Power Distribution System for a CubeSat

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May 19, 2023

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Contents

Objective

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

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

System Architecture

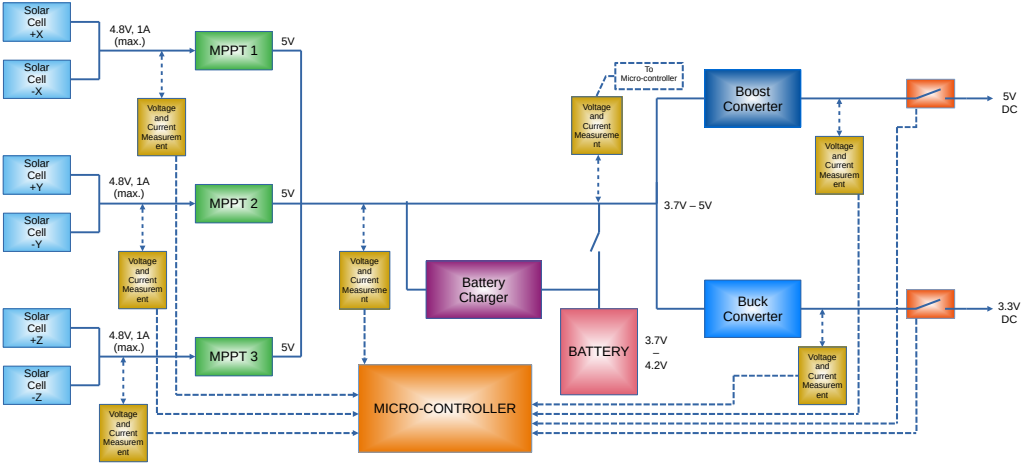

Figure 1: CubeSat EPS Architecture

Hardware Design - Buck and Boost Converters with Monitoring

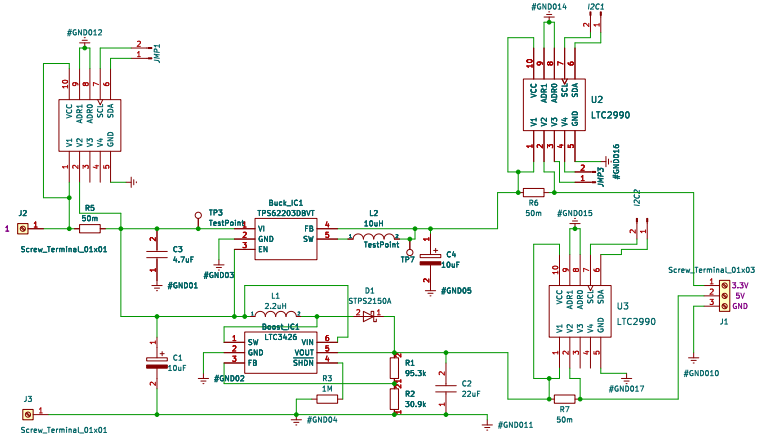

Figure 2: Circuit design of buck and boost converters with monitoring

Hardware Design - Buck and Boost Converters (Contd.)

Synchronous Buck Converter: TPS62203

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

Boost Converter: LTC3426

- Input Voltage: 3.6 - 5V
- Output Voltage: 5V
- Switching Frequency: 1.2MHz
- Output Current: 800mA (max.)

All converters operate in continuous conduction mode.

Hardware Design - Buck and Boost Converters with Monitoring (Contd.)

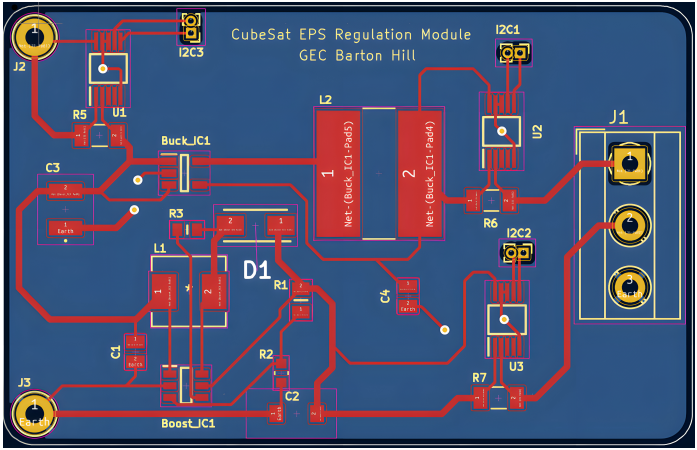

Figure 3: PCB Layout of buck and boost converters with monitoring (55mm x 35mm)

Hardware Design - Buck and Boost Converters with Monitoring (Contd.)

