Battery Management System for Automotive and industrial applications

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BL AAA
Distribution Business Development

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Automotive Global Megatrends
Driving the need for next generation silicon capabilities

Autonomy

Electrification

Connectivity

Target: Zero Emission
German court rules cities can ban diesel cars to tackle pollution | World news | The Guardian
Tue 27 Feb 2018 11.34 EST

Millions of heavily polluting vehicles could eventually disappear from roads across Germany after its top administrative court ruled that cities have the right to ban diesel motors in an effort to improve deadly air quality levels.
Electric Vehicle Timeline

18 Months Too Optimistic

- **Tesla**
  - Tesla to begin Model 3 volume production

- **Tesla**
  - Tesla targets annual sales of 500,000

- **PSA**
  - PSA to launch first electrified models on Efficient Modular Platform (EMP)

- **Jaguar**
  - JLR will electrify all models

- **Land Rover**
  - Land Rover

- **Renault-Nissan**
  - Renault-Nissan plans joint platform for EVs

- **Subaru**
  - Subaru to launch first full EV

- **Volvo**
  - Volvo targets 1mn total sales of electrified cars

- **Daimler**
  - Daimler plans 15-25% of production to be electric

- **Aston Martin**
  - Aston Martin plans all models to be hybrid by ‘mid-2020s’

- **GM**
  - GM plans to produce 500,000 electrified vehicles by year-end

- **Volvo**
  - Volvo will no longer sell cars solely powered by ICEs

- **Ford**
  - Ford to have 13 new electrified models

- **Porsche**
  - Porsche plans 50% of cars to be electric

- **VW**
  - VW plans to have 30 new EVs accounting for up to 25% of sales (2-3mn units)

- **Honda**
  - Honda plans two-thirds of sales to be electrified
2019/2020 a Key Period for xEV Launch
• 2030: ~50% of all vehicles sold contain electrified powertrains

• Dynamic market environment with emerging (xEV) OEMs

• China major market driver

• Europe leading in 48V hybrid
# Vehicle Electrification: Diversity of Approaches

<table>
<thead>
<tr>
<th>Electrification Levels</th>
<th>E0</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>E5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Name</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combustion Engine (ICE)</td>
<td>Ford Mustang</td>
<td>Honda Insight</td>
<td>Toyota Prius</td>
<td>FCA Pacifica</td>
<td>BMW i3</td>
<td>Nissan Leaf</td>
</tr>
<tr>
<td>Mild Hybrid (M-HV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Hybrid (F-HV)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Plug-in Hybrid (PHEV)</td>
<td></td>
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</tr>
<tr>
<td>Range Extended EV (RE-BEV)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pure Electric Vehicle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Combustion Engine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Battery System</strong></td>
<td>![12V]</td>
<td>![12V]</td>
<td>![LV]</td>
<td>![LV]</td>
<td>![LV]</td>
<td>![LV]</td>
</tr>
<tr>
<td><strong>Mains Charging</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>![green plug]</td>
<td>![green plug]</td>
<td>![green plug]</td>
</tr>
<tr>
<td><strong>Electric Traction</strong></td>
<td>![black battery]</td>
<td>![black battery]</td>
<td>![black battery]</td>
<td>![black battery]</td>
<td>![black battery]</td>
<td>![black battery]</td>
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<tr>
<td>10 – 20kW</td>
<td>15 – 60kW</td>
<td>40 – 80kW</td>
<td>40 – 80kW</td>
<td>&gt; 80kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CO₂ reduction at vehicle</strong></td>
<td>N/A</td>
<td>-20%</td>
<td>-30%</td>
<td>-50% to -75%</td>
<td>-50% to -75%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Battery Management System
Introduction
Main Functions of BMS Systems

### Safety
- Over voltage
- Extra heat
- Unstable chemical stage
- Thermal runaway => fire/explosion
- Low temperature charge

### Performance
- Safety & fast charging
- Discharge optimization
- State of charge (SOC) estimation
- State of health (SOH) estimation

### Multi-Cell function
- Up to hundreds of cells
- Manufacture mismatch
- Capacity degradation
- Lifetime degradation

### Key BMS Functions
- V/I/T measurement
- Cell balancing
- Under Voltage Limit
- Over Voltage Limit

### Challenges
- V/I/T measurement
  - Coulomb counting
  - Internal resistance calculation
Why Safety is Critical for Lithium-Ion Battery Applications

- **Battery over-voltage (OV):**
  - Secondary chemical reactions triggered: *battery overheating, smoke emission, inflaming or explosion* are very likely. OV typically close to 4 V

- **Thermal runaway (OT):**
  - Can start a positive temperature feedback mechanism, with the same consequences as an OV. OT typically close to 60 °C

- **Battery under-voltage (UV):**
  - Results in progressive breakdown of the electrodes substances. With LFP cells this may happen over a few cycles. UV typically close to 2 V

- **Battery over-current (OC):**
  - May result in the melting of the battery contactors. **Major safety issue: impossibility** to open the contactors and inability to drive the system to the disabled safe state

- **Battery under-temperature (UT):**
  - Loss of robustness of the contactors, *reduction of the battery capability to provide current*, dendrites. Need to limit current to avoid damage

- Need to comply with stringent safety standards –ISO 26262 for Automotive
# How to Select Lithium-Ion Cell Chemistries?

