Solar Charging Subsystem

Oregon State University
Group #12

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Design Impact Statement

It is evident that generating electricity from the solar panel instead of fossil fuels reduces greenhouse gas emissions. Greenhouse gas emissions lead to global temperature increase and climate change. By going solar, we can reduce demand for fossil fuels, which leads to very few air pollutants. Solar panels produce far lower greenhouse gas (GHG), fine particulate matter (PM 2.5), sulfur dioxide (SO2), carbon dioxide (CO2), and nitrogen oxides (NOx), all of which cause health problems [1]. According to the evidence from the National Renewable Energy Laboratory (NREL), solar power decreases the cases of chronic bronchitis, respiratory and cardiovascular problems [2]. As the NREL states, solar panels are safe and beneficial because they don't produce greenhouse gases or any toxic air.

Since lithium polymer batteries require lithium, the manufacturing of LiPo batteries could have cultural and social impacts. There have been many problems with the Ganzizhou Rongda lithium mine in Tibet. Fish in the nearby river were found dead following a chemical leak from the mine [3]. Mining lithium for the manufacturing of LiPo batteries can cause a negative impact on the culture of Tibet. Chile, another country with lots of lithium, is also affected. Mining lithium in Chile leaves big holes that destroy local habitats and polluting nearby grasslands and rivers [3]. The production of the LiPo battery we are using could have affected countries similar to Chile and Tibet.

Using a LiPo battery in our project has a lot of environmental impacts. Mining lithium for lithium battery manufacturing can cause lots of environmental damage [3]. Disposing lithium batteries also causes environmental damage [4]. There are many negative impacts to the environment from using a LiPo battery in our project. But there are some positive impacts. We are also using solar panels in our project to charge the batteries. Using solar panels to recharge the battery can help reduce the amount of batteries we dispose of. The less lithium batteries we dispose of and use the more we can help the environment. Looking at the bigger picture, solar panels can also be used to reduce carbon emissions. It provides a positive net environmental impact [5].

With increasing technological innovations and improvements, there have been cheaper and better solar charging systems that can be incorporated into our daily lives. Although using a solar powered system is beneficial, there are disadvantages to some people. One of the reasons is that the cost of energy is high and it can increase substantially [6]. People who live in a rural area or have not enough financial support, then it doesn't always make financial sense to install an energy storage system. As a member of this project, I can say that even making a smaller version of a solar charging system requires different knowledge on numerous concepts. If making a larger version of this product, the complicity of the solar system also increases. Also, the right type of environment or enough space might always not be available.

Project Timeline

The purpose of creating a project timeline is to track the chronological order of events. This gives us an understanding of a project at just a glance, keeping the group informed. The reason why we're choosing a gantt chart to create a project timeline is because it conveys information visually. This gives us an instant overview of a project, its associated tasks, and when these need to be finished. The project goal is to complete all of the required meetings, assignments, and any tasks before the due date, and have our project completed by May 12. We want to utilize this timeline efficiently to keep track of what's coming and what's being done.

Solar Charging Subsystems Timeline

Oregon State University

Project Start Date: 9/30/2020 (Wednesday) Display Week: 3

Project Manager: Donald Heer

Week 3 12 Oct 2020 | Week 4 19 Oct 2020 | Week 5 26 Oct 2020 | Week 6 2 Nov 2020 | Week 7 9 Nov 2020 | Week 8 16 Nov 2020 | Week 9 23 Nov 2020 | Week 10 30 Nov 2020