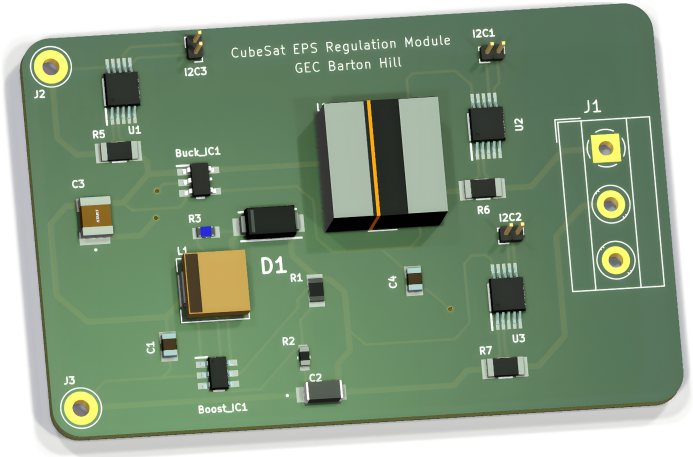

Figure 4: 3-D model of buck and boost converters with monitoring

Hardware Design - Voltage and Current monitoring IC

- IC: LTC 2990
- Operating Voltage: 2.9V - 5.5V
- Quad input
- 14 bit ADC
- Voltage ($\pm$0.1V accuracy) and Current Monitoring
- Inbuilt Internal Temperature Monitoring ($\pm$0.5°C Accuracy, 0.06°C Resolution)
- Communication via I2C serial interface

Hardware Design - Battery Charger

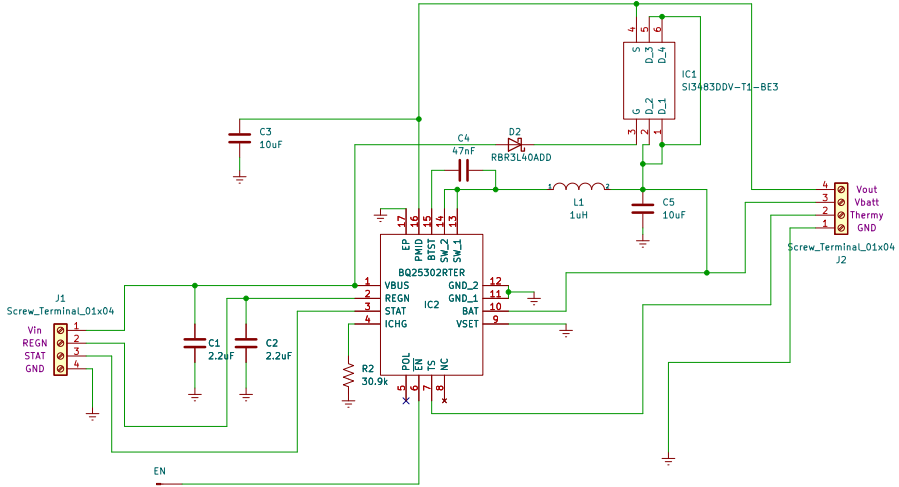

Figure 5: Circuit design of Battery Charger

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
- Track width: 0.25mm
- Power Path Track width: 0.52mm

Hardware Design - Battery Charger (Contd.)

