Agenda

- Vehicle Electrification

- Battery Management System

- MC33771C

- MC33664

- BMS System Architectures

Automotive Global Megatrends
Driving the Need for Next-generation Silicon Capabilities

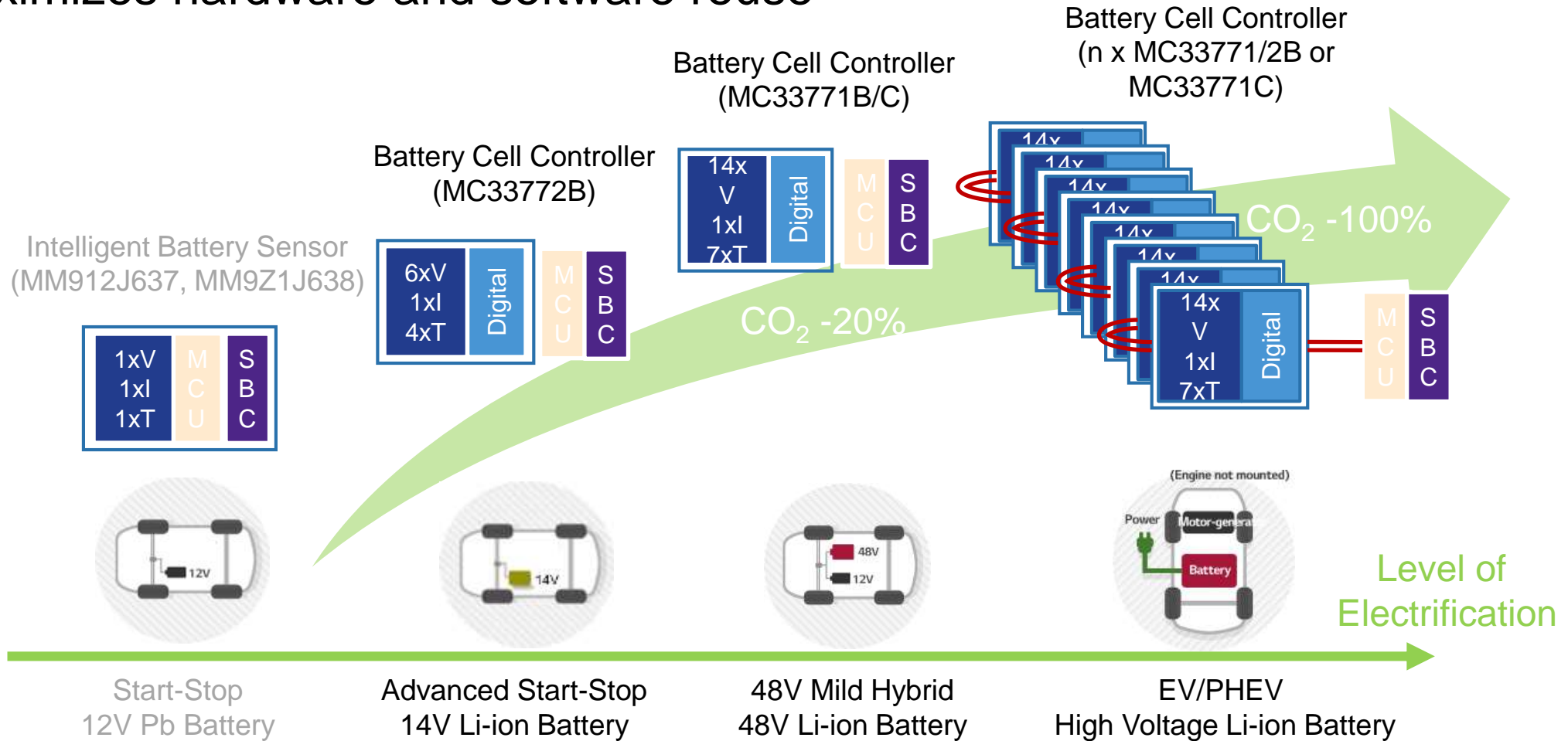Autonomy

Electrification

Connectivity

Target: Zero Emission
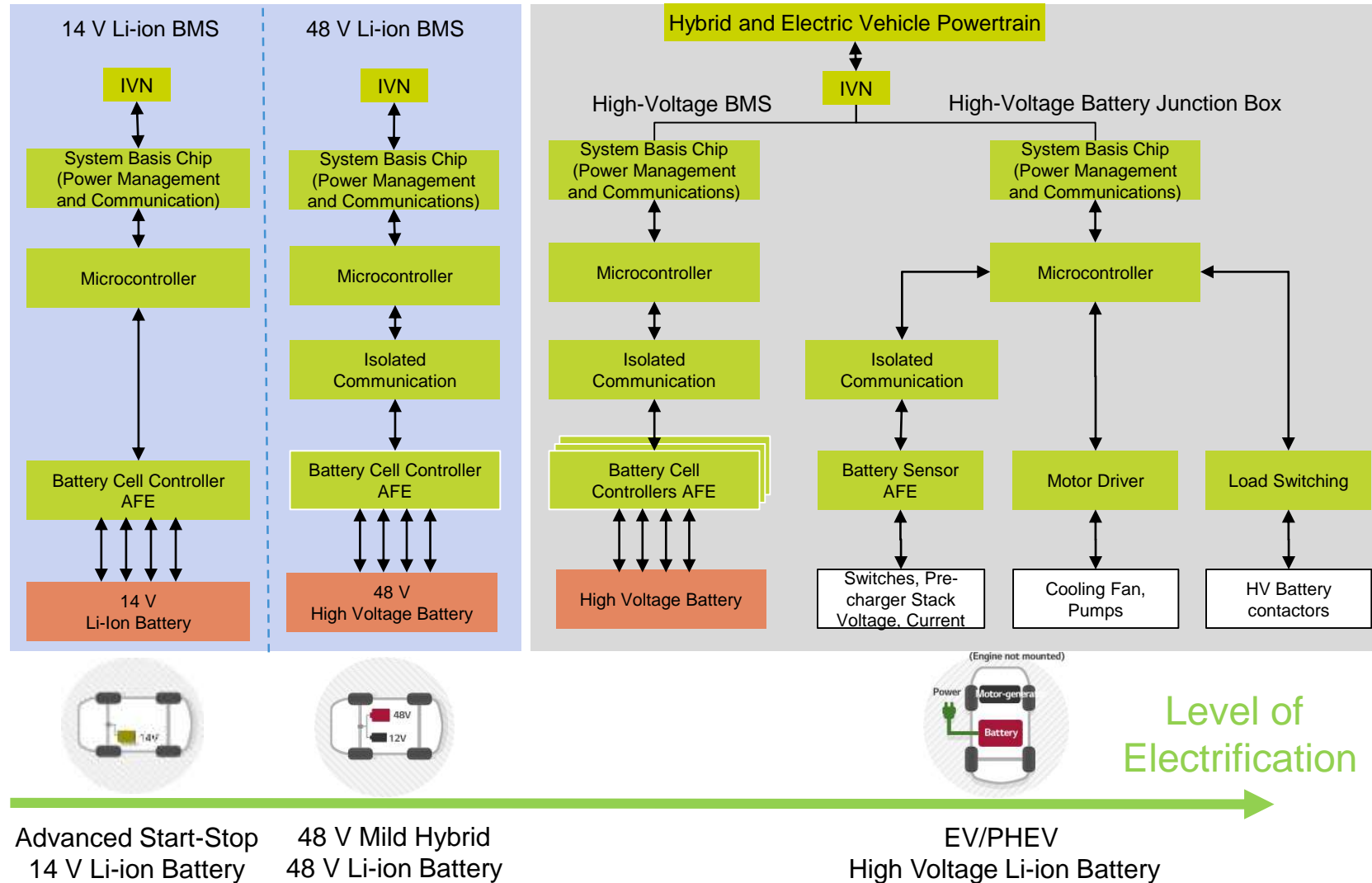
Vehicle Electrification: Diversity of Approaches

