Battery Passport Research Presentation

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WMG
THE UNIVERSITY OF WARWICK

WMG – Who are we and what do we do?

Academic department of the University of Warwick

- Post Graduate Students – Masters and PhD
- Industry Engagement Projects
- SME Support & Development

- Research Areas
  - Energy – Batteries for transport
  - Manufacturing Automation & Methods
  - Autonomous Vehicles
  - Materials – Analysis
  - Cyber Security

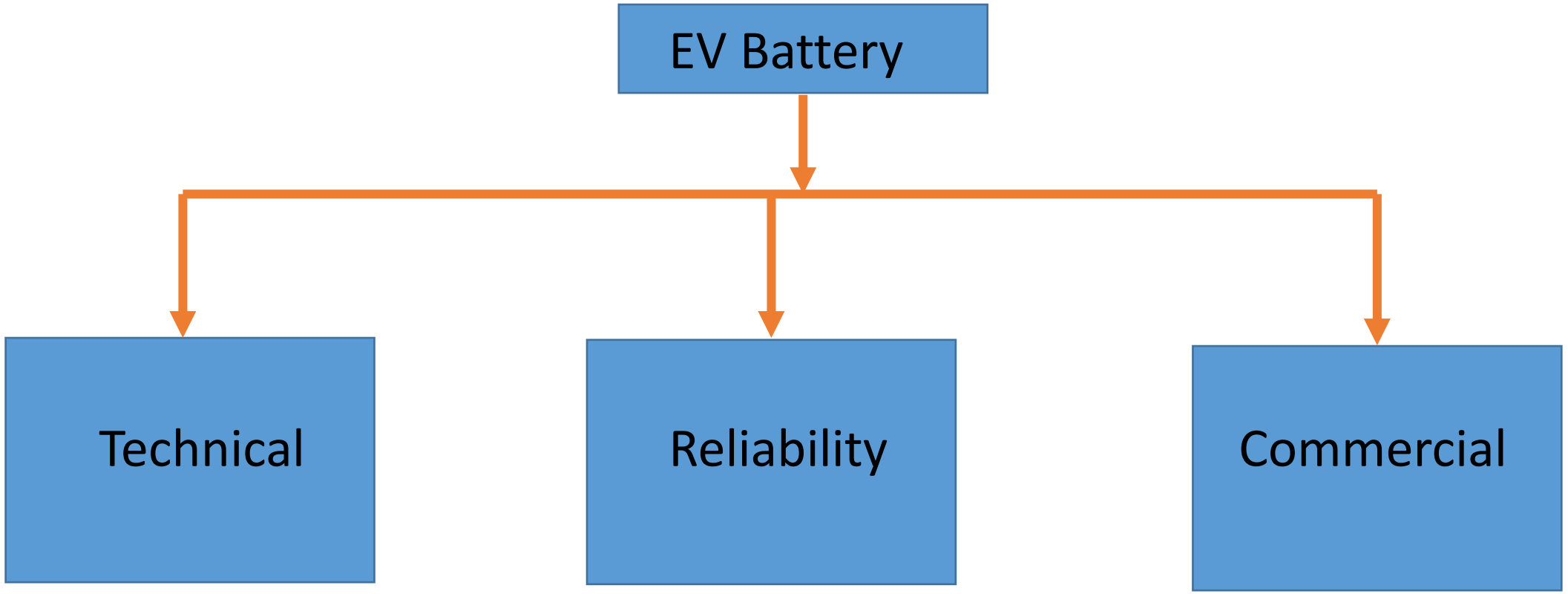
Contents

- Transport Drive to Electrification
- EV Battery Issues
- Mitigations
- What is a Battery Passport and why (Characteristics)
- MEMS Devices
- MEMS Technology + Passport Concept
- Battery in EV use - passport requirements
- Envisions MicroChip Battery Passport Development
- What are the Industry, Social & User Paybacks ?
- References

Transport Drive to Electrification

- Automotive
- Rail
- Light Rail/Tram
- Buses
- Civil Aircraft
- Off-Road Plant
- Agriculture

EV Battery Issues



EV Battery Issues (Technical)

