Power Distribution System for a CubeSat

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Contents

Objective

To design and implement a fully autonomous power generation, storage and distribution system for a CubeSat

Project Outline

Electrical Power System (EPS):

- Harvests energy from the solar panels
- Manages power storage and distribution
- Protects circuits from damage
- Redundant architecture

Literature Review

S.No.	Title	Author	Features
1	A Comprehensive Review on CubeSat Electrical Power System Architectures, in IEEE Transactions on Power Electronics, vol. 37, no. 3, pp. 3161-3177, March 2022	Amarendra Edpuganti , Vinod Khadkikar, Mohamed Shawky El Moursi, Hatem Zeineldin , Naji Al-Sayari, Khalifa Al Hosani	Architecture with PPT an regulated DC-bus was selected.
2	Output power analysis of Tel-USat electrical power system, AIP Conference Proceedings 2226, 030007 (2020)	Aulia Indana, Dharu Arseno, Edwar, Adilla Safira	Centralised architecture was selected.
3	Comparison of Peak Power Tracking Based Electric Power System Architecture for CubeSats, IEEE Transactions on Industry Applications, vol. 57, no. 3, pp. 2758-2768, May-June 2021	A. Edpuganti, V. Khadkikar, H. Zeineldin, M. S. E. Moursi, M. Al Hosani	Peak power transfer is preferred to direct power transfer.

Literature Review (contd...)

S.No	Title and Journal	Author	Features
4	A Review of Battery Technology in CubeSats and Small Satellite Solutions,Energies, vol. 13, 2020	Knap, Vaclav & Vestergaard, Lars & Stroe, Daniel-Ioan	Solar cells with Li-ion batteries for storage is preferred.
5	Review on the charging techniques of a Li-Ion battery, Third International Conference on Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE), 2015	E. Ayoub and N. Karami	Charging at 5-45°C

Methodology

- Identifying the power requirements
- Architecture design and topology selection
- Forming Specifications
- Design and simulation
- Procurement of components
- Fabrication and testing

Power Budget

Sub-system		Voltage (V)	Max. Current (mA)	Power (mW)	Contingency 5%	Margin 20%	Duty Cycle (%)	Energy (Wh)
ADCS	ADCS	3.3	20	66	69.3	83.16	100	0.133725438
	Magnetorquer	3.3	100	330	346.5	415.8	50	0.334313595
OBC	OBC	5	40	200	210	252	100	0.4052286
Rx-Tx	Telemetry	5	300	1500	1575	1890	11	0.334313595
	Beacon	5	20	100	105	126	100	0.2026143
	GPS	3.3	40	132	138.6	166.32	30	0.0802352628
Payload	LoRa	5	20	100	105	126	10	0.02026143
EPS	EPS	-	-	160	168	201.6	100	0.32418288
	Thermal	-	-	250	262.5	315	32	0.16209144
					Tot Power(mW)	**3575.88**	**Tot. Energy**	**1.997**

