Telemetry Balkan doo

Open Battery Pack

Architecture Design

v 0.2.0

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Contents

Overview

This document covers the basic architecture aspects of Open Battery Pack OPB-1. More detailed information about the operation principles, schematics, communication protocol and firmware/software algorithms can be found in the appropriate documents referenced here.

Revision History

Version	Date	Author	Changes	Notes
0.1.0	2022-12-25	Sergei L	Original Version	
0.2.0	2023-02-17	Sergei L	Added PCB and Schematics for main board	
0.3.0	2023-02-20	Sergei L	Described the charge level estimation algorithm	

Goals

The development of the open-source power bank pursued the following goals:

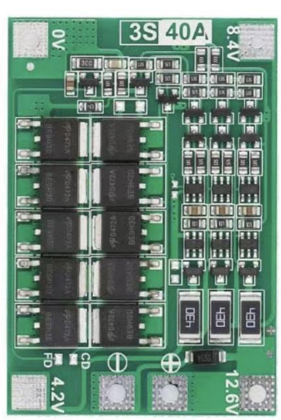
- Implement the power-bank with a stabilized configurable DC output and non-stabilized DC output, so that it can power both the computational modules and the power mechanism
- Allow the power bank to be charged, while still supplying the output power
- Make it possible for the applications to programmatically request power status with the USB interface, thereby allowing the solution to control the charge status and notify the user or take action when the charge level is low.

Interface

Interface Element	Type	Description
DC IN	DC 5.5x2.1 Female	12.5 V 5A DC Input to charge the power bank
DC OUT	DC 5.5x2.1 Female	11.4 V 10A DC Output
DC OUT STABILIZED	DC 5.5x2.1 Female	11.4 - 48 V 2A DC Output Stabilized
USB SERIAL	USB TYPE-B	USB Serial Interface
SWITCH 1	On/Off Switch	Cuts off the batteries set of all inputs/outputs
SWITCH 2	On/Off Switch	Cuts off the stabilized output