- Variable battery aging
  - Temperature
  - End of life capacity
  - Uneven cell capacity
  - Drive cycle variability
  - Charge – Speed-of-Charge, frequency and total number
  - Manufacturing variability
  - Time left fully charged and discharged
  - Chemistry
  - System ac ripple
  - Remaining usable life

EV Battery Issues (Reliability)

- Failures
  - Premature
    - Cell failure – hard or soft short
    - Loss of Capacity
    - Loss of power
  - Expected Characteristic
    - Cell impedance rise
    - Loss of Capacity
    - Loss of power

Commercial
(EV Battery Issues)

- Commercial
  - End of life application premature (80%) + inflates cost of battery
  - Cost of recycling/disposal
  - Difficult value assessment for used batteries + re-warranty issues

Mitigations
(EV Battery Solutions)

- Technical
  - Currently used

    Variable battery aging – Tracking characteristics by cell/pack/module sensing

    Prediction algorithms

    Historical logging at pack level
  - Additional possibility

    Variable battery aging - Logging of History at cell level
- Reliability
  - Currently used – limited temp. & voltage Sensing, active balancing - Prediction algorithms
- Failures
  - Currently used

    Battery Management system (BMS) – reports, detects and logs

Mitigations
(Commercial Battery Solutions)

- Commercial (future)
  - Premature End of life inflates cost
    - Re-use battery for different application
  - Cost of recycling/disposal
    - Extend life or pass all/partial cost to resale party
  - Difficult value assessment for used batteries + re-warranty issues
    - Log battery history and performance over time

Mitigation Thread

For Commercial Costs, battery redeployment is a key driver…

- Problem?
  - Battery Pack logging & monitoring not sufficient for redeployment in second life application
- Why?
  - The battery will likely need reconfiguration at cell or module level in different casing
  - Insufficient history, traceability and performance details
  - Likely second life applications – industrial and domestic grid store (different configurations)
- What is needed?
  - An integrated traceable history and performance within the cell

We call this a Cell Passport

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Great for customers with improved reliability and predictability

What is a Battery Passport and why ?

(Fundamental Battery Passport characteristics)

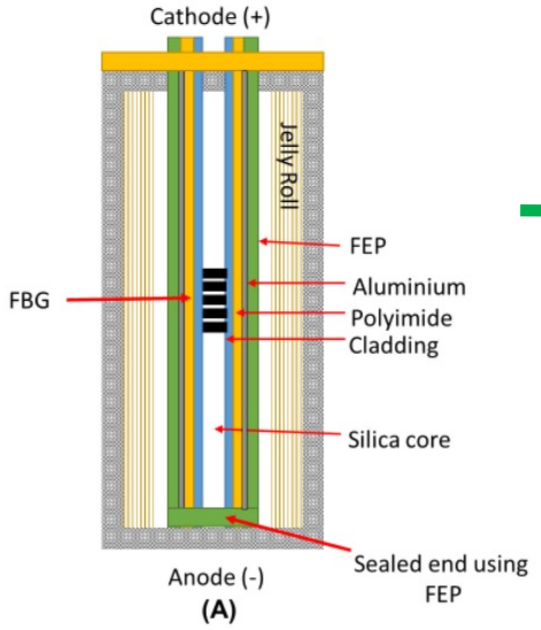
The Requirement…

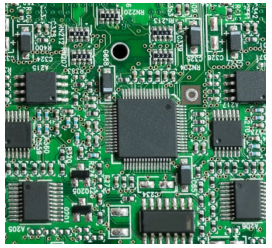
- From two primary areas
    - Battery reliability/predictability in EV use
    - Second life commercial viability

- Fundamentally to…
    - Know the history of use over time
    - Current State of battery health/predictive life
    - Disassemble a pack without Losing History

