Battery Management Systems Solution for Car Electrification

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SECURE CONNECTIONS FOR A SMARTER WORLD

Agenda

- Market trends: electrification and safety
- Battery Management introduction: what are the important parameters
- Applications solution for Battery Management systems
- Low voltage system solution with S32K MCU
- High voltage system solution with MPC5775B MCU
- MC33771, MC33772 Analog Front End and key features
- Safety Power Management for ASIL-D system
- Summary

Key Take-Aways

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
- System solution (MCU,SBC,BMS) and Functional Safety
- Provide unique capabilities
  - Highest cell voltage accuracy: 0.8 mV
  - Integrated current sense
  - Integrated 300 mA cell balancing
  - Automotive quality and longevity
  - ASIL-D power management Grade 0

Market Trends: Electrification and Safety

Industry Mega Trends
An Incredible Opportunity

CONNECTIVITY

AUTONOMY

ELECTRIFICATION

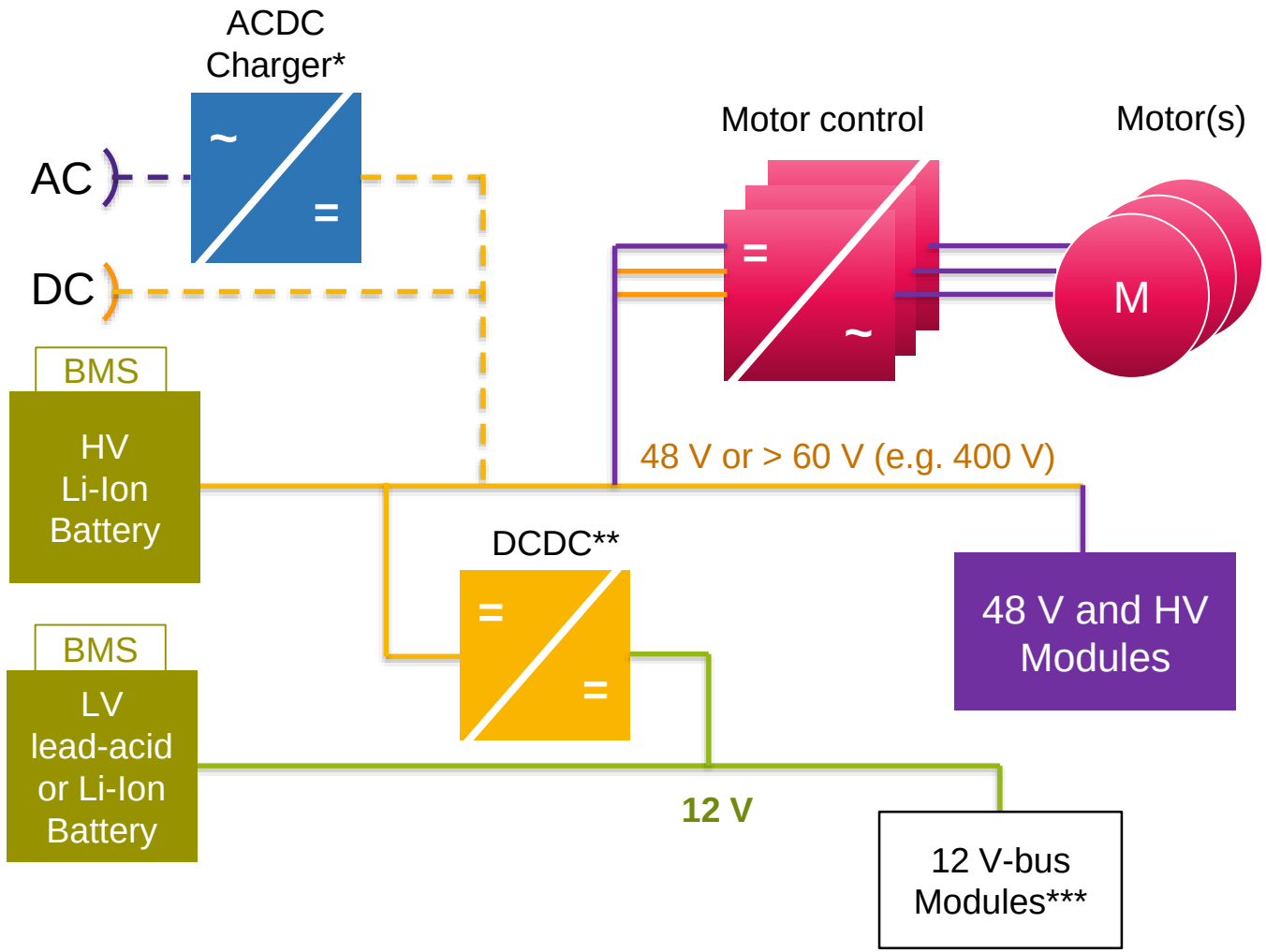
SAFE AND SECURE MOBILITY

MORE THAN TRIPLING THE SEMI VALUE PER CAR

New Applications Driving Automotive Market Growth

Major Components

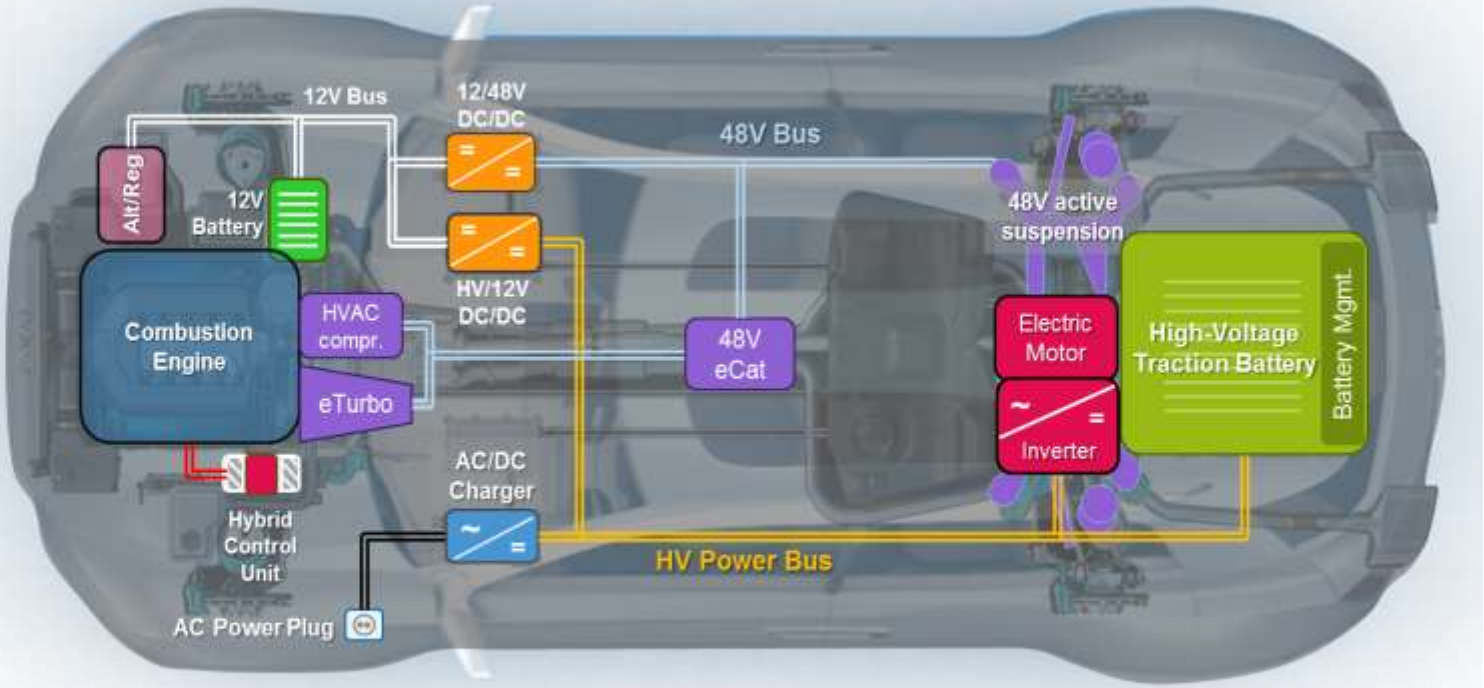
- Battery management system
- Motor control (inverters, HCUs)
- 48 V eMachine (BSG, ISG, HVAC)
- DC/DC voltage domain converter
- On-board charger AC/DC converter



* only in (P)HEVs, BEVs, omitted in 48 V MHEV systems
** bidirectional in 48 V systems
*** as in exisiting ICE-based vehicles

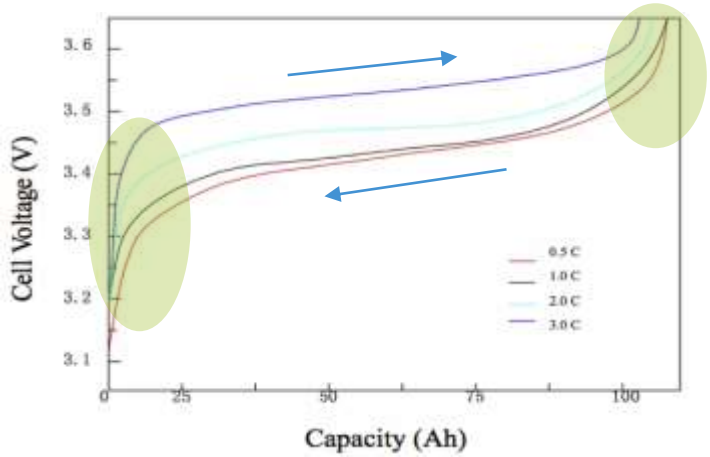
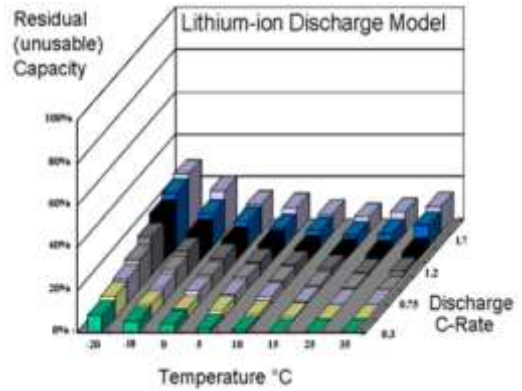
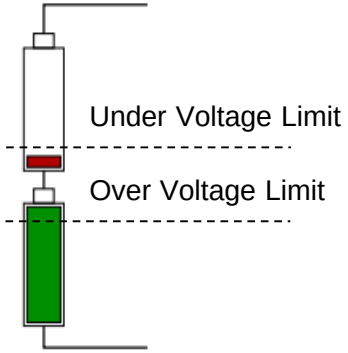
NXP Solutions for Cars' Electrification

	MCU	SBC	COMM	Driver	AFE
Battery management system	5775B	FS65	TJA104x	eSwitch	BCC77x
Motor control, inverter, HCU	5775E 5744P	FS65	TJA104x	GD3100	Software resolver
48V eMachine (BSG, ISG, HVAC)	S32Kx	FS45 UJA116x			
DC/DC voltage domain converter	S32K+		TJA104x		
On-board charger AC/DC converter	S32K+		TJA104x		



Battery Management Introduction: What are the Important Parameters

Main Functions of BMS Systems

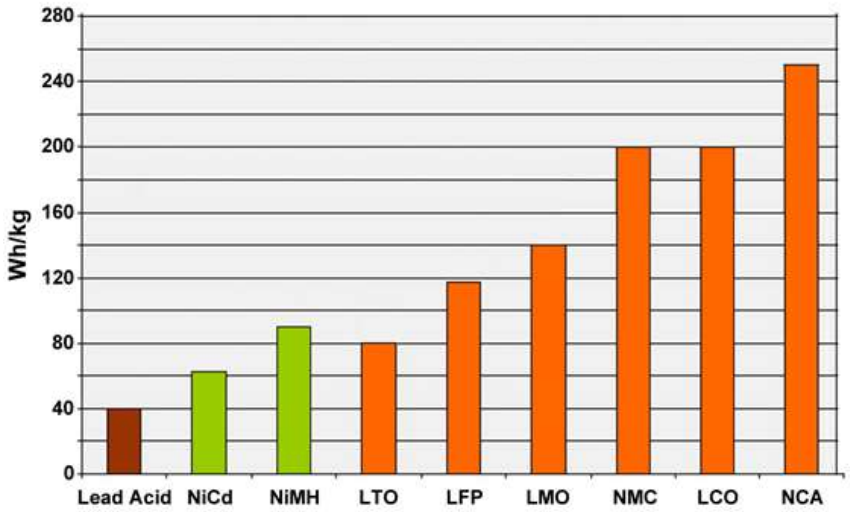
	Safety	Performance	Multi-Cell function
			
	Danger: • Over voltage • Extra heat • Unstable chemical stage • Thermal runaway=>fire/explosion • Low temperature charge	Requirements: • Safe & fast charging • Discharge optimization • State of charge (SOC) estimation • State of health (SOH) estimation	Challenges: • Up to hundreds of cells • Manufacture mismatch • Capacity degradation • Lifetime degradation
Key BMS Functions	V/I/T measurement	V/I/T measurement Coulomb counting Internal resistance calculation	Cell balancing

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 ?

Name	Chemistry	Symbol	Nominal voltage	Full charge	Full discharge	Safe	Cost USD/Kwh	Energy Density Wh/Kg	Discharge C-Rate	Cycle Life Times	Typical Auto Use Case
LCO	Lithium Cobalt Oxide	$LiCoC_2$	**3.6V**	4.2V	3.0 V	Low	Low	200	2C	500-1000	-
LMO	Lithium Manganese Oxide	$LiMn_2O_4$	**3.7V**	4.2V	3.0 V	High	High	150	1C	300-700	-
LFP	Lithium Iron Phosphate	$LiFePo_4$	**3.3V**	3.65V	2.5V	Very High	High	120	1C	1000-2000	14 V - 48 V
NCA	Lithium Nickel Cobalt Aluminum Oxide	$LiNiCoAlO_2$	**3.6V**	4.2V	3.0 V	Mid	Mid	260	1C	500	xEV
NMC	Lithium Nickel Manganese	$LiNiMnCoO_2$	**3.6V**	4.2V+	3.0 V	Mid	Mid	220	1C	1000-2000	48 V - xEV
LTO	Lithium Titanate	Li_2TiO_3	**2.4 V**	2.85V	1.8 V	Very High	High	80	30C	3000-7000	14 V
PB	Lead Acid	-	**2.0 V**	-	-	Thermally Stable	Very Low	30-50	0.2C	200-300	12 V

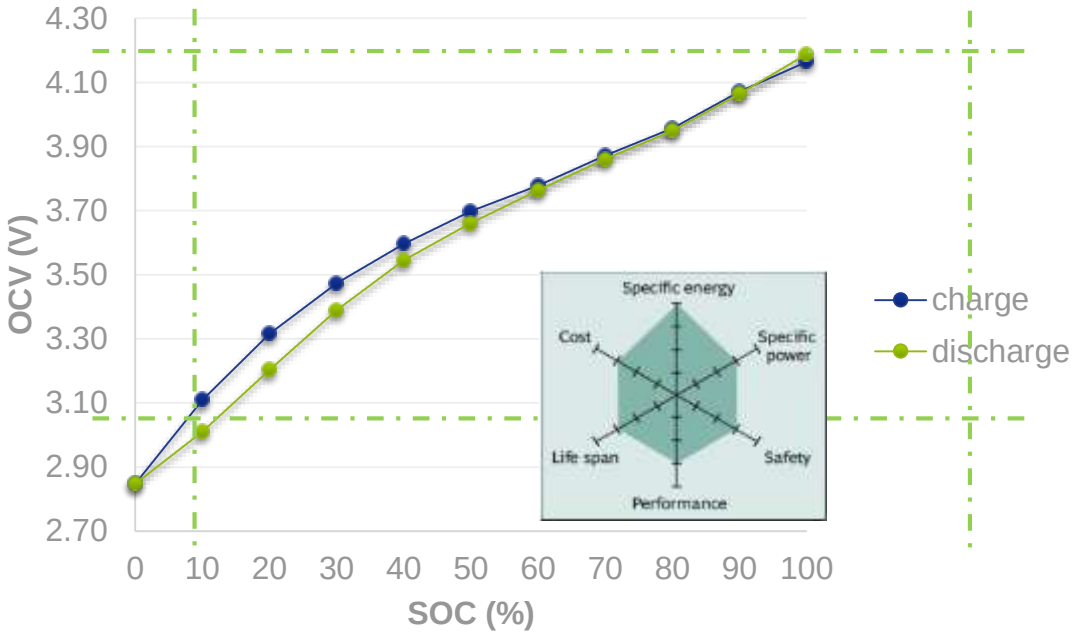


Source: http://batteryuniversity.com/learn/article/types_of_lithium_ion

Why Accurate Voltage Measurement for Better SoC Performances?

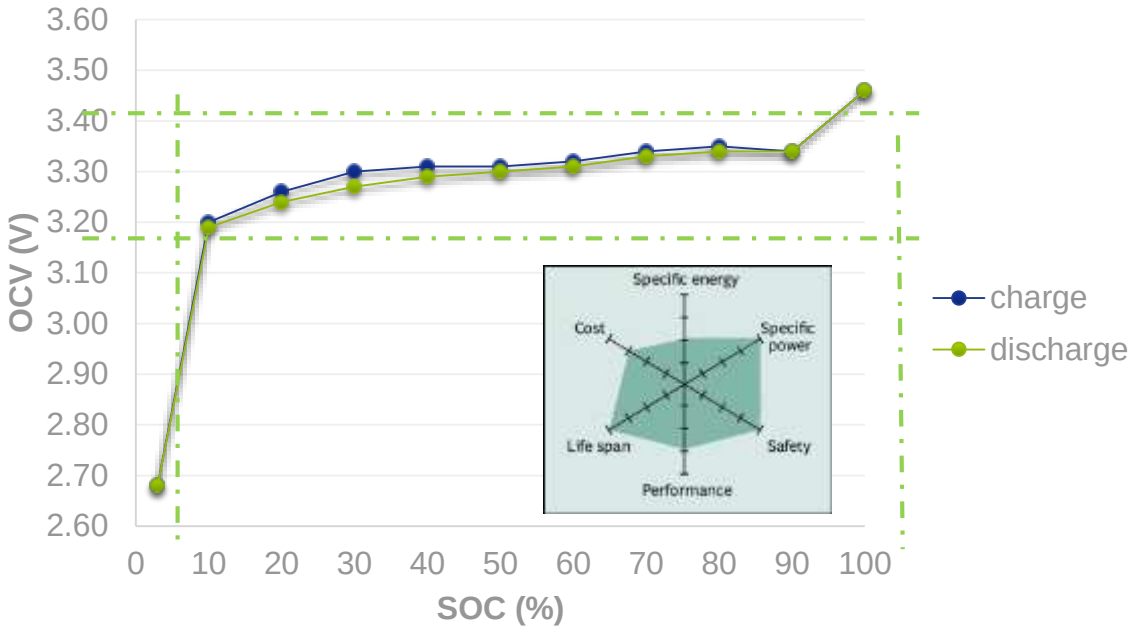
SOC accuracy depends on voltage measurement accuracy

