Design of an Electrical Power System for a PocketQube

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Introduction

The primary objective of this project is to design and implement an Electrical Power System (EPS) tailored for a PocketQube picosatellite. This system harvests solar energy through the utilization of Maximum Power Point Tracking (MPPT) technology. The EPS will efficiently store and manage solar energy in batteries, subsequently powering the satellite's bus system and various subsystems through either the solar cells or batteries serving as a crucial lifeline to the satellite.

Research Questions:

- **Question 1:** How much energy is needed and available for the PocketQube?
- **Question 2:** How can we harvest this energy as efficiently as possible?
- **Question 3:** How should the energy be stored and distributed to other subsystems of the PocketQube?
- **Question 4:**How can we implement all this onto a PCB with the PQ9 physical constraints 1P form factor?

Literature Review

The PocketQube Standard

The PQ9 "1P" form factor and CS214 PocketQube standards were researched to gain an understanding of the platform being built on.

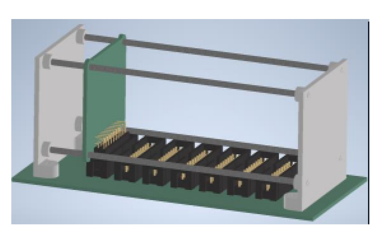
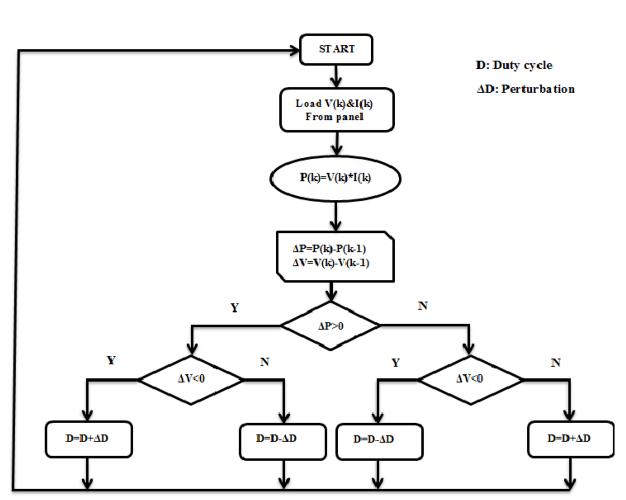


Figure 1. The PocketQube Structure [3].

Maximum Power Point Tracking (MPPT)

The main algorithm used for MPPT was the Perturb & Observe Algorithm. Which adjusts the output voltage of the panel through PWM of a buck/boost converter according to the below algorithm.



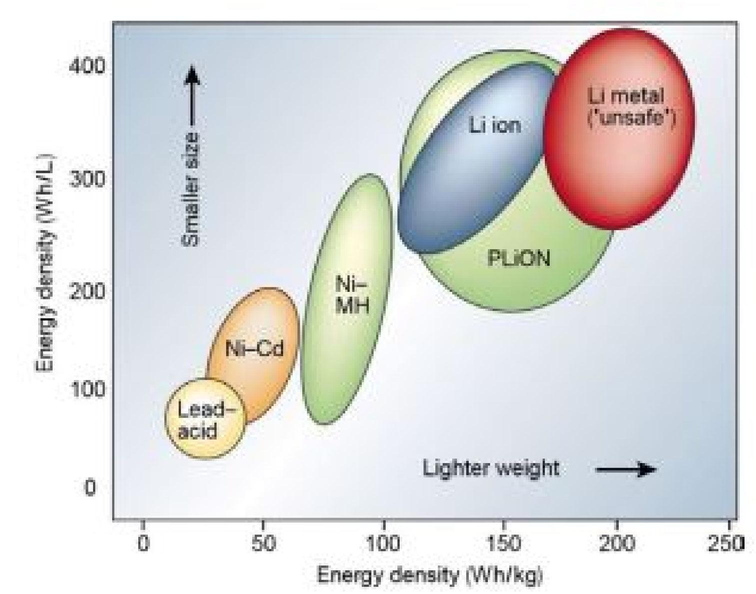
Research Objectives

- **Objective 1:** Asses and quantify the energy requirements of a PocketQube mission under various operational scenarios.
- **Objective 2:** Investigate, optimize and design efficient energy harvesting systems that maximise power under varying conditions.
- **Objective 3:** Explore energy storage options and develop an efficient energy distribution system to supply power to different subsystems.
- **Objective 4:** Design and validate a PCB layout that accommodates energy harvesting, storage, and distribution components within the constraints of the PQ9 1P form factor.