<table>
<thead>
<tr>
<th>Name</th>
<th>Chemistry</th>
<th>Symbol</th>
<th>Nominal voltage</th>
<th>Full charge</th>
<th>Full discharge</th>
<th>Safe</th>
<th>Cost USD/Kwh</th>
<th>Energy Density Wh/Kg</th>
<th>Discharge C-Rate</th>
<th>Cycle Life Times</th>
<th>Typical Auto Use Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCO</td>
<td>Lithium Cobalt Oxide</td>
<td>LiCoC$_2$</td>
<td>3.6V</td>
<td>4.2V</td>
<td>3.0 V</td>
<td>Low</td>
<td>Low</td>
<td>200</td>
<td>2C</td>
<td>500-1000</td>
<td>-</td>
</tr>
<tr>
<td>LMO</td>
<td>Lithium Manganese Oxide</td>
<td>LiMn$_2$O$_4$</td>
<td>3.7V</td>
<td>4.2V</td>
<td>3.0 V</td>
<td>High</td>
<td>High</td>
<td>150</td>
<td>1C</td>
<td>300-700</td>
<td>-</td>
</tr>
<tr>
<td>LFP</td>
<td>Lithium Iron Phosphate</td>
<td>LiFePO$_4$</td>
<td>3.3V</td>
<td>3.65V</td>
<td>2.5V</td>
<td>Very High</td>
<td>High</td>
<td>120</td>
<td>1C</td>
<td>1000-2000</td>
<td>14 V - 48 V</td>
</tr>
<tr>
<td>NCA</td>
<td>Lithium Nickel Cobalt Aluminum Oxide</td>
<td>LiNiCoAlO$_2$</td>
<td>3.6V</td>
<td>4.2V</td>
<td>3.0 V</td>
<td>Mid</td>
<td>Mid</td>
<td>260</td>
<td>1C</td>
<td>500</td>
<td>xEV</td>
</tr>
<tr>
<td>NMC</td>
<td>Lithium Nickel Manganese</td>
<td>LiNiMnCoO$_2$</td>
<td>3.6V</td>
<td>4.2V+</td>
<td>3.0 V</td>
<td>Mid</td>
<td>Mid</td>
<td>220</td>
<td>1C</td>
<td>1000-2000</td>
<td>48 V - xEV</td>
</tr>
<tr>
<td>LTO</td>
<td>Lithium Titanate</td>
<td>Li$_2$TiO$_3$</td>
<td>2.4V</td>
<td>2.85V</td>
<td>1.8 V</td>
<td>Very High</td>
<td>High</td>
<td>80</td>
<td>30C</td>
<td>3000-7000</td>
<td>14 V</td>
</tr>
<tr>
<td>PB</td>
<td>Lead Acid</td>
<td>-</td>
<td>2.0 V</td>
<td>-</td>
<td>-</td>
<td>Thermally Stable</td>
<td>Very Low</td>
<td>30-50</td>
<td>0.2C</td>
<td>200-300</td>
<td>12 V</td>
</tr>
</tbody>
</table>

Source: [http://batteryuniversity.com/learn/article/types_of_lithium_ion](http://batteryuniversity.com/learn/article/types_of_lithium_ion)
Why Accurate Voltage Measurement for SOC Better Performances?

SOC accuracy depends on voltage measurement accuracy

1 V ≡ 80% SOC
(12.5 mV/1% SOC)

140 mV ≡ 80% SOC
(1.75 mV/1% SOC)
Why Accurate Current Measurement for SOC Better Performances?

• Initial state of change estimation is necessary and needs to be accurate

• Then current is integrated by using the Coulomb counting function

• SOC accuracy depends on measurement accuracy of both current and voltage
Why Synchronized Measurements for SOH Better Performances?

- State of Health = SOH
- Internal cell resistance is one of the many factors used to determine SOH
- SOH measurement requires a **good synchronization** of current and voltage measurements – typically 100 us

\[
SOH = \left( \frac{R_i}{R_0} \right) \times 100
\]
Applications Solution for Battery Management System
Scalable Battery Cell Controller Portfolio
Targets Broad Range of Battery Management Applications

E-mobility
- Automotive
- Light EV
- Battery tram, ferry
- Urban delivery vehicles
- E-bike/scooter/snow scooter…
- …

Industrial
- Robot
- Autonomous guided vehicles
- Agricultural applications
- E-wheelchair
- …

Energy Storage System
- Smart grid ESS
- Home ESS
- UPS
- …

Consumer
- Hand tooling
- Garden tooling
- …
Li-ion BMS Application Overview

14 V Li-ion BMS

- IVN
- System Basis Chip (Power Management and Communication)
- Microcontroller
- Battery Cell Controller AFE
- 14 V Li-ion Battery