NMC



1 V ≡ 80% SOC
(12,5 mV/1% SOC)

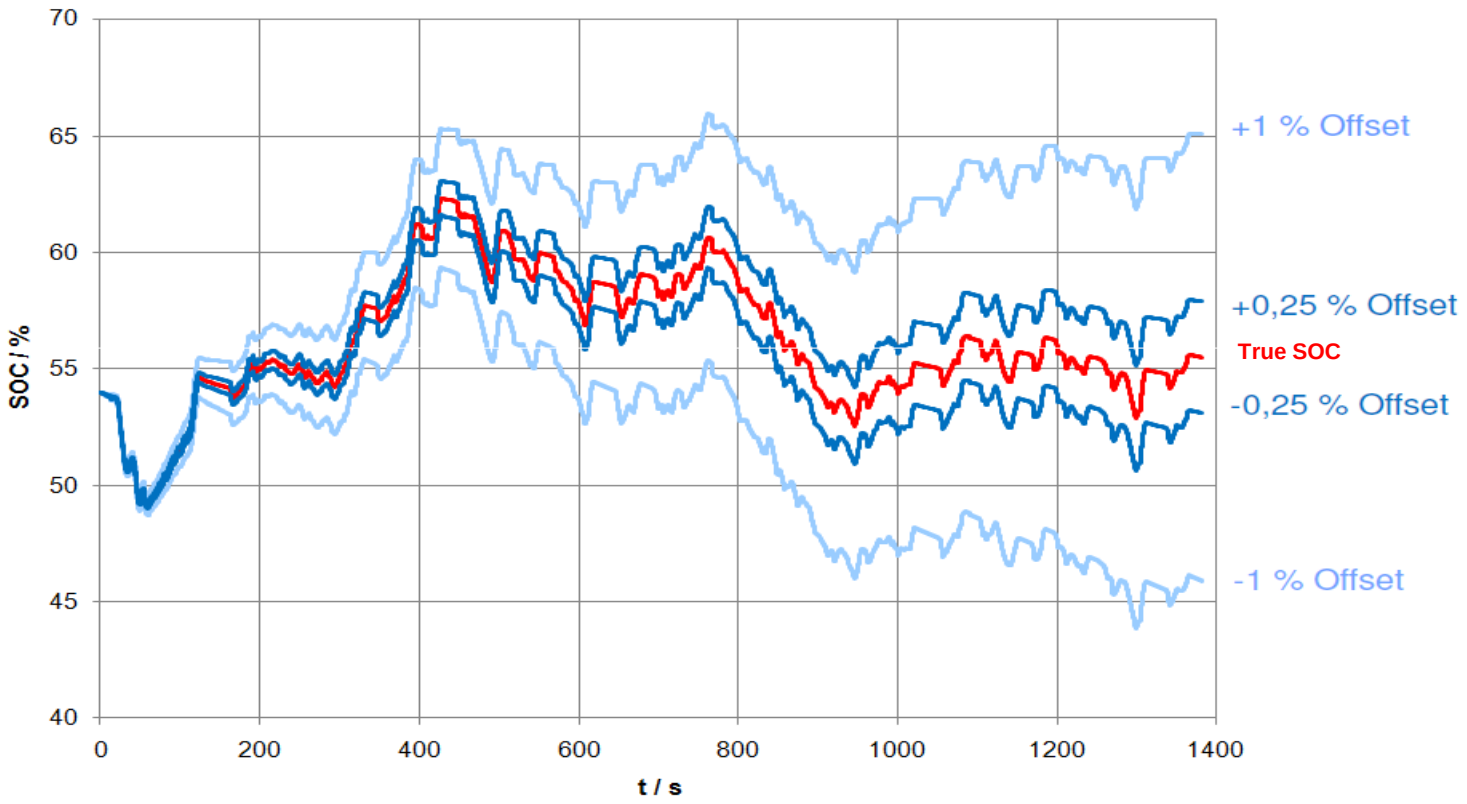
LFP



140 mV ≡ 80% SOC
(1,75 mV/1% SOC)

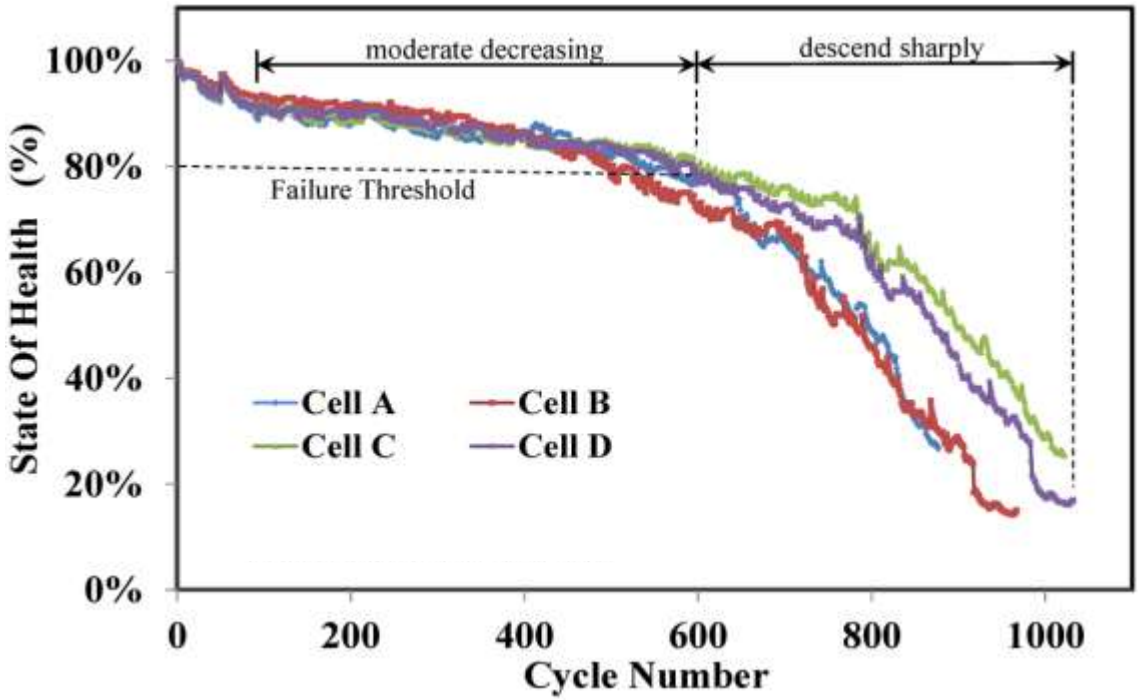
Why Accurate Current Measurement is Needed

- 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 are Neede

- 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



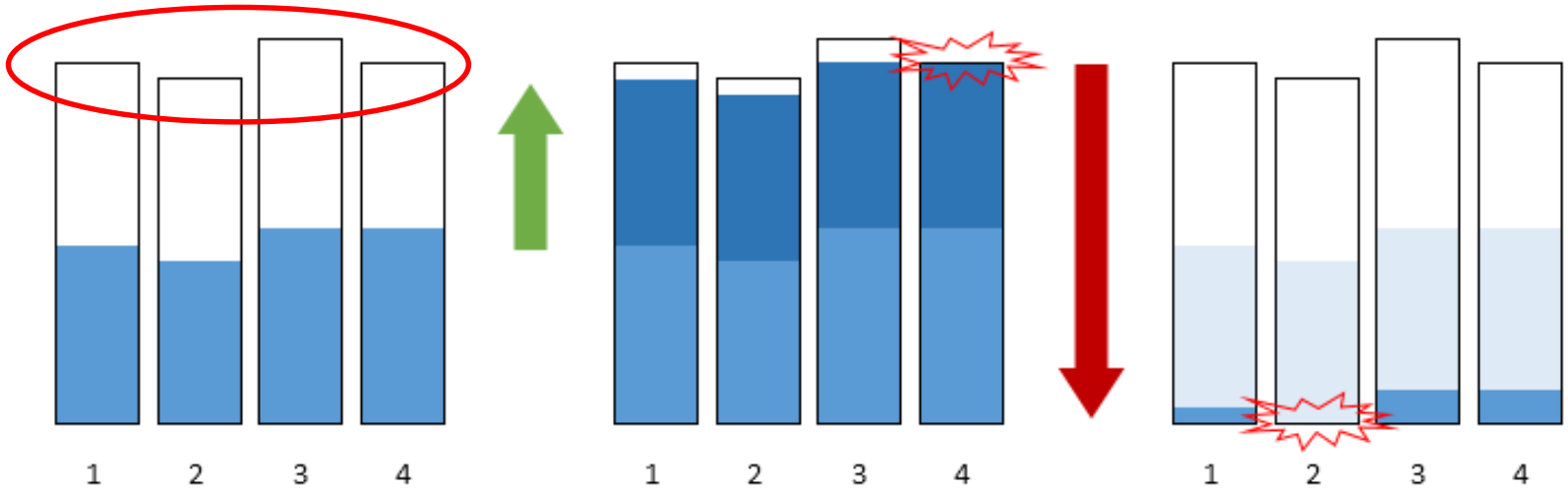
$$SOH = \left(\frac{R_i}{R_0}\right) * 100$$

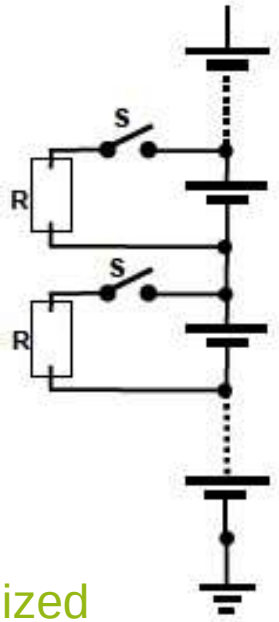
Why Balancing Cells for Battery Performances Enhancement ?

- Slight mismatch in capacity during manufacturing, additional mismatch during lifetime
- This results in wasted capacity during both charge and discharge

Passive Cell Balancing

Cell balancing is used to equalize SOCs

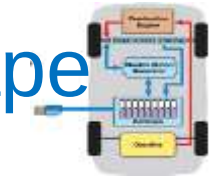




Without cell balancing, charge and discharge are not optimized

Applications Solution for Battery Management System

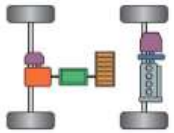
Electric Mobility Trends: Automotive Electrification landscape



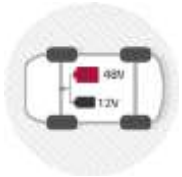
Motor

Motor + ICE

-25 to -35% Co2

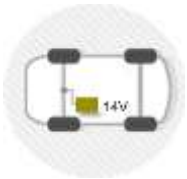


- 15 to -20% CO2



ICE + Motor

-4 to -6% CO2



ICE + Motor

Plug-In Capable

Extended Electrical Drive

Short Electrical Drive

Full Electrical Drive

ICE

Engine Assist

Regenerative Braking

Engine Start/Stop

Conventional ICE

Downsized ICE

Micro Hybrid

Mild Hybrid

Full Hybrid

Plug-in Hybrid

Full Electric

Additional cost

5000 $

2000 $

500 $

200 $

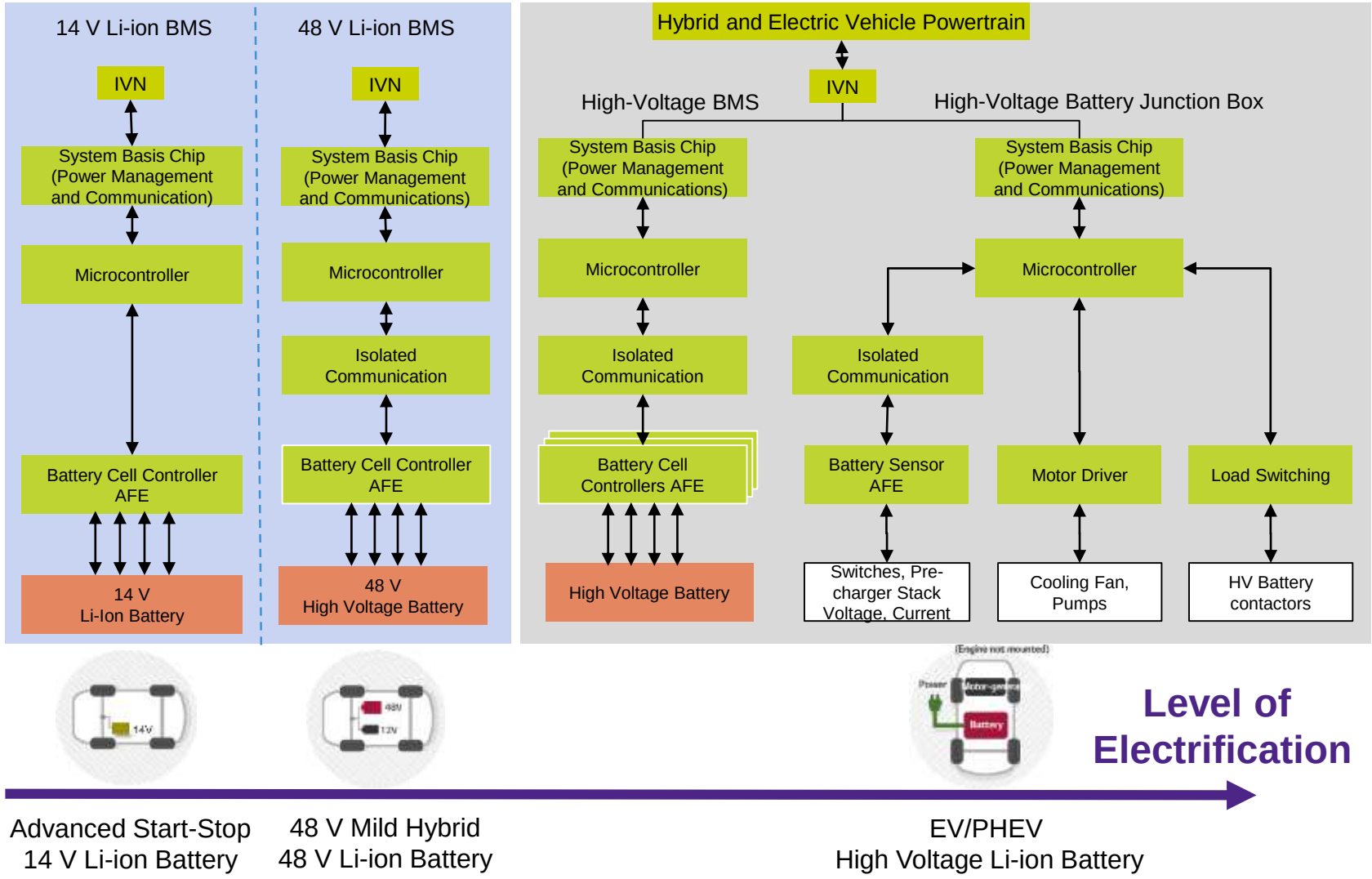
Hybrid Functions

Key drivers:
- Tax incentives
- Regulations (CO2)
- Oil shortage
- Eco mindset
- Technology trends

electric powertrain characteristic

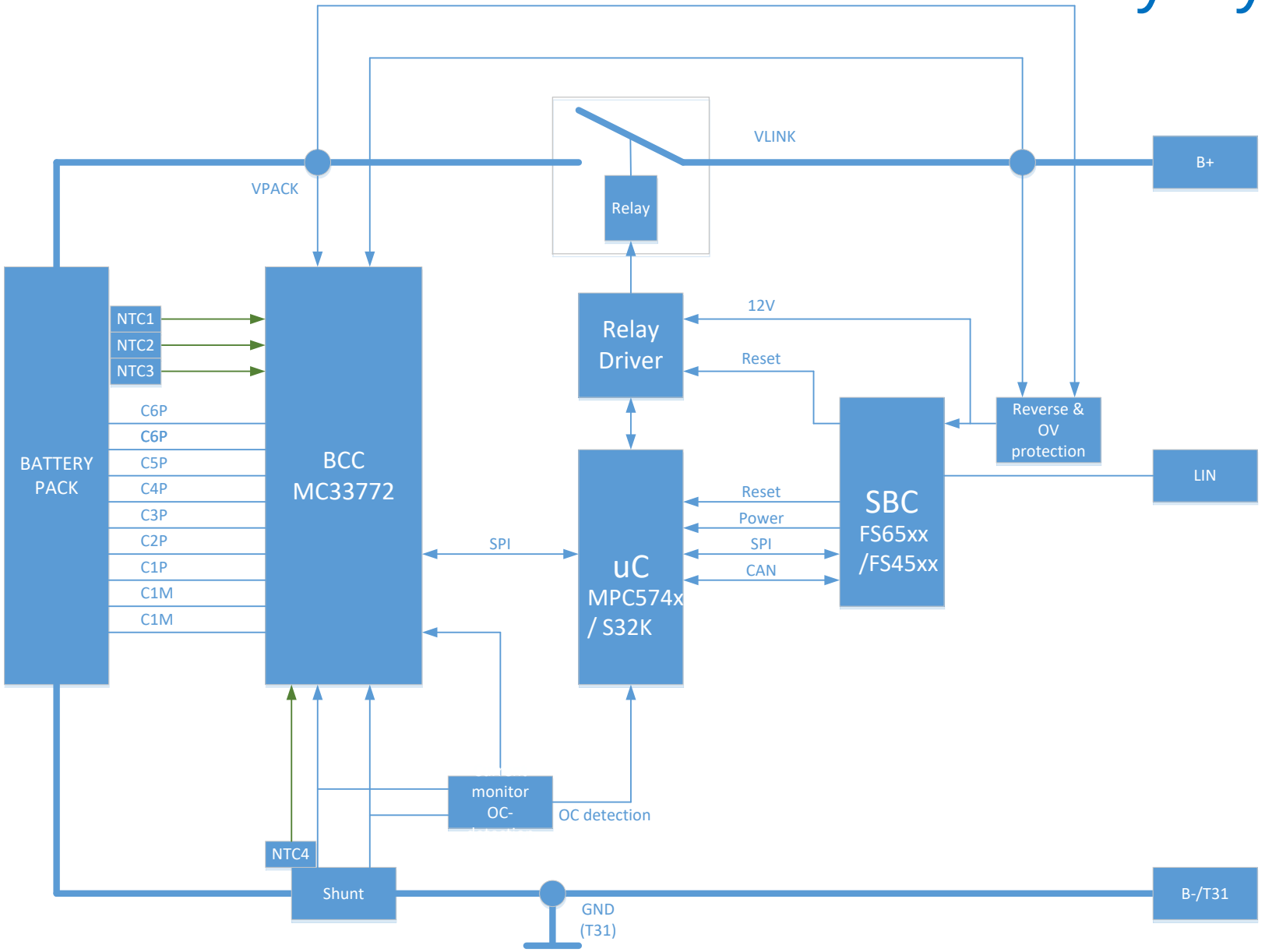
Traction Motor Power	2 to 10 kW	10 to 20 kW	15 to 60 kW	40 to 80 kW	>80 kW
Battery Voltage	12 to 48V	48 to 100V	100 to 300V	> 300V	> 400-800V

