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Modular Battery Management System for a fast Sampling of the Cell Voltages and Algorithms to Determine the Internal Impedance of Battery Cells

A battery management system (BMS) is used to measure the voltages of all cells in a battery system, e.g. in an electric vehicle. Fast measurements of the cell voltages and temperatures and also a knowledge about the internal impedance of the battery cells are essential to run precise algorithms to calculate parameters like the state of charge or the maximum charge and discharge currents at any time.

BMS often base on the master-slave principle. There is one master module, which controls at least one slave module. On the slave modules, the actual measurements of the cell voltages happen. The modular design allows it, to use as many slave modules as needed for the specific application. The algorithms and the communication to the outside world run on the master module.

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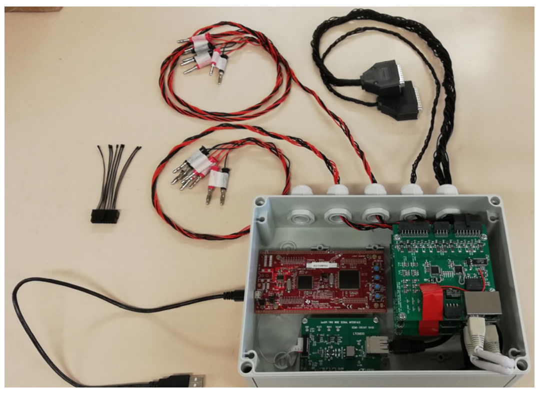
Introduction and Goals

The main goal of this work is the development of a prototype of a slave module with the capability to sample the cell voltages of up to twelve cells with at least 100 Hz. The slave module should also include additional protection circuitry. A demonstrator with at least two slave modules needs to be built.

The second goal is research and implementations of algorithms to estimate or calculate the internal impedance of the battery cells in Matlab/Simulink. In a later stage, the algorithms get implemented onto the microcontroller of the BMS.

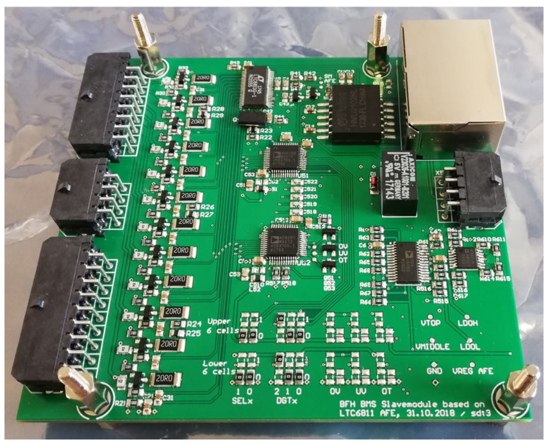


Additional Protection Circuitry

The slave module features an additional hardware-only protection circuit based on the AD8280 safety monitor IC also from Analog Devices. This IC features outputs which react to overvoltage, undervoltage and overtemperature conditions of the battery cells. The voltage threshold values can be set with external resistive voltage dividers. It also features self-test functions, which make it also ISO26262 and IEC61508 compliant (functional safety for electronic safety-related systems). The activation of any of the alarm outputs on any slave module in the battery system will trigger a specific act to countermeasure the source of the alarm, e.g. open the connections to the charging infrastructure.

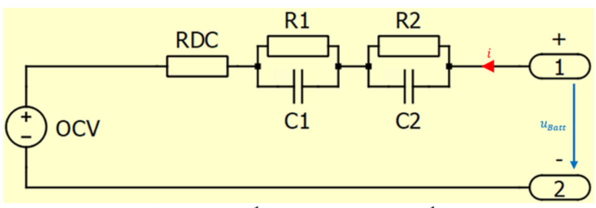
The Slave Module

The prototype of the slave module is based on the LTC6811-1 multicell battery monitoring IC from Analog Devices. This IC mainly incorporates fast and accurate A/D converters and output pins to control passive balancing resistors for up to twelve cells. Integrated diagnostic features make it ISO26262 compliant (functional safety requirements for road vehicles).



Estimation of the Internal Impedance

The algorithms to estimate the internal impedance base on a least square residuals fitting technique. The starting point of such algorithms is a mathematical representation of the used battery cell model, to which the laws of the least square fitting mathematics can be applied [2, 3]. The result is an algorithm, that estimates the resistances and capacitances of the battery cell model in real time during the operation of the battery system at each sample of the battery voltages and the battery current.



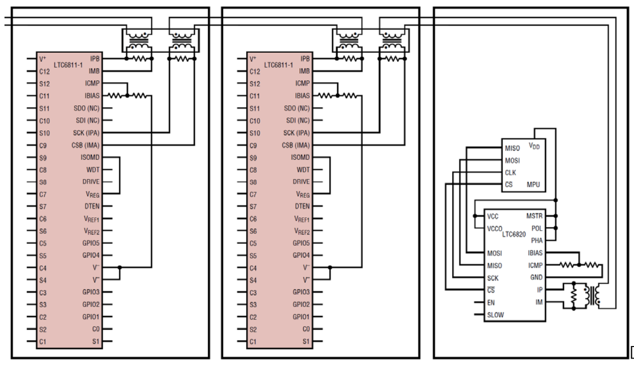
$$\begin{pmatrix} \frac{du_{C_1}}{dt} \\ \frac{du_{C_2}}{dt} \end{pmatrix} = \begin{bmatrix} -\frac{1}{R_1C_1} & 0 \\ 0 & -\frac{1}{R_2C_2} \end{bmatrix} \begin{pmatrix} u_{C_1} \\ u_{C_2} \end{pmatrix} + \begin{pmatrix} \frac{1}{C_1} \\ \frac{1}{C_2} \end{pmatrix} i$$

$$u_{Batt} = \begin{pmatrix} 1 & 1 \end{pmatrix} \begin{pmatrix} u_{C_1} \\ u_{C_2} \end{pmatrix} + R_{DC} i$$

Modular Design

The unique serial interface of the LTC6811-1 allows it to be daisy-chained in a very simple way. The only necessary components are signal transformers, which are also used in ethernet and CAN bus applications.

Hence, theoretically, any number of slave modules can be used to form a BMS for a very large amount of battery cells, like in an electric vehicle. The slave modules can be interconnected via standard RJ45 cables.



[1]

Summary and Impact

A prototype demonstrator with three daisy-chained slave modules was built and tested successfully. Some minor changes need to be implemented for a future version. Up to 36 cell voltages can be sampled with 500Hz. For even more cells, the sampling rate needs to be reduced.

An algorithm to estimate the internal impedance is now being tested in another project. The general functionality is given, but more research concerning numerical stability and robustness is needed.

The correct knowledge of the state of charge, the maximal charge and discharge current and other parameters is important to run a battery system in its optimal operating range, which leads to ecological and economical advantages, since the lifetime of the battery system can be increased. This in the end means that e.g. an electric vehicle reaches a higher mileage until the battery can no longer be used.

References

[1] Analog Devices, Datasheet of the LTC6811-1/LTC6811-2 Multicell Battery Monitors
[2] G. Plett, Battery Management Systems Volume II – Equivalent-Circuit Methods, 2016
[3] D. Simon, Optimal State Estimation – Kalman, H_∞ and Nonlinear Approaches, 2006

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