System Architecture

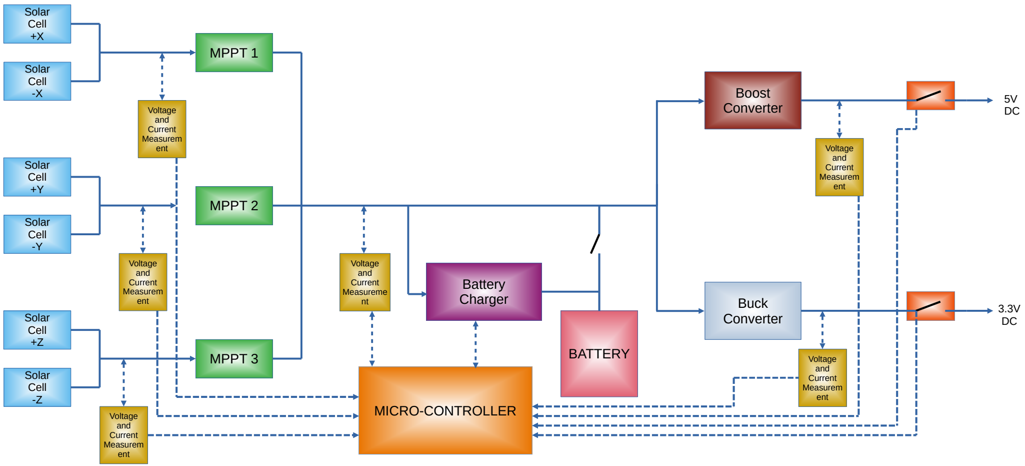

Figure 1: CubeSat EPS Architecture

Hardware Design - Buck and Boost Converters

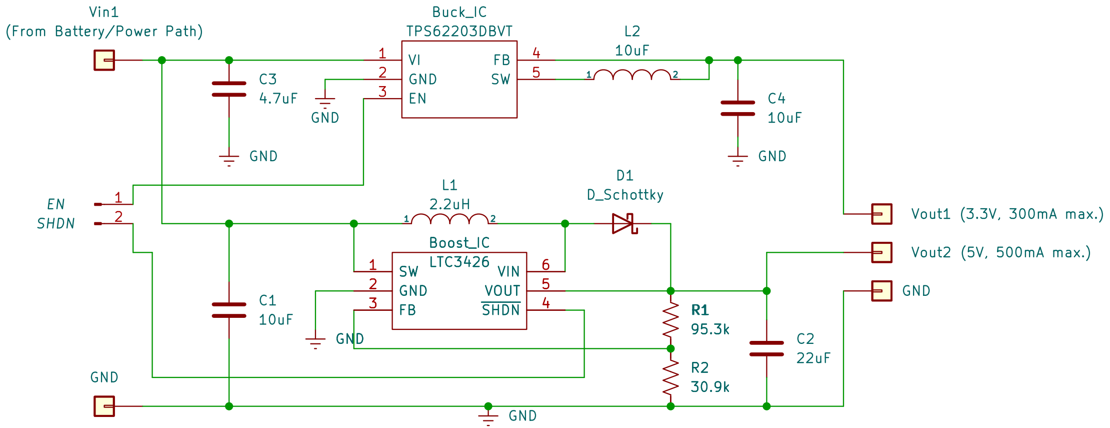

Figure 2: Circuit design of buck and boost converters.

Hardware Design - Buck and Boost Converters (Contd.)

Buck Converter:

- IC: TPS62203
- Input Voltage: 3.6 - 5V
- Output Voltage: 3.3V
- Switching Frequency: 1MHz
- Output Current: 300mA (max.)

Boost Converter:

- IC: LTC3426
- Input Voltage: 3.6 - 5V
- Output Voltage: 5V
- Switching Frequency: 1.2MHz
- Output Current: 500mA (max.)

All convertors operate in continuous conduction mode.

Hardware Design - Battery Charger

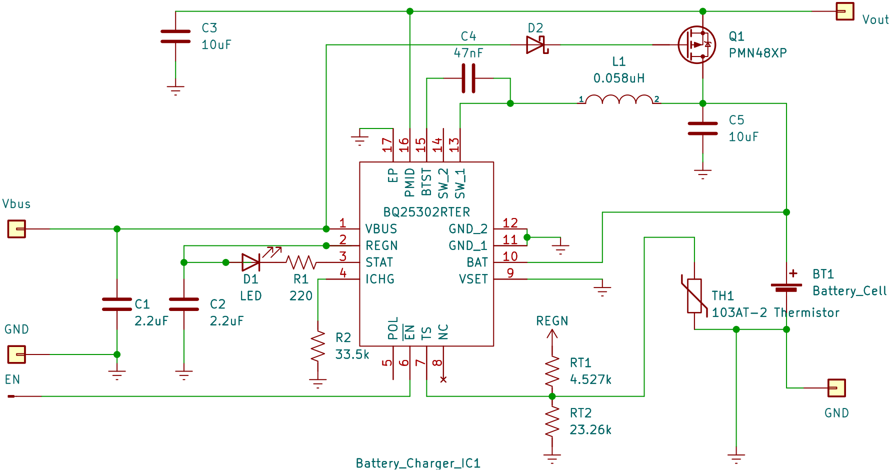

Figure 3: Circuit design of Battery Charger

Hardware Design - Battery Charger (Contd.)

Synchronous Buck Battery Charger:

- IC: BQ25302 (With External Power Path configuration)
- Input Voltage: 5V
- Output Voltage: 4.2V (max.)
- Switching Frequency: 1.2MHz
- Output Current: Limited to 1.2A
- Thermistor: Semitec 103AT-2 (10kΩ)
- Charging Temperature: Limited between 0 - 45 C

Hardware Design - MPPT

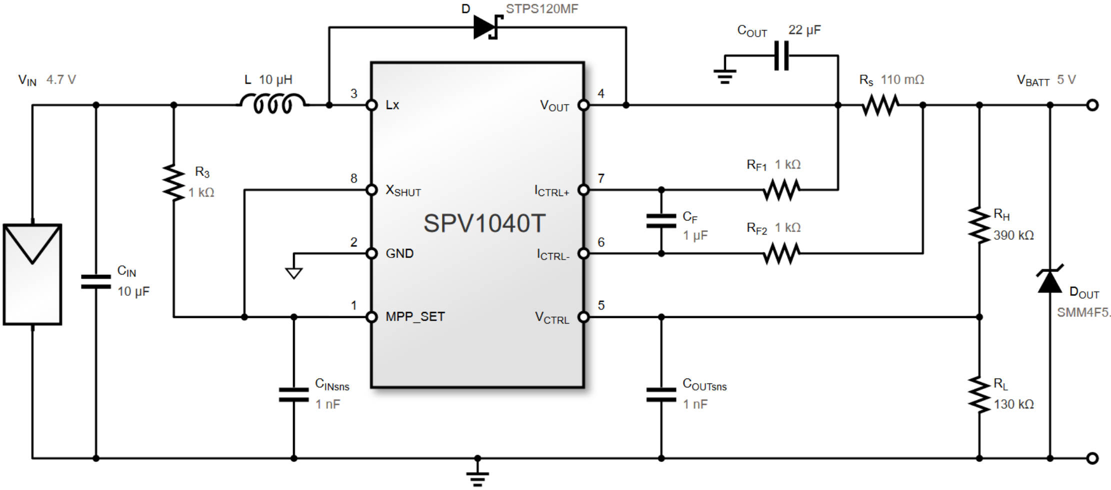

Figure 4: Circuit design of MPPT.