Electronics

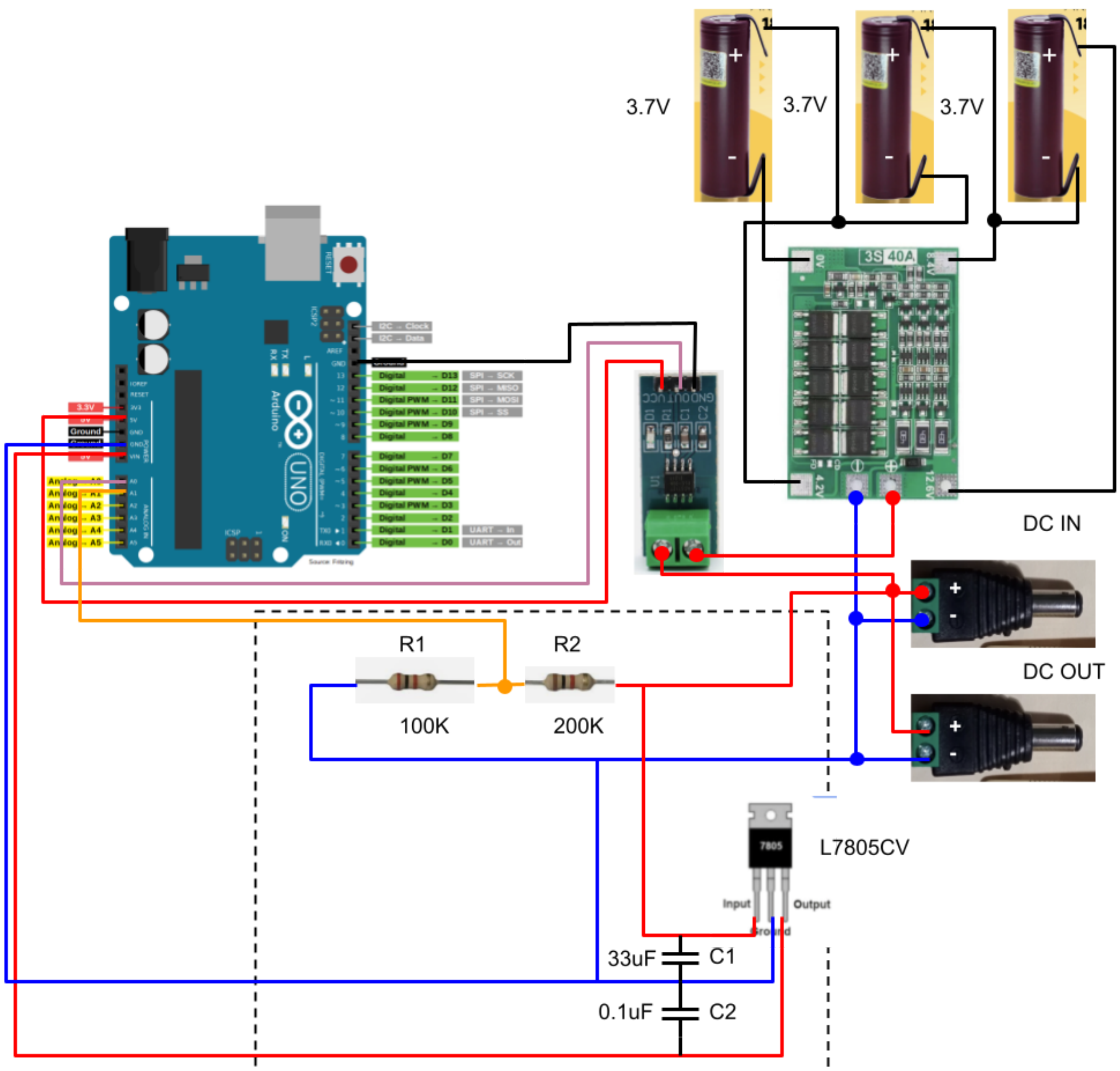
Hardware Components List

Component	Count	Description	Links
Arduino Uno	1		
BMS 3S Li-Ion charge controller	1		https://www.ozon.ru/product/2-sht-3s-40a-18650-bms-dlya-dvigatelya-bura-11-1-v-12-6-v-14-8-v-16-8-v-enhance-li-ion-467260999/?asb=qhQ6FteWuqprdrNrQULS16D0IueK3GiBE06ACm%252BFLbyLsgQhsdbPNCYEdduQZ25Q&asb2=I-bGhuhSEizKqWpYheULurQrRKwkLQPJW5tXK5WcK-Q8mOxZ5i9rG1kS-7LJNA3uxyqq9E27HqUHa3yfOSa6DiMy1wCWIY0Wr7uqvMUTCIot-MTh1I14GuWjqrhrmdkkqSCuvXSVC_uI7FcsEYcHvzpZniqefW8_Lf19Gj4GK8Q&avtc=1&avte=2&avts=1674113866&keywords=BMS+3s&sh=niRwoiW1Pw

