



UNIVERSITÀ DI TRENTO

Dipartimento di Ingegneria e Scienza dell'Informazione

Corso di Laurea in
Informatica

ELABORATO FINALE

BATTERY MANAGEMENT SYSTEM DEVELOPEMENT

Applications in a Formula SAE electric race car

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Ringraziamenti

...thanks to...

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Sommario

This thesis covers the challenges of developing a battery management system for a Formula SAE electric race car.

The document focuses on the error management software and cell balancing algorithms, explaining the implementation choices and analyzing experimental results.

Sommario è un breve riassunto del lavoro svolto dove si descrive l'obiettivo, l'oggetto della tesi, le metodologie e le tecniche usate, i dati elaborati e la spiegazione delle conclusioni alle quali siete arrivati.

Il sommario dell'elaborato consiste al massimo di 3 pagine e deve contenere le seguenti informazioni:

- contesto e motivazioni
- breve riassunto del problema affrontato
- tecniche utilizzate e/o sviluppate
- risultati raggiunti, sottolineando il contributo personale del laureando/a

1 Introduction

A battery management system is a safety-critical component of modern battery packs. Especially in an automotive environment, where electric vehicle batteries can be subject to unoptimal working conditions, the need of a control system that ensures that the battery operates safely and efficiently is necessary.

1.1 Formula SAE

Formula SAE is an international design competition founded by the Society of Automotive Engineers in 1980, in which university students have to develop, build and race an open-wheel, single seater race car. In Europe, Formula Student Germany emanates the rules that have to be followed in order to be accepted in any european competition. TODO: battery rules here?

1.2 Tractive System

The tractive system is the whole high-voltage system of the car. It comprises the battery pack, the inverters and the electric motors that drive the wheels of the car. The E-Agle TRT's car is powered by two independent three-phase permanent-magnet motors that drive the rear wheels of the car.

1.3 Battery Architecture

TODO: add circuits

A battery is an electrical energy storage system that relies on chemical reactions. The main properties of a battery are: nominal voltage, internal resistance, energy capacity and discharge rate.

The voltage of a battery is influenced by many factors including: state of charge, temperature and applied load. The open-circuit voltage of a Lithium-Ion battery cell is 4.2V at 100% state of charge and 3.0V at 0%. When a load is applied on a cell, the voltage drops according to Ohm's law:

$$V_{dropped} = R_{internal} * I_{load}$$

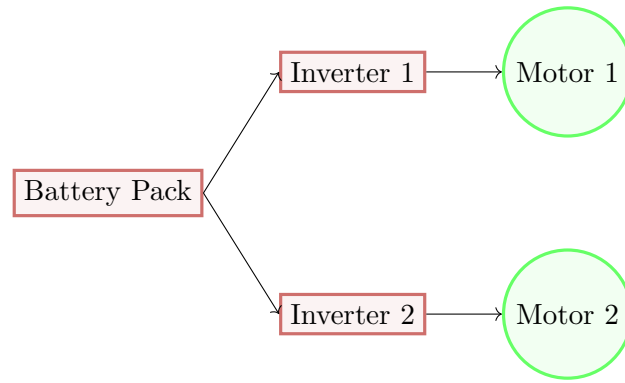


Figure 1.1: Tractive system block schema

1.3.1 Battery Pack

TODO: add circuits

A battery pack is a group of cells connected in series and parallel to form a bigger battery. Arranging the cells in series means that the current will only travel down a single path. TODO: embe'?

In a parallel arrangement, electrons travel down multiple paths, splitting the current across more cells. This increases the current output of the battery, but the voltage remains the same as a single cell. A parallel of cells is also called a module, as it acts as a single, bigger cell. The structure of a battery pack is decided on it's application's requirements. For example, if the battery needs to have an high voltage output, it will be composed of many modules in series. If the application requires an high power output, more cells in parallel will be arranged.

In a Formula SAE car, the optimal setting is to have an high-voltage high-power battery pack while still being lightweight. The resulting battery will have as many series as possible, and as few parallels to reach the desired power output. E-Agle TRT car's pack has 108 cells in series and only 4 in parallel, for a total of 432 cells and ~388V of nominal voltage (3.6V per cell). The high power requirement is fulfilled by the use of high-discharge rate cells, 45A in this case, totalling 180A of continuous discharge. The maximum theoretical power output is ~70kW.

