

The Solar Stroller

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Contents

1. Introduction.....	3
1.1 Statement of Purpose.....	3
1.2 Objectives.....	3
1.2.1 Goals and Benefits.....	3
1.2.2 Functions and Features.....	3
2. Design.....	4
2.1 Block Diagrams.....	4
2.2 Block Descriptions.....	4
2.2.1 Charging.....	4
2.2.1.1 PV Modules.....	4
2.2.1.2 Junction Box.....	4
2.2.1.3 Charge Controller.....	4
2.2.1.4 Battery.....	5
2.2.2 Controls.....	5
2.2.2.1 Buck Converter.....	5
2.2.2.2 Battery Status.....	5
2.2.2.3 Overcharge Protection.....	5
2.2.3 Load.....	5
2.2.3.1 Light Switch.....	5
2.2.3.2 LED Light Strip.....	6
2.2.3.3 LED Headlamp.....	6
2.2.3.4 USB Port.....	6
3. Requirements and Verification.....	6-9
4. Tolerance Analysis.....	9
5. Cost and Schedule.....	9
5.1 Cost Analysis.....	9
5.1.1 Labor.....	9-10
5.1.2 Parts.....	10
5.1.3 Total Project Cost.....	10
5.2 Schedule.....	11

1. Introduction

1.1 Statement of Purpose

Strollers have been a popular method of baby transport used across different cultures and time periods for children of all ages. Strolling makes life a little easier for the parent in terms of less work of carrying the baby, as well as everything that comes along: the diaper bag, snacks, bottles, toys, and their personal items. Our project aims to make a parent's life more convenient while on the go with their child. The Solar Stroller allows parents to remain active and productive with their child while keeping their electronic devices charged by harnessing the energy from the sunlight or artificial light on the sunroof canopy. Parents can now be worry-free about being away from home with an uncharged phone, tablet, or camera. With this portable source of power, The Solar Stroller can also activate its external LED lighting for visual purposes to others, as well as provide path visibility for the parent in a nighttime setting to ensure the safety of all. Several strollers on the market now with similar powering capabilities, but where the Solar Stroller differentiates itself is its all-in-one solution in providing a power bank to provide for on-board charging and illumination.

1.2 Objectives

1.2.1 Goals and Benefits

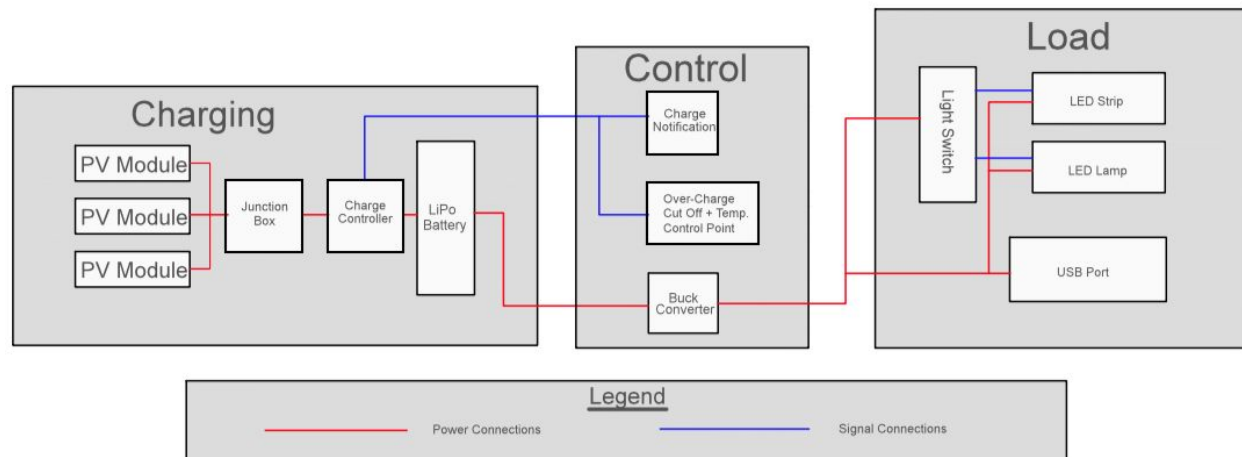
- Increase the parent's productivity while transporting their child
- Portable USB to charge small electronic devices while on-the-go
 - Convenience
 - Emergencies
 - Directions
- Battery powers multiple LED lighting features for safer nighttime travel
- Small user notification to show available battery charge
- PV modules to harness both sun and artificial light for maximum energy storage

