Battery Management System Development

Issues and applications in a Formula SAE electric race car
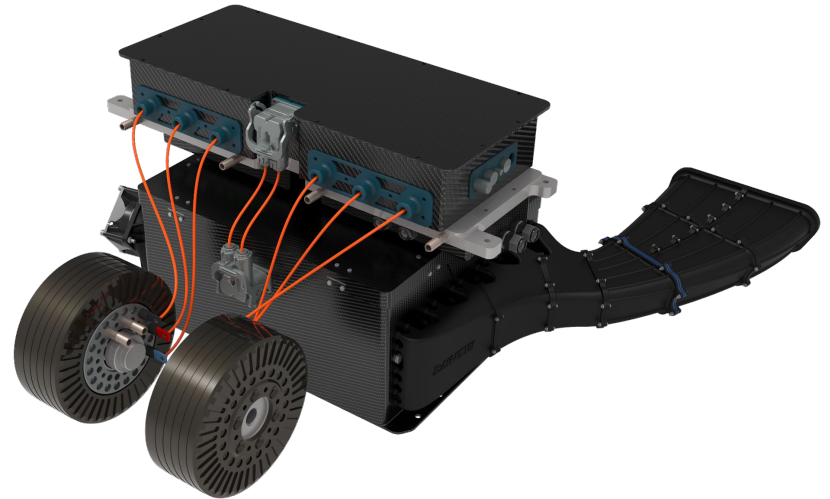
Supervisore
Roberto Passerone

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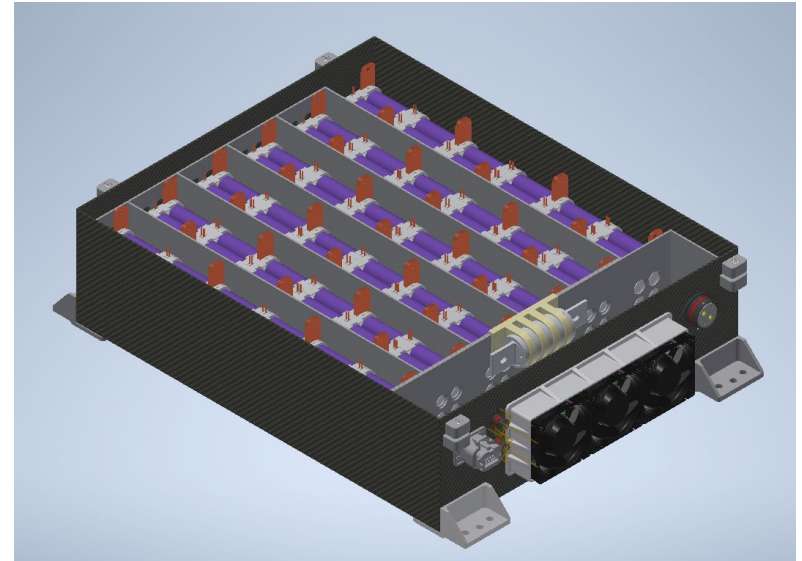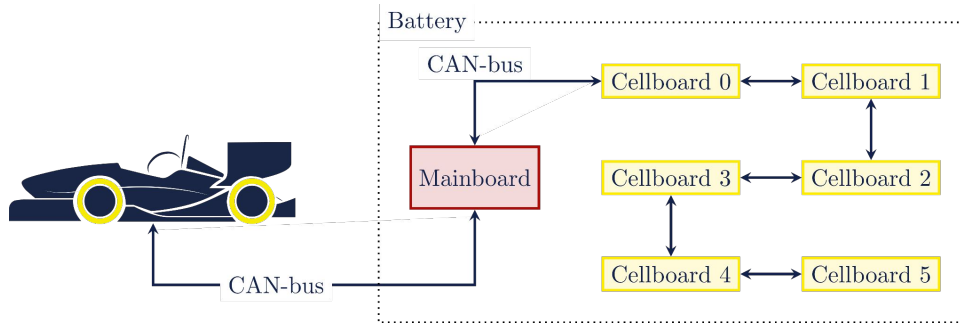
Laureando
Matteo Bonora