Automotive Li-ion BMS Application Overview

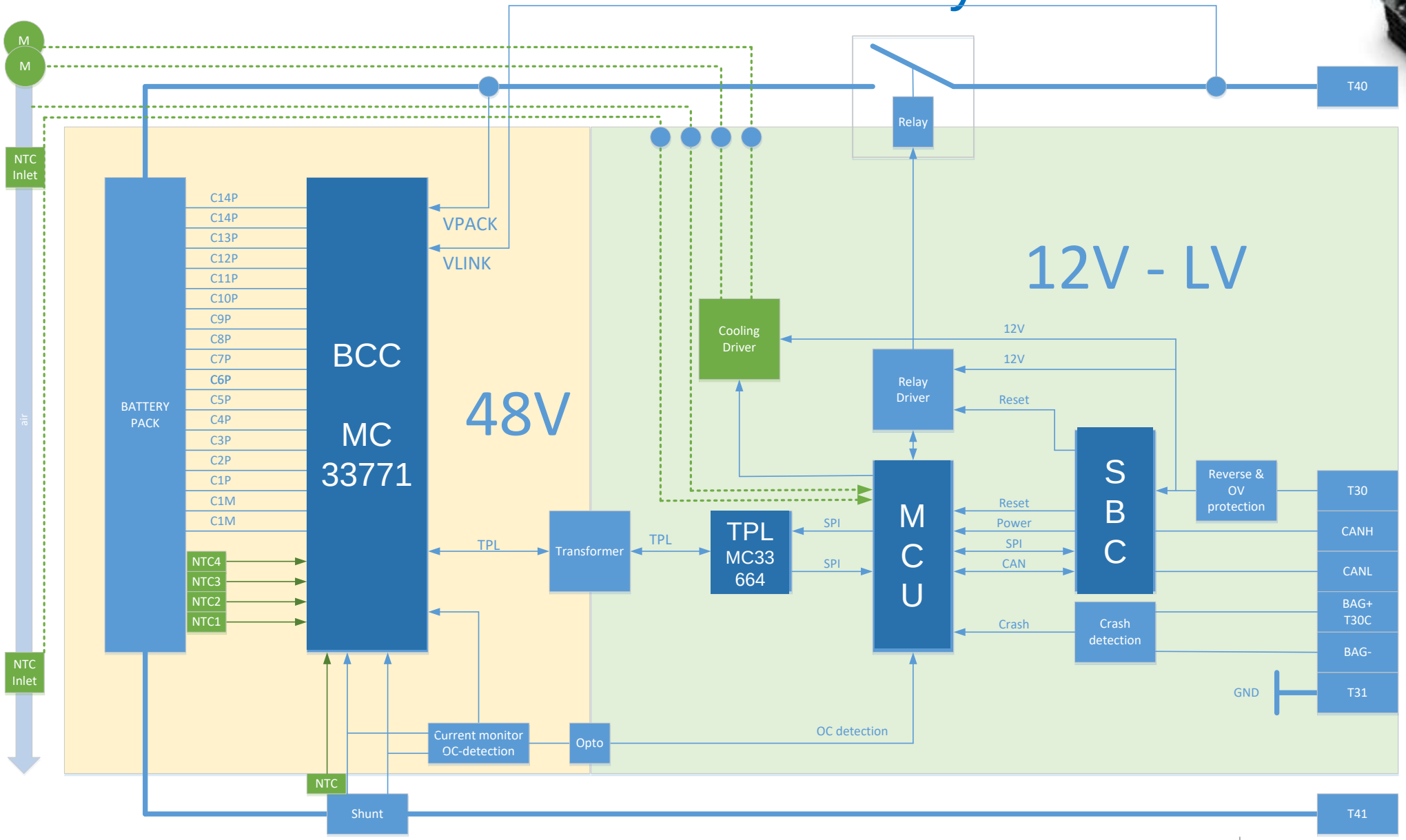


BMS Architectures : 14V Li-Ion Auxiliary Battery Systems

BMS Architectures : 14V Li-Ion Starter Battery Systems



BMS Architectures : 48V Lithium Ion Systems

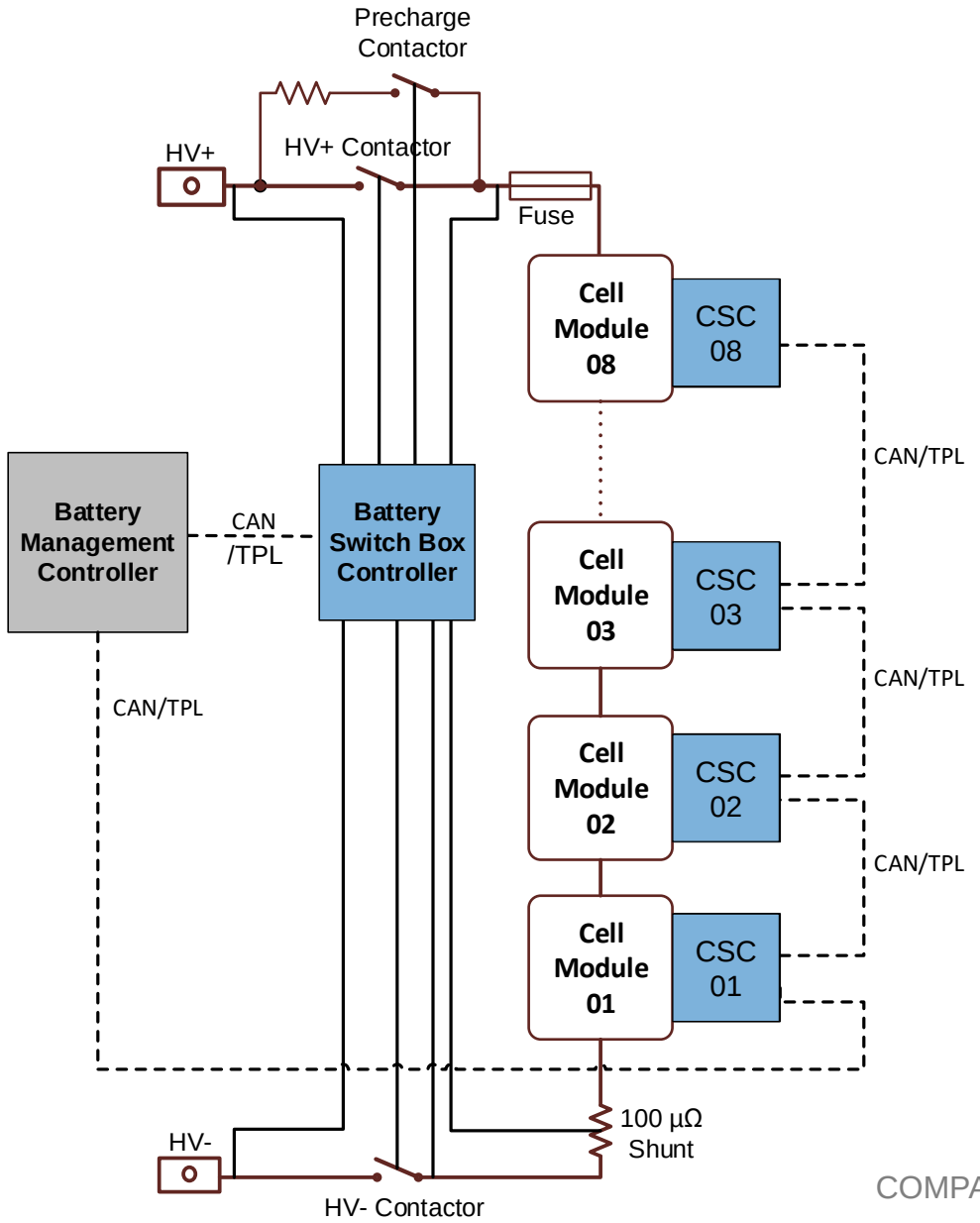


12V from main battery

Communication to the main ECU

Crash signals

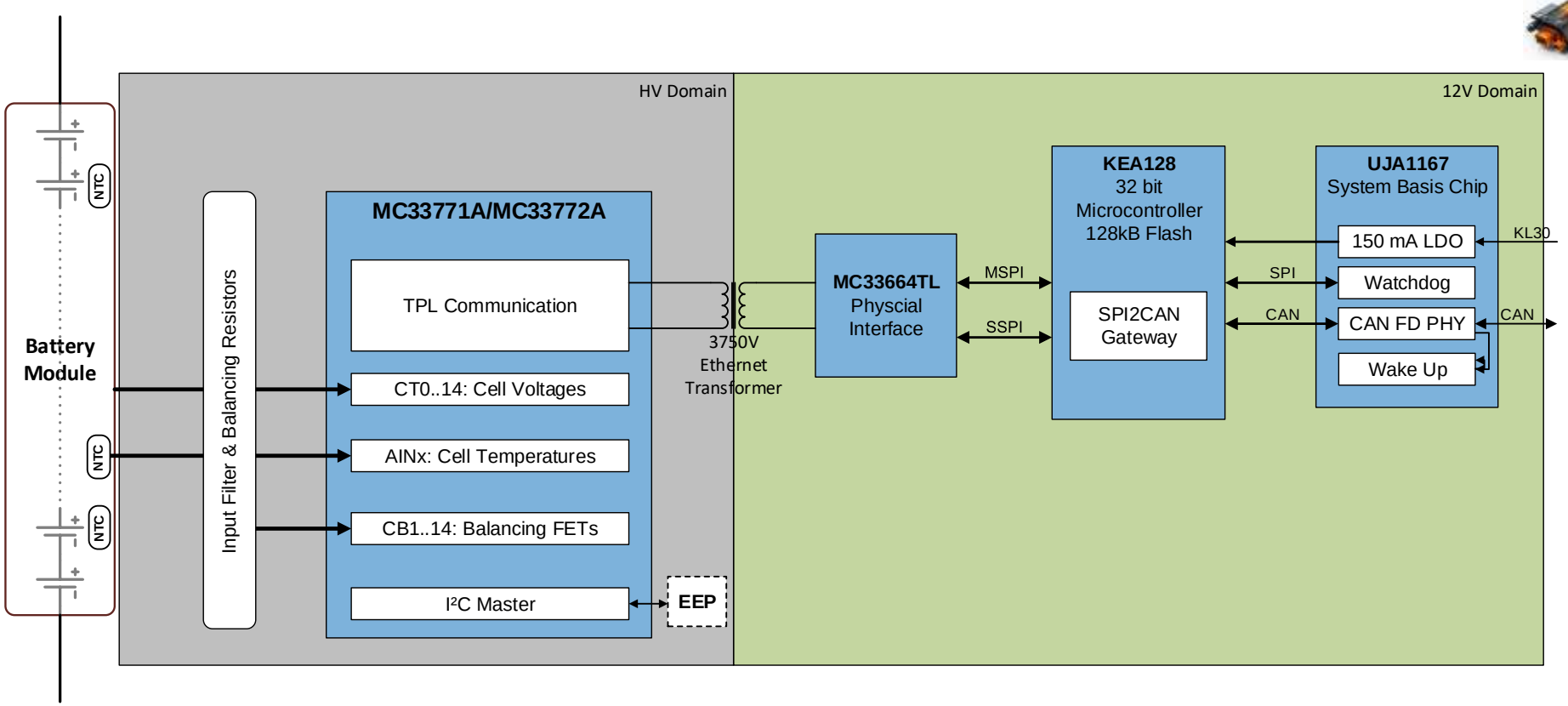
BMS Architectures : High Voltage Systems overview - 1/4



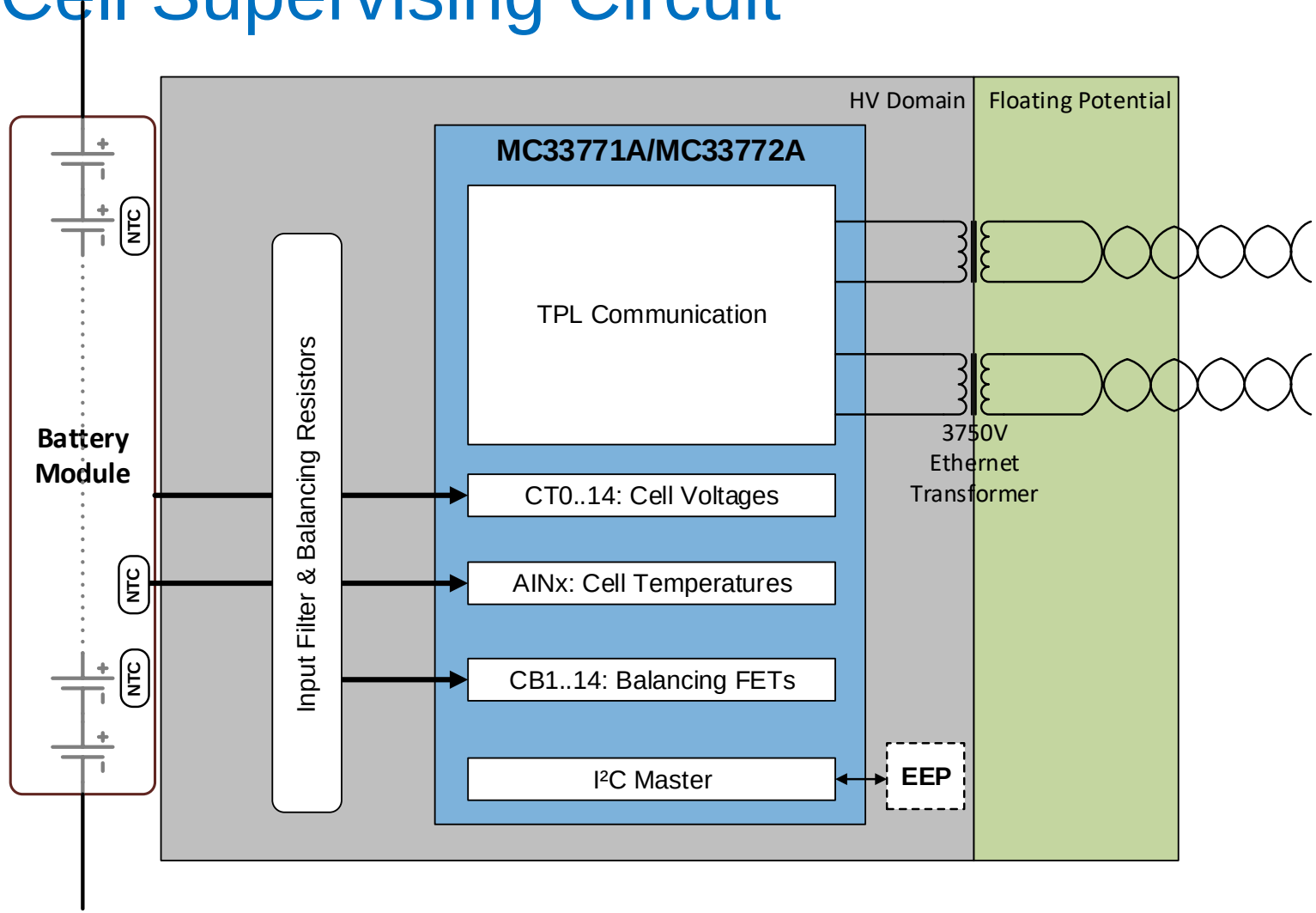
Cell Supervising Circuit 08

Cell Supervising Circuit 01

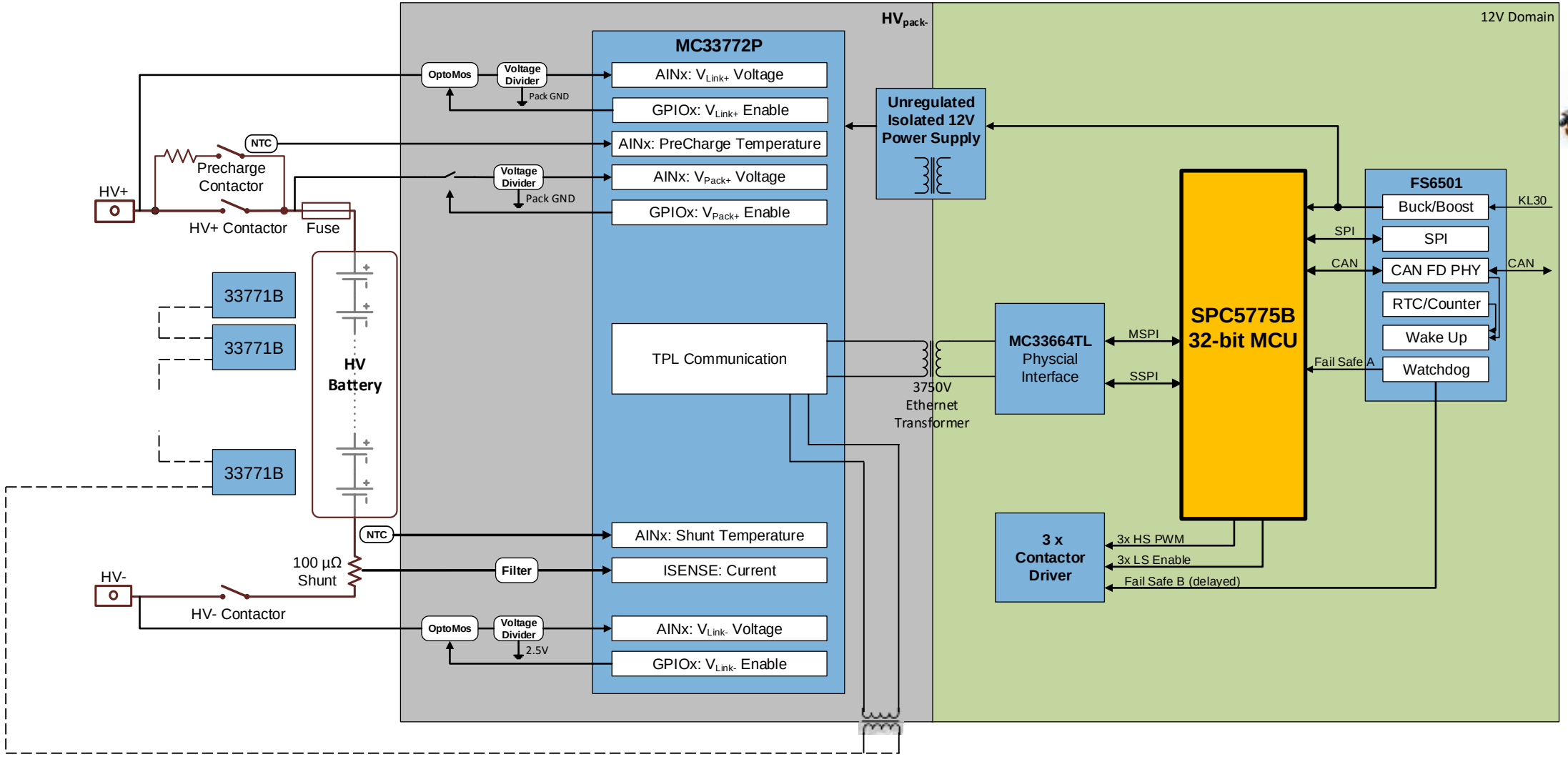
BMS Architectures: High Voltage Systems Overview - 2/4
CAN Based Cell Supervising Circuit



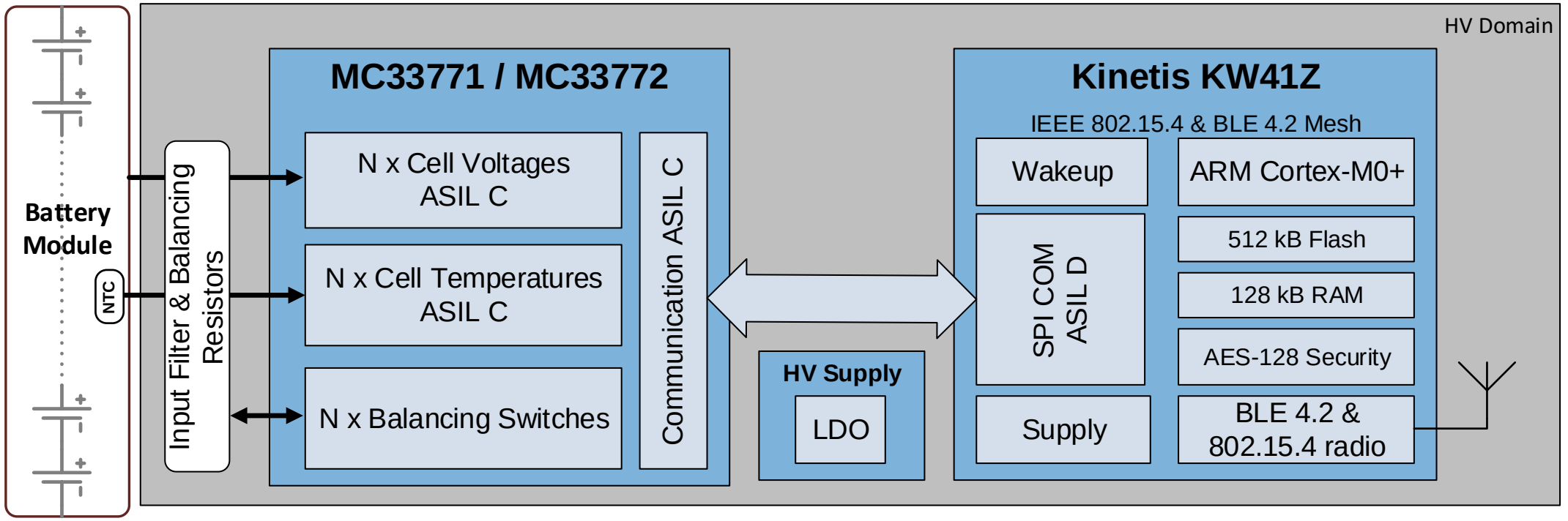
BMS Architectures: High Voltage Systems Overview - 3/4
TPL Based Cell Supervising Circuit



BMS Architectures: High Voltage Systems Overview - 4/4
Battery Management & High Voltage Switch Box Controller



Wireless BMS Solution



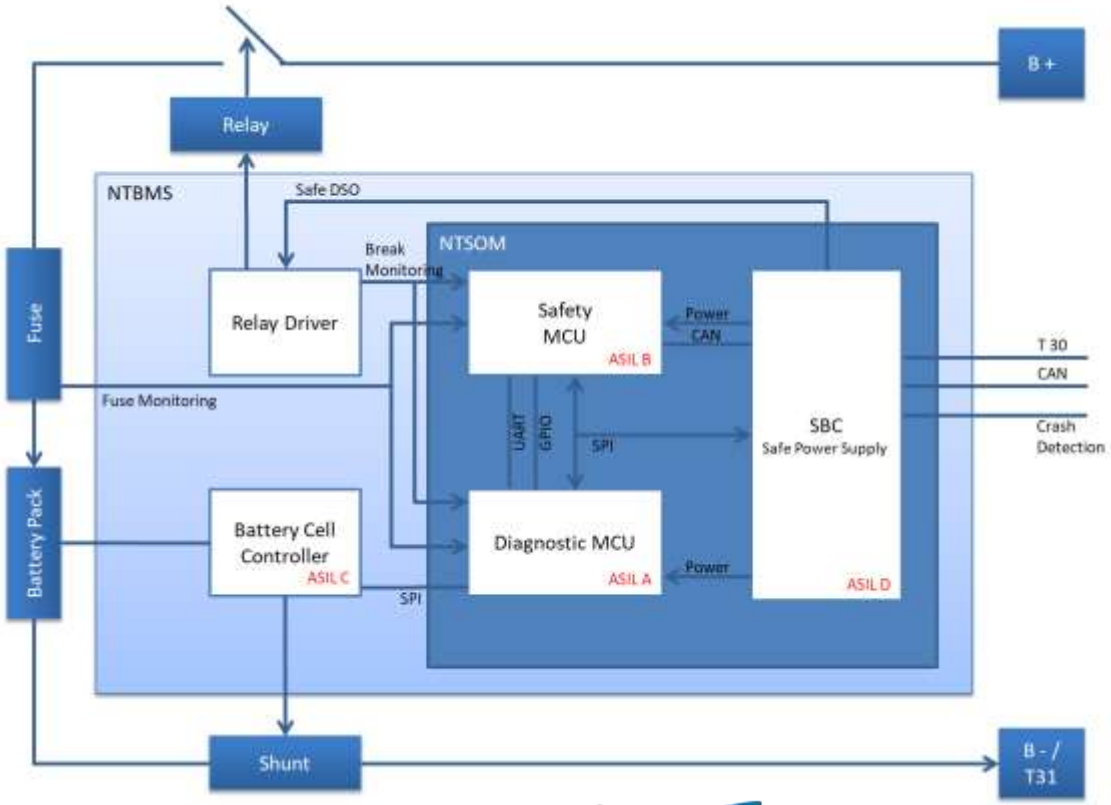
Low Voltage System Solution with S32K MCU

14V Battery Management System Platform with NTBMS and NTSafeSOM Boards

ASIL-C 14V Li-Ion BMS featuring low power, high accuracy, simultaneous I-V measurement, wide 5-18 V operating range and high system BOM integration