48 V Li-ion BMS

- IVN
- System Basis Chip (Power Management and Communication)
- Microcontroller
- Battery Cell Controller AFE
- 48 V High Voltage Battery

Hybrid and Electric Vehicle BMS

- High-Voltage BMS
  - System Basis Chip (Power Management and Communications)
  - Microcontroller
  - Battery Cell Controllers AFE
  - High Voltage Battery
  - Switches, Pre-charge Stack Voltage, Current
  - Cooling Fan, Pumps
  - HV Battery contactors

- IVN
  - System Basis Chip (Power Management and Communications)
  - Microcontroller
  - Battery Sensor AFE
  - Motor Driver
  - Load Switching

Level of Electrification

- Advanced Start-Stop
  - 14 V Li-ion Battery

- 48 V Mild Hybrid
  - 48 V Li-ion Battery

- EV/PHEV
  - High Voltage Li-ion Battery
Main advantages of centralized solution is to have short connections between each nodes (usually less than 0.5m) which brings the following benefits:

➢ Very limited signal attenuation/distortion allowing a 100% reliable communication up to 15 nodes (Rev B) on all temp range => excellent S/N and less attenuation

➢ Only one low cost single channel transformer between each nodes

➢ Loopback capability

*Production proven, reference design available
Differentiating features
NXP MC33771/2B Battery Cell Controller Solution

Differentiating Points

Battery topology flexibility
- Scalable SW & HW compatible BMS solution supporting **4 to 210 cells per daisy chain**
- MC33771B (7 to 14 cells) & MC33772B (3 to 6 cells) fully compatible
- Supporting centralized, distributed daisy chain, distributed CAN

High integration level
- Synchronized on-chip current sensor
- Synchronized on-chip coulomb counter
- Integrated passive balancing (300 mA per ch)
- Integrated power regulator

Fast & robust communication & DAQ
- 4.0 Mbps SPI or isolated 2.0 Mbps differential communication with transformer
- < 546 us conversion time for all measurements
- 3.6 ~ 4.1 ms for sending command and read back **96** cell 16-bit voltage data

High lifetime measurement accuracy
- ± 0.8 mV total voltage measurement error (after soldering & 1000 hrs HTOL aging)
- ± 0.5% total stack voltage measurement
- ± 0.5% accuracy integrated current sensor

Diagnosis and functional safety supporting ISO 26262 w/ single chip
- Single chip ASIL C capable (easy ASIL D)
- Sleep mode OV/UV and temperature monitor
- > 40 integrated safety mechanisms detecting internal and external faults

Automotive robustness
- ESD, EMC; Hot Plug, AEC-Q 100
- Temp range: -40°C to 105°C
- Operational low-power mode
BCC next Revision (Rev C)
MC33771C – Improved Daisy Chain

MC33771C TPL2 improvements:
- **Compatible** with MC33664
- Inductive & **capacitive** coupling support (current transformers & current external components)
- Up to **63 nodes in a single daisy chain**
- Support **20m** between each node
- **Loopback** support for 1 daisy chain.

MC33771C on chip **Averaging** measurement
- Reduces communication on TPL bus
- Higher acquisition frequency possible
- Smaller/cheaper anti-aliasing filter capacitor
- Improves noise performance

- The revC device is **pin compatible** with revB, the **Cell Management Controller (CMC)** PCB built with revB can be **fully reused**
- **Same Package and Pinout** between MC33771B & MC33771C
- **Minor TPL protocol** layer changes are required on the **Battery Management Controller (BMC)** when introducing the revC

MC33771B
- TPL PHY is a bus which is cut by internal switches
- Each wire segment, bus switch, and transformer contribute to signal attenuation and limit the number of nodes
- TPL is compatible with the MC33664

MC33771C
- TPL2 PHY bus is a series of lower power communication links
- Each node has a bidirectional repeater with transceivers for up and down communication
- TPL2 is compatible with the MC33664
## Battery Cell Controller Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MC33771B</th>
<th>MC33771C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Channels</td>
<td>7 - 14</td>
<td>7 – 14 w/ Averaging</td>
</tr>
<tr>
<td>Supply Vpwr Range (Max Transient)</td>
<td>9.6V..61.6V (75V)</td>
<td>9.6V..61.6V (75V)</td>
</tr>
<tr>
<td>Cell Terminal Input Voltage Range</td>
<td>-0.3V to 5V</td>
<td>-0.3V to 5V</td>
</tr>
<tr>
<td>Typical Measurement Error</td>
<td>± 0.8 mV</td>
<td>± 0.8 mV</td>
</tr>
<tr>
<td>Functional Safety</td>
<td>Single-chip ASIL C ASIL D Compliance</td>
<td>Single-chip ASIL C ASIL D Compliance</td>
</tr>
<tr>
<td>Isolated communication Speed</td>
<td>2 Mbps</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Communication Isolation</td>
<td>Inductive (Capacitive)</td>
<td>Inductive, Capacitive</td>
</tr>
<tr>
<td>Max Nodes per Daisy Chain</td>
<td>15</td>
<td>63 w/ Loopback</td>
</tr>
<tr>
<td>4Mbps SPI communication</td>
<td>Yes</td>
<td>No MPN (available w/ TPL MPN)</td>
</tr>
<tr>
<td>CRC Bit</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Comms bit</td>
<td>40</td>
<td>48</td>
</tr>
<tr>
<td>Integrated Balancing</td>
<td>&lt;300 mA</td>
<td>&lt;300 mA</td>
</tr>
<tr>
<td>Balancing sleep mode</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Deep sleep mode</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>GPIO / Analog measurement inputs</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Current Channels</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Coulomb counter</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Package</td>
<td>64-pin LQFP-EP</td>
<td>64-pin LQFP-EP</td>
</tr>
</tbody>
</table>