Introduction: Formula SAE

Battery Management System

- Safety device
- Data acquisition
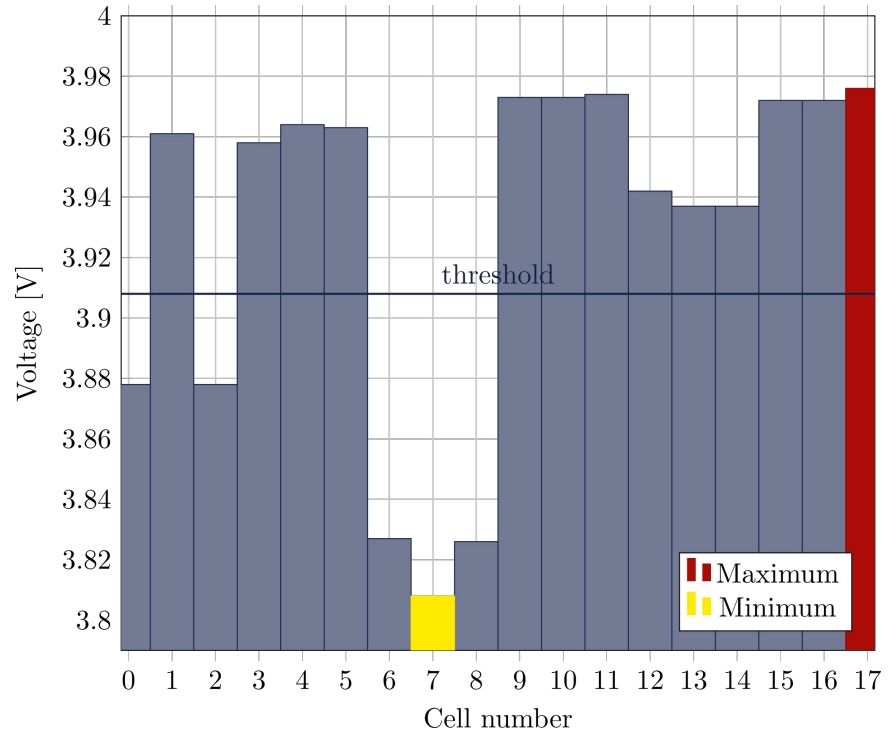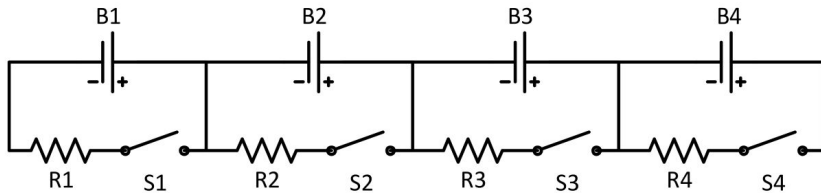- Decentralized architecture
- Balancing control

Balancing Explained

Problems
- Voltage of cells in series diverges with use
- Reduced usable energy

Solution
- Set a threshold
- Discharge cells that are over threshold
- Repeat at intervals until all cells are balanced

Cell Selection

Given a non-negative vector of imbalances `I[]` of size `n`, return the subset `D` of non-adjacent cells that **maximizes total imbalance**.

Let `C[i]` be the **maximum total imbalance** from compatible cells that can be obtained by **considering the first `i` cells**.

For each `i`:

   if `i` is picked, then `C[i]` = `I[i]` + `C[i-2]`

   if `i` is discarded, then `C[i]` = `C[i-1]`

$$C[i] = \begin{cases} 0 & i = 0 \\ I[0] & i = 1 \\ \max(C[i-1], C[i-2] + I[i-1]) & i \geq 2 \end{cases}$$

Solution Reconstruction

- `C[n]` represents the imbalance of the optimal solution. It is not the solution
- We can use `C[]` to reconstruct the solution set:

`C[i] = C[i-1]`: cell `i` has not been selected.

`C[i] = C[i-2] + I[i]`: cell `i` has been selected.

Error Management

Requirements:

- If an error persists for some time, the battery pack must be disconnected
- Multiple errors must be handled simultaneously

Solution:

