From Simulation to Embedded Edge Computing: Integrating Multiphysics Battery Models on Arduino Portenta H7

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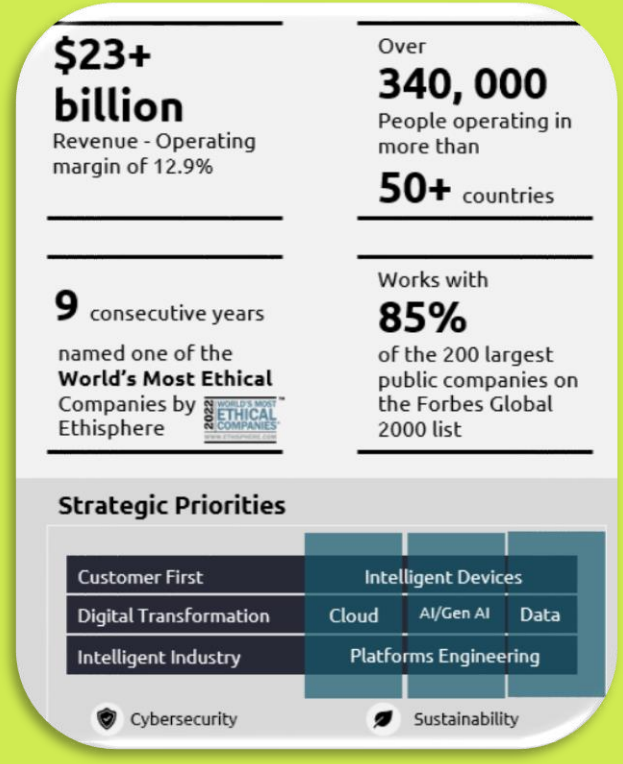

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Research paths in ENERGETIC Project

Battery cloud predictive maintenance

Capgemini shall develop and deploy a cloud architecture that can integrate data from a set o batteries and run with it the AI models developed by the other partners. The finality is to have a overview of the State of Health of a set of battery at each time.

Digital twin based BMS with hybrid AI

Capgemini is developing the Battery Management System (BMS) for the proof of concept of th ENERGETIC project.

One of the main challenges lies in integrating simplified AI models directly into the BMS hardware considering its limited computational capacity. Capgemini also plays a key role in defining th deployment strategy for these models, whether in the Cloud or embedded in the BMS, dependin on technical constraints and use cases. Additionally, the BMS system will feature 4G/5G connectivit to enable communication with the Cloud.

About ENERGETIC Project:

KEY DATA

Call: EU HORIZON-CL5-2022-D2-01
Total Budget: 4.17M€
Calendar: June 2023 – June 2026
Web site: energeticproject.eu

Context

Real-Time Estimation

- SOC estimation
- Voltage prediction
- Thermal monitoring

Electro-Thermal Coupling

- Electrical behavior
- Thermal dynamics
- Strong interaction

Embedded Constraints

- Limited CPU & memory
- Real-time requirements
- Reliability & safety

Bridging advanced multiphysics models from simulation to Real-world impact

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Capgemini in ENERGETIC – Implementation of Multiphysics Models

1- MODEL DEVELOPMENT
Multiphysics models

Electrical
- Equivalent circuits
- Electrochemistry

Thermal
- Heat generation
- Heat transfer

Aging
- Calendar aging
- Cycle aging

MODELING ENVIRONMENT

MATLAB® SIMULINK®

2- IMPLEMENTATION AND DEPLOYMENT
From model to Embedded Code

Model Preparation
- Model simplification
- Parameter identification

Code Generation
Simulink Coder / Embedded Coder

Integration & Testing
- Unit testing

Configuration
- Model parameters
- Execution settings

3- Edge BMS Gateway
Model Execution

EMBEDDED HARDWARE

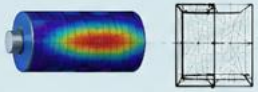
MUXLab Platform
Arduino Portenta H7

CAN LTE

REAL-TIME INPUTS

V Voltage | I Current | T Temperature | Other (SOC, etc.)

MULTIPHYSICS MODEL
(Electrical + Thermal + Aging)



ESTIMATED OUTPUTS

SOC | SOH | SOP | RUL | Tmax

MQTT / HTTPS
JSON Protocol

4- CLOUD
Data, Analytics & Intelligence

CLOUD PLATFORM

Google Cloud

Pub/Sub

AI & ANALYTICS
- State estimation
- Remaining Useful Life prediction
- Anomaly detection
- Performance analytics

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Why Embedded Deployment Matters ?

Edge Computing

The model runs locally inside the embedded BMS

Measurements are processed in real-time

SOC and thermal estimations are continuously updated

No need to wait for external

Reduced cloud dependency

•Critical estimations remain available even without internet connection

•Cloud is used for monitoring and advanced analytics, not for core safety decisions.

Lower latency for safety-critical functions

•Battery protection requires fast reactions.