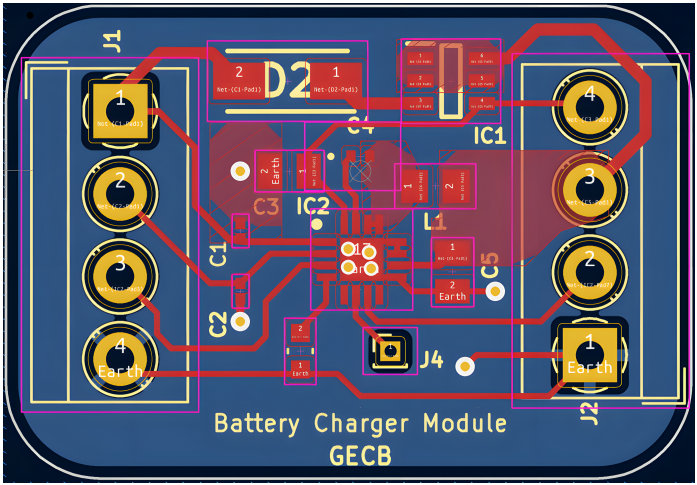

Figure 6: PCB Layout of Battery Charger (29mm x 20mm)

Hardware Design - Battery Charger (Contd.)

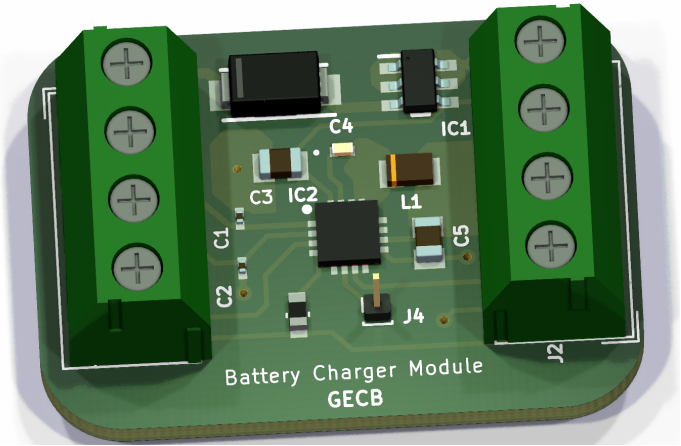

Figure 7: 3-D model of Battery Charger

Hardware Design - Maximum Peak Power Transfer (MPPT)

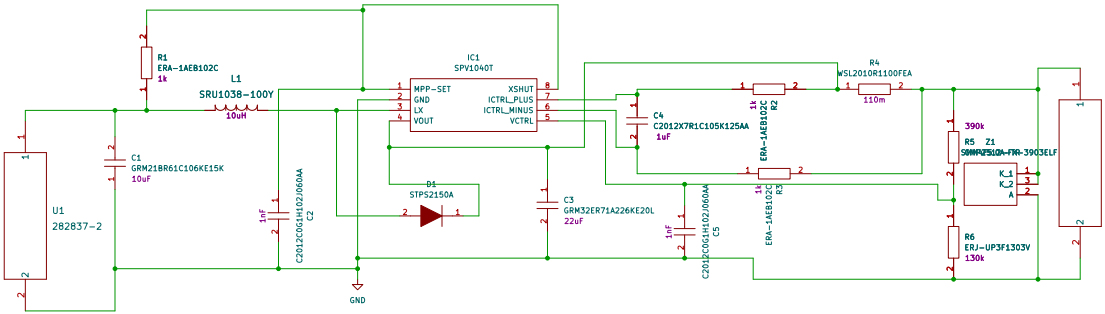

Figure 8: Circuit design of MPPT

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 - MPPT (Contd.)

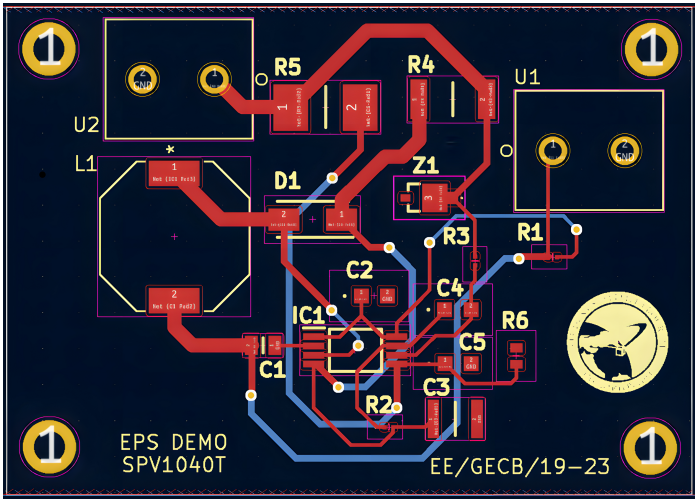

Figure 9: PCB Layout of MPPT (48mm x 34mm)

Hardware Design - MPPT (Contd.)