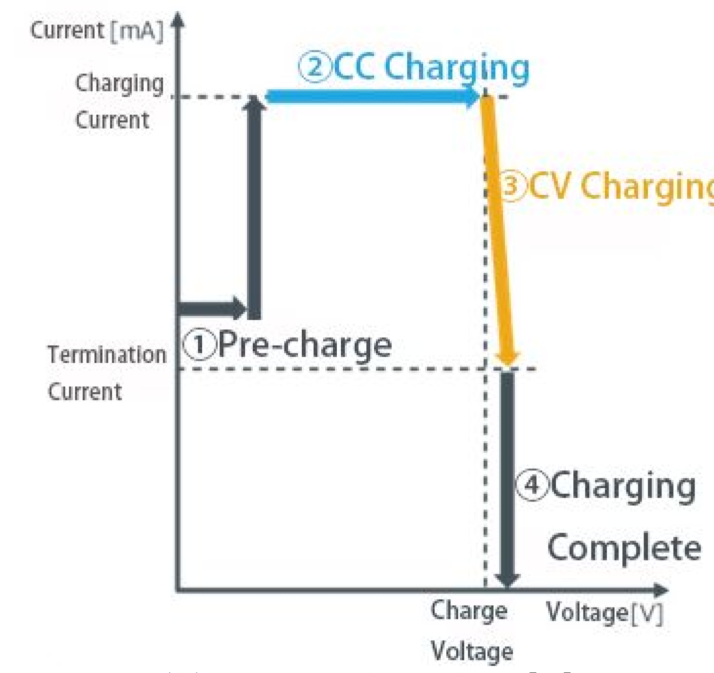
Literature Review

Battery Management Systems

Lithium ion batteries will serve as the main energy source during eclipse periods due to its high energy density. The battries will be charged using the CCCV algorithm.



(a) Li-ion energy density [2].



(b) CCCV Algorithm [1].