•Embedded execution avoids communication delays.

•Important for thermal monitoring and fault detection.

Scalable edge intelligence for EV and stationary storage

•Same embedded architecture can be adapted for EVs or stationary storage.

•Edge computing enables scalable intelligent BMS platforms.

ENERGETIC- BMS Edge Gateway

Hardware Platform ARDUINO PORTENTA H7

- High performance Dual core STM32H747XI
- ARM Cortex-M7 @ 480 MHz + Cortex-M4 @ 240 MHz
- 8 MB SDRAM + 16 MB NOR Flash
- Multiple communication interfaces: LTE/ CAN / SPI / I2C / UART
- AI Support: TensorFlow Lite Micro

Hardware Platform ARDUINO PORTENTA H7

- Data acquisition and processing
- Edge computing for BMS algorithms
- Local data buffering and logging
- Iot/Cellular connectivity
- Cloud Integration

Use cases in ENERGETIC Project

- CAN acquisition AFE
- Real-time SOC / SOH estimation
- Edge AI inference
- MQTT / HTTPS cloud communication
- 4G-enabled smart BMS gateway

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Key Challenges in embedded Multiphysics model Deployment

Multiphysics Models
(Electrical, thermal, aging)

Embedded Implementation
(Portenta H7)

Memory limitations

- Limited RAM and Flash
- Model parameters storage
- Data logging requirements

Portenta H7 resources remain limited compared to desktop environments

Real Time constraints

- CAN acquisition deadlines
- Periodic model execution
- Cloud communication
- Safety monitoring functions

Communication constraints

- LTE (4G/5G) Latency
- Data synchronization

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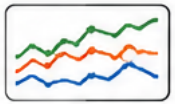
Embedded Deployment Validation (C Model)

The multiphysics Model is provided in C Code.
Validation focuses on correct integration, execution stability, output consistency and system performance on Portenta.

Output Consistency Check



- ✓ Outputs within realistic ranges (SOC, Temperature, Voltage...)
- ✓ Logical behaviour over time
- ✓ No abnormal values (NaN, Inf…)

Real Time Validation

- ✓ Execution time per cycle measured
- ✓ Meets the required period
- ✓ No abnormal values (NaN, Inf…)

Memory & stability monitoring

- ✓ RAM usage within limits
- ✓ Flash usage checked
- ✓ Long duration test
- ✓ No memory leaks

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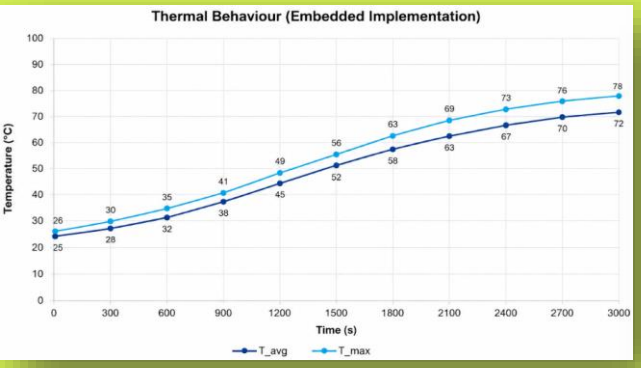
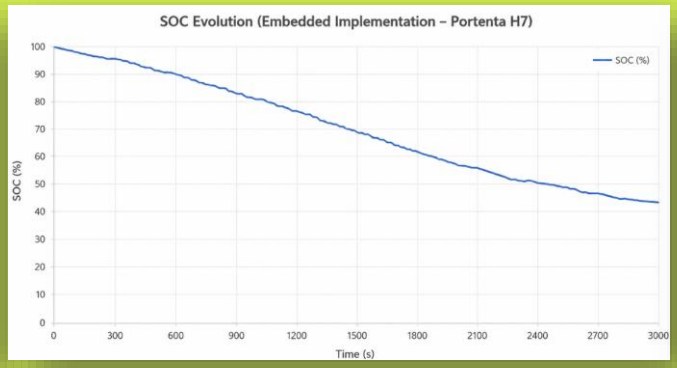
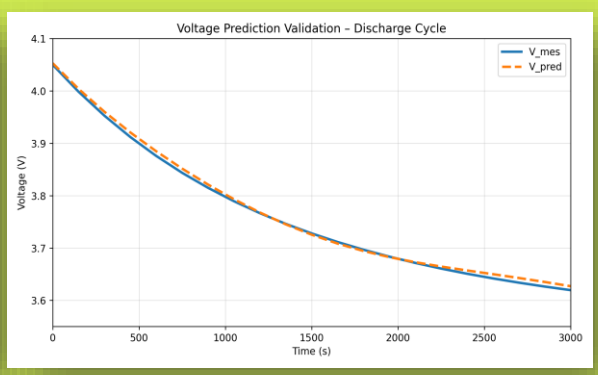
Deployment Results







Parameter	Value
Target Platform	Arduino Portenta H7
Model size	50 kB
Time step	1 s
Model Execution Time	24 us-30 us
Compiled Firmware Size	166 kB
CPU Load (for sampling time 100 ms)	0.024 % - 0.030 %
Memory Usage	8 % of Flash memory
System Stability	No reset, no crash

The validation results demonstrate that multiphysics battery models can be efficiently deployed on embedded hardware while maintaining real-time performance, stability, and low resource consumption.