- Increased bus bandwidth
- Improved noise
- 25% R/C BOM reduction
- Extended daisy chain
- Capacitive isolation
- Enhanced safety

The information given in this document is non-binding and preliminary and provided without legal commitment whatsoever. It may be subject to changes and amendments and it may be terminated at any time.
Reference Designs
• Permanent measurement of cell voltages
• Over-temperature protection
• Overcurrent / overvoltage detection
• Safe relay (breaker) control (ASIL C)
• Various definable Safe States
• LIN and CAN bus interface
• Crash detection
• Overcurrent control fuse
• Power supply with watchdog protection
• Control of up to 6 Lithium-ion battery cells
Ready to Use MC33772 Based Safety BMS

Features
- 4 to 6 cell Li-ion battery
- Cell balancing circuit
- Intrusive diagnostics (MCU)
- Battery disconnecting switch control circuit
- 200 A perm/ 800A for 300ms
- Low power self-power consumption
- Cell voltage/ current/ temperature monitoring
- CAN bus interface

Customer Benefits
- Off the shelf 14V BMS ref design
- Application level safety concept
- NewTec professional Service
Battery Cell Controllers Reference Design Overview
Mature reference designs accelerating customer development

48V Mild Hybrid
Auxiliary Battery
- Complete system design, targeting automotive applications
- Using MC33771B, MPC5744, FS6500
- Isolated communication with transformers
- Standard BOM based on revB datasheet
- Example integration with AutoSAR

High Voltage
Centralized BMS
- 56 cell support on 4x MC33771C
- S32K1 Microcontroller
- Designed and validated for automotive applications

High Voltage Distributed
BMS
- BOM cost optimized CMC based on MC33771C
- Can be used in long daisy chain applications with up to 62 nodes
- Tested with S32K1 based BMC

Smart Battery for Drones
- 6-24 V single-chip BMS solution with MC33772B
- Compact low cost design
- S32K1 Microcontroller
- NFC / Authentication

# High Voltage Board Overview

<table>
<thead>
<tr>
<th>Functions</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage measurement</td>
<td>7~14 cells on each AFE, up to 56 cells, stackable</td>
</tr>
<tr>
<td>Temperature measurement</td>
<td>Each AFE have 1 channel for onboard cell balancing resistor measurement, 6 channel for external NTC measurement</td>
</tr>
<tr>
<td>Cell balancing</td>
<td>100~300mA per channel, configurable by solder CB resistors</td>
</tr>
<tr>
<td>Communication</td>
<td>On-board capacitor or Transformer Isolation selectable</td>
</tr>
<tr>
<td></td>
<td>Off-board Transformer Isolation, stackable with other board</td>
</tr>
<tr>
<td></td>
<td>MCU module could be bypass by resistor selection</td>
</tr>
<tr>
<td></td>
<td>1Mbps CAN baud rate</td>
</tr>
</tbody>
</table>
High Voltage Block Diagram Overview

- **HV Connector**
  - EMC
  - Cell Balancing 100~300mA
  - Filter
  - AFE MC33771

- **MCU**
  - S32K144
  - AFE MC33771
  - Filter
  - Cell Balancing 100~300mA
  - EMC

- **TPL**
  - MC33664
  - Filter
  - Cell Balancing 100~300mA
  - EMC

- **Connector**
  - HV Connector
  - LV Connector
  - NTC
  - Link +
  - Link -

- **Components**
  - Lead Acid 12V
  - Global CAN
  - SPI
  - CAN
  - I/O
  - LV Connector
  - SPI
  - Global CAN

- **Isolation**
  - Off-board Transformer Isolation
  - On-board Capacitor Isolation
  - Transformer Isolation is optional
  - On/Off-board Transformer Isolation
  - Resistor selection to bypass MCU module for flexible usage
Block Diagram Example for Drone/E-Bike applications (No Safety and No isolation)
Half Distributed HV BMS SYSTEM
Architecture based on TPL communication

Battery Junction/Switch Box
HV Current & Voltage Measurement

BMC

MCU
SPI
MC3366x
SPI⇒TPL
Transformer
Connector

CSC 0

MC3377x
Node 1
Transformer/Caps
MC3377x
Node 2
Transformer/Caps
MC3377x
Node 3
Transformer/Caps
MC3377x
Node 4
Transformer/Caps