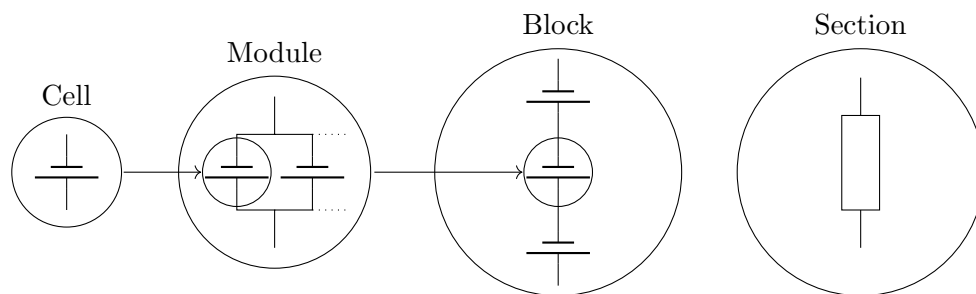


Figure 1.2: Battery pack elements naming scheme

Phisically, the pack is subdivided in six sections, each section is made of six blocks, that are a series of three modules. As said before, a module is made of four cells in parallel.

1.3.2 Pack Components

To better control the pack, two Accumulator Isolation Relays (AIR) are located at the terminals of the battery to disconnect the output of the pack when it is not needed. These relays are controlled by the BMS and can also be switched off by external devices such as emergency buttons located around the car.

TODO: delete?

Modern automotive batteries are made of lithium-ion cells, because of their high energy and power density and relatively low mass. is made of many small cells connected in series and parallel to each other to form an higher voltage and capacity pack. In the case of the battery in question, the pack is

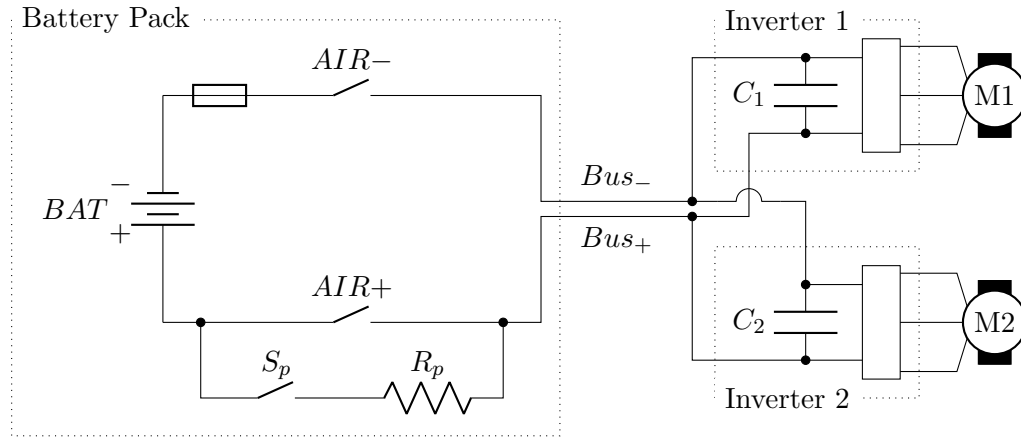


Figure 1.3: Tractive system schema

made of 432 cylindrical (21mm diameter, 70mm height) cells, arranged in a 108s4p configuration. As per Formula SAE regulations, the pack is physically split into six sections of 18 modules each

1.4 Battery Management

Battery management is a collection of operations that ensure the safety and efficiency of the battery pack's operating conditions.

A battery management system should constantly measure cell temperatures, module voltages along with the total pack current output and check that each of those values is nominal. If there are any anomalies the battery should be turned off immediately.

1.5 Module Balancing

Cells are not perfectly identical and can have slight variations in internal resistance between each other. This imperfection means that after some use, modules can start to deviate in voltage output. This poses a limitation on the depth at which the battery can be charged or discharged, reducing the total usable capacity of the pack.

Example: TODO: module voltages chart and explanation

2 BMS Hardware

The need to measure an high amount of voltages and temperatures scattered around the battery pack means that a decentralized structure for the BMS components is preferable. The two main types of logic boards are the **Mainboard** and the **Cellboard**. Every cellboard measures voltages and temperatures of a *section* of the pack, and sends data back to the Mainboard via CAN bus. The Mainboard interprets the received data and takes actions based on them.

2.1 Mainboard

The Mainboard is the central control unit of the BMS. It consists of a microcontroller that handles the pre-charge circuit, two CAN-bus lines and some external peripherals.