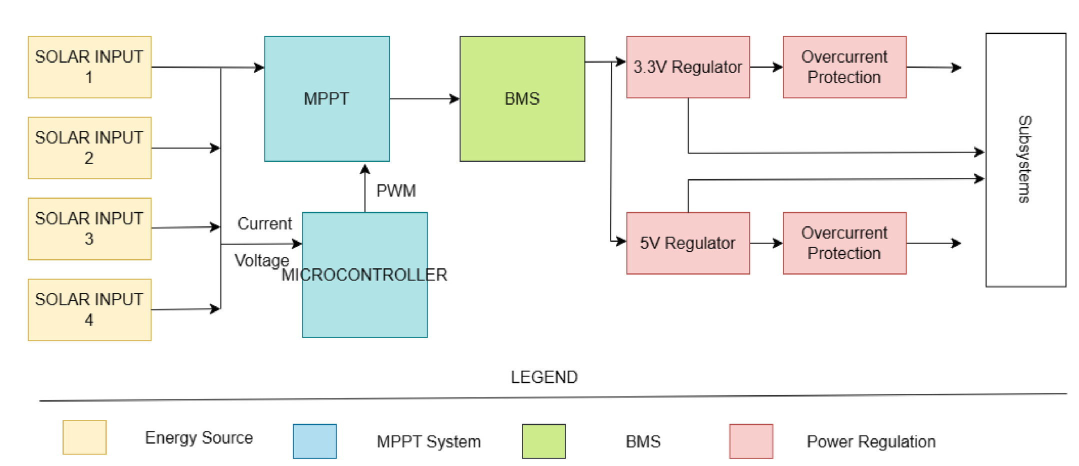
Power Regulation and distribution

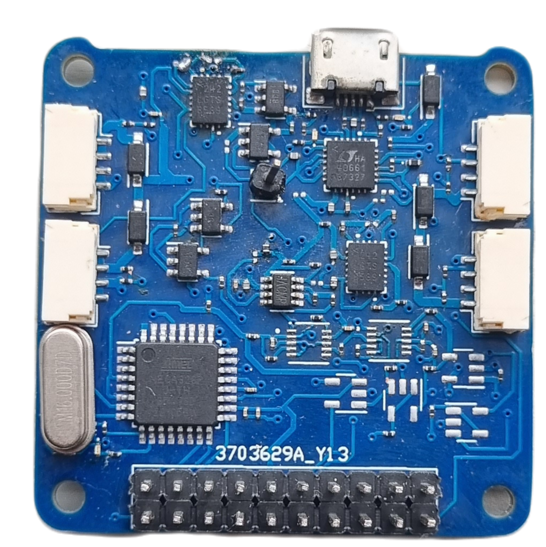
Buck and Boost converters will be the main methods of stepping voltages up or down due to its high efficiency capabilities.

Results and Discussion

PCB

A PCB was designed and realised according to a proposed system diagram containing a energy harvesting, battery management and power regulation and distribution system.





Regulators

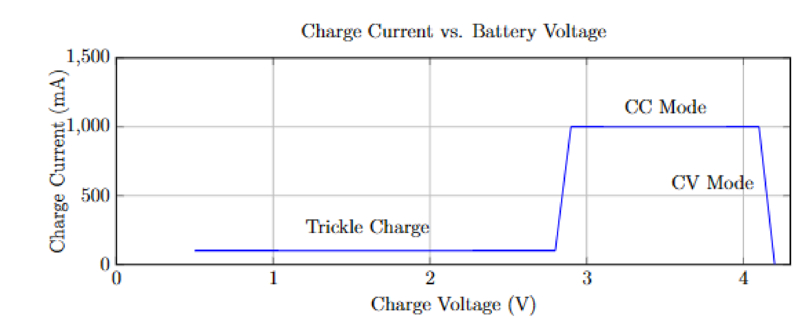
Regulator	Load Condition	Output Voltage (V)	Output Current (mA)	Efficiency (%)
LTC3130-1	Light Load	3.3	110	85
	Heavy Load	3.3	400	82
MP3414	Light Load	3.6	50	86
	Heavy Load	3.6	650	88

The Regulators delivered an average efficiency of 85%. The MP3414 failed to deliver 5V due to the wrong component being ordered.

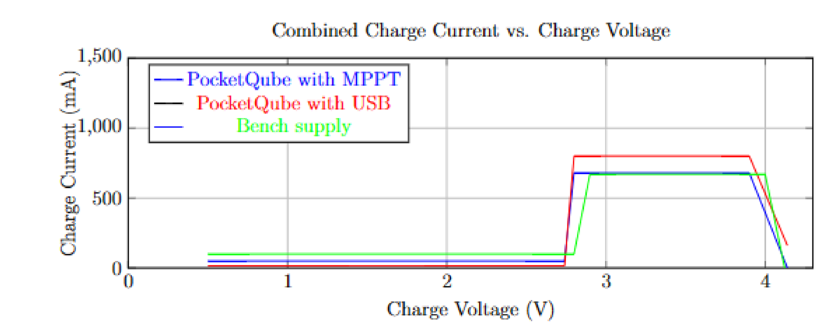
Results and Discussion

Battery Management System

The BMS was expected to charge the battery at a constant charge current of 1A and switch over to the constant voltage charge at 4.1V until eventually reaching 100% SOC. The BMS also has protection features such as overvoltage, undervoltage and short circuit protection.



(a) BMS Expected results.

