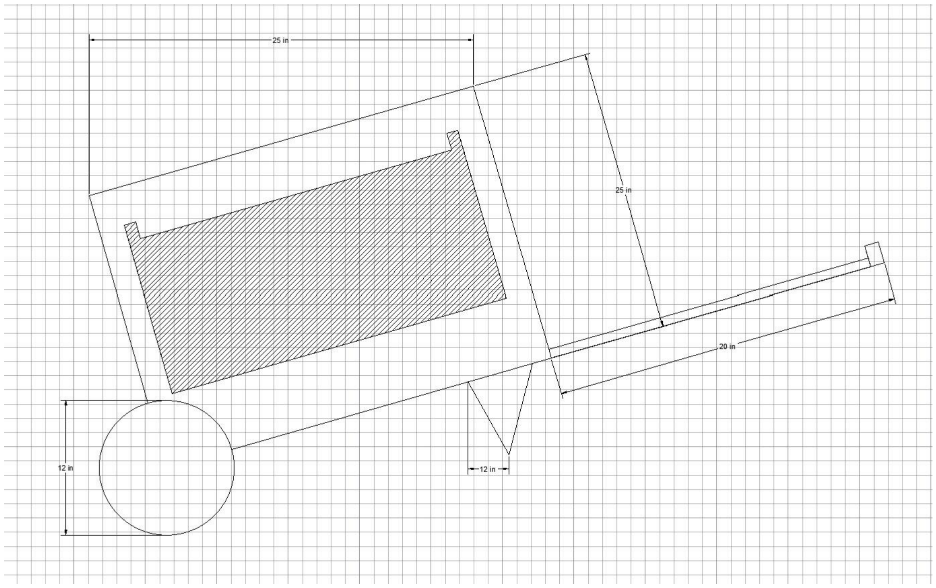

*Figure (6): Solar Panel Frame

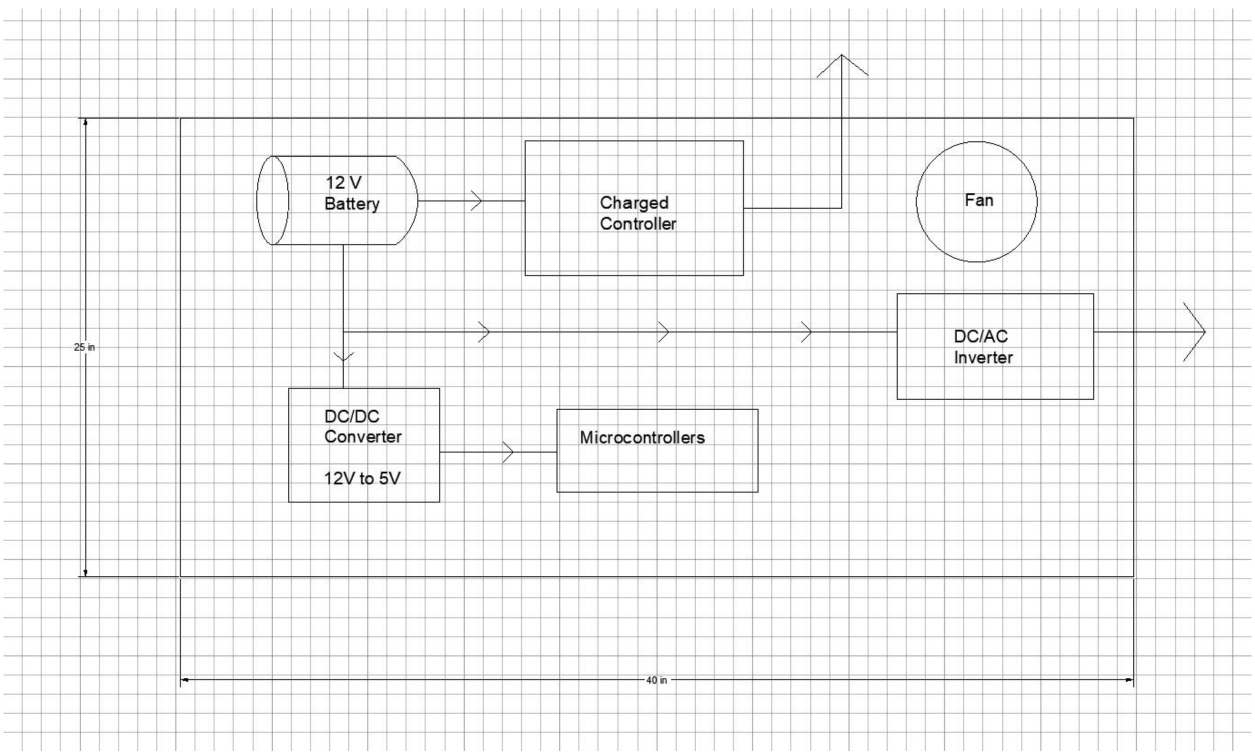

*Figure (7): Interior View of the Structural Base

14.2. Electronic Design Block Diagram

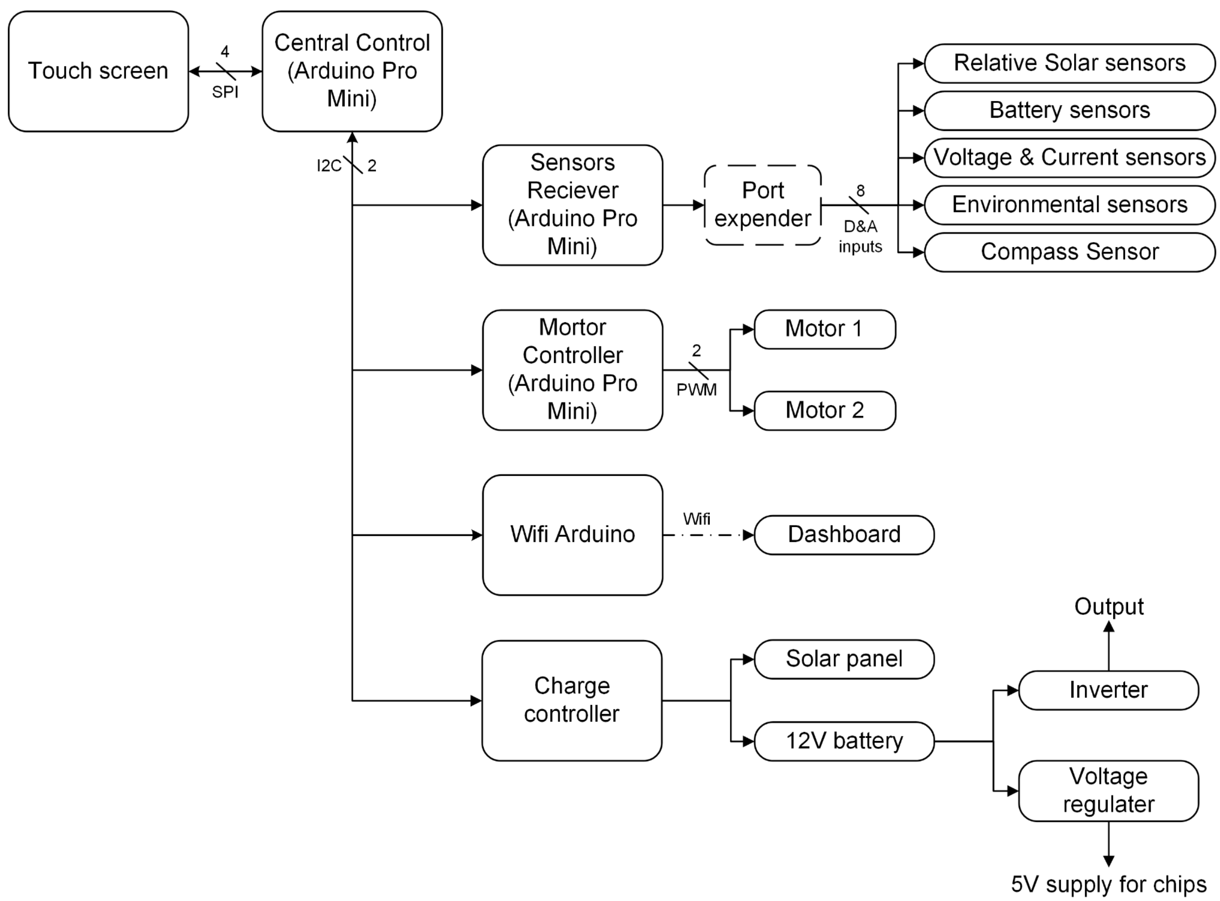

*Figure (8): Electronic Design Block Diagram

The central control, sensor receiver, and mortar controller will be implemented by an Arduino Pro Mini MCU. Since the limited input ports of the board, a port expander is possibly needed to receive multiple digital or analog signals from sensors. Moreover, I2C may not be capable of transmitting wifi data between wifi Arduino and central Arduino while 4-ports SPI would be wanted as an alternative. In that case, a port expander may be needed again to expand SPI ports on the central Arduino.