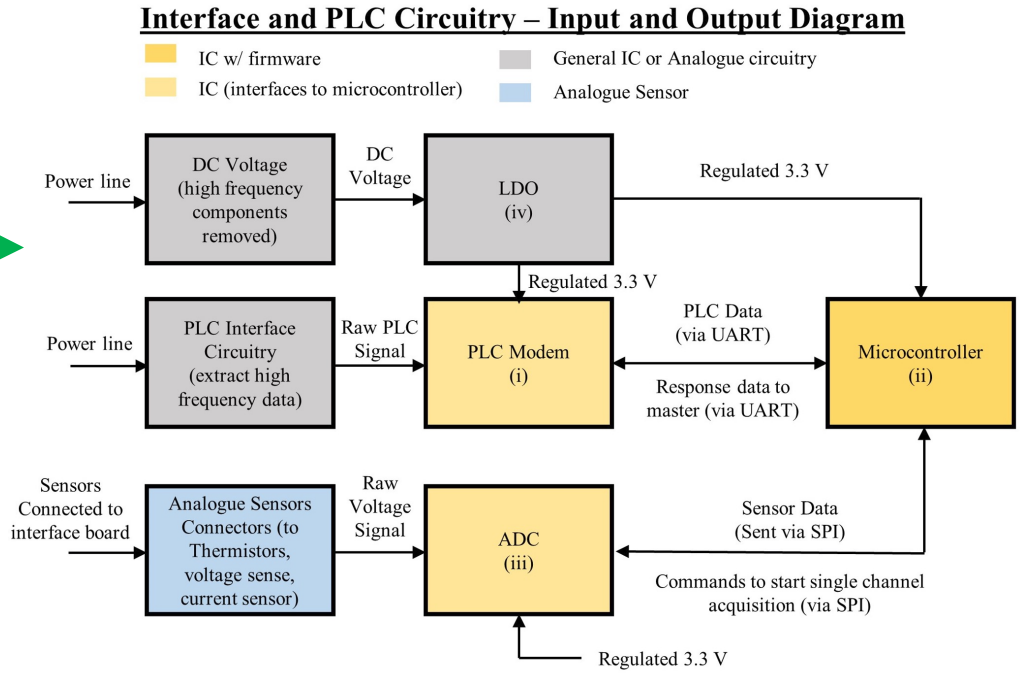
Where we are at the moment?

- WMG have implemented some of the sensing and passport functionality including power line communication





External Board Prototype electronics
to be embedded in cell
(miniaturisation phase)



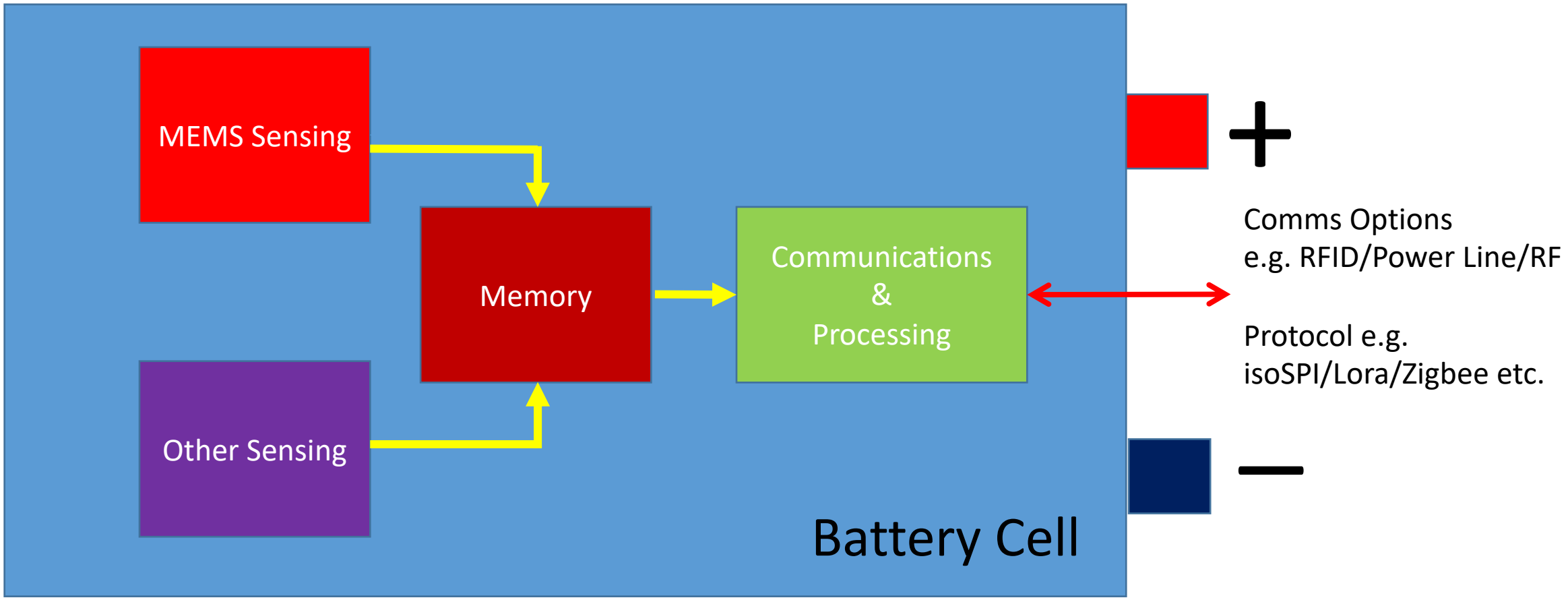
MEMS Devices (Micro-Electro-Mechanical-Systems)