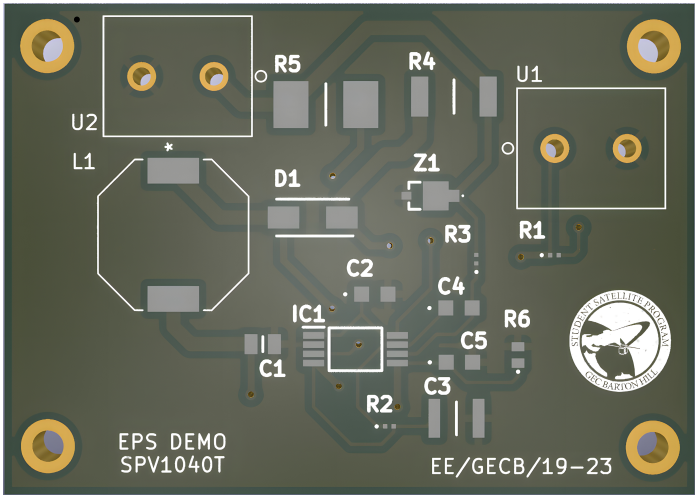

Figure 10: 3-D model of MPPT

Bill of Materials

Sl NO.	MANUFACTURER PART#	DESCRIPTION	QUANTITY
1	C1210C475K4RACAUTO	Multilayer Ceramic Capacitors MLCC - SMD/SMT 16V 4.7uF X7R 1210 10% AEC-Q200	4
2	ERA-1AEB102C	Thin Film Resistors - SMD 0201 1Kohm 0.1% 25ppm	10
3	C2012X7R1C105K125AA	Multilayer Ceramic Capacitors MLCC - SMD/SMT 1.0UF 16V 10% 0805	4
4	MCT0603MD1004BP500	Thin Film Resistors - SMD .125W 1Mohms .1% 0603 25ppm	4
5	WSL2010R1100FEA	Current Sense Resistors - SMD 1/2watt .11ohms 1%	4
6	SI3483DDV-T1-BE3	MOSFET P-CHANNEL 30-V (D-S)	4
7	CMP2512-FX-3903ELF	Thick Film Resistors - SMD ResHighPower 2512 390k 1% 1.5W TC100	4
8	C2012C0G1H102J060AA	Multilayer Ceramic Capacitors MLCC - SMD/SMT	6
9	ERJ-PB6B3002V	Thick Film Resistors - SMD 0805 Anti-Surge Res. 0.1%, 30Kohm	4
10	GRM32ER71A226KE20L	Multilayer Ceramic Capacitors MLCC - SMD/SMT	4
11	GRM21BR61C106KE15K	Multilayer Ceramic Capacitors MLCC - SMD/SMT 10UF 16V 10% 0805	10
12	ERJ-UP3F1303V	Thick Film Resistors - SMD 0603 Anti-sulfurated anti-surge resistor	4
13	CL03A225KP3CRNC	Multilayer Ceramic Capacitors MLCC - SMD/SMT X5R, 2.2uF, +/-10%, 10v, 0201	6
14	0805YC106KAT2A	Multilayer Ceramic Capacitors MLCC - SMD/SMT 16V 10uF X7R 0805 10%	11
15	RC0603FR-0730K9L	Thick Film Resistors - SMD 30.9 kOhms 100mW 0603 1%	7
16	SRN1060-100M	Power Inductors - SMD 10uH 20% SMD 1060	4
17	IHLP2020CZER2R2M8A	Power Inductors - SMD 2.2uH 6.6A 26Mohm	5
18	C1005X8R1C473M050BB	Multilayer Ceramic Capacitors MLCC - SMD/SMT	10
19	LTC3426ES6#TRMPBF	Switching Voltage Regulators 1.2MHz Boost DC/DC Conv in SOT-23	3
20	SPV1040T	Battery Management Hi efficiency solar battery charger	3
21	CR0805-FX-9532ELF	Thick Film Resistors - SMD 95.3K 1%	5
22	WSLP1206R0500FEA	Current Sense Resistors - SMD 1Watt 0.05Ohms 1%	10
23	C3216JB1C226M160AB	Multilayer Ceramic Capacitors MLCC - SMD/SMT	4
24	STPS2150A	Schottky Diodes & Rectifiers 2.0 Amp 150 Volt	5
25	SRU1038-100Y	Power Inductors - SMD 10uH 30% SMD 1038	4
26	IHHP0805ZHER1R0M01	Power Inductors - SMD 0805 1uH 20%	4
27	LTC2990CMS#PBF	I2C V, C & Temp Mon	3
28	LTC4361CDC-2#TRMPBF	Overvoltage/Overcurrent Prot Cntr	3
29	TPS62203DBVT	Switching Voltage Regulators 3.3V Out Hi-Eff Step-Down Converter	3
30	BQ25302RTER	Li ion Battery Charger	3
31	511-SMM4F5.0	ESD Suppressors / TVS Diodes 400W HI JCT TMP	3
32	STPS2150A	Schottky Diodes & Rectifiers 2.0 Amp 150 Volt	3