Features

- 6 cell BMS with small, compact footprint and integrated CAN
- 5-18 V ±5mV stack measurement w/ <0.2% relative error
- 0.5-5 V ±2mV cell measurement w/ <0.2% relative error
- Tri-range I measurement from ±30 A ±0.5% to ±1500 A ± 2%
- Integrated system diagnostic functions
  - Overcurrent protection
  - Overcharge protection
  - Overtemperature protection
  - Overvoltage and Undervoltage (short circuit) protection
  - Unintended relay close and relay open
  - Crash detection
- Integrated current sensor, balancing MOSFETs & diagnostics
- Simultaneous I-V measurement with < 130 µs sampling Δ
- 100 uA low power sleep w/ 8 sec cyclic cell measurement
- SoC Coulomb Counting during both active & sleep modes



NewTec
System-Entwicklung und Beratung

BMS Safety System-On-Module: NTSafeSOM

Ready to use safety computer reference design targeting industrial and automotive applications

Features

- Target ISO26262 ASIL-C and IEC 61508 SIL 2 System level certification
- Dual MCU and safety PMIC architecture
  - S32K144 – Cortex M4F MCU
  - KEA – Cortex M0+ MCU
  - FS45 – Safety & Power Management System IC
- Different support package options from NXP and Newtec
  - Free-of-charge reference documents
  - Development kit hardware with application software
  - up to complete system development with safety certification
- First application designed for 6 cells Li-Ion BMS using MC33772 battery cell controller

Applications

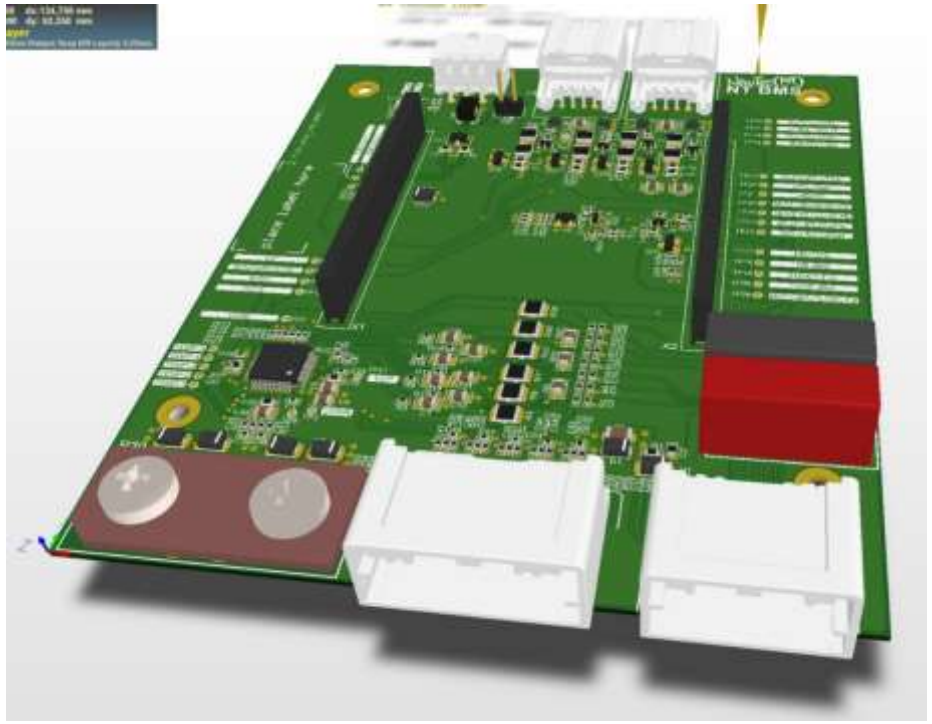
- Industrial, medical or automotive system requiring functional safety certification

Availability / SRP

- December 2018 starting at 750€

NewTec
System-Entwicklung und Beratung

NTBMS and NTSafeSOM Boards



3D Model of the NTBMS

NTSafeSOM mounted on top of NTBMS board

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NXP

Support Packages Options for NTSafeSOM + NTBMS

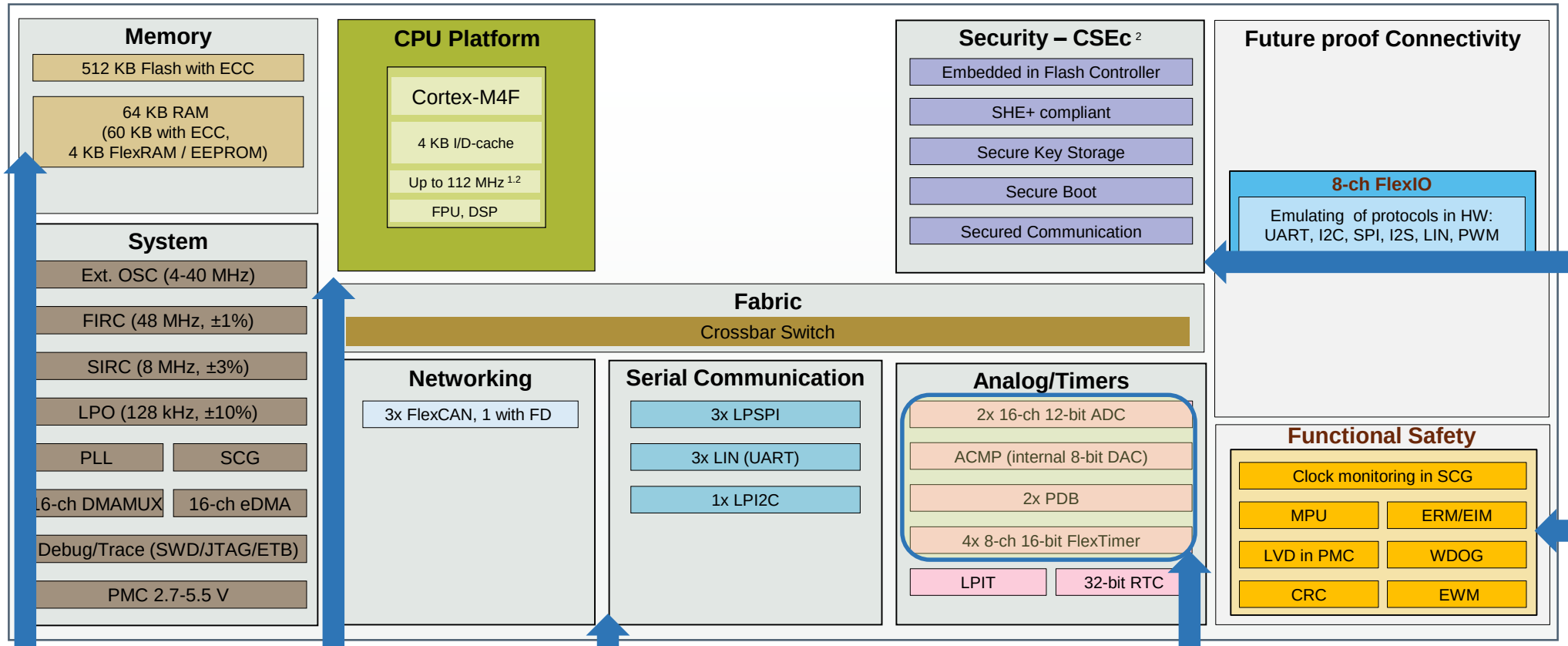
BMS Package and Services	Reference Design	Board Package	Safety SW Package	Safety Package	Certification Package
Evaluation Board (EVB)		✓	✓	✓	✓
Schematic	✓	✓	✓	✓	✓
Layout with Gerber Files	✓	✓	✓	✓	✓
Application Software with Driver (Non Safe)	✓	✓	✓	✓	✓
Introduction Guide for ASIL C	✓	✓	✓	✓	✓
Templates and FMEDA Results	✓	✓	✓	✓	✓
HowTo Guide for ASIL C		✓	✓	✓	✓
Safety Software for BMS (Object Code)		✓		✓	✓
Safety Software License for BMS (Source Code)			✓		✓
Complete Safety Documentation for certification				✓	✓
Certification					✓
Support			✓	✓	✓
Price list	free	750€ 875$	35k€ 41k$	45k€ 53k$	98k€ 115k$

[Platform Link for order]

NewTec
System-Entwicklung und Beratung

NXP

S32K144: ASIL-B 512K General Purpose MCU with HW Security



Security
- HW Security against tampering/ hacking
- SHE+ compliant
- (CSE: Cryptographic Services Engine)

Safety
- Core Self-test SW
- Clock monitoring & voltage monitoring
- ECC on memory

Memory
- Robust internal Flash
- OTA support[3]

CPU Platform
- Powerful high speed ARM CPU
- Optimized for Real-time system

Advanced Automotive Peripherals
- Fast auto comm. support by CAN FD
- Emulation of various protocols by FlexIO

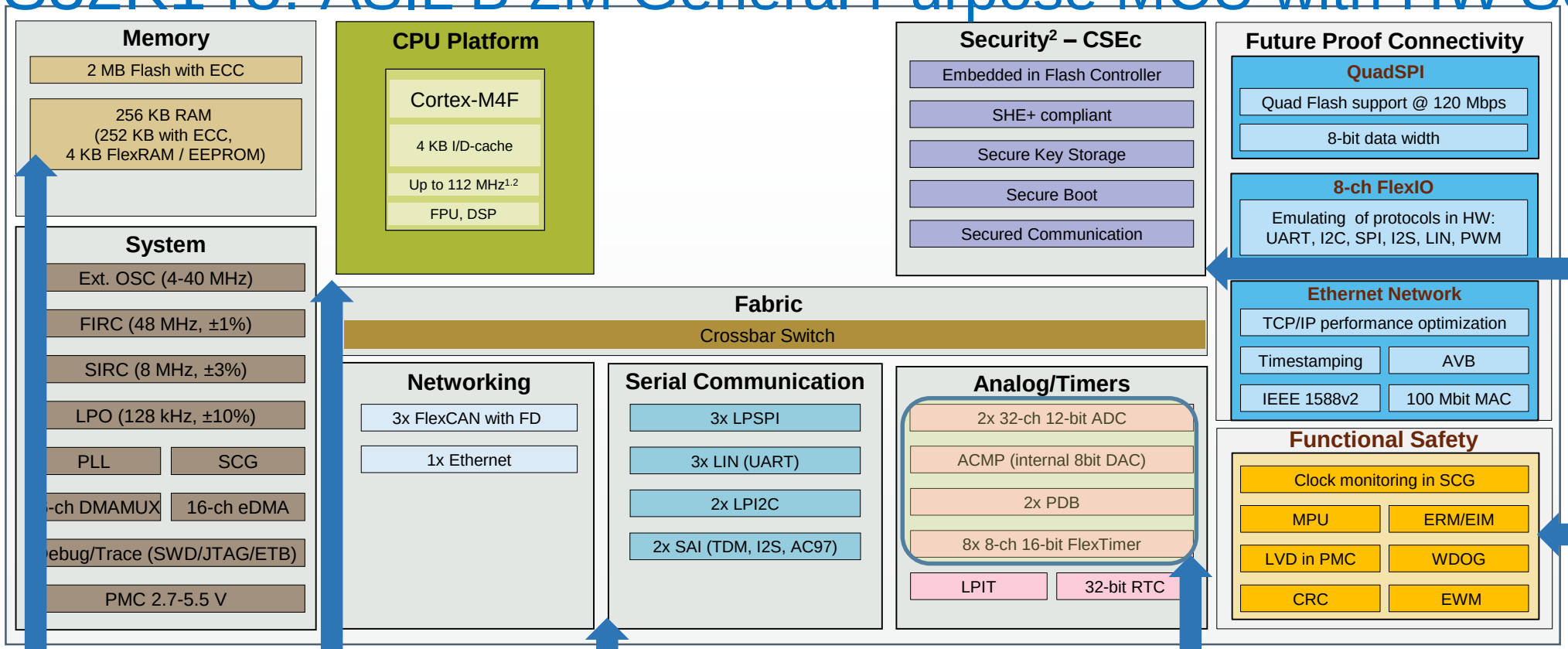
Motor Control
- On-chip motor control sub-system
- Offloading CPU

Key Info
- -40C to 125C Temp
- 64LQFP, 100BGA, 100LQFP

- **Future-proof**
- **Minimize complexity**
- **Maximize R&D Efficiency**

Footnote:
1. 112MHz not valid with M temp (125C).
2. Write or erase access to security (CSEc) or EEPROM is allowed only when device operating in RUN mode (up to 80MHz). No write or erase access to security and EEPROM allowed when device running at HSRUN mode (112MHz).
3. Refer to Link for more details

S32K148: ASIL B 2M General Purpose MCU with HW Security



Security[3]
- HW Security against tampering/ hacking
- SHE+ compliant
- (CSE: Cryptographic Services Engine)

Safety
- Core Self-test SW
- Clock monitoring & voltage monitoring
- ECC on memory

Memory
- Robust internal Flash
- OTA support[1]
- External expansion by QuadSPI

CPU Platform
- Powerful high speed ARM CPU
- Optimized for real-time system

Advanced Automotive Peripherals
- Fast auto comm. support by Ethernet & CAN FD
- TDM audio support
- Emulation of various protocols by FlexIO

Motor Control
- On-chip motor control sub-system
- Offloading CPU

Key Info
- -40C to 125C Temp
- 100BGA, 144LQFP, 176LQFP

- **Future-proof**
- **Minimize complexity**
- **Maximize R&D Efficiency**

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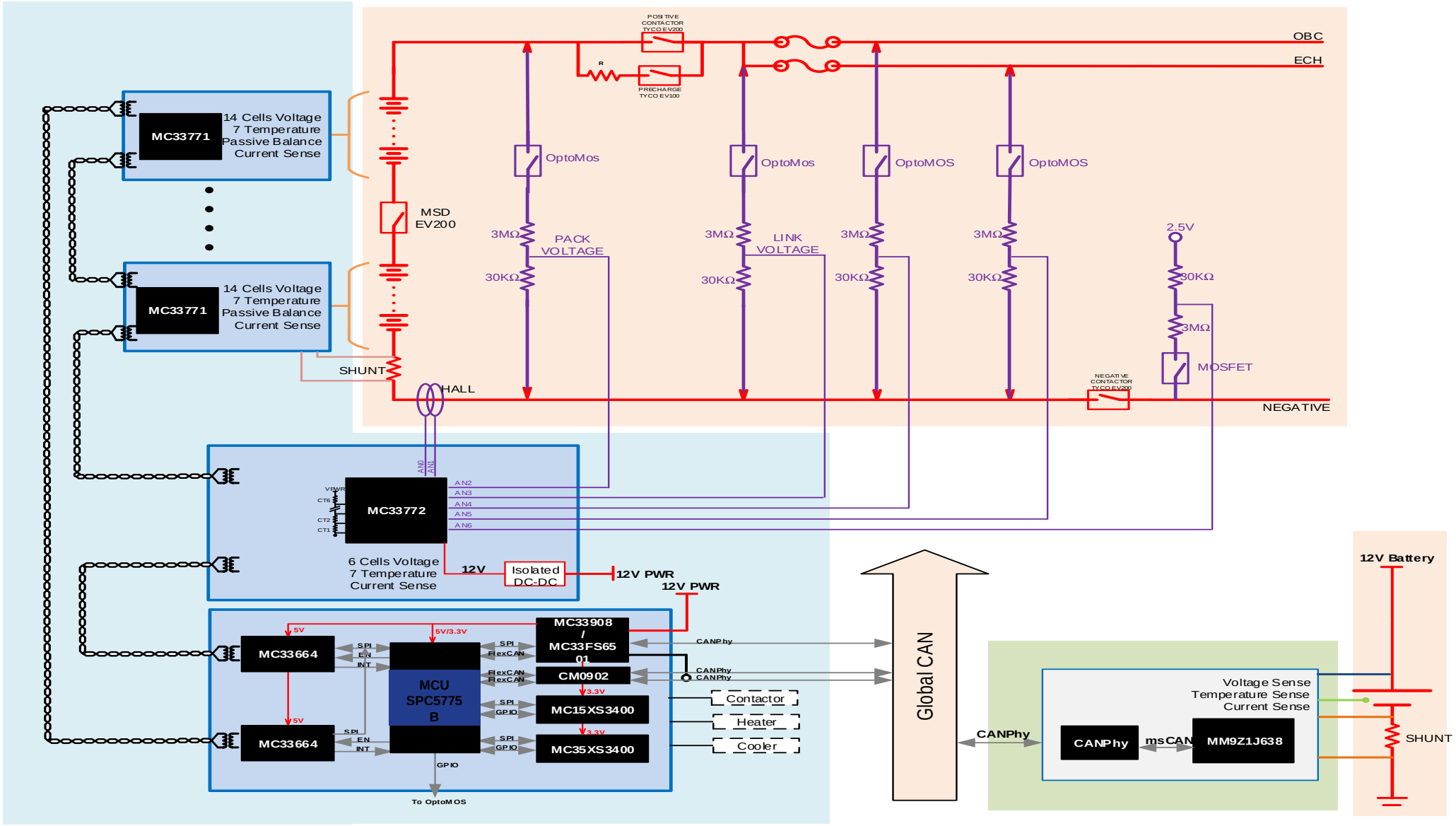
High Voltage System Solution with MPC5775B MCU

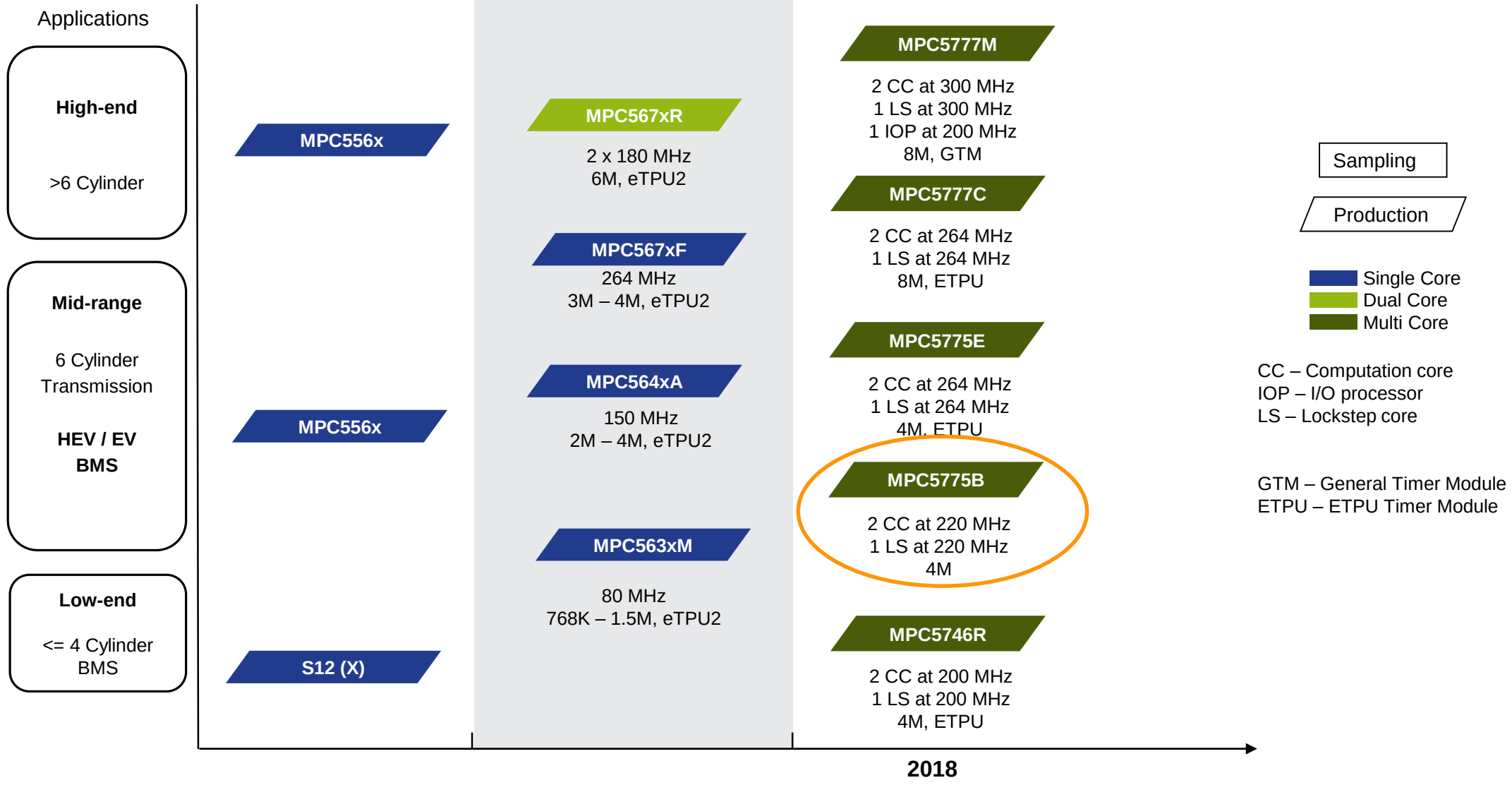
Cell Supervising Circuit & Switch Box with Isolated Communication