- Essentially transducers or (energy converters)
- miniaturized mechanical and electro-mechanical elements using the microfabrication techniques
- Applied to temperature, pressure, inertial forces, chemical species, magnetic fields, radiation
- Applications – automotive, medical, RF switching, Comms. - tuned circuits, Energy scavenging

MEMS and Integrated Future Battery Sensing

- MEMS devices
  - Cell by Cell pressure measurement
  - Mechanical shock – accelerometers
  - Cell orientation (aerospace) gyroscopes
- + Other electronic sensing
  - Cell internal thermal shock (overcurrent)
  - Cell electrode colour change
  - Electrolyte gassing detection
  - Voltage, Current (magnitude and direction)
- + Logging
  - Memory & Processing
  - Communications – RFID, Power-Line, RF

MEMS Technology + Passport Concept



Environmental Challenges in Batteries

- Corrosive Electrolyte
- Wide range of temperatures -50 to +70 in aerospace
- Small Package required to not infringe on Coulomb storage capacity
- High vibration environment
- Magnetic fields in operation
- Calibration & Drift

Battery in EV use - passport requirements

- Parameters required:
  - Date of manufacture + Serial Number + Revision number + Cell type
  - Initial Ah Capacity, Current Ah Capacity
  - Hours in operation (since first charge – Low power timer only mode needed)
  - Total hours charging, Total hours discharge
  - Peak current magnitude and duration
  - Cell Temperature & other sensing - Max & Min + max event duration
  - Current State of charge
  - Cell Voltage - Max & Min cell voltage (half cell potential – with third electrode)
  - Thermal event early detection /prediction (using third electrode)
  - 24 hours of FIFO sensing history, sample time 1 second (operational)
    (BMS trigger start or current threshold auto start selectable)
  - Battery system ‘off’ 5 min cell sample (low power wake-up) – temp. & Voltage only

Integration Challenges

- Conventionally - Multiple devices in combination
- Electro mechanical sensing, electrical sensing, processing, memory, communications

  (Silicon based devices have temperature limitations)
- Conventional MEMS devices offer some integration
- EEPROM can leak charge at high temperatures (data may be lost)
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Envisions MicroChip Battery Passport

- Microchip ‘Zero-Amp’ technology
- Nano-electro-mechanical switches (NEM)
- Chip Technology - wide temperature -55 to +300 deg. C
- ‘Mechanical’ non-volatile RAM
- FPGA and multi-layer stacking
- Memory more likely to be intact after ‘black box’ emergency event.

Microchip ‘Zero-Amp’ Battery application research needed.

- Magnetic field tolerance
- FPGA array size for full functionality
- Tolerance of hostile chemical environments
- Sleep & wake-up modes
- Serial comms implementations (software & Hardware)
- Mechanical packaging
- Vibration robustness

What are the Industry, Social & User Paybacks ?

- User
  - Battery reliability/predictability in EV use
  - Current State of battery health/predictive life

- Industry & Commercial
  - Second life commercial viability + pass or share disposal costs
  - Known history of use over time – Warranty claims
  - Easing approval for safety critical applications – Aerospace

- Social & Environment
  - Green credentials – longer useful battery life
  - Lower waste – longer re-cycle time

References

- ZeroAMP — Ultra low-power computing for everywhere
- Smart | Connected | Secure | Microchip Technology

Thank you

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Any questions