WBS	Task	Lead	Start	End	Days	% Done	Work Days
1	**Benchmarks**	[Name]					
1.1	Prototype	Field, C	Mon 11/02/20	Fri 12/11/20	39	100%	30
1.2	BOM Selection	Kim,J.	Mon 11/02/20	Fri 12/11/20	39	100%	
1.3	Circuit Design	All	Mon 11/02/20	Fri 12/11/20	39	100%	
1.4	Circuit Simulation	All	Mon 11/02/20	Fri 12/11/20	39	100%	
1.5	PCB Fabrication	All	Mon 11/02/20	Fri 12/11/20	39	100%	
1.6	PCB Testing	All	Mon 11/02/20	Fri 12/11/20	39	100%	
1.7	Code Debugging	Field, C	Mon 11/02/20	Fri 12/11/20	39	100%	
1.8	Order Parts	Kim, J.	Mon 11/02/20	Fri 12/11/20	39	100%	
2	**Milestone**	[Name]					
2.1	Tech Demo Check	All	Mon 10/12/20	Fri 12/11/20	1	100%	45
2.2	Block 1 Check-off	All		Week 13	1	100%	
2.3	Block 2 Check-off	All		Week 16		100%	
2.4	Final Block Check-off	All		Week 19		100%	
2.5	Initial System Check-off	All		Week 24		100%	
2.6	FInial System Check-off	All		Week 27		100%	
2.7	Senior Expo	All		Week 29		0%	
2.8	Party	All		Week 30		0%	

WBS	Task	Lead	Start	End	Days	% Done	Work Days
3	**Technical Demonstration**	[Name]					
3.1	Circuit and Layout	Field, C	Mon 10/12/20	Fri 12/11/20	1	100%	45
3.2	Circuit and Layout	Kim, J.	Mon 10/12/20	Fri 12/11/20	1	100%	45
3.3	Circuit and Layout	Chen, J	Mon 10/12/20	Fri 12/11/20	1	100%	45
3.4	[Insert new rows above this one, then hide or delete this row]						
4	**Meetings**	[Name]					
4.1	Introductory Meeting w/Proj	Kim, J.	Mon 10/12/20	Mon 10/12/20	1	100%	1
4.2	Biweekly Progress Video #1	Field, C	Thu 10/15/20	Thu 10/15/20	1	100%	1
4.3	Scope and Requirements M	Kim, J.	Mon 10/19/20	Mon 10/19/20	1	100%	1
4.4	Biweekly Progress Video #2	Field, C	Thu 10/22/20	Thu 10/22/20	1	100%	1
4.5	Meeting with Project Partne	Kim, J.	Tue 10/27/20	Tue 10/27/20	1	100%	1
4.6	Team Communication Evalu	Kim, J.	Thu 11/05/20	Thu 11/05/20	1	100%	1
4.7	Biweekly Progress Video #3	Field, C	Thu 11/05/20	Thu 11/05/20	1	100%	1
4.8	Instructor System Architectu	Kim, J.	Mon 11/09/20	Mon 11/09/20	1	100%	1
4.9	Meeting With Project Partne	Kim, J.	Tue 11/10/20	Tue 11/10/20	1	100%	1
4.10	Biweekly Progress Video #4	Field, C	Tue 11/10/20	Thu 11/19/20	1	100%	8
4.11	Meeting with Project Partne	Kim, J.	Tue 11/10/20	Tue 11/24/20	1	100%	11
4.12	Biweekly Progress Video #5	Field, C	Tue 11/10/20	Thu 12/03/20	1	100%	18

WBS	Task	Lead	Start	End	Days	% Done	Work Days
4.12	Biweekly Progress Video #5	Field, C	Tue 11/10/20	Thu 12/03/20	1	100%	18
4.13	[Insert new rows above this one, then hide or delete this row]						
5	**Group Assignment**	[Name]					
5.1	Engineering Requirements I	All	Wed 10/14/20	Thu 11/26/20	1	100%	32
5.2	Team Protocols and Standa	All	Wed 10/14/20	Thu 10/15/20	1	100%	2
5.3	Risk Register Assignment	Field, C	Wed 10/14/20	Thu 10/15/20	1	100%	2
5.4	Risk Register Assignment	Kim, J.	Wed 10/14/20	Thu 10/15/20	1	100%	2
5.5	Risk Register Assignment	Chen, J	Wed 10/14/20	Thu 10/15/20	1	100%	2
5.6	Block Diagram Draft	All	Wed 11/04/20	Thu 11/26/20	1	100%	17
5.7	Project Charter Assignment	All	Tue 11/10/20	Thu 11/12/20	1	100%	3
5.8	[Insert new rows above this one, then hide or delete this row]						
6	**Professional Development**	[Name]					
6.1	Professional Development A	Field, C	Thu 10/15/20	Sun 11/29/20	1	100%	32
6.2	Professional Development	Kim, J.	Thu 10/15/20	Sun 11/29/20	1	100%	32
6.3	Professional Development A	Chen, J	Mon 10/12/20	Sun 11/29/20	1	100%	35