2.2 Cellboard

The Cellboards are dedicated to the measurement of module voltages and cell temperatures. The reading of those values is handled by a specialized battery management chip that communicates via

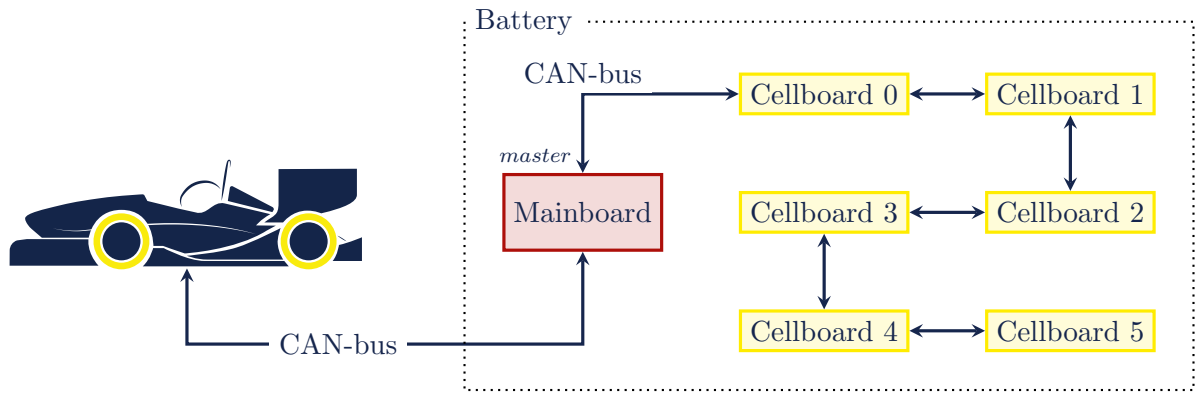


Figure 2.1: BMS hierarchy

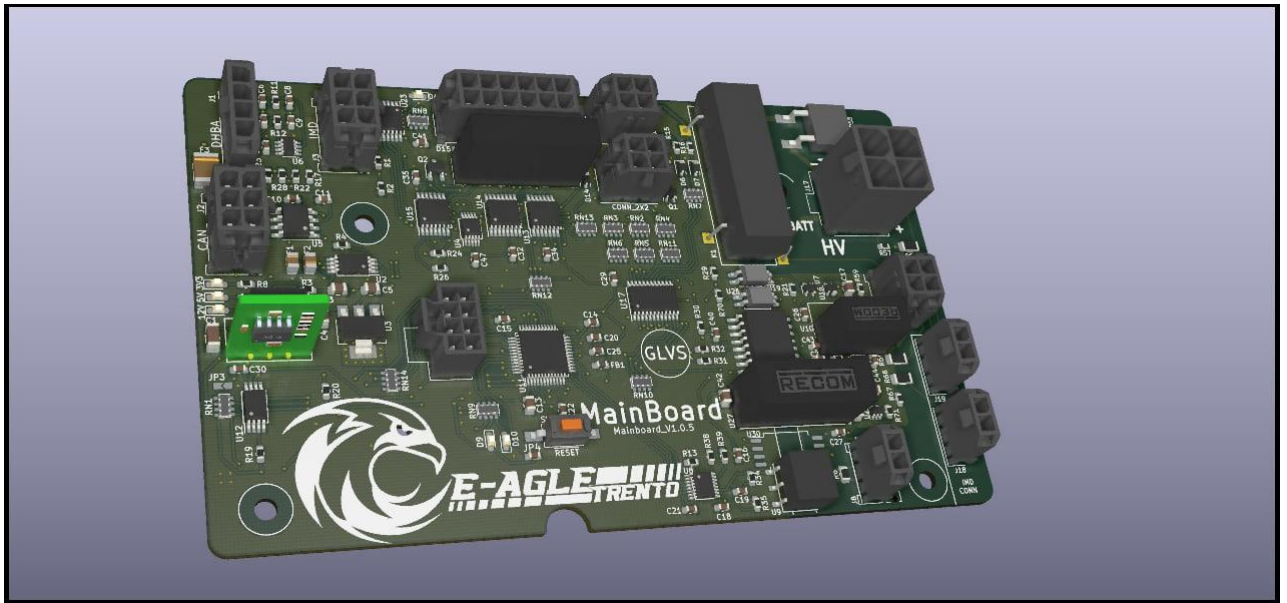


Figure 2.2: Mainboard PCB

SPI to the on-board microcontroller.

3 Conclusioni

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Bibliography

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Allegato B Titolo secondo allegato

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