A Direct Power Injection Setup for the Susceptibility Measurement of Battery Management Systems Using a Battery Stack Emulator

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***Abstract*—In this contribution we present a complete direct power injection setup suitable for the susceptibility measurement of battery management systems. To provide a defined state, we propose the use of a battery stack emulator circuit, which applies adjustable and reproducible inputs to the battery monitoring system.**

I. Extended Abstract

The mileage of Hybrid Electric Vehicle (HEV) and Fully Electric Vehicles (FEV) is highly dependent on the efficiency of their energy storage systems. In order to increase the battery lifetime a battery management system (BMS) is used, which controls the charge and discharge of each battery cells in accordance with voltage and temperature measurements carried out by the BMS. In order to ensure a save operating of the battery pack even in the harsh electromagnetic environment of HEVs and FEVs the susceptibility of the battery monitoring system to electromagnetic disturbances has to be ensured. Susceptibility measurements are most widely done either by the bulk current injection (BCI) or by the direct power injection (DPI) method, while the latter is dedicated to its use by measurements for integrated circuits when influences of e.g. the cable harness or other connected systems are not of interest as is the case for the BCI method.

In this work we present a complete DPI setup for battery management systems according to the standardization given in [1]. Therefore, the system under test must operate in a defined state. However, a battery management system is a signal processing system for which the cell voltages act as input signals. In order to ensure those defined states, the inputs have to be adjustable and reproducible during the measurements. For this purpose a battery stack emulator was developed which makes adjustable battery voltages available for the measurement inputs of the monitoring system. The proposed DPI setup is depicted in fig. 1. The device monitoring and the failure detection are accomplished by a DSP communicating via a digital serial interface with the IC under test. On the DPI test board the injection paths for RF disturbances were placed together with the IC under test on the top layer. The injection paths were implemented as microstrip lines with a line impedance of 50 Ohms in order to match the impedance of the RF injection sources and to minimize injection losses according to [1]. In order to operate the system as a fully functioning BMS while minimizing their influences on the measurement, all other circuit components have been placed on the bottom layer of the four layered PCB. The two mid layers are the ground plane and routing layer where the former is located next to the top layer. With the described RF injection concept it is possible to expand the frequency range of the DPI method above 1 GHz as specified in [1]. Design considerations for multi layer

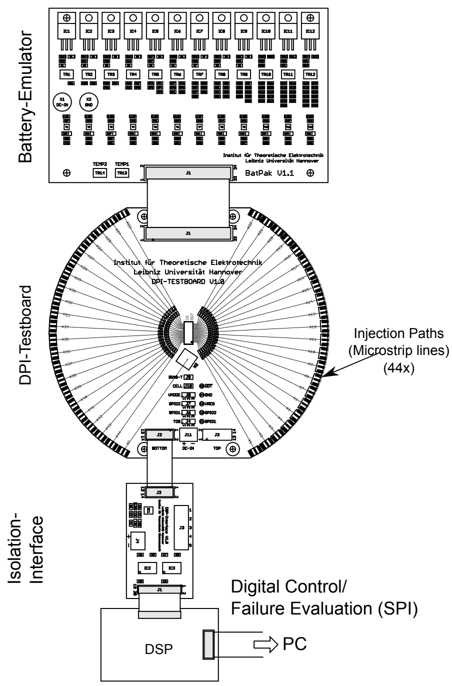

Fig. 1. Proposed DPI measurement setup for battery management systems

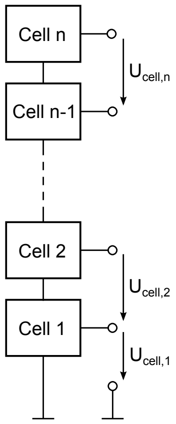

Fig. 2. Battery stack

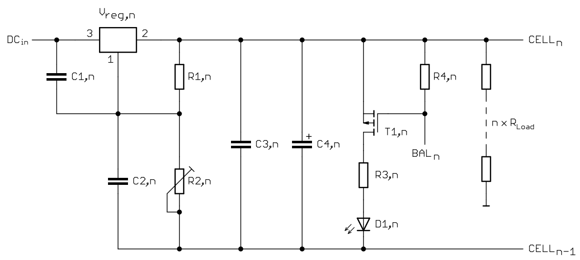

Fig. 3. Battery stack

injection boards up to 2 GHz are given in [2]. A model for the power losses of the direct injection method is described in [3].

To adapt the DPI method for susceptibility measurement of battery management systems adjustable and reproducible inputs for the cell voltage sensing ports of the BMS are necessary. Since the cell voltages of real batteries vary with time and also comprise safety risks when applying RF signals, it is not recommend using real batteries during a DPI measurement. For this purpose we developed a battery stack emulator on the basis of stacked voltage regulators as shown in fig. 2. A detailed schematic of the circuit producing the n-th cell voltage is depicted in fig. 3. The voltage regulators provide a constant voltage of $1.25\,\mathrm{V}$ over $\mathrm{R}_{1,n}$. The adjustable voltage divider $\mathrm{R}_{1,n}$ and $\mathrm{R}_{2,n}$ defines the cell voltage supplied to the BMS. To stabilize the stacked emulator circuit, $\mathrm{C}_{1,n}$ through $\mathrm{C}_{4,n}$ prevent oscillations of each stage. The PMOS transistor $\mathrm{T}_{1,n}$ is used for passive balancing purposes, i.e. when the BMS IC discharges individual cells. The LED indicates when a balancing procedure is in progress. By stacking the proposed circuit n times, we are able to recreate differential voltages like a battery pack comprised of n cells connected in series and to execute balancing procedures.

In the final version of the paper we will present some measurement results of a BMS built with the LTC6803-1 battery monitoring IC.

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References

[1] E. I. 62132-4, "Integrated circuits – Measurement of Electromagnetic Immunity, 150 kHz to 1 GHz – Part 4: Direct RF Power Injection Method," 2006.

[2] H. Pues and D. Pissoort, "Design of IEC 62132-4 compliant DPI test Boards that work up to 2 GHz," in *Electromagnetic Compatibility (EMC EUROPE), 2012 International Symposium on*, 2012, pp. 1–4.

[3] A. Alaeldine, R. Perdriau, M. Ramdani, and V. Veeragandham, "Electrical model for power losses in direct power injection," *Science, Measurement Technology, IET*, vol. 1, no. 5, pp. 284–289, 2007.