Scope & Engineering Requirements Summary

The scope of this project will be two fully functional designs for a solar charging subsystem; a low output current (100mA) design and a high output current (5A) design will constitute the main deliverables. The designs will be small, solar powered, contain their own battery and have schematic and pcb layouts that are easy for ECE students to read/modify/manufacture.

The engineering requirements of this project are listed below. The first requirement is that the system must report state of charge information accurately, which will be achieved using a Coulomb counter with the appropriate resolution. The second requirement is that the system must be at least 90% efficient in the power flow from the solar cell to the output. The third requirement is that the system output must be controlled by an enable signal, additionally, when disabled the system will drain no more than twice the battery self-discharge rate. The fourth requirement is that the system will communicate all relevant data over an I2C serial interface. The fifth and sixth requirements are that the high and low current designs will provide reliable output for Y hours and X hours, respectively, which will be determined by the capacity of the battery chosen. The seventh requirement is that the system designs should have easy-to-read KiCAD files, which will be tested via a doodle poll 7 question quiz for ECE capstone seniors based on viewing of our system schematic. The final eighth requirement is that the low and high current designs will properly charge when used with a specific voltage range of solar panels.

1. **Customer Requirement:** The system must provide information over a serial communication interface
   Engineering Requirement: The system must provide S.O.C., battery voltage, and current data via I2C

2. **Customer Requirement:** The system must use Coulomb Counter in both designs
Engineering Requirement: The system must report remaining amp-hours correctly within 5% Ah for both the 100mA and 5A design.

3. **Customer Requirement:** The system must be as energy efficient as possible.
Engineering Requirement: The system must lose no more than 10% power when transferred from solar cell to the output.

4. **Customer Requirement:** The system must be able to be controlled from another system
Engineering Requirement: The system must have an enable signal that when disabled, the system will drain no more than twice the battery self discharge rate.

5. **Customer Requirement:** The system must have a high current design
Engineering Requirement: The high current design must provide 5A for at least 6 minutes.

6. **Customer Requirement:** The system must have a low current design
Engineering Requirement: The low current design must provide 100mA or at least 15 minutes.

7. **Customer Requirement:** The system should be "plug and play."
Engineering Requirement: The system must have schematics and PCB design files that are easy to read for 9 out of 10 ECE seniors who can answer a 7 question technical quiz about the design after viewing the schematic for 5 minutes. Q1. What serial communication protocol is being used between the coulomb counter and the microcontroller? Q2. What section of the system must be changed to have different output current? Q3. What type converter is being used on the charging circuit? Q4. What resistor must be changed to alter the resolution of the coulomb counter? Q5. Does the schematic contain a battery protection circuitry? Q6. Does the microcontroller in the design provide information to the external users? Q7. Based on these two design files, which one is the high current design and which one is the low current design?

8. **Customer Requirement:** The system must be solar powered
Engineering Requirement: The LC System will charge with panels between 1.5V and 5V while the HC System will charge from at least 12V.

Risk Register

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance Indicator	Responsible Party	Action Plan
R1	Estimating/scheduling errors due to time conflict for each member	Planning, Program management, Timeline, communication	10%	L	Text or email notification, regulatory meeting	Student B will look at each member's schedule to figure out the best time to meet	Reduce, stick to the schedule and show up
R2	Weather could interrupt solar panel testing protocols	External, environmental, facilities	30%	M	Highly divergent temperatures , weather channel	Student C will keep an eye on the forecast and maintain testing schedule	Retain, postpone testing is needed
R3	Vendor delay could interrupt board assembly and testing protocols	Cost, technical, external	30%	M	Email from vendor, news regarding COVID	Student A will keep an eye on the supplies deadline due to COVID situation	Retain, buy extra components/ parts
R4	Incompatible interface can cause system malfunction	Technical, communication	20%	H	Specs and requirement not matching, feedback from project parner, datasheet mismatch	Student B will investigate any missing information	Reduce, clearly states definitions before testing