Automotive MCU Solutions for Battery Management Systems (BMS): SPC5775B

- To better address the growing HEV/EV market NXP Auto MCUs developed the SPC5775B
- This MCU will offer the performance, safety and security needed for Battery Management Systems (BMS)
- MPC5775B offers lockstep cores to support ASIL-D, 4 MB of Flash, 12-bit ADCs, CAN-FD and CSE security module.
- 100% compatible and scalable to SPC5777C for higher memory and performance
- The SPC5775B is qualified now and ready for production

Powertrain Microcontrollers Portfolio

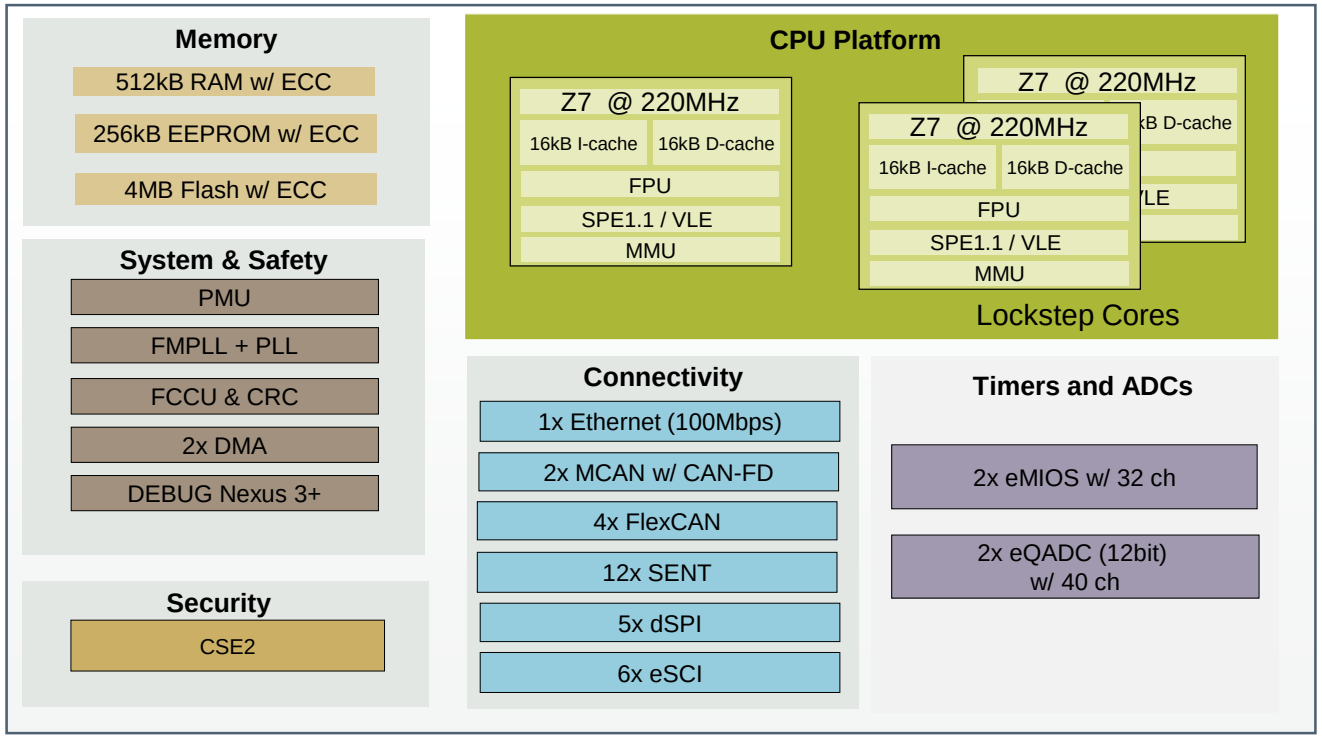


SPC5775B Feature Set Comparison

Feature	MPC574xP	MPC574xR	MPC5775B	MPC5775E	MPC5777C
Core, Clock	Z4 LS, 200/180/150MHz	Z4 LS+Z4, 200/150MHz	**LS z7 + z7 220MHz**	LS z7 + z7, 264MHz	LS z7 + z7, 264/300MHz
ASIL	D	D	D	D	D
FPU	Yes	Yes	Yes	Yes	Yes
DMA (ch)	32+ 32	64+ 64	64+ 64	64+ 64	64+ 64
FLASH	1/1.5/2/2.5MB	2/3/4MB	4MB	4MB	**8MB**
RAM	128/192/256/384KB	128/192/256KB	512KB	512KB	512KB
SPI	4	4 or 5 + 2 MSB	**5**	5	5
CAN-FD	0	0	**2**	2	2
Non CAN-FD	3	4	4	4	4
LIN/UART	2	3 or 4 + 2 MSB	5	5	5
Ethernet 100MBit/s	Yes (Only in 257)	Yes	Yes	Yes	Yes
SENT	4	6	12	12	12
Zipwire	1	1	0	0	1
PSI5 channels	0	0	0	0	2
ADC unit x channels	4x SAR12bit. 64 ch total	4x SAR 12bit ADC, 3x SD 16bit ADC	2x eQADC 12bit, 40 ch total	4x eQADC 12bit, 70 ch total, 4x SD, 20 ch total	4x eQADC 12bit, 70 ch total, 4x SD, 20 ch total
Timer (eMIOS) / FlexPWM	2 FlexPWM, 3 eTimer, 18 ch total	2 eMIOS, 32 ch total	2 eMIOS modules, 32ch total	2 eMIOS modules, 32ch total	2 eMIOS modules, 32ch total
eTPU	No	2x 64ch total	None	**3x 96 ch total**	**3x 96 ch total**
Security	No	No	**CSE**	**CSE**	**CSE**
Packaging	LQFP 144 or MAPBGA 257	LQFP 144/176 or MAPBGA 252	416 MAPBGA	416 MAPBGA	416 / 516 MAPBGA
Ambient Temperature	-40°C..125°C	-40°C..125°C	-40°C..125°C	-40°C..125°C	-40°C..125°C

SPC5775B Safe & Secure BMS MCU

10k SRP = $13.05



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 mm^2, 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

MPC5775B Enablement

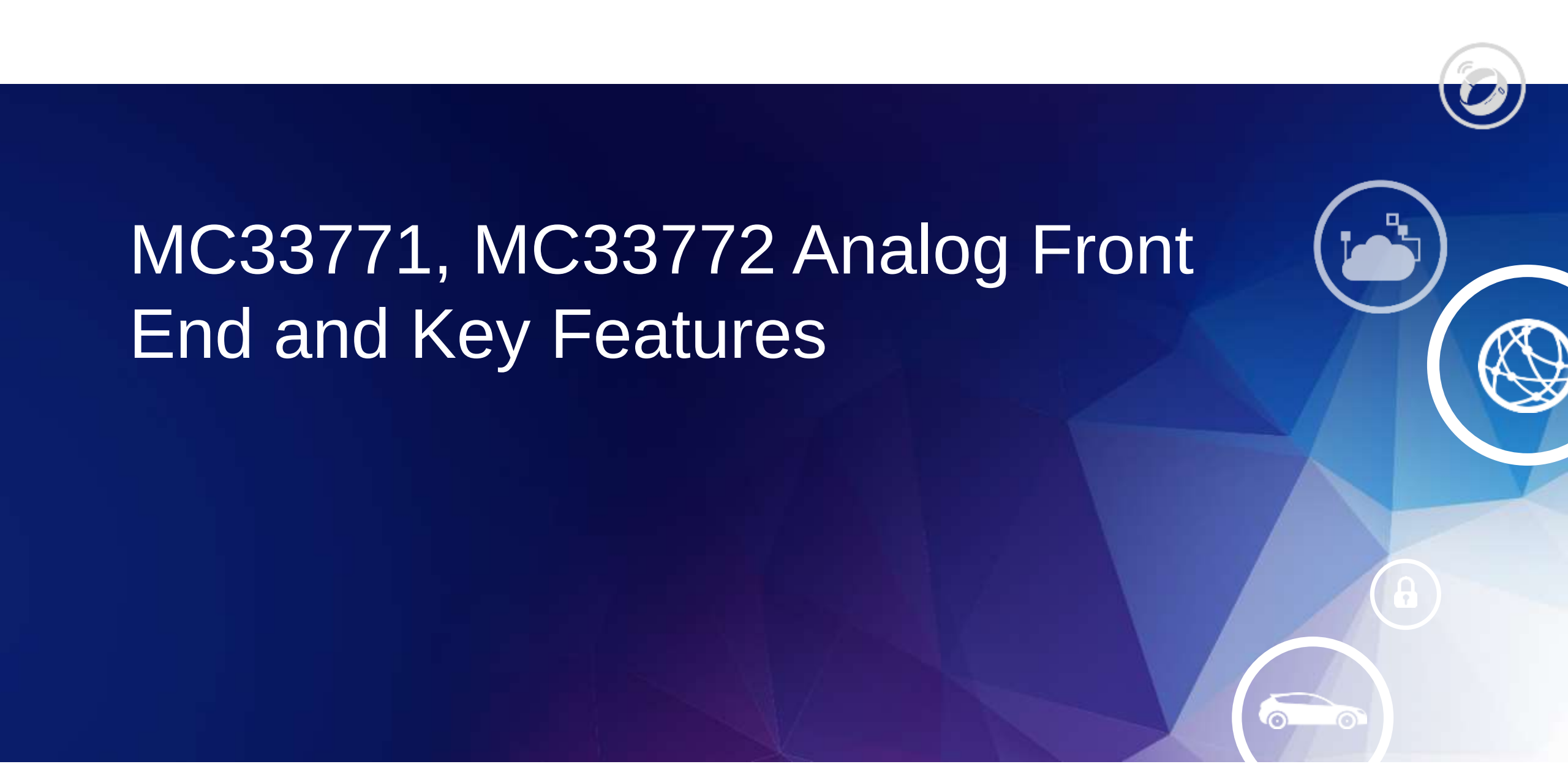
Hardware:	Software:

• **EVB:** MPC5775BE-416DS
  • EVB supports both MCP5775B and MPC5775E (incl. 1pc sample of both)
• **URL:** www.nxp.com/MPC5775BE-EVB
• **SRP:** $295 for adapter (standalone mode)
	• **S32 Design Studio IDE for Power Architecture**
	• **SDK *production grade:**
	  • Available in Q4'18
	• **AutoSAR MCAL and OS:**
	  • Available now

Documentation:	**Reference Designs:**

• Datasheet/Reference Manual:
  • URL: www.nxp.com/MPC5775BE
• **10+ Apps notes and Initialization guides available**
	• **BMS:**
	  • 14V Li-Ion systems: available Q1'19 (MCU MPC5744P + FS65 + MC33772)
	  • 48V Li-Ion systems: available Q1'19 (MCU MPC5744P + FS65 + MC33771 + MC33664)

MC33771, MC33772 Analog Front End and Key Features



Battery Cell Controllers Overview – MC33771B / MC33772B

- Cell Voltage Monitoring
  - MC33772 - 3 to 6 cells
  - MC33771 - 7 to 14 cells
- Total stack voltage measurement
- Current Measurement and Coulomb Counter
  - From some µA to several 1000A (shunt resistor)
- Synchronized Cell Voltage/Current measurement
- Temperature Sensing / other voltage measurements
  - 1 internal temperature, up to 7 external temperatures/voltages
- Cell Balancing
  - Onboard 300mA passive cell balancing with diagnostics
- Functional Verification and Diagnostics
  - Designed to support ISO26262, up to ASIL-D safety capability
- 4.0 Mbps SPI or Isolated 2.0 Mbps Communication for Daisy Chain capability
- Significant Reduction in BOM & Overall System Cost

Automotive Qualification in compliance with **AEC-Q100**

NXP MC33771/2B Battery Cell Controller Solution Differentiating Points

Battery Topology Flexibility

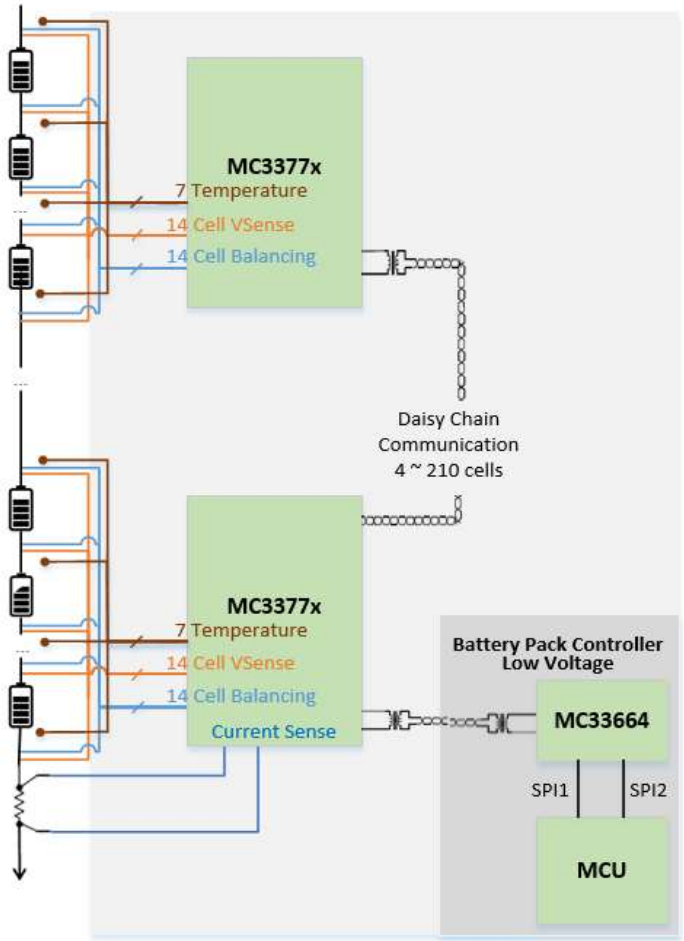
- Scalable SW & HW compatible BMS solution supporting **3 to 210 cells** per daisy chain
- MC33771B (7 to 14 cells) & MC33772B (3 to 6 cells) fully compatible
- Supporting Centralized, Distributed Daisy Chain, Distributed CAN

High integration level

- Synchronized on-chip current sensor
- Synchronized on-chip coulomb counter
- Integrated passive balancing (300mA per ch)
- Integrated Power Supply

Fast & robust communication & DAQ

- 4.0Mbps SPI or isolated 2.0Mbps differential communication with transformer
- 3.6 ~ 4.1ms for sending command and read back **96** cell 16-bit voltage data



High measurement accuracy

- Voltage measurement accuracy after soldering and aging within full operation Voltage & Temperature range
- ± 0.5% total stack voltage measurement
- ± 0.5% accuracy integrated current sensor

Diagnosis and functional safety supporting ISO26262 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

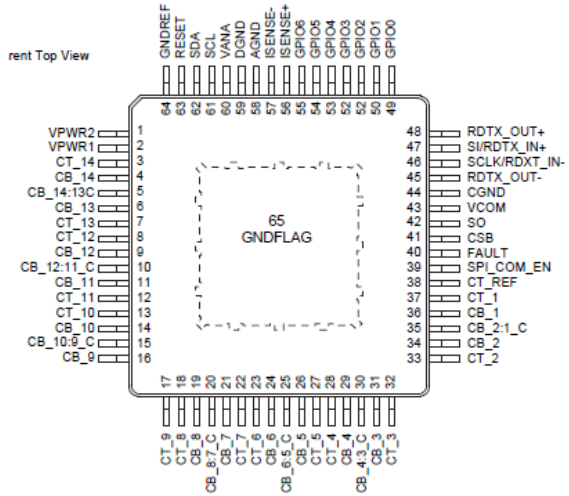
Automotive robustness

- ESD, EMC; Hot Plug, AEC-Q 100
- Temp range: -40°C to 105°C
- Operational Low Power Mode

MC33771 – 14 Cell Battery Cell Controller AFE

Features:

- Operating Voltage: 9.6V ≤ VPWR ≤ 61.6V Operation, 70V Transient
- SPI or Isolated 2 MHz Differential Communication
- 7 to 14 Cell Voltage Measurement Channels
- Total Stack Voltage Measurement
- Current sensor with ±0.5% accuracy from milliamps to kiloamps
- Coulomb Counter (also in low-power mode)
- 7 ADC/GPIO/Temperature Sensor Inputs
- Addressable on Initialization
- 5.0V @ 5mA Reference Supply Output
- Integrated Sleep Mode Over/Under Voltage & Temperature Monitoring
- Over/Under Voltage, Over/Under Temperature Fault Verification
- Onboard Passive Cell Balancing with Diagnostics and balancing timers
- Open Cell Terminal Detection
- Internal Diagnostics
- Hot Plug Capable
- Operational Low Power Mode
- 64-LEAD LQFP-EP
- Temp range: -40°C to 105°C
- AEC-Q100 Automotive Qualified
- EMC/ESD Robustness



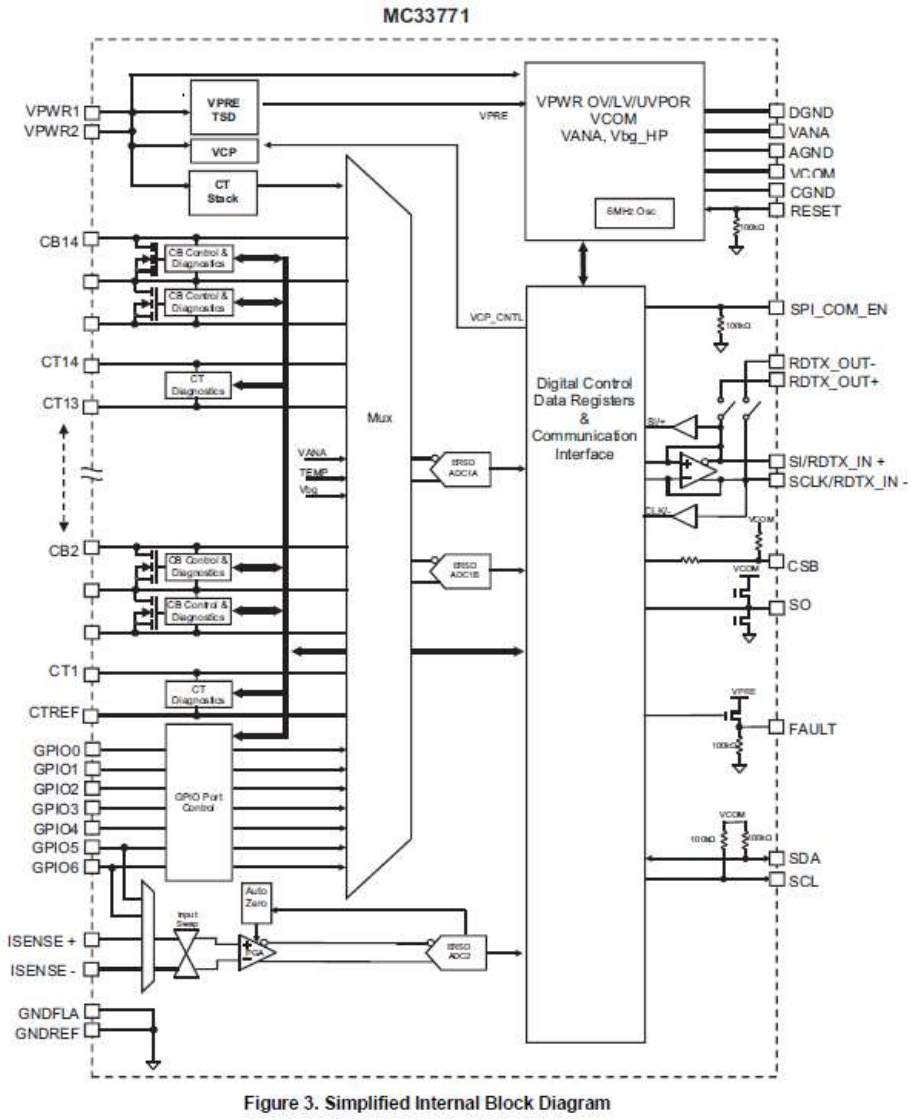


Figure 3. Simplified Internal Block Diagram

MC33772 – 6 Cell Battery Cell Controller AFE

Features:

- Operating Voltage:
  - 5V ≤ VPWR ≤ 30V Operation, 42V Transient (for SPI communication)
  - 7V ≤ VPWR ≤ 30V Operation, 42V Transient (for TPL communication)
- SPI or Isolated 2 MHz Differential Communication
- 3 to 6 Cell Voltage Measurement Channels
- Total Stack Voltage Measurement
- Current sensor with ±0.5% accuracy from mA to kA
- Coulomb Counter (also in Low-power mode)
- 7 ADC/GPIO/Temperature Sensor Inputs
- Addressable on Initialization
- 5.0V @ 5mA Reference Supply Output
- Integrated Sleep Mode Over/Under Voltage & Temperature Monitoring
- Over/Under Voltage, Over/Under Temperature Fault Verification
- Onboard Passive Cell Balancing with Diagnostics and balancing timers
- Open Cell Terminal Detection
- Internal Diagnostics
- Hot Plug Capable
- Operational Low Power Mode
- 48-LEAD LQFP-EP
- Temp range:
  -40°C to 125°C (for SPI communication)
  -40°C to 105°C (for TPL communication)
- AEC-Q100 Automotive Qualified
- EMC/ESD Robustness