Hardware Design - MPPT (Contd.)

- IC: SPV1040
- MPPT with Perturb and Observe algorithm
- Input Voltage: 0.3 - 5.5V
- Output Voltage: 5V
- Switching Frequency: 100kHz
- Inbuilt over-current, temperature protection
- Efficiency: 95%

Hardware Design - Microcontroller

STM 32:

- CPU: ARM 32-bit Cortex M4
- Flash memory: 512KB
- Up to 81 I/O ports with interrupt capability
- Up to 78 fast I/Os up to 42 MHz
- 3 x I2C interfaces, 3 USARTs, 4 SPIs
- All I/O ports are 5 V-tolerant

Hardware Design - Solar panels

Solar panel:

- TJ Solar Cell 3G30C
- 30% Triple Junction GaAs Junction Solar Cell
- Average Open Circuit Voltage: 2.7V
- Maximum Power Point Voltage: 2.41V
- Average Short Circuit Current: 520.2 mA
- Maximum Power Point Current: 504.4mA
- Average Efficiency at 1353 W/m^2: 29.8%

Hardware Design - Solar panels (Contd.)

Solar panel:

- Each side has 2 cells in series
- Max. current per side: 0.5A
- Panels on opposite faces are connected in parallel
- Max. voltage per side: $<$4.8V

Hardware Design - Battery

Battery:

- Panasonic NCR 18650 GA Li Ion cell
- Voltage: 3.7V - 4.2V
- Capacity: 3500mAh
- 1800 cycles till capacity reduces to 60%

Hardware Design - Voltage and Current monitoring IC

- IC: LTC 2990
- Quad input
- Voltage and Current Monitoring
- Communication via I2C serial interface

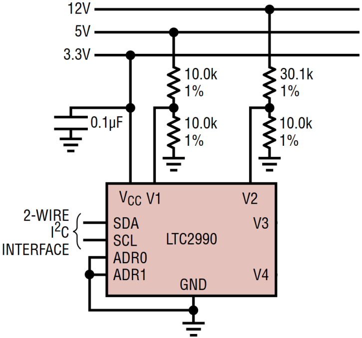

Figure 5: LTC2990

Circuit protection

- IC: LTC4361-2
- Over voltage and over current protection
- Auto reset after the event
- Mosfet used as switch

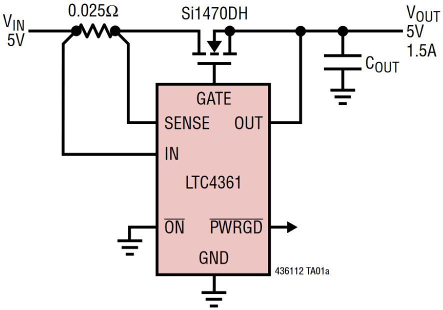

Figure 6: LTC4361-2 Overvoltage/Overcurrent Protection Controller

Requirements

Equipments Requirements:

- SMD Soldering Station
- Oscilloscope
- Power Supply
- Function Generator

Software Requirements:

- MATLAB/Spice
- KiCad
- STM32 CubeIDE

Budget Estimate: Component cost

Sl No.	Component	Description	No.	Cost per unit	Total Cost
1	SPV1040T	MPPT IC	6	400	2400
2	BQ25302	Battery Charger IC	2	150	300
3	NCR18650	Battery	2	800	1600
4	TPS62203DBVTGH	Buck Converter	2	150	300
5	LTC3426ES6#TRPBF	Boost Converter	2	500	1000
6	LTC2990CMS#TRPBF	Voltage, Current Measuring	5	560	2800
7	LTC 4361CT68-1	Overvoltage, overcurrent protection	5	500	2500
8	STM 32 F401RE	Microcontroller	1	2500	2500
9	Miscellaneous costs				2000
					15400

Budget Estimate: Fabrication cost

Sl. No.	**Item**	**Amount (Rs.)**
1	PCB Printing	5000
2	SMD soldering	990
3	Inductor Fabrication	1000

Project Timeline

Activity	Oct week 3-4	Nov week 1-2	Nov week 3-4	Dec week 1-2	Dec week 3-4
Literature Review					
Hardware Design					
Report Writing					
Component selection					
Component Procurement					

References

[1] Knap, Vaclav & Vestergaard, Lars & Stroe, Daniel-Ioan (2020)
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Third International Conference on Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE), 2015, pp. 50-55

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Thank You