15. Preliminary Test Procedures

15.1. Unit testing

Battery:

Connect a 12V input device e.g fan across battery terminals

PASS: Fan turns on

FAIL: Fan fails to run

Inverter:

Connect input to battery and output to a 110V outlet.

PASS: Current flows out of outlet

FAIL: No current flow to device connected at outlet

Solar Panel Motors:

Send commands from Arduino to rotate it around

PASS: Motors move in the direction specified by Arduino

FAIL: Motors do not respond to Arduino commands

Solar Panel:

Leave panel in the sun for a while and measure the voltage on an oscilloscope

PASS:Voltage supply is observed across the panel

FAIL: No input is observed - zero DC voltage at the terminals

Charged Controller:

Connect input to a solar panel and output to a fully charged battery

PASS: Battery does not charge further

FAIL: Charged controller indicates continued battery charging

Connect input to a solar panel and output to a partially charged or no charge battery

PASS: Battery starts to charge

FAIL: Battery does not charge.

Light Sensor:

Connect sensor to Arduino and read the values from sensor

PASS:

15.2. Acceptance testing

15.2.1. Terrain

T1. Drive fully assembled generator through different terrains like gravel, sand, and dirt

PASS: Generator wades through all terans without trouble

FAIL: Generator disassembles while being transported

15.2.2. Functionality

T2. Make sure that all actuators, microcontrollers, solar panels, casing, sensors and battery are present as described in the requirements.

Pass: All components are available.

Fail: Some parts are missing.

T3. Observe response of the solar panel to changes in position of the sun

Pass: Solar panels adjust position to track the sun

Fail: Solar panels do not change their alignment in response to the sun's position

T4. Measure the voltage drop across the output terminals of the generator

Pass: Voltage is 110V with frequency 60Hz

Fail: Voltage is either higher or lower than 110V, or no constant voltage output

T5. Confirm that the website displays the operating conditions of the generator

Pass: Website shows a recent report of the generator and updates every now and then

Fail: Website either freezes, shows obsolete information or gives false information

Fail: System runs out of battery in less than 8 hours

15.3. Power Usage

T6. Allow the system to charged battery to full capacity, disconnect solar panels and connect a continuous load of 15 amps to the outlet. Observe usage time.

PASS: System runs for at least 3.2 hours at the rated continuous load of 15 amps

Fail: Systems runs out of battery before 3.2 hours.

T7. Allow the system to charge battery to full capacity, disconnect solar panels and connect a quarter rated load of 15 amps to the outlet. Observe usage time.

Pass: System provides power for at least 8 hours

15.4. Stress testing

This will be testing to see if it satisfies the requirement to "accommodate various but reasonable terrain.". We can do these by basically subjecting it to different terrains under different weather conditions, both extreme and normal.

SURFACE	Windy	Rainy	Storm
Inclined Plane			
Flat Plane			
Rocky Terrain			
Wet terrain			
Grassy terrain			

*Figure (9): Table to be used for test

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16. Solar Kit Study

While planning out the design for our project we decided we wanted to make use of a foldable solar panel, to allow for greater portability. However, this meant we no longer were able to make use of the all in one solar kits we have researched before. While these ktis were convenient, they all came with solar panels that were rigid, as well as being murch larger than what we wanted. Below are the list parts that we will be using in replacement for an all in one solar kit.

16.1. Rational

For the solar panel, we want it to be relatively small and flexible. The Renogy SuitCase hits both of those marks. As the name would suggest, the panel folds up like a suitcase, providing the necessary flexibility. The panels themselves also sport relatively slim dimensions, listed in the table below. The 100 watt rating is also acceptable for what we want from this system. While higher wattage would always be niccr, that comes at the cost of larger solar panels. This panel also had the added bonus over other standalone foldable solar panels in that it came with a charge controller. We've also been looking at an Allpowers solar panel, listed in the table below. However this product does not seem to have a readily available datasheet, making us hesitant to use it.

For the battery, we were also looking for something relatively small. The Renogy battery we picked only weighs 26lbs while still providing the 100Ah and 12V that we are looking for. It also has the added convenience of coming from the same manufacturer as the solar panel, making comptalbiy easier.

For the Sine Wave inverter, we decided to stay in the same brand as the battery and solar panels.

The Renogy inverter is rated for 2000W, which should be just fine for our purposes. The main appeal of this product is the low weight, at only 12 pounds. This is a significant improvement over some of the earlier models we were looking at, at over 50 pounds.