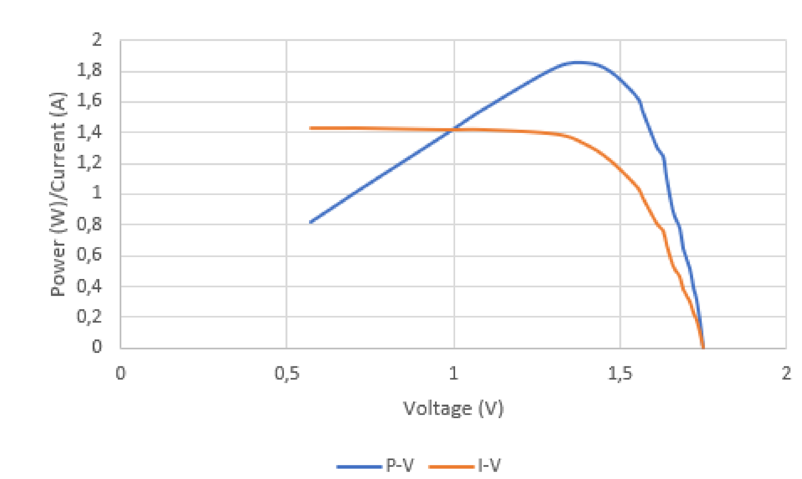


(b) BMS Actual Results.

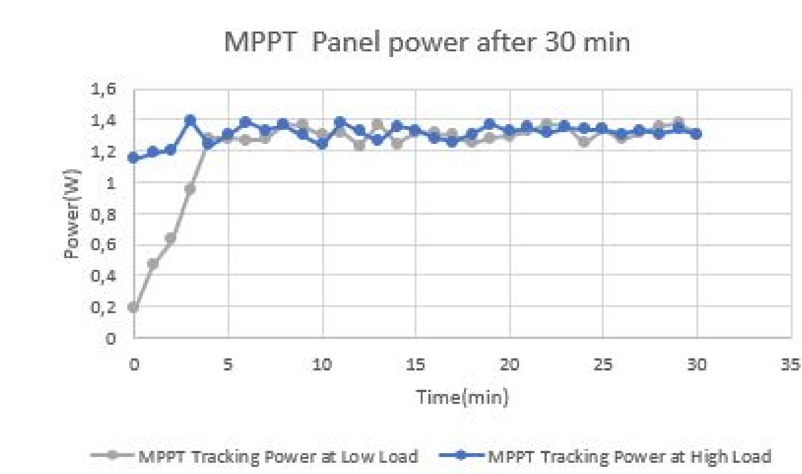
The BMS successfully charged the battery through multiple methods such as a bench supply, USB and the MPPT. The deviation from the expected charge current was due to the source not being able to supply enough current for both the load and the BMS. The protection features worked according to the design parameters.

MPPT

The MPPT is expected to track and deliver 1.8W of power.



(a) MPPT Expected results.



(b) MPPT Actual Results.

The MPPT actually delivered around 1.3W of power after 4 min of running the P&o algorithm.

Conclusions

- **MPPT:** Tracked the MPP at 1.3W, a 30% deviation from what was expected.
- **BMS:** Successfully charged the battery according to the CCCV algorithm while providing protection against overvoltage, undervoltage and short circuits to the battery.
- **Regulators** Delivered power at an average of 85% efficiency to the lines of the subsystems.

References

[1] Charging method | charge control ics | electronics basics | rohm. `https://www.rohm.com/electronics-basics/battery-charge/charging-method`, 2023. Accessed: 2023-10-22.

[2] Da Deng. Li-ion batteries: basics, progress, and challenges. *Energy Science Engineering*, 3, 09 2015.

[3] S. Radu, M.S. Uludag, S. Speretta, J. Bouwmeester, A. Menicucci, A. Cervone, A. Dunn, T. Walkinshaw, P.L. Kaled Da Cas, C. Cappelleti, and F. Graziani. PocketQube Mechanical Interface Standard. DataverseNL, 2018.