1.2.2 Functions and Features

- On-board battery to utilize stored energy while not charging
- PV modules on adjustable sunroof canopy
- Rechargeable 7.4V / 8000mAh LiPo battery for energy storage
- USB 2.0, Type A port located in the bottom storage compartment
- LED light strips and LED headlamp that can be activated for nighttime use

2. Design

2.1 Block Diagram



2.2 Block Descriptions

2.2.1 Charging

2.2.1.1 PV Modules

The 9V 150mA photovoltaic modules on the sunroof canopy of the stroller harnesses both sun and artificial light while providing shade to the child. The energy that is harvested by the solar panels is fed for storage in the battery through the voltage regulator. Ultimately, this harvested energy will be utilized through the LED light features and/or USB port at the user's convenience.

2.2.1.2 Junction Box

The junction box takes the incoming power from the PV Modules and splices them together into the charge controller in the charging block.

2.2.1.3 Charge Controller

The charge controller circuit for the LiPo Battery communicates to the control block with signals to the charge notification, as well as the overcharge protection switch. The charge controller allows for the LiPo batteries to be charged optimally without overcharging. The charge controller is a critical subset to the charging system because it protects the battery life, as well as the user and their child.

2.2.1.3 Battery

The battery used is a 7.4V 8000mAh. This battery is large enough to power a 5W cell phone from dead to full-charge and LED lights for 2 hours on a full charge. The battery stores the energy in the charging block and has the ability to be discharged from the various loads. The battery will be charged using the “1C” rule and discharged using the “20C” rule (discussed in the R&V table below).

2.2.2 Control

2.2.2.1 Buck Converter

In order to make the 7.4V battery applicable for the 5V outputs for the LEDs and USB Port, a Buck Converter is used to convert the voltage while transporting energy from the charging block to the load block. This converter is essential to be able to utilize the harvested energy by the LiPo battery while keeping the power to the loads are an optimum level.

2.2.2.2 Charge Notification

One helpful feature in the control is the user display that shows the available battery charge. With this, the user can determine whether or not to use the stroller at night before recharging it during the day or with artificial light. This allows the user to know approximately how much time the battery will be able to power the stroller’s LED lighting features and USB port for charging their electronic devices.

2.2.2.3 Overcharge/Undercharge Protection

The overcharge protection is fed from a signal coming from the charge controller in the charging block. The overcharge protection will detect if the battery is full, and at that point, will send a signal to the charge controller to isolate the battery from being overcharged. Similarly, the battery cannot fall below below a certain voltage when in use. Doing so will severely degrade the battery. For this reason, we need to make sure that our 7.4V LiPo battery never falls below 6.4V (3.2V per cell) while in use or never charges beyond 8.4V (4.2V per cell). This type of set-up calls for battery balancing for both cells.

2.2.3 Load

2.2.3.1 Light Switch

The Light Switch is a simple metal contact switch and sends signals to the LED Light Strip and LED Headlamp to power on when the switch is closed. The switch will be implemented with a push-button.

2.2.3.2 LED Light Strip

A 5V LED Light Strip acts as an optional load to the battery for nighttime use. The light strip provides external lighting around the stroller for its visibility to others. The energy for the light strip is fed through the buck converter in the control block from the LiPo battery in the charging block. The light switch controls whether the light strip is off or on, corresponding with the switch being open and closed.

2.2.3.3 LED Headlamp

The 1.6W LED Headlamp acts as an optional load to the battery for nighttime use. The headlight provides path lighting in front of the stroller for the parent's use. The energy for the LED Headlamp is fed through the buck converter in the control block from the LiPo battery in the charging block. The light switch controls whether the LED Headlamp is off or on, corresponding with the switch being open and closed.

2.2.3.4 USB Port

The single USB 2.0, type A port acts as an optional load to the battery for the user to portably charge their small electronic devices. The USB Port is fed through the buck converter in the control block from the LiPo battery in the charging block.