PCB Specifications

- Manufacturer: ROBU.IN
- Material: FR-4 (Flame retardant epoxy resin and glass fabric composite)
- Board Thickness: 1.6mm
- Surface finish: HASL[1](with lead)
- Finished Outer Layer Copper: 1 oz
- Finished Inner Layer Copper: 0.5 oz
- PTH[2] Via diameters: 0.8 mm, 0.6mm (For thermal)
- PTH Via hole: 0.4 mm
- No. of boards: 4 designs x 5 pcs.
- Total cost: Rs. 3096

[1] Hot Air Solder Levelling

[2] Plated Through Hole

Hardware Testing- MPPT

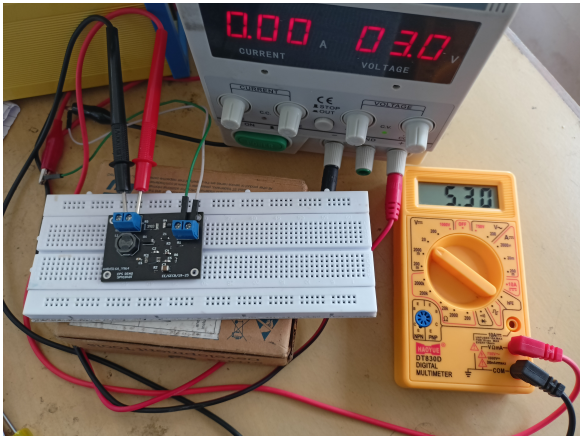

Figure 11: MPPT output

Hardware Testing- Boost circuit

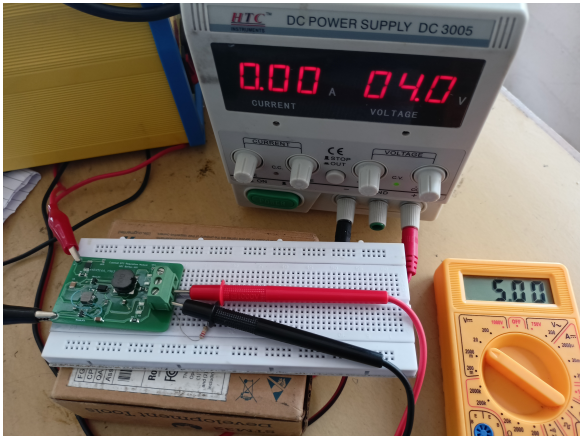

Figure 12: Boost converter output

Hardware Testing- Buck circuit

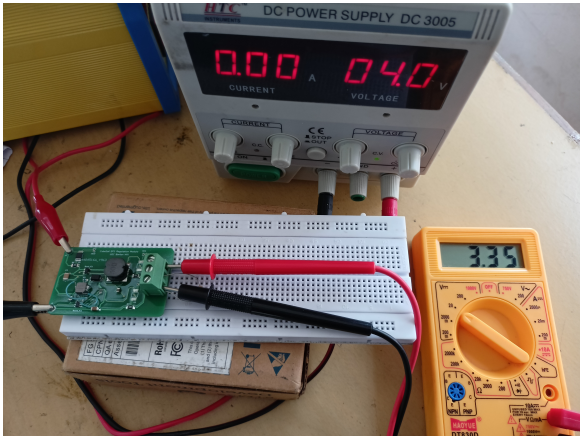

Figure 13: Buck converter output

Hardware Testing: Battery charger

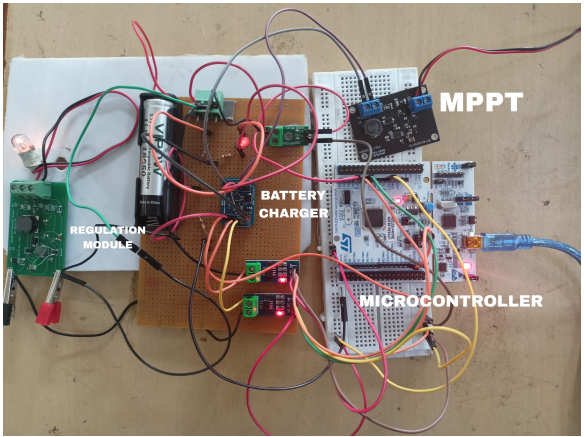

Figure 14: Battery charger testing setup

Hardware Testing: Battery charger

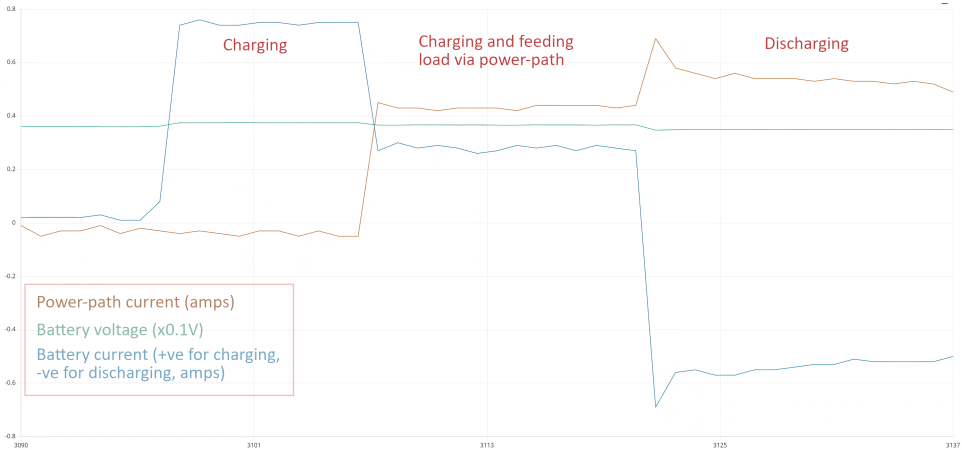

Figure 15: Battery Charger: Modes of Operation

Work Accomplished

- PCB design, fabrication and soldering
- Preliminary testing of all modules
- STM32 Programming:
  - Flash Memory access
  - I2C detection
  - Battery charger test setup automation

Work to be Accomplished

- Development of Variable Load using MOSFETs for testing
- Testing
  - Line regulation
  - Load regulation
  - Startup Dynamics
  - Thermal Stabilization

  STM32 Programming:
  - I2C interfacing
- Final PCB design as per PC/104 specifications

Project Timeline

Activity	Jan week 3-4	Feb week 1-2	Feb week 3-4	Mar week 1-2	Mar week 3-4	Apr week 1-2	Apr week 3-4	May week 1-3
PCB design and fabrication								
Component procurement								
Microcontroller programming								
Soldering								
Troubleshooting								
Testing								
Report Writing								

References

[1] Knap, Vaclav & Vestergaard, Lars & Stroe, Daniel-Ioan (2020)
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[2] A. Edpuganti, V. Khadkikar, H. Zeineldin, M. S. E. Moursi and M. Al Hosani (2021)
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IEEE Transactions on Industry Applications, vol. 57, no. 3, pp. 2758-2768, May-June 2021

[3] E. Ayoub and N. Karami (2015)
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[7] PC/104 Embedded Consortium (2008)
PC/104 Specification Version 2.6

Thank You