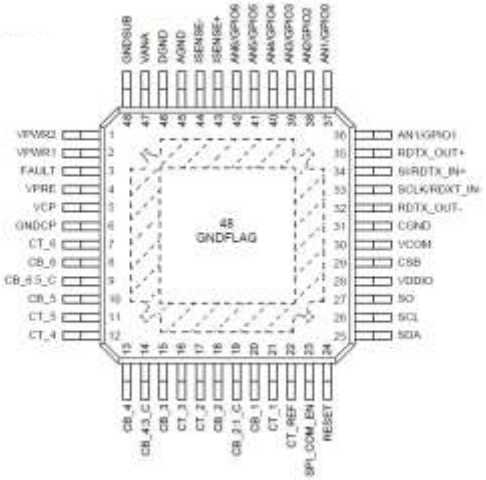
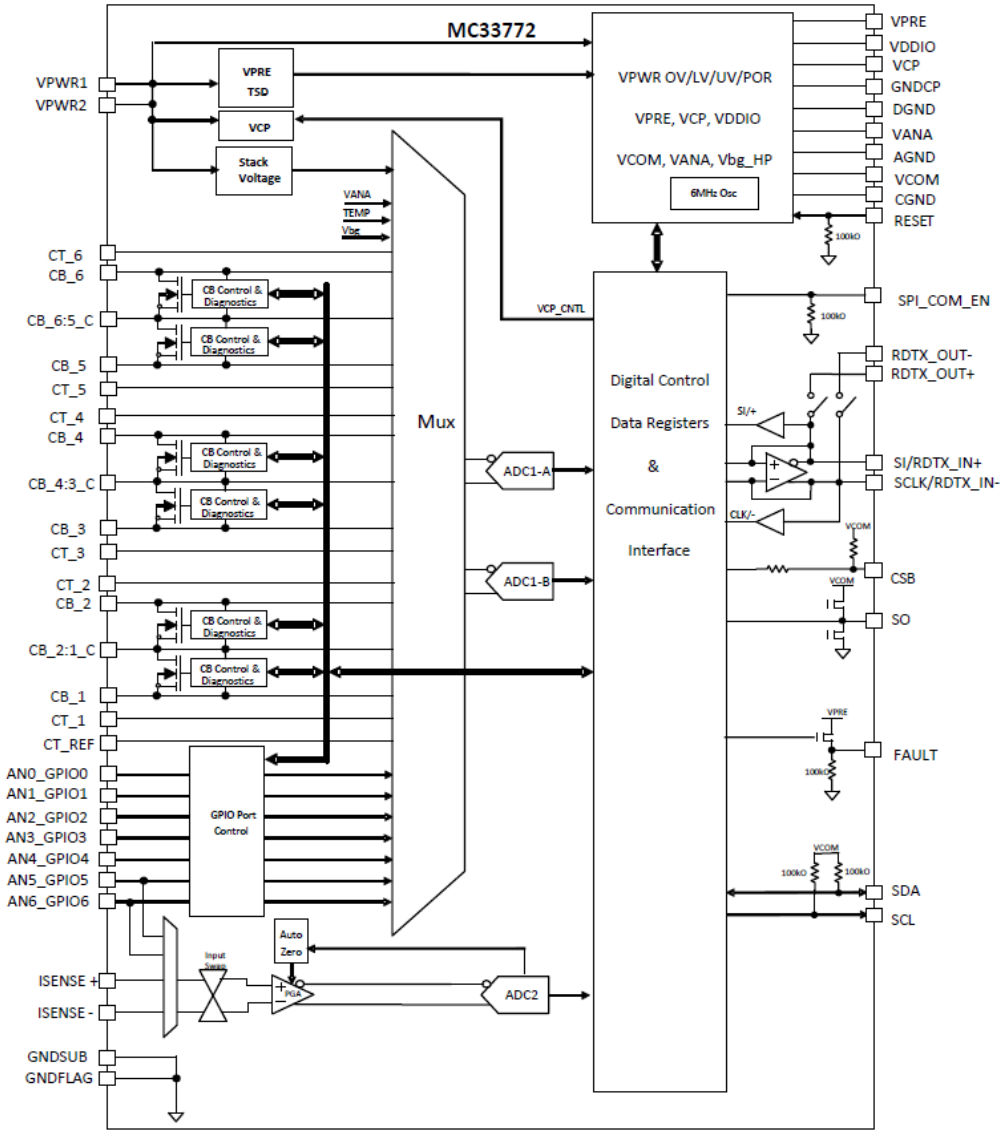


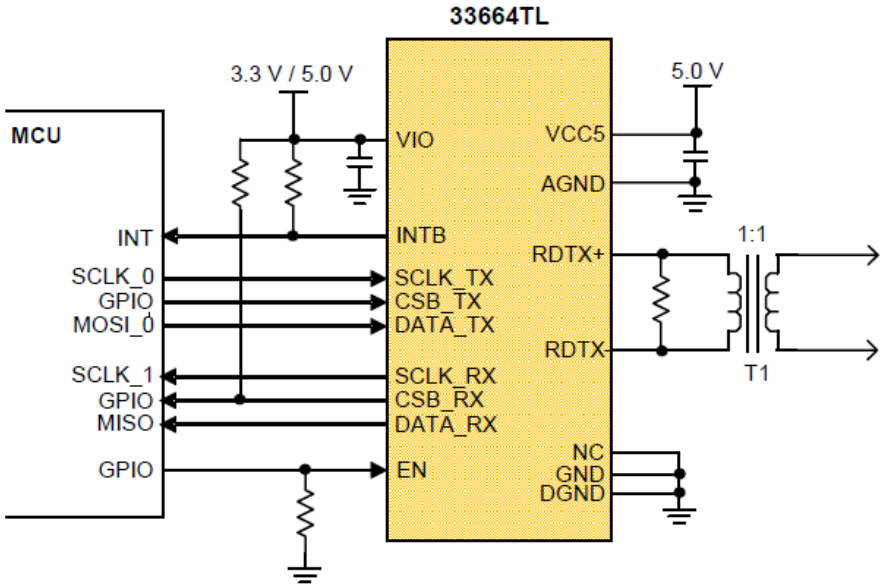
Figure 4. 33772 Pinout Diagram



MC33664ATL Transformer Physical Layer

Features:

- **2Mpbs** Isolated Network Communication Rate
- Dual SPI Architecture for **Message Confirmation**
- Robust Conducted and Radiated Immunity with Wake-up
- 3.3V and 5.0V Compatible Logic Thresholds
- Low Current **Sleep** Mode with Automatic **Wake-up**
- **Sine Wave** Transmission for low Radiated Emission



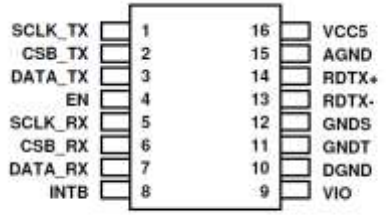


Figure 3. PC33664TL 16-Pin SOIC Narrow Body Pin Diagram

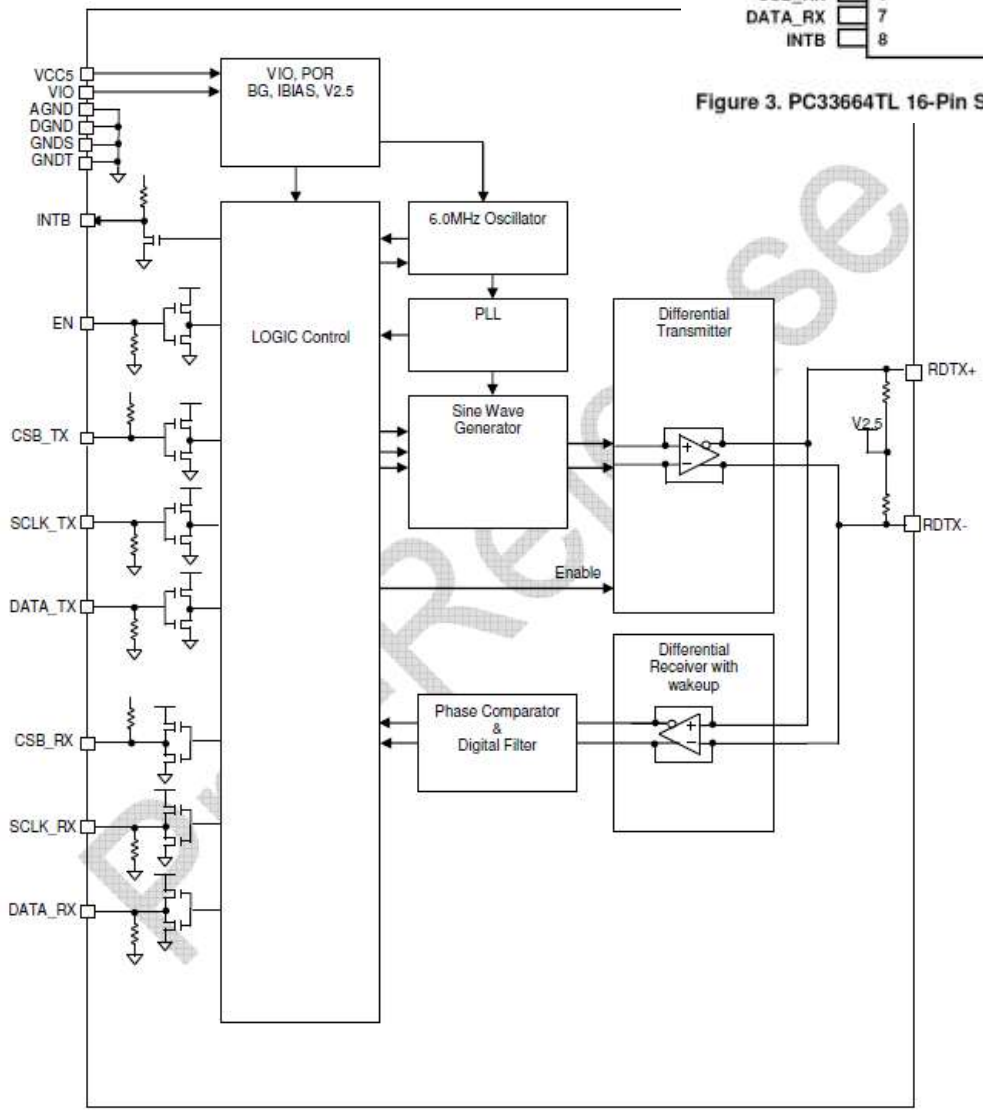
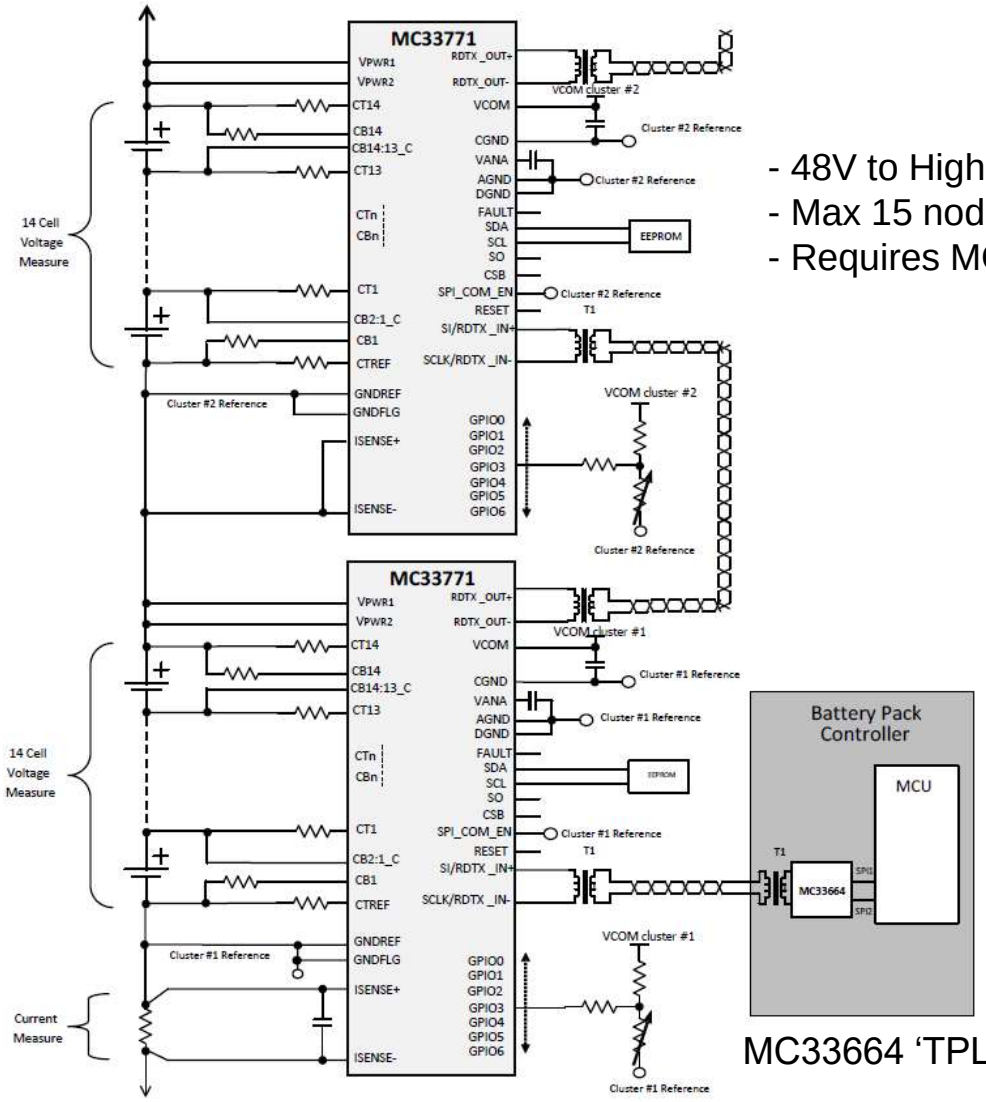


Figure 2. Internal Block Diagram

MC3377x – Connectivity Options

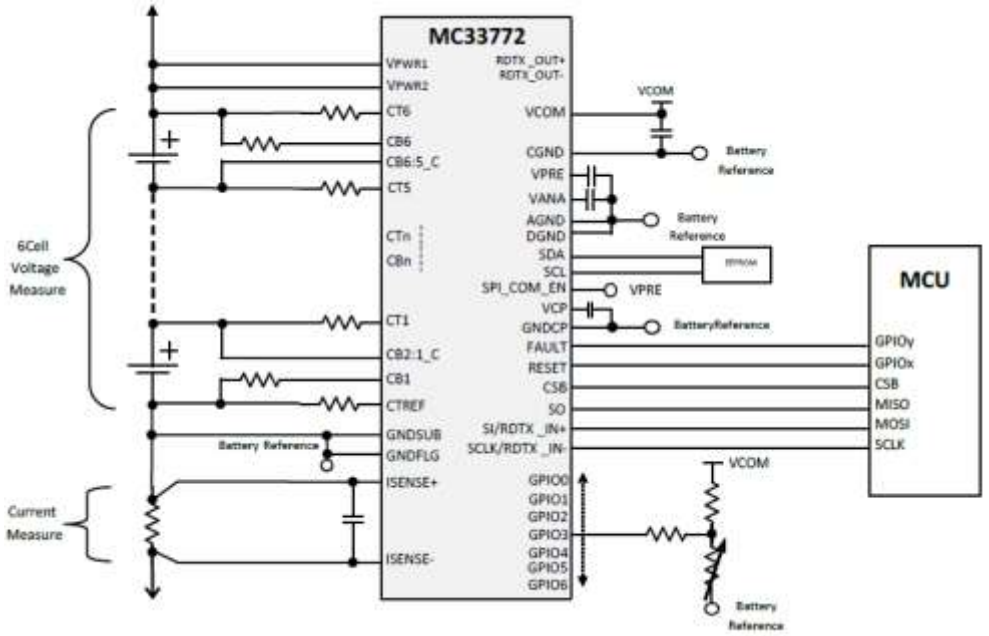
HV Daisy Chain Solution



- 48V to High Voltage
- Max 15 nodes / 210 cells
- Requires MC33664

MC33664 ‘TPL’

LV SPI Solution



- Typical 12v application

TPL Daisy Chain Performances – Distributed System

Functional performances: NXP has done simulation and tests of many configurations.

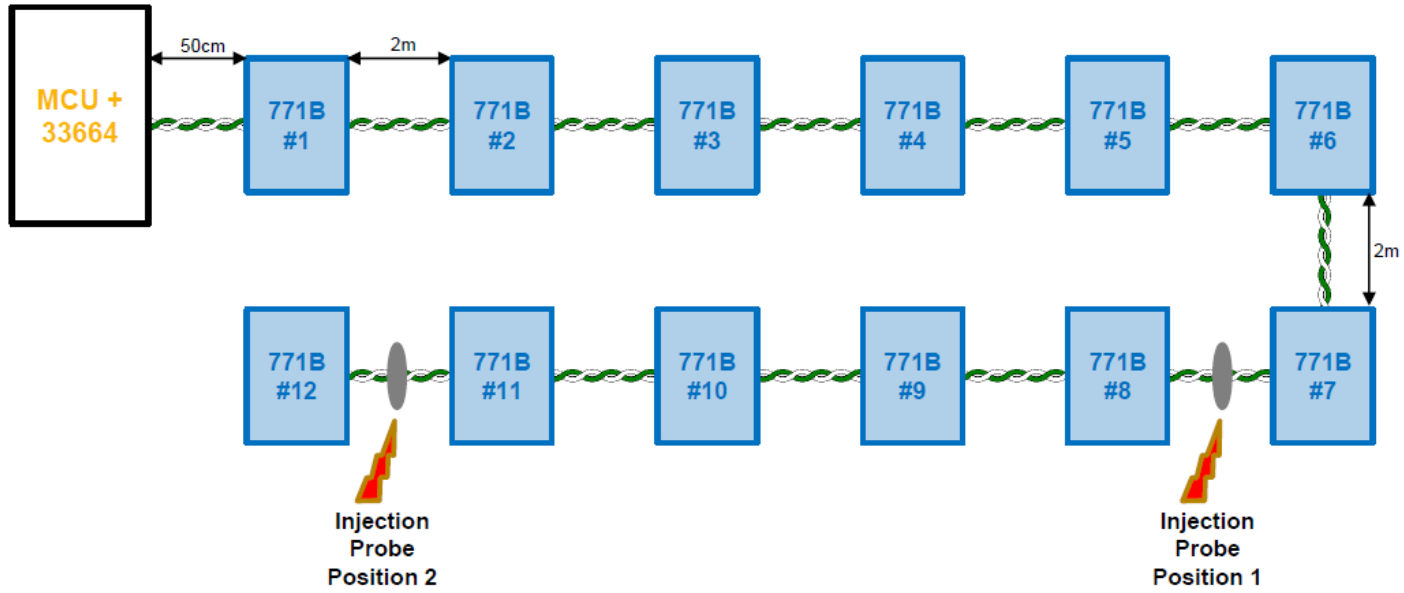
With MC3377xB and Pulse transformers HM2102NL (dual channel + CMC) / HM2103NL (single channel + CMC), following cable length can be achieved, with no communication errors (100% success rate), from -40°c to +105°c Ta. See table below, for a distributed system.