3. Requirements and Verification

Requirement	Verification
PV Cells 1) Provide a $9V \pm 1V$, 150mA output in direct sunlight 2) Compatible with charge controller specifications 3) Spatially fit on the canopy of the stroller	1) Measure open circuit voltage, ensure it is 10.8V. Measure short circuit current, ensure it is 165mA with multimeter. 2) Measure PV string voltage and current. Add resistor to charge controller to increase charge current if needed (Consult with Dr. Pilawa). 3) Measure dimensions of modules and stroller canopy. Verify modules fit.
Junction Box/Combiner 1) Combine the output of the PV modules to a single conductor	1) Verify that the component has enough I/O connections to support all of the modules.
Charge Controller 1) Limit voltage/current to battery based on each cell's current charge 2) Ensure combined cells do not exceed	1) Test with fully charged battery. Ensure controller limits voltage/current to prevent over-charge with multimeter.

8.4V 3) Balance charge between cells to ensure overcharge/depletion does not occur 4) Control the flow of current to the “1C” rule 5) Provide MPPT to maintain optimal module performance	2) At full charge ensure each cell is at no more than ~4.2V. 3) Measure cell voltage with a multimeter when the charge controller cuts off the loads. Confirm the voltage is ~3.2V. Measure when charge controller cuts off the PV. Confirm the cell voltage is less than 4.2V 4) Measure charging current to battery with a multimeter. Verify current does not exceed “1C” rule (cannot be charged with more than 1 times the capacity). 5) Consult with Dr. Pilawa
7.4 V LiPo Battery 1) Provide $7.4V \pm 1V$ at full charge 2) Provide appropriate current to load without breaking the “20C” discharge rule.	1) At full charge, measure battery voltage with multimeter. Confirm it is ~8.4V. 2) Test battery under max load. Use multimeter to confirm that battery does not break the “20C” rule (cannot draw more than 20 times the capacity).
7.4 V DC to 5.0 V DC Buck Converter 1) Modify voltage from battery to meet the load requirements of $5V \pm .2V$ 2) Adjust duty ratio to maintain sufficient power to loads 3) Provide multiple outputs to run the various loads (5V 1A - iPhone, 5V 1.6W - LED Lamp, 5V 120mA/2.5” - LED Strips).	1) Measure output voltage with multimeter under equivalent resistive loads to ensure specification is met. 2) Vary the input voltage with a DC power supply to confirm the duty ratio auto-adjusts to maintain a steady output. 3) Measure voltage outputs with various equivalent resistive loads attached using a multimeter. Confirm loads are receiving appropriate power. 4) Probe output with oscilloscope. Confirm ripple is within specification.
Charge Notification 1) Battery voltage output reading 2) Visual representation in LEDs	1) Take voltmeter readings for the range of 6.4V to 8.4V for the LiPo battery for full charge to depleted battery

	2) Determine and test controller to signal red LED for low battery (<6.9V) and signal for charged battery (>8.0V)
Overcharge Protection 1) Overcharge detection 2) Isolation	1) Ensure that the battery balancing circuit can detect when 3.2V is read from either of the two cells 2) Have the protection circuit be able to isolate from the charging circuit once overcharging is detected.
Light Switch 1) Deliver power via metal contact to LEDs 2) Open/close contact in response to physical push from user	1) Inspect switch alone. Press to confirm metal contact closes. Press again to confirm metal contact returns to “open” position. 2) Connect 50-ohm resistor in series with switch. Using a multimeter measure resistance with switch open and closed. While closed multimeter should read value of resistor.
LED Light Strip 1) $5V \leq V_{in} < 6V$ 2) Max 5V @ 120mA/2.5” strip segment	1) Drive LEDs with DC power supply. Verify brightness peaks ~5V. 2) While driving with DC power supply, measure current with multimeter. Confirm it is ~120mA/2.5”.
LED Headlamp 1) $P_{rated} \leq 1.6W$ 2) $4.5V < V_{in} < 5.5V$	1) Drive LED with DC power supply. Verify brightness peaks at ~5V. 2) Measure voltage and current with multimeter to confirm ~1.6W power consumption.
USB Port 2.0, Type A 1) $V_{in} = 5V \pm 0.25V$ 2) $I_{in} = 1.5A$	1) Attach a 5-ohm resistor to output of USB port (iPhone equivalent resistance @ 5V 1A). 2) Measure current and voltage via multimeter to confirm specifications are met.