16.2. Optional Parts and Specifications

Part	Vendor	Datasheet	Where to Buy	Specs
Renogy 100 Watt Solar SuitCase(w/ charge controller) B01NADR1CI	Renogy	Link	Link	Max Power: 100W Weight: 19.40 lbs Folded dimensions 21.1 x 21.5 x 3.1in Charge Controller: Rated Charging Current 20A: Normal Battery Voltage: 12V Max Battery Voltage: 17V Dimensions: 6.38 x 3.82 x 1.34 Weight: 0.88 lbs?
ALLPOWERS Foldable Solar Panel 200W, Portable Solar Panel kit			Link	● Huge Power to Output】: ALLPOWERS 200W portable solar panel kit is made in the US, up to 22% efficiency and 1/3 lighter than the same power of solar silicon. 200W Output can provide more power to your devices and charge it faster. ● ▸【Compatible with Most Solar Generators】: ALLPOWERS 200W foldable solar panel is compatible with most portable power stations on the market. The portable solar panel kit includes different sizes of connectors for portable solar generators(MC-4 to Anderson / MC-4 to DC). ● ▸【Waterproof, Durable and safe】: The foldable solar panel 200W constructed with durable and waterproof IP66 nylon and adjustable bracket. The outdoor foldable solar charger is FCC, RoHS, CE certified. It can help your devices receive the most effective sunlight safely. ● ▸【Foldable & Portable】: Folded size only 25.6x20.3x2.4inch,13.9lb, portable solar panel 200W is great for traveling without electricity and won't take up much room in your bag. ALLPOWERS foldable solar charger features MC-4 output(25A max), providing endless power for power stations in camping, outdoor, garden, motorhome, and caravan under the sun.

				● ▸【Package Contents】: ALLPOWERS 200W foldable solar panel, MC-4 to 5.5x2.5mm cable, MC-4 to Anderson cable, DC 8mm adapter, DC 3.5x1.35mm cable, DC 5.5x2.1mm cable, instruction manual, 18 months warranty and friendly customer service.
Renogy 12V 100Ah Battery RBT100LFP12S-G1	Renogy	https://www.renogy.com/content/RBT100LFP12S-G1/LFP100S-Manual.pdf	Link	Rated Capacity 100Ah Nominal Voltage: 12.8V Max Continuous Charging Current: 50A Max Continuous Discharge Current: 100A Dimensions: 11.4 x 6.8 x 7.4 inch Weight: 26 lbs
Renogy Power inverter	Renogy	https://www.renogy.com/content/RNG-INVT-2000-12V-P2/INVT-P2-Manual.pdf	Link	Rated 2000W: Input voltage: 12V Efficiency: > 90% Output voltage: 115V AC Dimension : 17.8 x 8.6 x 4 in Weight 11.7 lbs
MMPT Solar Charge Controller	Renogy		Link	● System Voltage: 12V/24V Auto Recognition (for non-lithium batteries) ● Max Battery Voltage: 32V ● PV Input Voltage Range: 15V – 100V VOC ● Max Power Input: 12V @ 520W; 24V @ 1040W ● Self Consumption: ≤1.5W ● Temperature Compensation: -3mV/℃/2V, excludes LI ● Controller Terminals: 20-6 AWG ● Operating Temperature: -4°F ~ 113°F

*Figure (10): Optional Parts and Specifications Table

16.3. Battery Calculations:

Our battery is rated 100Ah**.** A ninja BN701 Pro Series operates at a max Power of 1400W. In order for a 12V battery to meet this demand, 116 amps will be required. That means if this blender was run continuously it would last for about 51 minutes assuming a full charge. This calculation also assumes 100% efficiency from the inverter, which is not realistic. At the worst possible efficiency 90%, the blender would operate for 46 minutes.

100Ah*12V = 1200W
(1200/1400)*60 = 51 minutes

Another potential usage example is the SLPAC10 AC. This product is rated for 1,150 Watts. At the minimum 90% efficiently this will last for 56 minutes and at max efficiency 62 minutes.

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17. Informational Website

This website will be the main source of focumention for our Senior Design Project. Within the website you will be able to find the main motivation for the problem, design objectives, metrics, and constraints that make up the project. Additionally, the website will identify concepts from courses you have taken that may apply to your problem, and identify any concepts you may need to learn as your project progresses. Any preliminary conceptual designs and test plans produced by the team will be included as well.

Website is constantly evolving as the project progresses and develops further. Current changes being made include updating project specifications and updating standardized diagram labeling.

The website can be found here: Senior Design 2023 Website