- Active errors are saved in a list, sorted by expiration time.
- An hardware timer is always set to follow the first error in the list
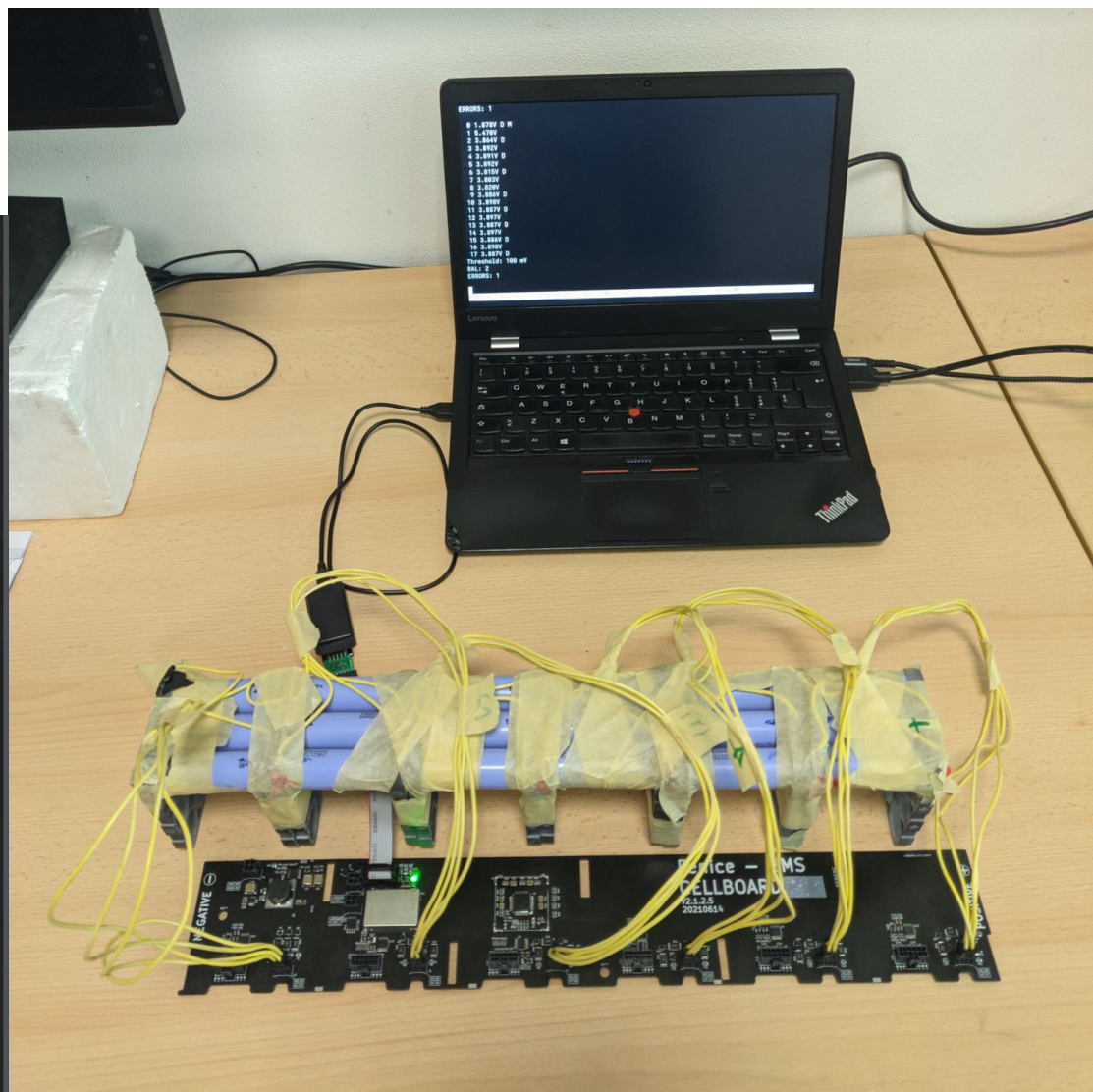
Timer Scheduling