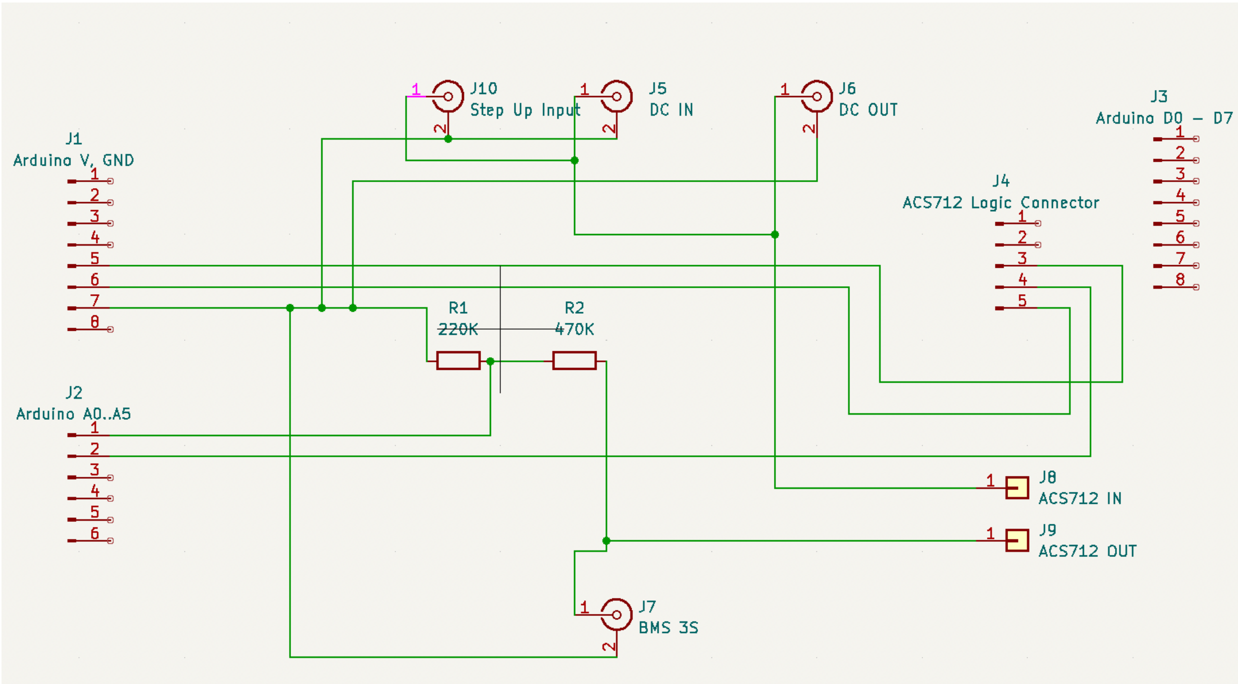
ACS-712 20A Current Sensor	1		https://www.ozon.ru/product/datchik-toka-acs712-20a-10-sht-716268062/?asb=xNif6CqCWXgSCddITRqr0SNtZ12nogcXxb6iFmz6bgI%253D&asb2=B4R6hMvkhhFo76f95W4D4VSpUfBbv-vhpQ4DEP1_WD12Pc6g1gwU8pEOlhEPj9Vr&avtc=1&avte=2&avts=1674113990&keywords=acs712&sh=niRwokluaA
Female DC Power Jack	2		https://www.ozon.ru/product/shteker-pitaniya-shteker-razem-pitaniya-dc-montazhnyy-razem-10-sht-5-par-12-v-3a-5-5x2-1-mm-401051994/?asb=m3t8nty5%252FG%252F%252BwuxyC1JkyjoGN3vEtRjI35AIfMvQvpk%253D&asb2=MVsalBCQ63DGkg7oeUquYRfXIVtWV_IP5a4_YU630RCcBVz116pZffEcWDoqeHBo&avtc=1&avte=2&avts=1674114144&keywords=dc+connector&sh=niRwotI-IQ
18650 3000 mAh 3.7v accumulator	3		https://www.ozon.ru/product/vysokotokovyy-akkumulyator-18650-hg2-moshchnaya-litiy-ionnaya-batareya-akb-18650-dlya-526420728/?asb=VcJ6BOFmqrLiqWZ9NxcMhks2jf7T18%252FPLC9G4LM51UoydoZTWKDEQ0xFJwnIfSwf&asb2=CausUhCIsmyvkehRxZQz56zf3ZX4e1uCp2UdOpcjCq1GDJEmcBDoz11NI1qsVeUBRvT4WmnXwk75hg-42qddTHs73FPNTFjVmnkrJVa-N1FJsAztsGnXfgpZIZNbp_-drRhgRNoEjutNJNdMF3rZPIDhGjd3R9ko2YgdaZ8YEm_Pdzp3BsVk7rUkuIZMCN0qBuyJUk8KornX3qjfkJuoGtYJ4Ne9gM7EtmJfBgavEAQ&avtc=1&avte=4&avts=1674114493&keywords=18650+аккумулятор&sh=niRwoma66g
Step-Up DC-DC converter	1		