CSC 1

MC3377x
Node 8
Transformer/Caps
MC3377x
Node 7
Transformer/Caps
MC3377x
Node 6
Transformer/Caps
MC3377x
Node 5
Transformer/Caps

MC3377x
Node 5
Transformer/Caps
MC3377x
Node 6
Transformer/Caps
MC3377x
Node 7
Transformer/Caps
MC3377x
Node 8
Transformer/Caps

Transformer
Transformer/Caps
Transformer/Caps
Transformer/Caps
Transformer/Caps
Transformer/Caps
Functional Safety Support
NXP’s Safe Assure Program

Simplify Customer Experience
ISO26262 system compliance process

Optimize Customer R&D Efficiency
Reduces time and complexity required to develop
ISO26262 safety systems

Reduce Risk of Harm
Supports the most stringent Automotive Safety
Integrity Levels (ASILs)

Safety Starts with Quality
Zero defect methodology from design to manufacturing
to help ensure our products meet the stringent
demands of safety applications
SafeAssure Communities: Customer Support for Functional Safety

**SafeAssure Community**
Public Space for knowledge distribution and industry-wide news [here](#)

**SafeAssure NDA**
Private NDA space for customer to access safety documentation [here](#)

**Support**
Safety Expert Group composed of Safety Managers and Architects, Field and Application Engineers

Self Sufficient: Community users find answers to their questions and safety documentation requests
Functional Safety Community

- [https://community.nxp.com/community/safeassure-community](https://community.nxp.com/community/safeassure-community)

- Register and click ‘Download NDA’. Complete and send to safeassure@nxp.com

- Once approved, click ‘GET YOUR ACCESS NDA DOCUMENTS’ banner

- Click on ‘MCUs and MPUs NDA Documents’ link to get –
  - Safety Manual
  - Standardized FMEDA
  - Safety Analysis Report (also known as ‘FMEDA Report’)
  - Confirmation Measures report
  - PPAP
FMEDA calculates the safety metrics required by ISO26262

- **SPFM**: Single point fault metric.
  - Failure which is immediately violating one of the application safety goal (>99% for ASIL D)
- **LFM**: Latent point fault metric
  - Failure in the Safety Detection Mechanism (also called monitoring) which could lead to the violation of the application safety goal in conjunction with a single point fault (>90% for ASIL D)
- **PMHF**: Probability Metric of Hardware Failure
  - Residual probability to violate a safety goal (<10^-8 for ASIL D)
BCC Rev C Enablement Tools
Battery Cell Controllers evaluation boards and SW for revC

High Voltage Centralized BMS
- 56 cell support on 4x MC33771C
- S32K1 Microcontroller
- Designed and validated for automotive applications

High Voltage Distributed BMS
- BOM cost optimized CMC based on MC33771C
- Can be used in long daisy chain applications with up to 62 nodes
- Orderable on NXP.com

DUAL TPL EVB
- Extension for S32K1 MCU
- 2x MC33664 for loopback capability
- To be used with HVBMS distributed BMS
- Orderable on NXP.com

- Evaluation GUI : S32K144EVB + DualTPL EVB ----- TPL ----- 33771C EVB : Q1 2020
Supports S32K FW update if needed
Supports TPL communication for daisy chain
Provide device registers configuration and measurements access