Nodes qty	Cable length max between nodes	Total cable length
1	100m	100m
5	10m	50m
12	2m	24m
15	0.5m	7.5m

- Communication baudrate fixed 2Mb for all configurations
- Twisted basic CAN cable (120ohms) between nodes

TPL Daisy Chain Performances – Distributed System 3/3

- BCI test setup and results
  - Strong TPL EMC robustness due to transformer isolation
  - Complete EMC qualification: BCI, DPI, RE, CE
  - Setups aligned with German and American Car OEM requirements



Setup	Injection level	Chain	Injection posittion	Failure criteria	Results
Setup1	200mA	12 nodes – 22.5m total chain length	Position 1 (between BCC7 and 8)	Communication loss, CTx accuracy (>6mV)	✓ Pass
Setup2			Position 2 (between BCC11 and 12)		✓ Pass

Portfolio - Battery Cell Controller

Premium for 14/ 48 V BMS	Advanced for HVBMS	Basic for redundancy	Current for HV junction/ switch box
MC3377xBS**P** (SPI comm) MC3377xBT**P** (TPL comm)	MC3377xBS**A** (SPI comm) MC3377xBT**A** (TPL comm)	MC3377xBT**B** (TPL comm)	MC33772BT**C** (TPL comm)
Precise differential cell voltage measurement	Precise differential cell voltage measurement	Precise differential cell voltage measurement	Precise differential cell voltage measurement
Cell OV/UV	Cell OV/UV	Cell OV/UV	Cell OV/UV
Synchronized current measurement	Synchronized current measurement	Synchronized current measurement	Synchronized current measurement
Coulomb count	Coulomb count	Coulomb count	Coulomb count
Cell balancing	Cell balancing	Cell balancing	Cell balancing
Temp measurement, O/U temperature	Temp measurement, O/U temperature	Temp measurement, O/U temperature	Temp measurement, O/U temperature
Functional verification & diagnostics	Functional verification & diagnostics	Functional verification & diagnostics	Functional verification & diagnostics
Communication • 2 MHz half duplex differential • SPI 4 MHz	Communication • 2 MHz half duplex differential • SPI 4 MHz	Communication • 2 MHz half duplex differential • SPI 4 MHz	Communication • 2 MHz half duplex differential • SPI 4 MHz
Package: 64/48-ld LQFP EP	Package: 64/48-ld LQFP EP	Package: 64/48-ld LQFP EP	Package: 48-ld LQFP EP
Temp range: -40 C to +105C	Temp range: -40 C to +105C	Temp range: -40 C to +105C	Temp range: -40 C to +105C

Collateral Material

Battery Cell Controller devices

- MC33771B
  - MC qualified. PPAP available
  - Final Datasheet **rev 5** available
  - Safety documents are finalized and available (FMEDA rev. C & Safety Manual rev. B)
  - **New EVBs and samples** available *June* (end of June for delivery)
- MC33772B
  - MC qualified. PPAP available
  - Final datasheet **rev 4** available
  - Safety documents are finalized and available (FMEDA rev. B & Safety Manual rev. B)
  - **New EVBs and samples** available *June* (end of June for delivery)

Transformer Physical Layer device

- MC33664
  - MC qualified. PPAP available
  - Final Datasheet **rev 4** available (Customer Information Notification CIN 201802023I sent to customers)
  - **New EVBs** available *June* (end of June for delivery)

Public documentation	NDA documentation *(even after mass-market release)*
• Short Datasheet • MC3377x non-NDA presentation (available on distribution extranet)	• Datasheet, Safety Manual & FMEDA available • Detailed BMS training presentation • Application notes - MC33771/33772 Programming guide (AN12084 available) - Daisy chain guideline (on going) - Safety application (how to reach single chip ASIL-D) (AN12142 Q3 2018) - Layout and EMC guideline (Q3 2018)

Battery Cell Controller Evaluation Boards

MC33664 Freedom Kit
- FRDM33664BEVB

MC33771B Evaluation Kits
(14 cell)

- FRDM33771BTPLEVB
- FRDM33771BSPIEVB

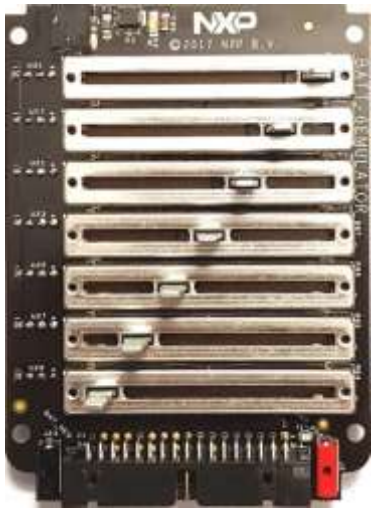
MC33772B Evaluation Kits
(6 Cell)

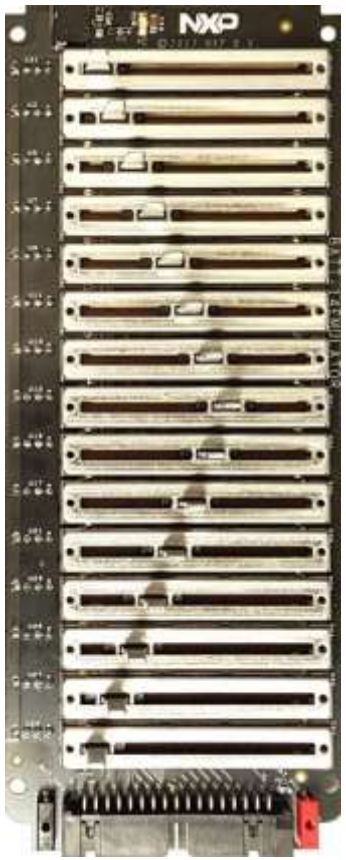
- FRDM33772BTPLEVB
- FRDM33772BSPIEVB

Battery Pack Evaluation Boards

14-Cell AAA Battery Pack
(compatible with 6-Cell)

6 / 14-Cell Battery Emulator

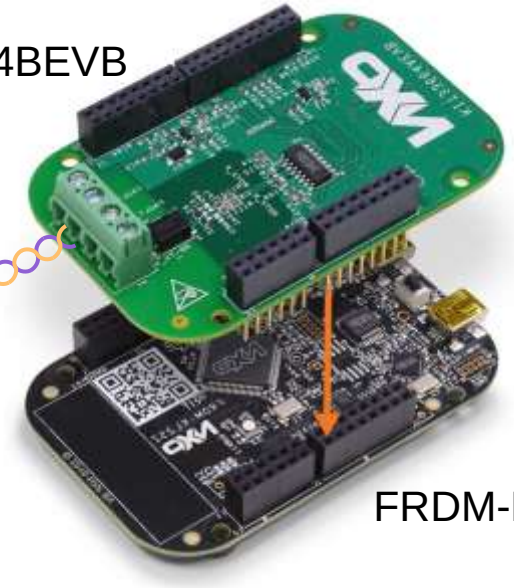




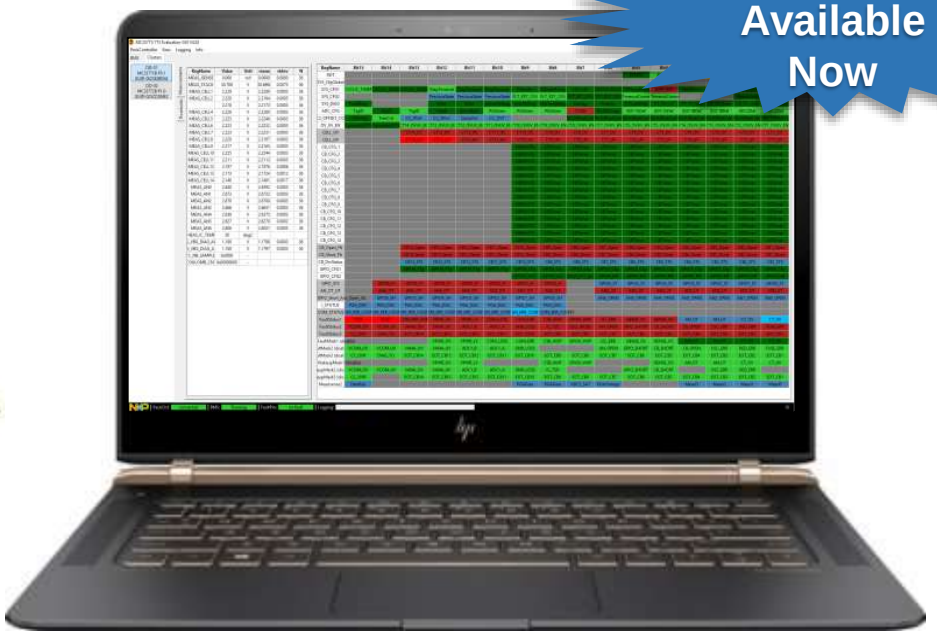
NXP BCC Evaluation Kit Setup

v4.10 Available Now

FRDM33664BEVB



FRDM-KL25Z



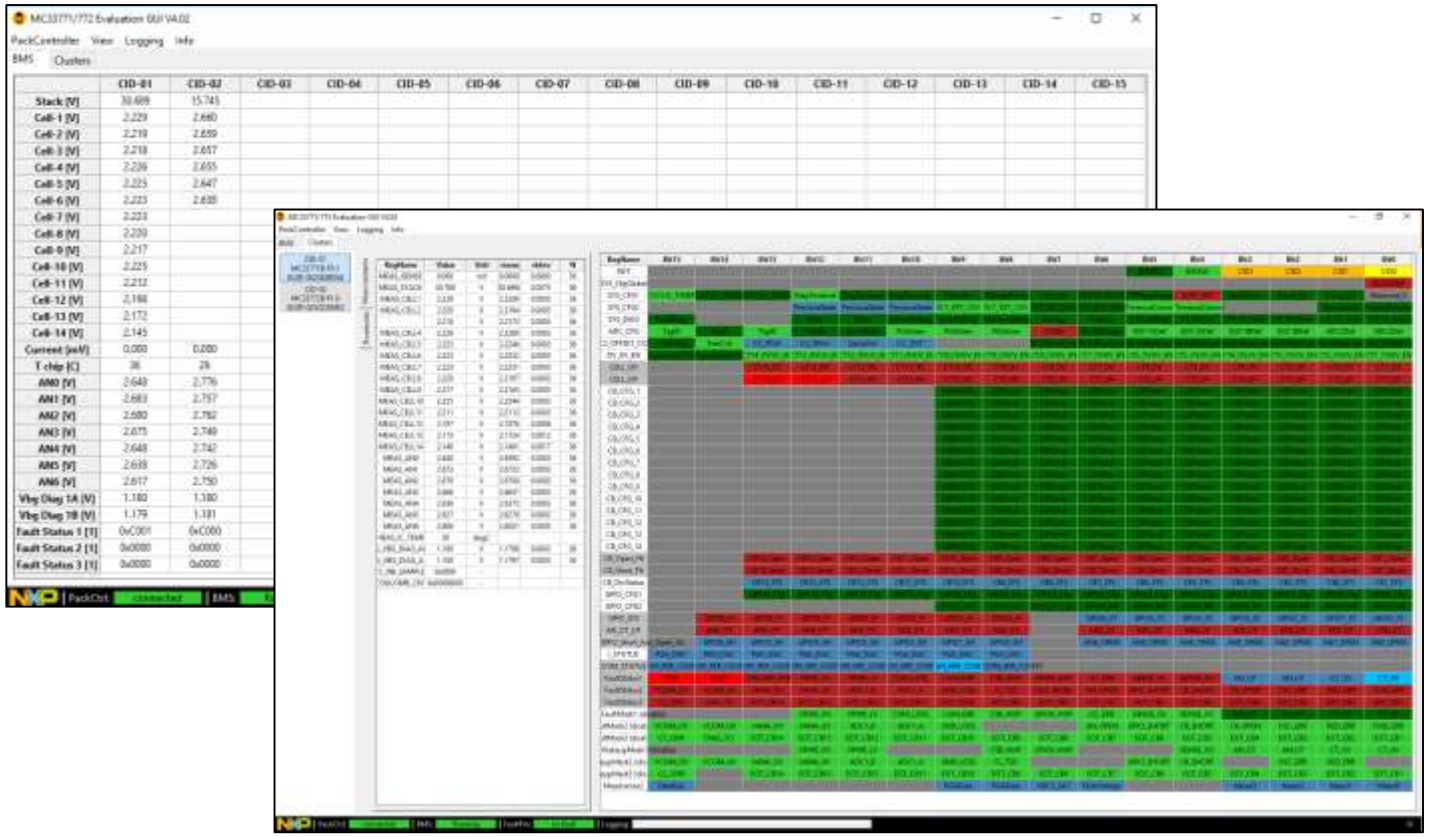
FRDM33771BTPLEVB
FRDM33771BSPIEVB

BATT-14AAAPACK

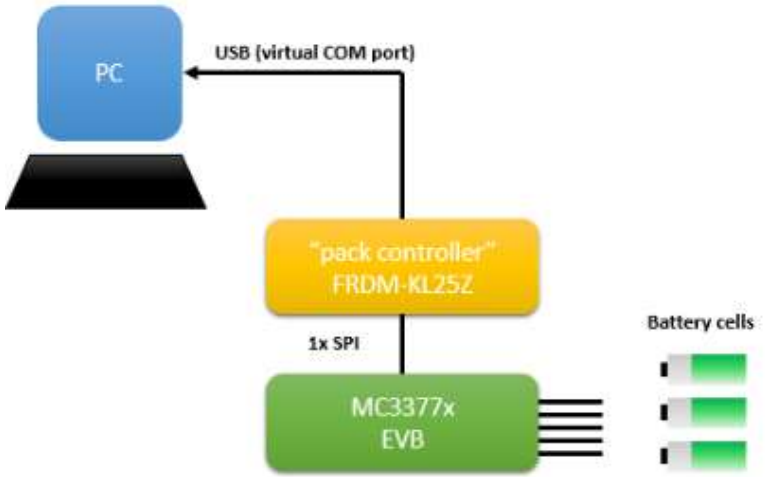
NXP BCC Evaluation GUI (with KL25Z Firmware)

v4.10 Available Now

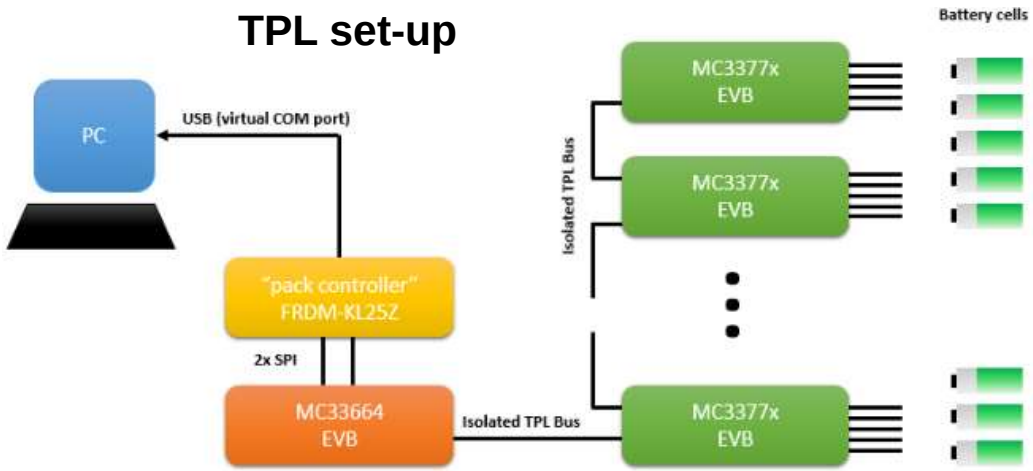
Supports KL25Z FW update if needed
Supports SPI communication
Supports TPL communication for daisy chain
Provide device registers configuration and measurements access



SPI set-up



TPL set-up



Battery Cell Controller – Analog Expert SW Driver

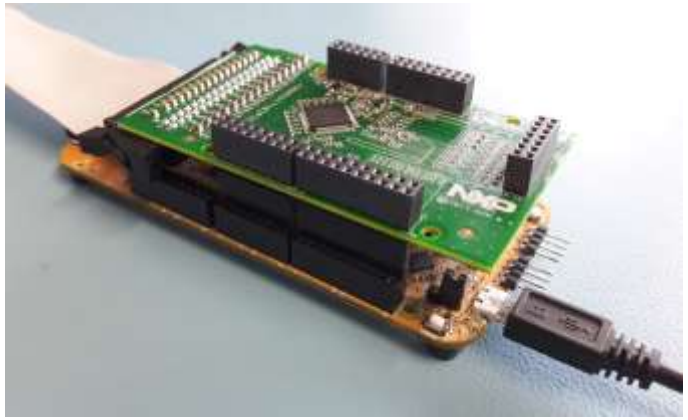
Function Name	Description
BCC_Init	Initializes the Battery Cell Controller device or devices (depends on configuration). It Assigns CID, initializes communication interface according to selected mode (classic SPI or TPL) and configures the device with predefined values from Processor Expert properties.
BCC_Deinit	Deinitializes the components used by Battery Cell Controller component. Note that this method does not reset the device.
BCC_WriteRegister	This method writes a value to addressed register of selected Battery Cell Controller device.
BCC_WriteGlobalRegister	This method writes a value to addressed register of all configured Battery Cell Controller devices. This method is available when communication mode is TPL.
BCC_ReadRegisters	This method reads a value from addressed register of selected Batter Cell Controller device.
BCC_Sleep	Set sleep mode of all Battery Cell Controller devices. MC33664TL goes to sleep mode automatically.
BCC_WakeUp	Sets normal mode of all Battery Cell Controller devices. MC33664TL goes to normal automatically.
BCC_StartConversion	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.
BCC_IsConverting	Checks status of conversion defined by End of Conversion bit in ADC_CFG register.
BCC_GetRawMeasurements	Reads the measurement registers and returns raw values. You can use macros defined in header file to perform correct unit conversion.
BCC_GetAverageCurrent	Computes average current with use of the Coulomb counter. Restart of the Coulomb counter depends on settings of BCC (see "Action on Read CC" property).
BCC_GetStatus	Reads the 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, GPIO_STS, AN_OT_UT_FLT, GPIO_SHORT_Anx_OPEN_STS, I_STATUS, PGA DAC, COM_STATUS, FAULT1_STATUS, FAULT2_STATUS, FAULT3_STATUS.
BCC_RunDiagnostic	Call internal diagnostic functions.
BCC_SoftwareReset	Resets Battery Cell Controller device using software reset. It enters reset via SPI or TPL interface.
BCC_HardwareReset	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).
BCC_SetGPIOOutput	Sets output value of Batter Cell Controller GPIO pin. This method is available when at least one GPIO is in output mode.
BCC_SetCBDrivers	Sets state of cell balancing drivers. It is designated to control all the drivers at once.
BCC_GetNtcCelsius	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.

Analog expert SW driver details:
- Tools chain supported
  - S32 DS 2018.R1
  - S32 SDK EAR 0.8.6
- S32K144 Project examples
  - BCC6 / BCC14
  - SPI / TPL communication
  - Diagnostics / Measurements
  - Freemaster 2.0

Supported HW:
- S32K144EVB-Q100
- FRDM33664BEVB
- FRDM3377xBTPLEVB
- FRDM3377xBSPIEVB

Documentation:
- SW User's Guide and readme file
- Programmers' guide

MC33771B SPI EVB Compatibility w/ S32K FRDM33771BSPIEVB, SCH-30047-REV A



JP17	1-2 (default)	JP33	open (default)
JP18	1-2 (GPIO0_TEMP, default)	JP34	open (default)
JP19	1-2 (GPIO2_TEMP, default)	JP36	open (unsolder)
JP26	open (unsolder)	JP37	1-2 (SCLK_ALT1, solder)
JP27	1-2 (CSB_ALT1, solder)	JP38	open (default)
JP28	open (default)	JP39	2-3 (FAULT_ALT1, resolder)
JP29	1-2 (MOSI_ALT0, default)	JP40	open (default)
JP30	open (default)	JP41	open (default)
JP31	open (default)	JP42	1-2 (RESET_ALT0, default)
JP32	1-2 (MISO_ALT0, default)	JP43	2-3 (5V SPI, resolder)

Rework for S32K144EVB-Q100

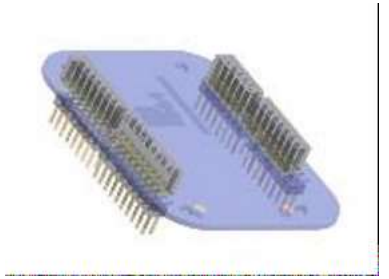
Default configuration is for FRDM-KL25Z usage

FRDM33664BEVB (for BCC TPL EVB) Compatibility with S32K SCH-28860-REV C

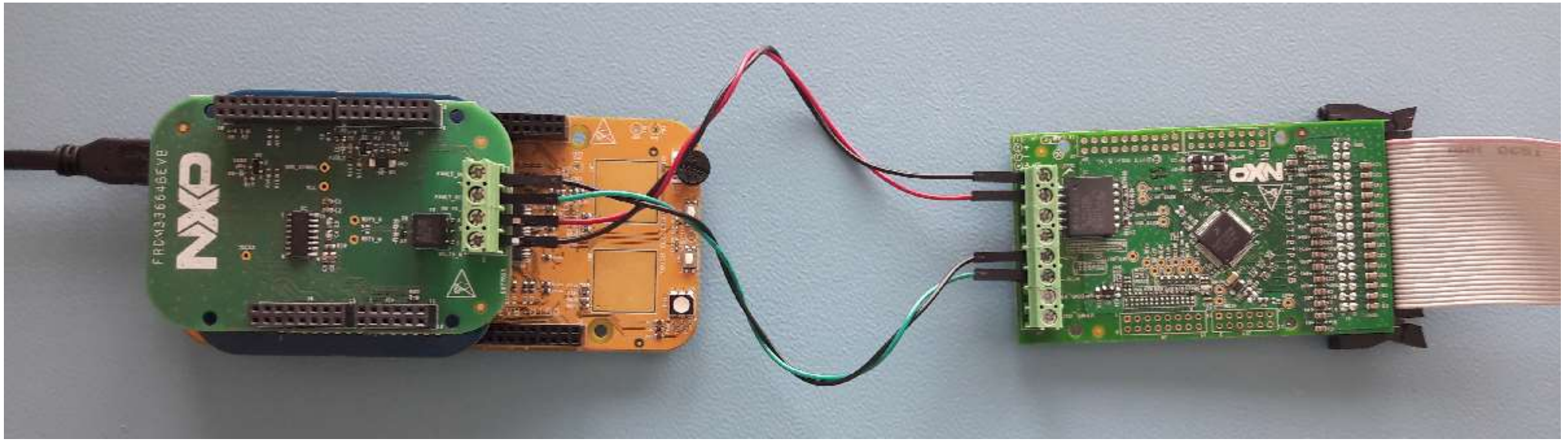
Add: R32 0R, R38 0R

Remove: R1, R2, R4, R6, R9, R21, R27, R29, R37, R40

Translator board
X-DEVKIT-TRANSLT
mandatory



Translator board only available on demand



Rework for S32K144EVB-Q100

Default configuration is for FRDM-KL25Z usage

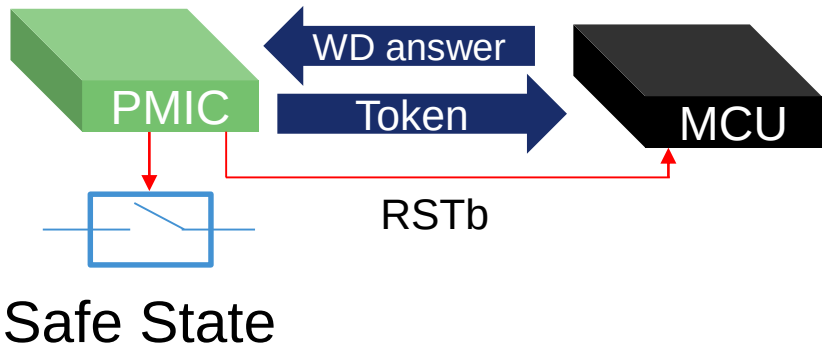
MC33FS45xx, MC33FS65xx MC35FS45xx, MC33FS65xx Safety Power Management for ASIL-C/D Applications