Switch	2		
Resistor 220K	1		
Resistor 470K	1		

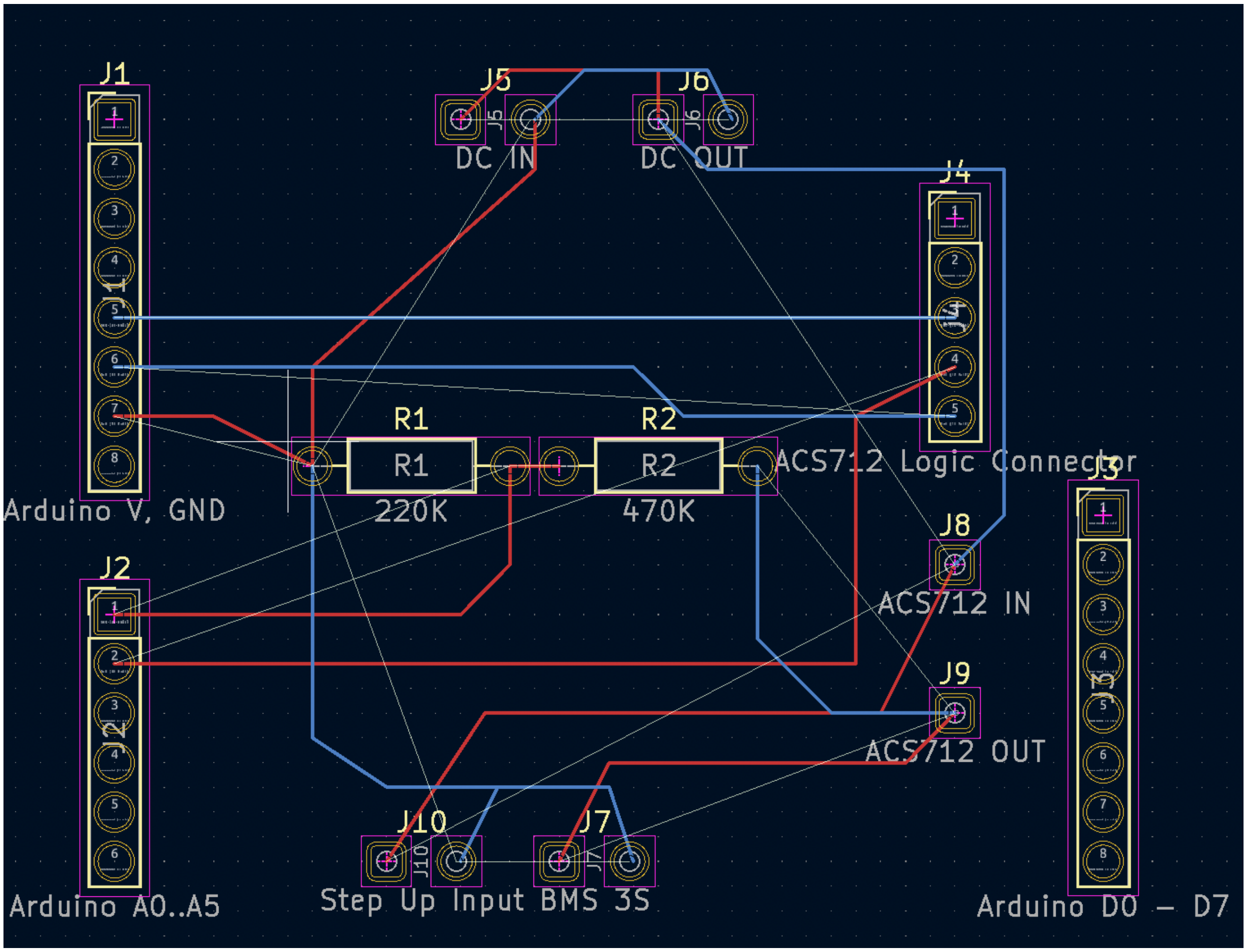
High-Level Scheme Sketch



Main Board Schematic



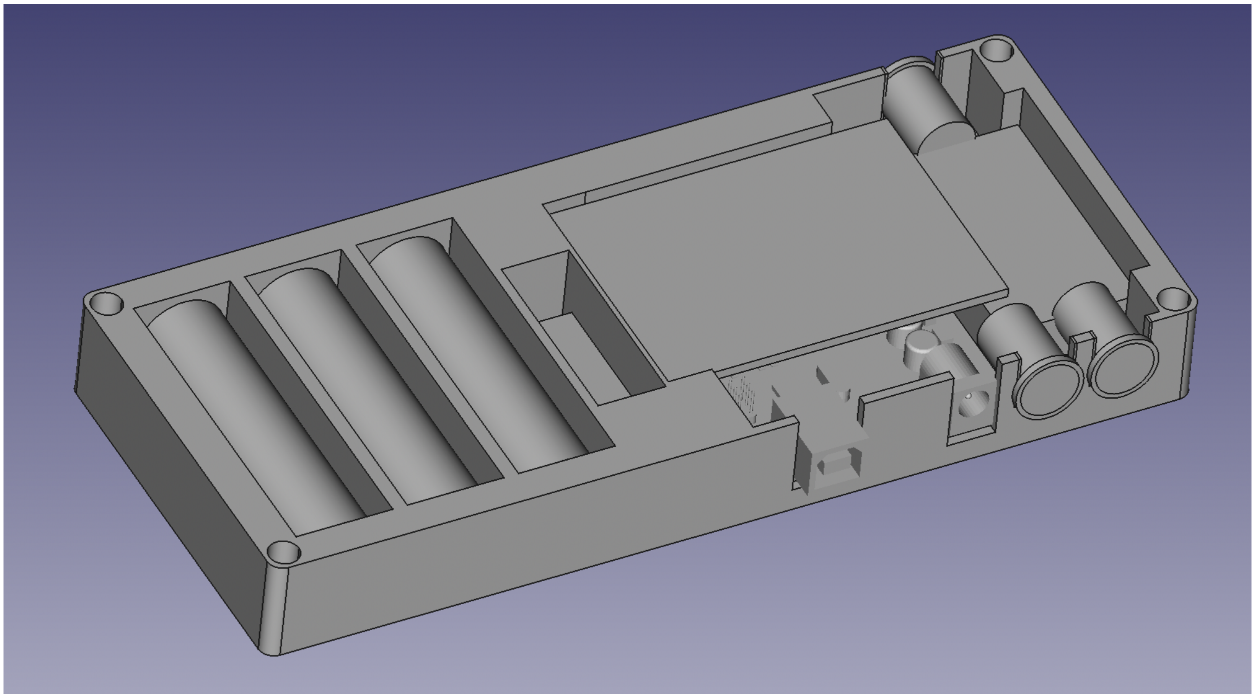
Main Board PCB



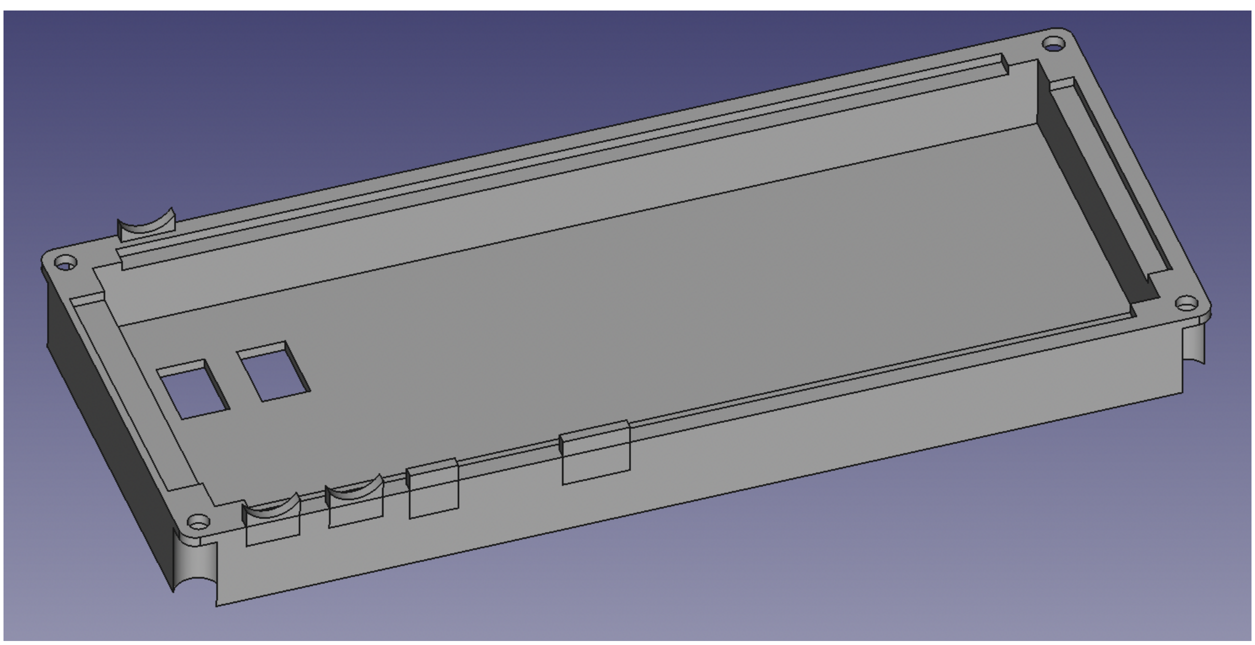
Body Design

OBP-1

Body



Cover



Standard Components

Component	Count	Image	Link
M4 Threaded Rivet	4		
M4 Bolt	4		

Communication Protocol

Media	USB Serial
Baud Rate	115200
Frames Format	Open Serial Peripheral Protocol: https://www.telemetrybalkan.com/specs/

Firmware

Features

- Measures Voltage (V), Current (I)
- Estimates the state of charge (SOC)
- Report V, I and SOC values via USB Serial interface

Charge Level Estimation algorithm

The algorithm is based on the estimation of the voltage drop which is caused by the either positive (charge) or negative (discharge) current value. When the current is low - the reference Voltage value is recorded. When current becomes significant immediately after it is low - the difference in the voltage if recorded for the low current and high-current cases.
Once the correspondence of the voltage difference (deltaV) to the the current value (I) is recorded - it can be used to estimate the anticipated battery voltage in the idle state and convert it to the SOC value.