GUI v5.x
## Battery Cell Controller rev C – Analog Expert SW Driver

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCC_Init</td>
<td>Initializes the Battery Cell Controller device or devices (depends on configuration). It Assigns CID, initializes communication interface according to selected mode (classic SPI or TPL) and configures the device with predefined values from Processor Expert properties.</td>
</tr>
<tr>
<td>BCC_Deinit</td>
<td>Deinitializes the components used by Battery Cell Controller component. Note that this method does not reset the device.</td>
</tr>
<tr>
<td>BCC_WriteRegister</td>
<td>This method writes a value to addressed register of selected Battery Cell Controller device.</td>
</tr>
<tr>
<td>BCC_WriteGlobalRegister</td>
<td>This method writes a value to addressed register of all configured Battery Cell Controller devices. This method is available when communication mode is TPL.</td>
</tr>
<tr>
<td>BCC_ReadRegisters</td>
<td>This method reads a value from addressed register of selected Battery Cell Controller device.</td>
</tr>
<tr>
<td>BCC_Sleep</td>
<td>Sets sleep mode of all Battery Cell Controller devices. MC33664TL goes to sleep mode automatically.</td>
</tr>
<tr>
<td>BCC_StartConversion</td>
<td>Starts ADC conversion. It sets Start of Conversion bit and new value of TAG ID in ADC_CFG register. TAG ID is increment for each conversion. You can use method IsConverting to check conversion status.</td>
</tr>
<tr>
<td>BCC_IsConverting</td>
<td>Checks status of conversion defined by End of Conversion bit in ADC_CFG register.</td>
</tr>
<tr>
<td>BCC_GetRawMeasurements</td>
<td>Reads the measurement registers and returns raw values. You can use macros defined in header file to perform correct unit conversion.</td>
</tr>
<tr>
<td>BCC_GetAverageCurrent</td>
<td>Computes average current using use of the Coulomb counter. Note that the Coulomb counter depends on settings of BCC (see “Action on Read CC” property).</td>
</tr>
<tr>
<td>BCC_GetStatus</td>
<td>Reads status registers and returns raw values. List of read registers: CELL OV FLT, CELL UV FLT, CB OPEN FLT, CB SHORT FLT, CB_DRV Status, CB1 AN OT UT FLT, GPIO SHORT Anx OPEN_STS, I STATUS, PGA DAC, COM STATUS, FAULT1_STATUS, FAULT2_STATUS, FAULT3_STATUS.</td>
</tr>
<tr>
<td>BCC_RunDiagnostic</td>
<td>Call internal diagnostic functions.</td>
</tr>
<tr>
<td>BCC_SoftwareReset</td>
<td>Resets Battery Cell Controller device using software reset. It enters reset via SPI or TPL interface.</td>
</tr>
<tr>
<td>BCC_HardwareReset</td>
<td>Resets Battery Cell Controller device using software reset. It enters reset via RESET pin. This method is available when RESET pin is enabled in properties (“Reset pin” set to Enabled).</td>
</tr>
<tr>
<td>BCC_SetGPIOOutput</td>
<td>Sets output value of Battery Cell Controller GPIO pin. This method is available when at least one GPIO is in output mode.</td>
</tr>
<tr>
<td>BCC_SetCBDrivers</td>
<td>Sets state of cell balancing drivers. It is designated to control all the drivers at once.</td>
</tr>
<tr>
<td>BCC_GetNtcCelsius</td>
<td>This method calculates temperature from raw value of MEAS ANx register. You can use method GetRawMeasurements to get values of measurement registers. It uses precomputed values stored in BCC_NTC_TABLE table.</td>
</tr>
</tbody>
</table>

## Analog expert SW driver details:
- Tools chain supported
  - S32 DS 2018.R1
  - S32 SDK EAR 3.0.0
- S32K144 Project examples
  - BCC14
  - TPL communication
  - Diagnostics / Measurements
  - Freemaster 2.0

## Supported HW:
- S32K144EVB-Q100
- FRDM33664BEVB
- RD33771CDSTEBV

## Documentation:
- SW User’s Guide and readme file
- Programmers’ guide
Evaluation platform – distributed system

SW TOOLS:
- MC33771C software driver for 32-bit Microcontrollers
- Evaluation GUI for Windows PC to connect to S32K144EVB
Evaluation platform – centralized system

**SW TOOLS:**
- MC33771C software driver for 16-bit or 32-bit Microcontrollers (ARM, PPC or S12 core)
- CAN protocol documentation
- S32 Design Studio
MPC5777C-DEVB
Low-Cost, Standalone, Development Board for NXP’s SPC5777C, FS65xx and TJA11xx Family of Products

• The MPC5777C-DEVB board includes a complete NXP system solution with the highly integrated SPC5777C MCU as well as the advanced MC33FS6520LAE system basis chip and the TJA1100 and TJA1145T/FD Ethernet and CAN FD PHYs.

• These products offer the system performance, safety and security needed for a range of applications from traction motors and battery management systems (BMS) to internal combustion engines and transmissions.

• MC33FS6520LAE is providing robust, scalable power management to the SPC5777C MCU with Fail Silent safety monitoring measures that fit for ASIL D. Software Library is available to ease Design integration as 1 HW + SW solution.

• The SPC5777C offers 264MHz lockstep cores to support ASIL-D, 8 MB of Flash, CAN-FD, Ethernet, advanced complex timers and a CSE hardware security module.
MPC5777C-DEVB
Low-Cost, Standalone, Development Board for NXP’s SPC5777C, FS65xx and TJA11xx Family of Products

• The MPC5777C-DEVB has the benefits over the existing motherboard + daughterboard in that it is significantly less expensive ($279 SRP vs $734), offers a smaller form factor and includes more interfaces for development and debug.

• The MPC5777C-DEVB will include a User Guide for fast start up and support of Lauterbach, P&E Multilink and GreenHills tools as debuggers.

• MPC5777C-DEVB available for online ordering.

• MSRP $279
Toulouse BMS laboratory certification
BMS System Validation Lab

BCI Testing
- Faraday Chamber
- 1 EMC Technician
- IEC 63132-3

Fault Injection
- Battery Emulator + NI PXI
- Automatic bench
- in line with ISO26262 norm

ISO Pulse
- ISO Pulse standard
- ISO 7637, ISO 16750, LV 124, LV 148

Use Cases
- Daisy Chain
- State Machine
- Tests in Temperature

Hotplug set-up
- Battery terminals plugged randomly
BMS IC Validation EMC Lab

Conducted, Direct Pin Injection method
IEC 62132-4 Immunity

Conducted Emission, 1Ω/150Ω direct coupling method
IEC 61967-4

Radiated Immunity, TEM-cell method
IEC 62132-2

Radiated Emission, TEM-cell method
IEC 61967-2

Radiated Immunity, Bulk Current Injection method
IEC 62132-3

Radiated Emission, TL 81000
External TLS Labs

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Safety Power Management for ASIL-C/D applications