4. Tolerance Analysis

The most essential component of The Solar Stroller that affects the performance of this project is the power output of the solar panel. The solar panel power output controls the ability to charge the battery and thus, provide a source of power to the USB port and various LED lights. More importantly, this device needs a method of controlling the voltage and current delivered to the battery. This will be implemented via a charge controller.

The charge controller will be required to prevent over-charging, keep the battery at least 20% charged, and ensure each cell of the battery is balanced appropriately. Given that the battery being used is rated at 7.4V and 8000mAh, each cell will have a voltage of 4.2V when fully charged and will contain 4000mAh. With this in mind, each cell should never drop below 3.2V to prevent internal damage to the battery. In contrast, the charge controller must also ensure that the cumulative battery voltage does not exceed 8.4V. If it does, this will result in over-charging which causes internal damage to the battery. In addition, the charge controller must be able to follow the “1C” rule to ensure safe charging. This means that the battery will be charged with 1 times the capacity (8000mAh) until each cell reaches $4.2V \pm 0.5\%$. Once each cell is fully charged the controller will work to keep a constant voltage of 4.2V on the battery until the charge current drops below 0.2C. The last feature of this charge controller is recharging the battery safely if the cell voltage should drop below $\sim 2.8V$. If this occurs, the controller must provide a 0.1C charge current until the cell is charged back to its safe zone of $\sim 2.8V$, it will then resume charging at 1C.

5. Cost and Schedule

5.1 Cost Analysis

5.1.1 Labor

Total cost of labor is determined by the hourly rate multiplied by the number of hours the project will take to complete, and multiplied by 2.5 to emulate the cost to the engineering company.

Name	Hours Invested	Hourly Rate	Cost factor to Engineering Co.	Total Cost
Jeffrey Calhoun	220	\$33.00	2.5	\$18,150.00
Jamie Padilla	220	\$33.00	2.5	\$18,150.00
Mike Replogle	220	\$33.00	2.5	\$18,150.00
Total	660	\$99.00		\$54,450.00

5.1.2 Parts

Item	Quantity	Total Cost
Sundance Solar 9V 150mA Solar Cell	10-12	\$100-130
Vant Battery 7.4V 8000mAh 2S Cell 40C-80C LiPo Battery Pack: Vant Battery: VAN2S4690	1	\$50.00
Adafruit Digital RGB 5V LED Strip	1	\$29.95
Piranha LED Light Board	1	\$2.37
Molex, LLC USB Port 2.0	1	\$1.24
Kolcraft Cloud Umbrella Stroller	1	\$29.99
3-10VDC to 5VDC buck converter	1	\$3-8 (TBDesigned)
MCP73213 Dual-Cell Li-Ion/Li-Polymer Battery Charge Management Controller with Input Overvoltage Protection	1	\$1.79
Various Resistors, Capacitors, Inductors	Various	\$5.00
Total		\$223.24-258.34

5.1.3 Total Project Cost

The total project cost is determined based on the sum of costs for labor and parts.

Section	Total
Labor	\$54,450.00
Parts	\$223.24 - \$258.34
Grand Total	\$54,673.24 - \$54,708.34

5.2 Schedule

Week	Task	Responsibility			
		ALL	JC	JP	MR
7-Feb	Prepare and Finalize Project Proposal - Power Consumption Analysis - Solar Panels - Battery, Analog Controls	X	X	X	X
14-Feb	Prepare Mock Design Review - Order Parts - Begin Buck Converter - Begin Charge Controller		X	X	X
21-Feb	Prepare Design Review	X			
28-Feb	Finalize Design Review	X			
6-Mar	Begin prototype building: - PV Array - Converter - Charge Controller		X	X	X
13-Mar	Complete PCB Layout	X			
20-Mar	Construct Prototype	X			
27-Mar	Run Initial System Testing	X			
3-Apr	Testing and Debugging System	X			
10-Apr	Optimization	X			
17-Apr	Prepare Project Demonstration	X			
24-Apr	Finalize Project Demonstration	X			
1-May	Finalize Project Presentation Finalize Final Paper Lab Checkout	X X X			