Role of the Safety Power Supply in a Fail Silent System

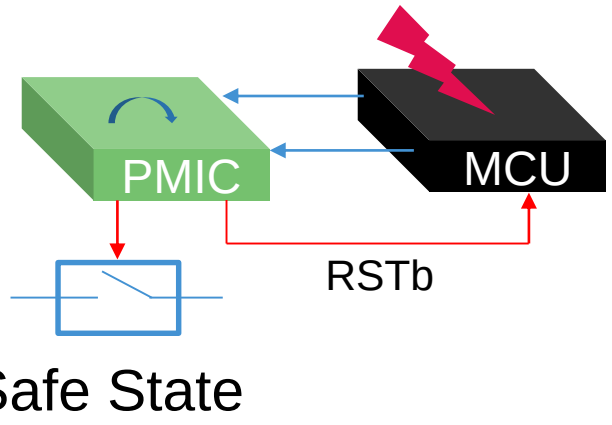
- Main tasks
  - **Deliver** safety related supply rail(s) to the MCU and other peripherals of a safety system
  - **Monitor** safety related supply rails for OV and UV (Detection)
  - **Request** for a system degradation in case of fault in the Fault Tolerant Time (Safe State)

Additional safety mechanisms to facilitate system integration

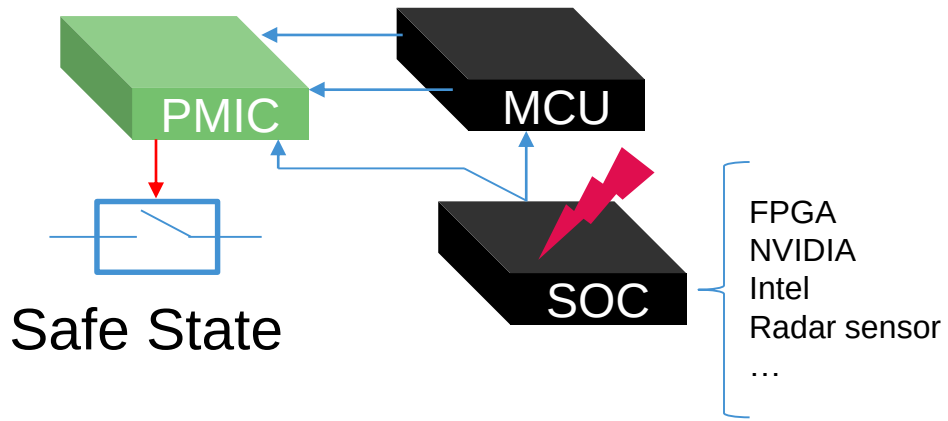
Challenger WD



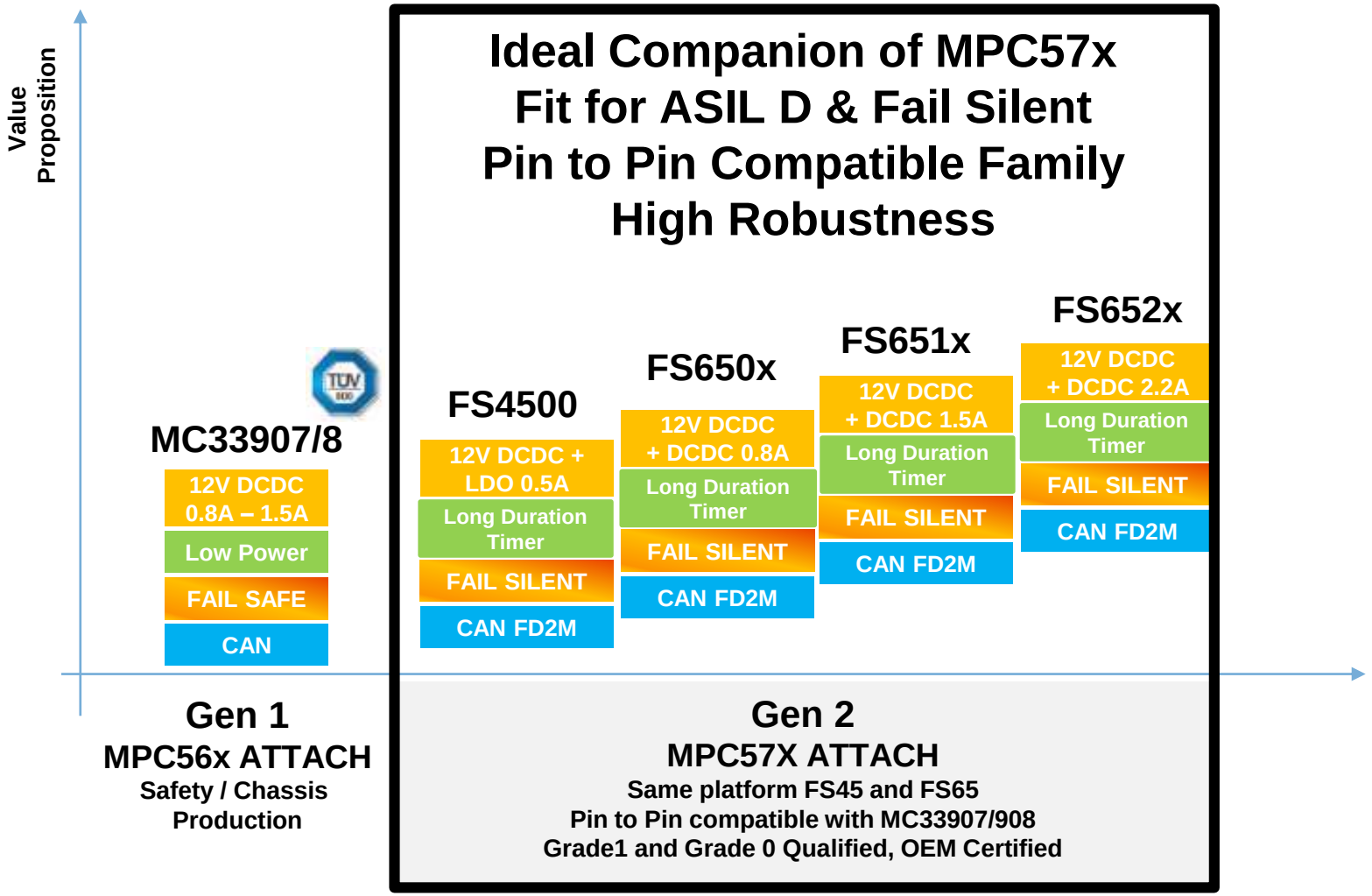
HW fault monitoring



SOC HW failure monitoring



Safety Power Management – Attach with MPC57xx
Powertrain Electrification Safety Power Management



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

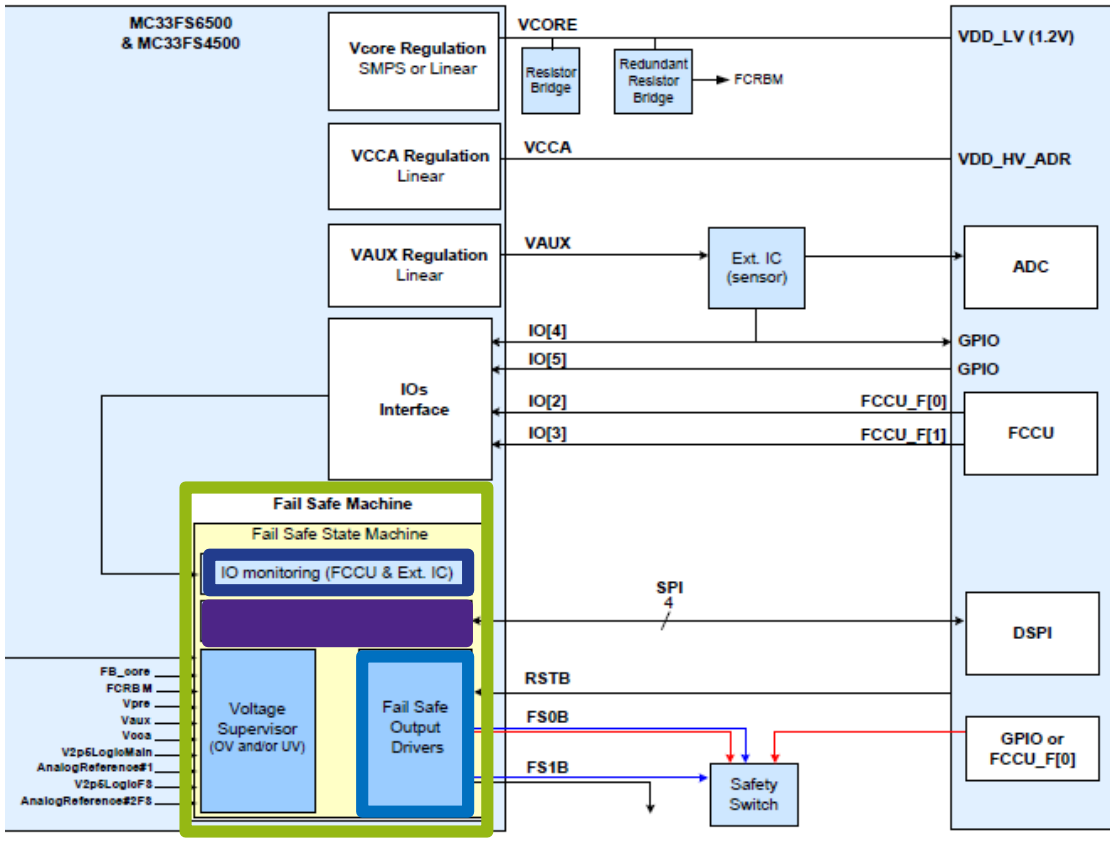
- ISO 26262 ready documentation
- System validation test (eFAST)
- Global ecosystem (incl HW & SW)

MCU + FSBC fitting for ASIL D Backbone
HW & SW Added Values for Fail Silent Requirements

Independent Fail Safe State Machine
- Physical & Electrical independance to fit for ASILD
- Power Management Monitoring Unit (UV / OV)
- Analog & Digital Built In Self Test to minimize Latent Faults
- Own Reference & Supply to Reduce Common Cause Failure

Advanced Watchdog
- Challenger
- Replace external MCU Monitoring

Safety SBC - FS65 **Safety MCU**



All safety mechanism reaction are < FTTI < 10ms
FTTI = Faul Tolerant Time Interval

HW Redundancy
- Vcore external Monitoring

MCU Monitoring
- FCCU : Fault Collection Control Unit
- Monitor Dual Core Lock Step Modes MCUs

RSTb – Fail Silent Mode
- Configurable RSTb activation giving more system availability

Fail Safe Pin (FS0b) :
- Redundant System Fail Safe enabler
- Second Fail Safe pin to assert safety path with configurable delay after failure

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

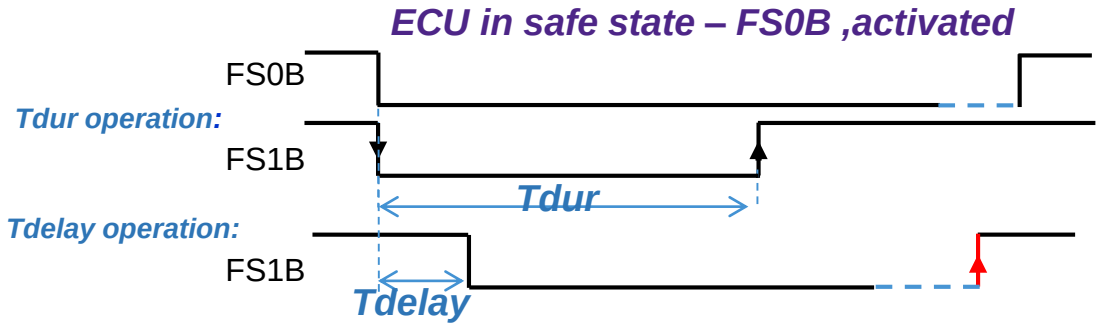
- SPM>90%, LT>99%, PHMF<10-8
- Analog & Digital Safety Mechanisms to fit for ASILD
- All safety mechanism reaction are < FTTI < 10ms

- 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)

- FAIL SILENT MODE

- REDUNDANT FAIL SAFE PIN (FS0B & FS1B)

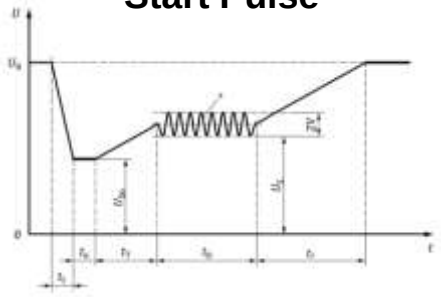


- OPTIONAL RESET at SAFE STATE to enable MCU Diag
- CONFIGURABLE SAFE STATE, independently for each failure
- SYSTEM AVAILABILITY : No MCU shutdown after multiple failures
- SMART DEGRADED MODE : safe and available operation

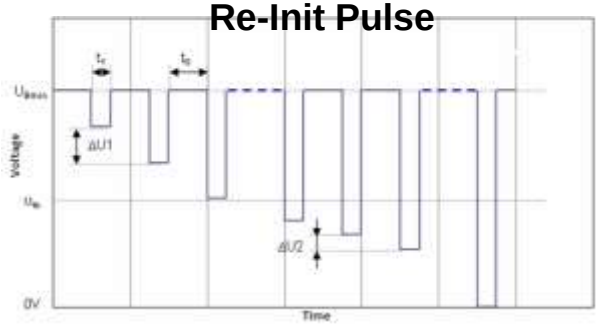
- T duration OPERATION : Inhibit CAN during *Tdur* duration
- T delay OPERATION : Safe delay of BMS load desactivation

Functional Robustness Automated Battery Test Validation Platform

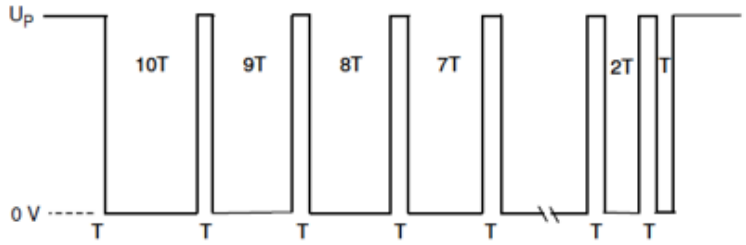
Start Pulse



Re-Init Pulse



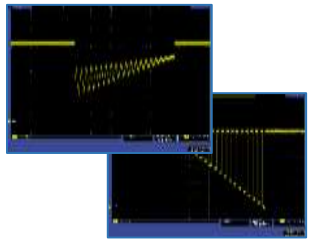
CI260B Pulse



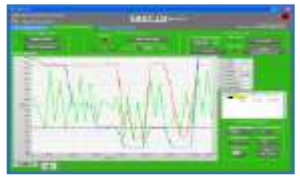
✓ **UNIQUE**

Automated Execution

Sweepy



LabView



Hardware

Control & Monitoring

Configuration & Results

Equipments

DUT

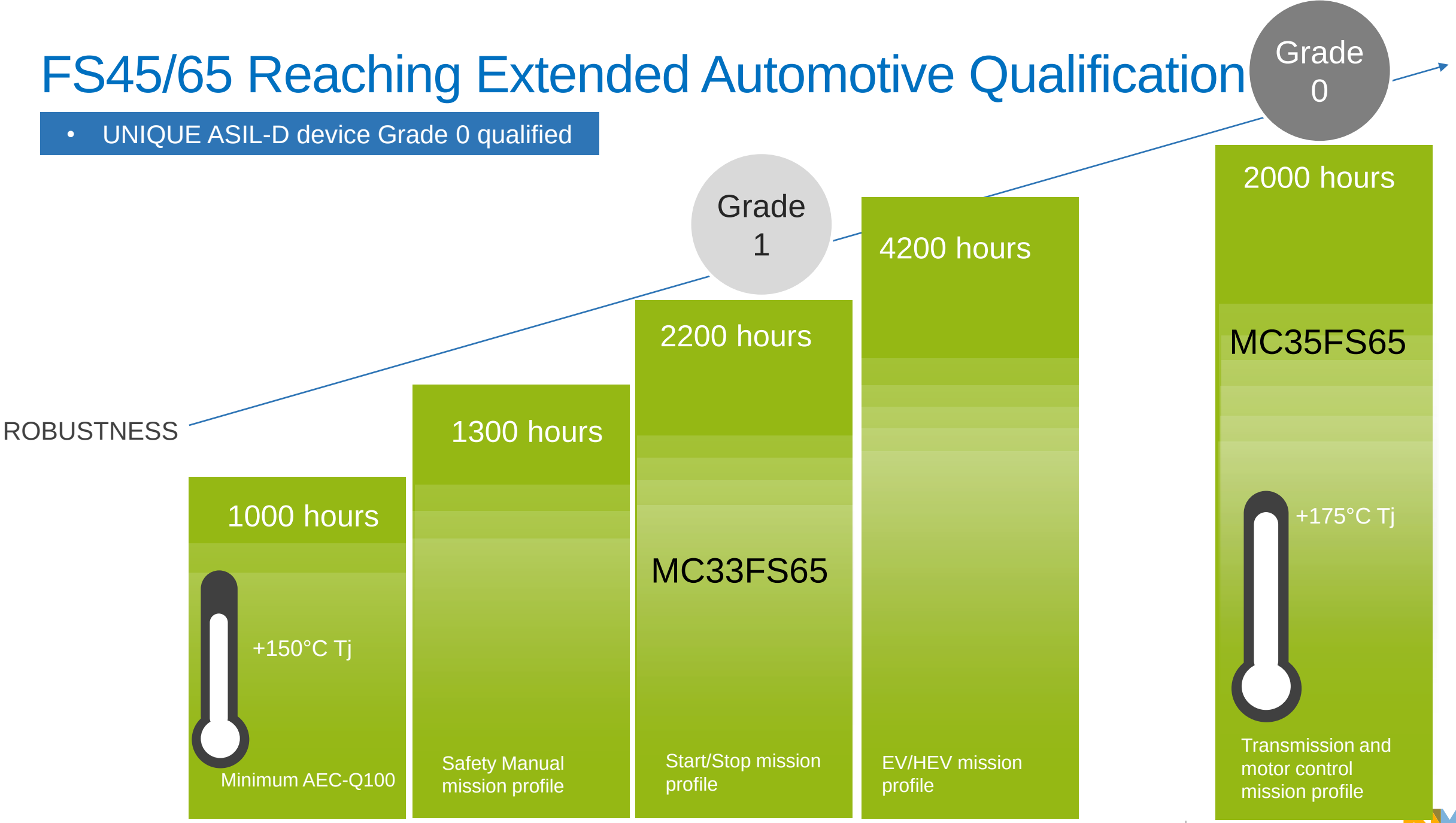
Reports

BENEFITS – EXTENDED VALIDATION

Car OEMs PULSES - Database
INCREASE USE CASE Coverage - Break the limit. (x10)
ACCELERATE VALIDATION – Reduce validation by 4
ISO26262 COMPLIANT - Full Traceability
MULTIPURPOSE - Non-ISO, Funct. Validation

FS45/65 Reaching Extended Automotive Qualification

- UNIQUE ASIL-D device Grade 0 qualified



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
- 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
  - ASIL-D Power management Grade 0

SECURE CONNECTIONS
FOR A SMARTER WORLD