MC33FS45xx, MC33FS65xx
MC35FS45xx, MC33FS65xx
Role of the Safety Power Supply in a Fail Silent System

Main tasks
- Deliver safety related supply rail(s) to the MCU and other peripherals of a safety system
- Monitor safety related supply rails for OV and UV (Detection)
- Request for a system degradation in case of fault in the Fault Tolerant Time (Safe State)

Additional safety mechanisms to facilitate system integration
Safety Power Management – Attach With MPC57xx

Powertrain Electrification Safety Power Management

Ideal Companion of MPC57xx
Fit for ASIL D & Fail Silent
Pin to Pin Compatible Family
High Robustness

Secured & Safe System Solutions
- ISO 26262 architecture (TUV SUD proven)
- Functional robustness (non ISO pulse, EMC, HTOL)
- Security (SM transition and Power Gate)

High Efficient Solutions
- Target 12 V, 24 V, 48 V (application note)
- DCDC & LDO architecture (Vpre + Vcore)
- Ultra low power modes (low Iq, long dur. timer)

Safety Simplified Solutions
- ISO 26262 ready documentation
- System validation test (eFAST)
- Global ecosystem (incl HW & SW)

Value Proposition

Gen 1
MPC56x ATTACH
Safety / Chassis Production

Gen 2
MPC57X ATTACH
Same platform FS45 and FS65
Pin to Pin compatible with MC33907/908
Grade 1 and Grade 0 Qualified, OEM Certified

MC33907/8
- 12V DCDC
- 0.8A – 1.5A
- Low Power
- FAIL SAFE
- CAN

FS4500
- 12V DCDC + LDO 0.5A
- Long Duration Timer
- FAIL SAFE
- CAN FD2M

FS650x
- 12V DCDC + DCDC 0.8A
- Long Duration Timer
- FAIL SAFE
- CAN FD2M

FS651x
- 12V DCDC + DCDC 1.5A
- Long Duration Timer
- FAIL SAFE
- CAN FD2M

FS652x
- 12V DCDC + DCDC 2.2A
- Long Duration Timer
- FAIL SAFE
- CAN FD2M

FS4500
FS650x
FS651x
FS652x
FS45/65 Solution for BMS: System Added Values
Enabling ASIL D Fail Silent Operations, Simplify Design and Reduce System Cost

✓ Fit for ASIL-D applications
- SPM>90\%, LT>99\%, PHMF<10\-8
- Analog & Digital Safety Mechanisms to fit for ASILD
- All safety mechanism reaction are < FTTI < 10ms

✓ Fail silent mode
- Optional reset at safe state to enable MCU Diag
- Configurable safe state, independently for each failure
- System availability: No MCU shutdown after multiple failures
- Smart degraded mode: safe and available operation

✓ Long duration timer
- Internal SBC Counter from few sec to 6 months
- Active in Run and Low Power Operations
- Measure time during Parking Mode (Low Power)
- Measure time during BMS Operation (Run)
- Optional Cyclic Wake Up (every week)

✓ Redundant fail safe pin (FS0B & FS1B)

- T duration operation: Inhibit CAN during Tdur duration
- T delay operation: Safe delay of BMS load desactivation
Conclusion
Summary

NXP Solutions are designed to:

• Address main BMS applications with scalable SW/HW compatible solutions
  - Optimized feature set for 48V & 14V Li-ion BMS
  - Efficient solutions supporting different High Voltage Battery topologies

• Leverage System solution (MCU, SBC, BMS) and Functional Safety

• Provide unique capabilities
  - Highest cell voltage accuracy: 0.8mV
  - Integrated current sense
  - Integrated 300mA Cell Balancing
  - Automotive quality and longevity
Microcontrollers for BMS
Automotive MCU Solutions for Battery Management Systems (BMS) and HEV/EV Inverter Applications

MPC5775B and MPC5775E

- To better address the growing HEV/EV market NXP Auto MCUs developed the MPC5775B and MPC5775E
- These MCUs will offer the performance, safety and security needed for Battery Management Systems (BMS) and Electric Vehicle Inverter applications.
- Both MCUs offer lockstep cores to support ASIL-D, 4 MB of Flash, CAN-FD and CSE security module.
- The MPC5775B is targeted for BMS applications
- The MPC5775E is targeted for Inverters with the inclusion of complex motor control timers (eTPU) and higher core performance
- 100% compatible and scalable to MPC5777C for higher memory and performance
- The MPC5775B and MPC5775E are qualified now and ready for production
**SPC5775B Safe & Secure BMS MCU**

### Specifications:
- **CPU:** 2 x Z7 220 MHz in LS & 1x Z7 220 MHz  
- **Memory:** 4 MB Flash, 512 KB RAM, 256 KB EEPROM, all with ECC  
- **Analog:** 2 x eQADC  
- **Package:** 416 MAPBGA (27 x 27 mm², 1mm pitch)  
- **Temp Range (Ta):** -40 to 125°C (150°C Tj), AEC-Q100 Grade 1