R5	Limited lab access can delay technical demonstration due to COVID situation	Technical, facilities, planning	10%	M	Doodle poll sign up for lab access, email notification from class	Student A will schedule for a lab manufacture r the board	Retain, get lab access at Kelly if needed

Pretty much every risk register listed above occurred during our project life cycle. Because our project involved using a solar panel as an input (light source) and the system review happened in early spring, the weather interrupted the solar panel testing protocols. Due to COVID, we had vendor delay as well as limited lab access, which interfered with assembly and testing protocols. Luckily, we did not have incompatible interfaces, which didn't cause a system malfunction. One lesson learned throughout this process is to plan ahead and correspond our test dates with good weather so we don't get inaccurate readings from the solar panels. We also learned to plan ahead and reserve lab spots early due to the limited lab availability.

Future Recommendations

Recommendation	Reasoning	Starting Point
1. Choose SMD components with large metrics (2512+ for passives). Use through hole components as much as possible.	Our team chose 0805 metrics for our SMD components and had a lot of difficulty with soldering. Accidentally losing components also became a huge issue when they fell off of a workstation onto the floor and were impossible to locate. We had only one larger SMD resistor at 2512 metric and it was significantly easier to work with than 0805. Additionally, through hole components were in general much easier to use than SMD components.	When working on the design, make sure to check the actual dimensions for available components before finalizing. It will save a lot of time. You may find the component you are relying on is not available in a reasonable size for soldering..
2. Heavily simulate and test circuits early on in the design stage (fall-winter terms).	Our team did not begin construction for many of the required circuits until spring term. We discovered many	After coming up with basic initial circuit designs, heavily simulate them in SPICE and plot transient results of

	issues that in some cases required a complete redesign of entire blocks, which thus resulted in an extremely heavy workload that could have been prevented by early testing and simulation.	current and voltage versus time to make sure the circuitry is behaving exactly as expected. Purchase components and test them on a protoboard with an oscilloscope or multimeter. Do this as early as possible.
3. When designing battery protection, use high side PMOS transistors instead of NMOS low side transistors.	Our team used NMOS battery protection which created a lot of ground voltage issues due to the on resistance of the MOSFET. This can be avoided with high side PMOS that allows the whole circuit to be on the same ground.	When selecting PMOS transistors, it is very important to make sure they have a maximum drain current rating that exceeds the output requirements. It is also very important to make sure the PMOS is “logic-level” drive, which means that they turn fully on at $\|V_{gs}\| <= \sim 5V$. Ideally they should be fully on at $\|V_{gs}\| = V_{batt}$.
4. Use wide 2oz copper traces for high current designs.	Our team waited too long to order our PCB and thus could not order a board with 2oz copper since the shipping time would have put us past the due date. As such with the 1oz copper option we had to make ridiculously wide traces for a 5A output, which in turn made PCB layout much more tedious and difficult.	Finish testing and simulation early on so that time is not an issue for ordering the right board. Plan on 2oz copper board shipping times from the beginning for high current designs. Use a PCB trace width calculator (many available online) and make the traces to be a factor larger than the minimum.
5. For high current designs, use multiple lithium ion cells in parallel.	Our team’s design only uses one lithium ion battery. This results in a low capacity for the high current design. Connecting multiple identical lithium ion cells in parallel would increase the capacity by a factor of = (# cells)*(cell capacity). This would greatly improve the system’s total battery life and allow for longer usage duration.	Find your target duration in hours and load current in amps, then multiply to find the amp hour capacity required and use that to determine the number of batteries needed in parallel. Make sure parallel connected batteries are identical and are at the exact same voltage to prevent damage. Also, use a larger charging current.