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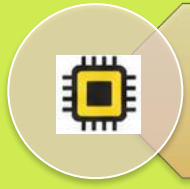
Conclusion

Key Takeaways

Multiphysics battery models provide deeper insight into battery behaviour by combining electrical, thermal and aging phenomena.

Automatic code generation enables an efficient transition from simulation environment to Embedded deployment.



The Arduino Portenta H7 offers a flexible Edge-Computing platform for battery intelligence.

The ENERGETIC architecture bridges Embedded BMS, edge computing and Cloud services.

The challenge is not building the model, but making it run reliably on Embedded hardware

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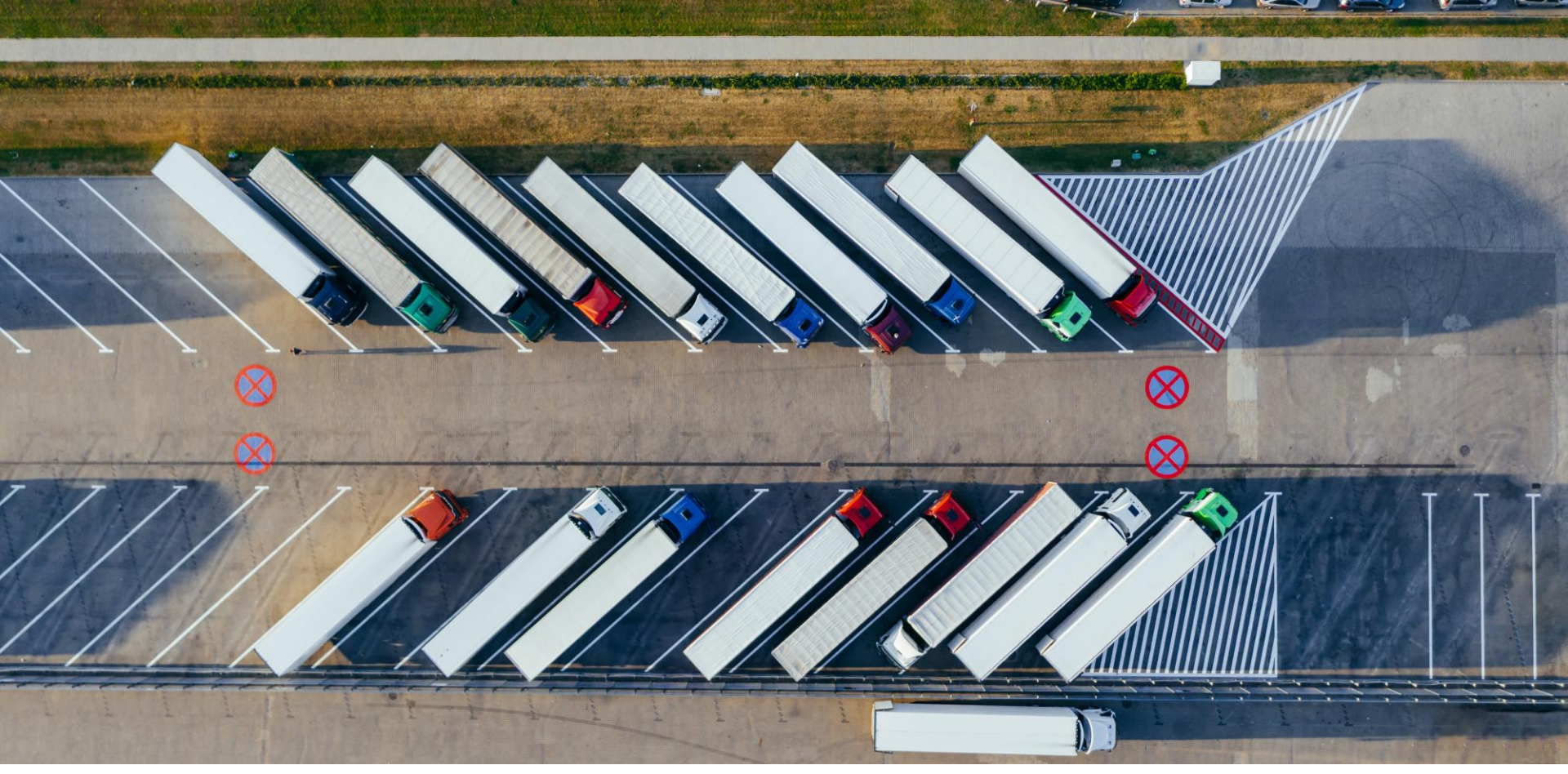

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