### Benefits:
- **Functional Safety:** as per ISO 26262 with target ASIL D: Lock step cores, ECC, temperature and voltage sensors, clock monitoring, Fault Collection Unit.  
- **Security:** Hardware module (CSE) with encryption/decryption, secure boot and key storage. Security firmware pre-programmed onto devices to simplify production  
- **Communication Peripherals:** CAN FD, Ethernet, SPI, LIN  
- **SW Enablement:** AUTOSAR MCAL, S32 Design Studio IDE support

### Table:

<table>
<thead>
<tr>
<th>Memory</th>
<th>CPU Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>512kB RAM w/ ECC</td>
<td><a href="#">Z7 @ 220MHz</a> 16kB I-cache 16kB D-cache FPU SPE1.1 / VLE MMU</td>
</tr>
<tr>
<td>256kB EEPROM w/ ECC</td>
<td><a href="#">Z7 @ 220MHz</a> 16kB I-cache 16kB D-cache FPU SPE1.1 / VLE MMU</td>
</tr>
<tr>
<td>4MB Flash w/ ECC</td>
<td><a href="#">Z7 @ 220MHz</a> 16kB I-cache 16kB D-cache FPU SPE1.1 / VLE MMU</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System &amp; Safety</th>
<th>Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMU</td>
<td>1x Ethernet (100Mbps)</td>
</tr>
<tr>
<td>FMPLL + PLL</td>
<td>2x MCAN w/ GAN-FD</td>
</tr>
<tr>
<td>FCCU &amp; CRC</td>
<td>4x FlexCAN</td>
</tr>
<tr>
<td>2x DMA</td>
<td>12x SENT</td>
</tr>
<tr>
<td>DEBUG Nexus 3+</td>
<td>5x dSPI</td>
</tr>
<tr>
<td></td>
<td>6x eSCI</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Security</th>
<th>Timers and ADCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSE2</td>
<td>2x eMIOS w/ 32 ch</td>
</tr>
<tr>
<td></td>
<td>2x eQADC (12bit) w/ 40 ch</td>
</tr>
</tbody>
</table>
SPC5775E Safe & Secure Inverter MCU

**Specifications:**
- **CPU:** 2 x Z7 264 MHz in LS & 1 x Z7 264 MHz
- **Memory:** 4 MB Flash, 512 KB RAM, 256 KB EEPROM, all with ECC
- **Analog:** 4 x eQADC, 4 x SD ADC
- **Package:** 416 MAPBGA (27x27 mm², 1 mm pitch)
- **Temp Range (Ta):** -40 to 125°C (150°C Tj), AEC-Q100 Grade 1

**Benefits:**
- **Traction Motor Control:** High performance cores with advanced programmable motor control timer and analog modules
- **Resolver Interface:** Managed through SD ADC, motor control timer and software without expensive external dedicated device.
- **Functional Safety:** as per ISO 26262 with target ASIL D: Lock step cores, ECC, temperature and voltage sensors, clock monitoring, Fault Collection Unit.
- **Security:** Hardware module (CSE) with encryption/decryption, secure boot and key storage. Security firmware pre-programmed onto devices to simplify production
- **Communication Peripherals:** CAN FD, Ethernet, SPI, LIN
- **SW Enablement:** SW for resolver interface, AUTOSAR MCAL, S32 Design Studio IDE support

**CPU Platform**
- Z7 @ 264MHz
  - 16kB I-cache
  - 16kB D-cache
  - FPU
  - SPE1.1 / VLE
  - MMU

**Lockstep Cores**
- Z7 @ 264MHz
  - 16kB I-cache
  - 16kB D-cache
  - FPU
  - SPE1.1 / VLE
  - MMU

**Connectivity**
- 1x Ethernet (100Mbps)
- 2x MCAN w/ CAN-FD
- 4x FlexCAN
- 12x SENT
- 5x dSPI
- 6x eSCI

**Timers and ADCs**
- 96ch Programmable motor control timer
- 2x eMIOS w/ 32 ch
- 4x SD ADC w/ 20 ch
- 4x eQADC (12bit) w/ 70 ch

**Memory**
- 512kB RAM w/ ECC
- 256kB EEPROM w/ ECC
- 4MB Flash w/ ECC

**System & Safety**
- PMU
- FMPLL + PLL
- FCCU & CRC
- 2x DMA
- DEBUG Nexus 3+

**Security**
- CSE2

**Specifications:**
- **CPU:** 2 x Z7 264 MHz in LS & 1 x Z7 264 MHz
- **Memory:** 4 MB Flash, 512 KB RAM, 256 KB EEPROM, all with ECC
- **Analog:** 4 x eQADC, 4 x SD ADC
- **Package:** 416 MAPBGA (27x27 mm², 1 mm pitch)
- **Temp Range (Ta):** -40 to 125°C (150°C Tj), AEC-Q100 Grade 1