Constants

Constant	Default Value	Description

OBP_NEAR_ZERO_CURRENT	250 mA	The maximal absolute value of the current within which the current is considered to be low and not impacting the battery voltage value
OBP_SIGNIFICANT_CURRENT	1000 mA	The significant value of the current, which will impact the voltage value of the battery. If the current is higher than this value - the voltage drop can be recorded for the further SOC estimation
OBP_AFTER_ZERO_ITERATIONS	10	Number of the firmware main loop interactions within which the current increase from zero to non-zero value is considered to happen recently. And thereby the anticipated idle voltage value can not change much.

Charge Level States

TO FROM	WAITING_FOR_ZERO	ZERO_CURRENT	NON_ZERO_CURRENT
WAITING_FOR_ZERO	N/A	IF V<OBP_NEAR_ZERO_CURRENT	N/A
ZERO_CURRENT	N/A	N/A	IF V >= OBP_NEAR_ZERO_CURRENT
NON_ZERO_CURRENT	IF after_zero_iterations>OBP_AFTER_ZERO_ITERATIONS	IF V<OBP_NEAR_ZERO_CURRENT	N/A

Variables

Name	**Default Value**	**Units**	**Description**

pos_i	0	mA	Last measured significant positive current (I) value.
pos_delta_u	0	mV	Voltage drop (deltaU) corresponding to the measured positive (I) value
neg_i	0	mA	Last measured significant negative current (I) value
neg_delta_u	0	mV	Voltage drop (deltaU) corresponding to the measured negative (I) value
obp_voltage	0	mV	Voltage measured in the current iteration
obp_current_draw	0	mA	Current draw measured in the current iteration

Algorithm

1. Set pos_i =0; pos_delta_u =0; neg_i = 0; neg_delta_u = 0;
2. Read V (obp_voltage) and I (obp_current_draw) values
3. If the absolute value of current abs(obp_current_draw) is below the OBP_NEAR_ZERO_CURRENT
    a. Record the voltage value as a **last_zero_current_voltage =** obp_voltage**.**
    b. Move the FSM state to OBP_FSM_STATE_ZERO_CURRENT
    c. Set after_zero_iterations = 0
4. If the absolute value of the current is higher than OBP_NEAR_ZERO_CURRENT
    a. If FSM is in OBP_FSM_STATE_NON_ZERO_CURRENT or OBP_NEAR_ZERO_CURRENT state
        i. Move FSM state to OBP_FSM_STATE_NON_ZERO_CURRENT
        ii. If current is higher than OBP_SIGNIFICANT_CURRENT
            1. If obp_current_draw >= 0
                a. pos_i = obp_current_draw
                b. pos_delta_u = obp_voltage - **last_zero_current_voltage**
            2. If obp_current_draw < 0
                a. neg_i = obp_current_draw
                b. neg_delta_u = obp_voltage - **last_zero_current_voltage**
        iii. Increment the after_zero_iterations++
        iv. If after_zero_iterations > OBP_AFTER_ZERO_ITERATIONS
            1. Move FSM state to OBP_FSM_STATE_WAITING_FOR_ZERO
5. Calculate noLoadU (anticipated idle voltage) as the current voltage minus expected voltage drop due the the current value measured
    a. If obp_current_draw >=0
        i. deltaUExpected = obp_current_draw * pos_delta_u / pos_i

   b. if obp_current_draw < 0
      i. deltaUExpected = obp_current_draw * neg_delta_u / neg_i
   c. noLoadU = obp_voltage - deltaUExpected
6. Calculate State of Charge
   a. obp_soc = OBP_MAX_CAPACITY * (noLoadU - OBP_MIN_V) / (OBP_MAX_V - OBP_MIN_V);

Implementation

The arduino source code can be found on github repository:
https://github.com/sergei-nntu/obp/blob/main/src/arduino/OpenBatteryPack/OpenBatteryPack.ino

Software

The software library to communicate with the battery pack is available on github repository:
https://github.com/sergei-nntu/obp

See README.md for more instructions.