6. Use 18650 lithium ion battery cells.	Initially our team was using rectangular 3.7v lithium ion cells that use Micro JST connectors. These batteries were very difficult to work with due to built in protection circuits and no direct access to the terminals. Switching to 18650 cylindrical cells made our lives a lot easier due to direct access to the terminals and no built in protection circuits.	Lots of high capacity 18650 cells can be purchased from 18650 battery store website: https://www.18650batterystore.com/ I recommend the Samsung batteries, some of which are rated at fairly high continuous discharge currents of >20A.
7. Use an adjustable voltage regulator to limit output current by connecting a resistor to the Vout pin and connecting the ADJ pin to the end of the resistor.	Initially our team selected a specialized IC to be our high side switch/current limiter. This component ended up being so small and practically non solderable that we had to redesign our output control block completely. The redesign was using a PMOS as the switch and an adjustable voltage regulator as a current limiter, which worked very well and was much simpler to use.	This youtube video really helped me understand how to limit output current with an adjustable voltage regulator: https://www.youtube.com/watch?v=bT_cLojINhk[7] Since the regulator maintains a fixed voltage between Vout and ADJ, connecting ADJ to the end of a resistor connected to Vout creates a fixed current through the resistor. The output load connects to the resistor in series and now it can only draw a maximum current given by Vref/R. Vref is the fixed voltage between Vout and ADJ and can be found in the datasheet of the regulator you decide to choose. Make sure the maximum output current rating of the regulator is larger than the maximum current given by Vref/R.
8. Use a TP4056 module(s) to charge the batteries.	Our team used TP4056 modules and from the beginning they worked very reliably and consistently for the whole project duration. They are very cheap and can	Connect the battery terminals to +B and -B. Connect the solar panel terminals to +/-. I recommend buying the modules off of amazon with prime shipping:

	be found easily on amazon. They also come with a micro USB connector which means they can easily charge the batteries from a computer or a wall adapter if needed. They also have built in overcharge protection which makes designing battery protection circuitry a lot simpler.	https://www.amazon.com/HiLetgo-Lithium-Battery-Charging-Protect/dp/B00LTQU2RK/ref=sr_1_3?dchild=1&keywords=Tp4056&qid=1621495904&sr=8-3
9. For high current designs, use heatsinks for power mosfets and other ICs that are in the high current path.	Without a heatsink our current limiting voltage regulator was going into thermal shutdown every 15 seconds when outputting >5A. After solving a thermal resistance network calculation and attaching a heatsink with the proper theta, our system could steadily provide 5A without ever getting close to thermal shutdown.	Use a thermal resistance network to calculate the required heat sink theta. In addition, apply thermal paste between the transistor and the heatsink. If a metal enclosure is used, design the system such that high temperature components can dissipate heat into the enclosure.
10. For I2C communications, use polling and not interrupts.	Since I2C has only one interrupt vector in AVR chips and there are a lot of different situations that cause the microcontroller to jump to that vector, it is not very simple to implement a single interrupt service routine to handle every one of these situations. Switching to polling makes handling I2C communications a lot simpler and more effective.	Use an external I/O pin as a global indicator to notify all devices on the network when the bus is being used. This will prevent collisions and allow for smoother and simpler communications via polling.

References

[1] *The Environmental and Public Health Benefits of Achieving High Penetration of Solar Energy in the United States, EERE.* [Online]. Available: https://www.energy.gov/eere/solar (visited 4/15/2021).

[2] *The Environmental and Public health Benefits of Achieving High Penetrations of Solar Energy in the United States, NREL.* [Online]. Available: https://www.nrel.gov/docs/f y16osti/65628.pdf (visited 4/15/2021).

[3] *"Is the Nobel Prize-winning lithium-ion battery really having a positive impact on the environment?,"NS Energy. [O*nline]. Available:https://www.nsenergybusiness.com/features/lithium-ion-battery-environmental-impact/ .[Accessed: 17-Apr-2021].

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[6] *Solar Power 101: Advantages & Disadvantages, Environmental Science.* [Online]. Available: https://www.environmentalscience.org/solar-power-101(visited 2/25/2021).

[7]*Back to Basics II: Adjustable Current Regulator with the LM317*. https://www.youtube.com/watch?v=bT_cLojINhk&t=13s YouTube, 2018.