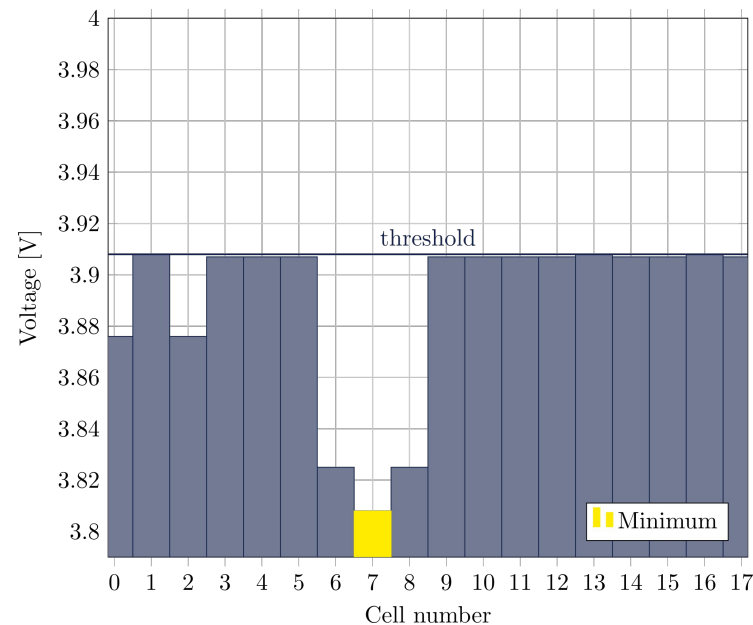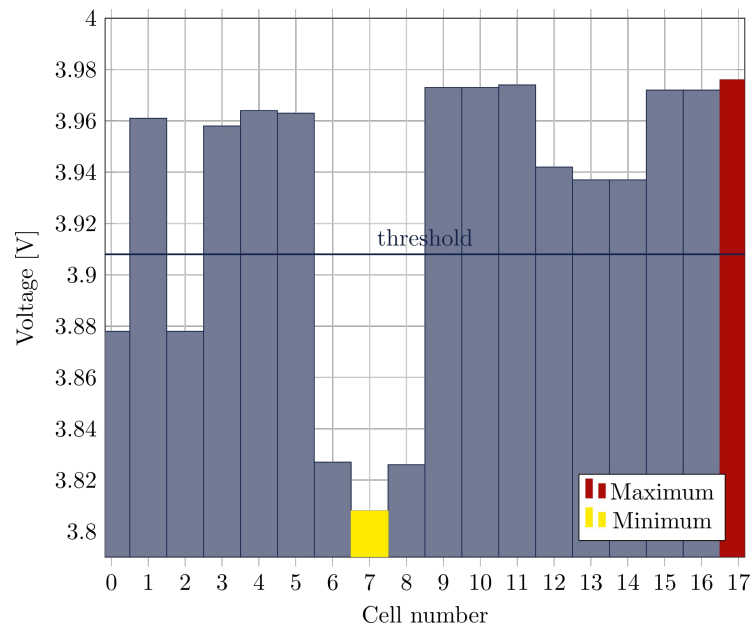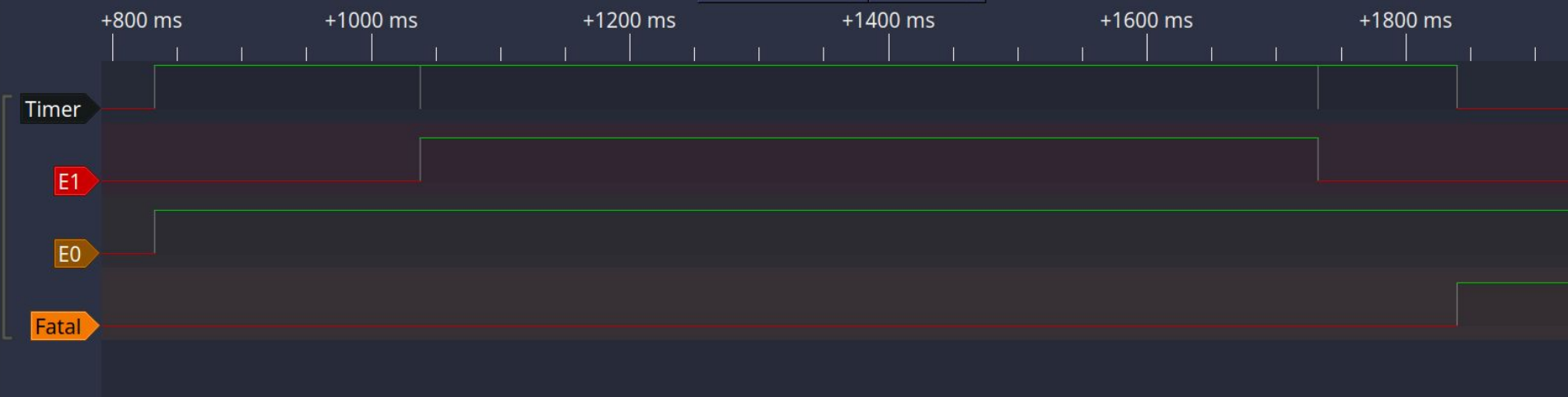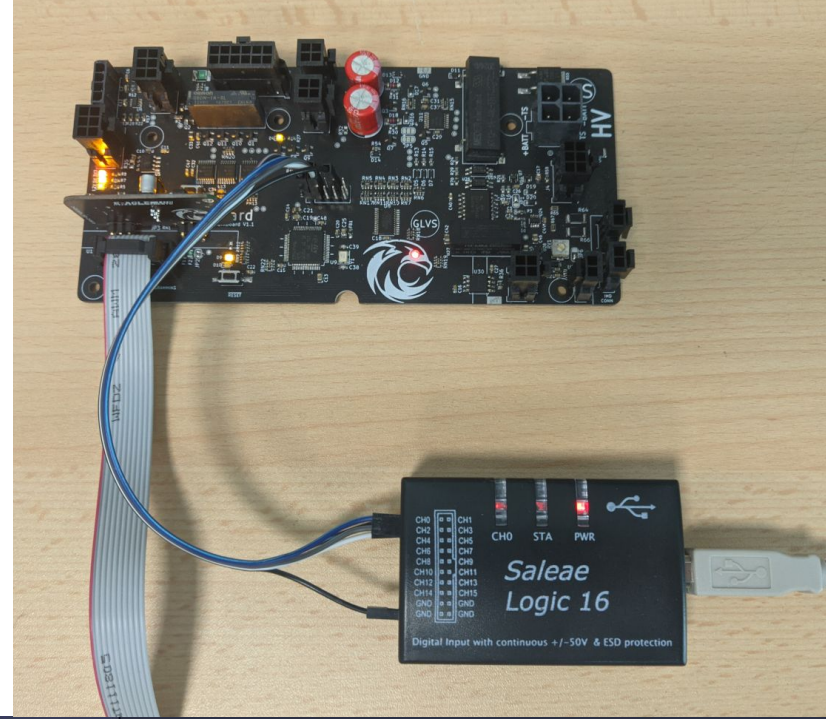| Time	Event
T+100	E_0 Set
T+300	E_1 Set
T+600	E_1 Reset
T+1100	E_0 Expires
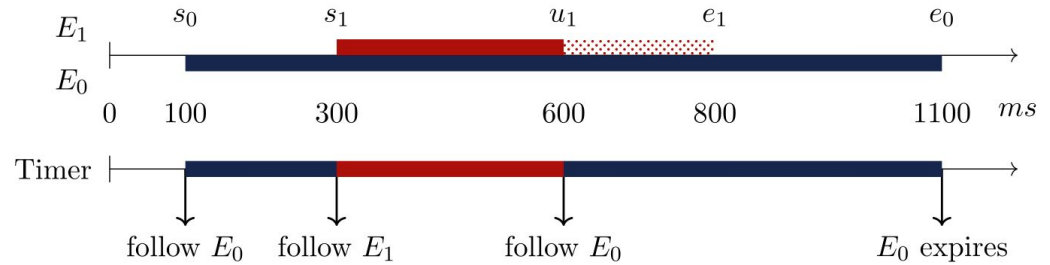
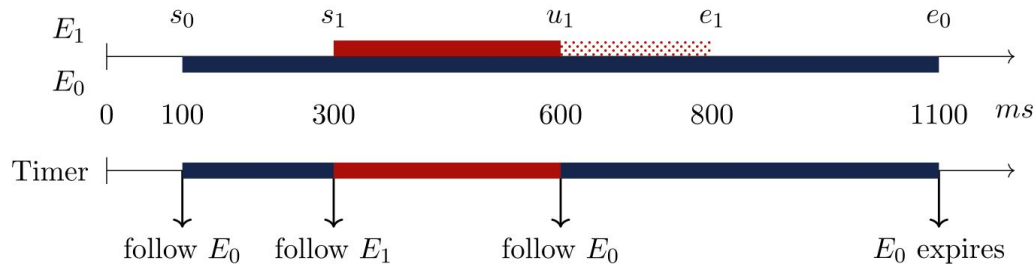# Conclusions

Balancing Validation


```
 0 3.921V
 1 3.918V D
 2 3.874V
 3 3.907V
 4 3.905V
 5 3.907V
 6 3.824V
 7 3.808V M
 8 3.823V
 9 3.908V
10 3.908V
11 3.904V D
12 3.907V
13 3.907V
14 3.907V
15 3.903V D
16 3.908V
17 3.908V
Threshold: 100 mV
BAL: 2
ERRORS: 1
```

Balancing Results

Timing Validation

Thanks for your attention