	Combustion Engine (ICE)	Mild Hybrid (M-HEV)	Full Hybrid (F-HEV)	Plug-in Hybrid (P-HEV)	Range Extended EV (RE-BEV)	Pure Electric Vehicle (BEV)
Combustion Engine	● ● ● ●	● ● ● ●	● ● ●	● ● ●	● ●	
Battery System	12V	12V / 48V	LV / HV	LV / HV	LV / HV	LV / HV
Mains Charging	-	-	-	🔌⚡	🔌⚡	🔌⚡
Electric Traction	-	10 – 20 kW	15 – 60 kW	40 – 80 kW	40 – 80 kW	> 80 kW
CO_2 reduction at vehicle	n.a.	-20%	-30%	-50 to -75%	-50 to -75%	100%

NXP's Scalable Battery Management Portfolio

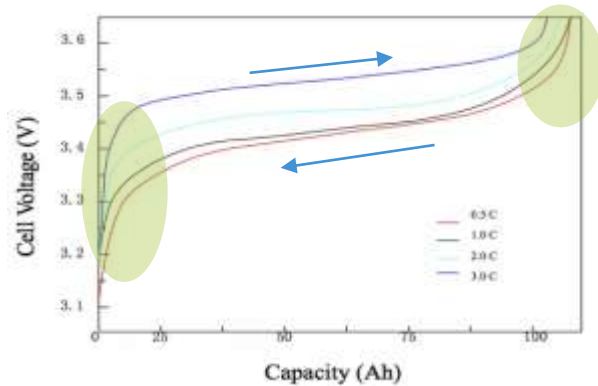## Addresses all Automotive Battery Management Applications – maximizes hardware and software reuse

Intelligent Battery Sensor
(MM912J637, MM9Z1J638)

Battery Cell Controller
(MC33772B)

Battery Cell Controller
(MC33771B/C)

Battery Cell Controller
(n x MC33771/2B or MC33771C)

CO_2 -20%

CO_2 -100%

Level of Electrification

Start-Stop
12V Pb Battery

Advanced Start-Stop
14V Li-ion Battery

48V Mild Hybrid
48V Li-ion Battery

EV/PHEV
High Voltage Li-ion Battery

Automotive 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 Communications) → Microcontroller → Isolated Communication → Battery Cell Controller AFE → 48 V High Voltage Battery

Hybrid and Electric Vehicle Powertrain

IVN

High-Voltage BMS

System Basis Chip (Power Management and Communications) → Microcontroller → Isolated Communication → Battery Cell Controllers AFE → High Voltage Battery

High-Voltage Battery Junction Box

System Basis Chip (Power Management and Communications) → Microcontroller

Isolated Communication → Battery Sensor AFE → Switches, Pre-charger Stack Voltage, Current

Motor Driver → Cooling Fan, Pumps

Load Switching → HV Battery contactors

(Engine not mounted)

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 Functions of BMS Systems

Safety	Performance	Multi-Cell function

Danger:
- Over Voltage
- Extra Heat
- Unstable Chemical Stage
- Thermal Runaway
- Low Temperature Charge

Requirements:
- Safe & Fast Charging
- Discharge Optimization
- State of Charge (SOC)
- State of Health (SOH)

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
Insure Safety	Monitor Available Energy Monitor Ageing	Increase Battery Life Enhance Stored Energy

NXP Battery Cell Controller Portfolio

Parameter	MC33771B	MC33771C
Voltage Channels	14	14
Supply Vpwr Range (Max Transient)	9.6V..61.6V (75V)	9.6V..61.6V (75V)
Cell Terminal Input Voltage Range	-0.3V to 5V	-0.3V to 5V
Max Total Measurement Error (TME) for Cell Terminal Voltage (After aging: MLS3 & 1000h HTOL)	± 3.9 mV Vpwr=9.6~61.6V, Vcell=1.5~4.3V -40~60°C	± 3.9 mV Vpwr=9.6~61.6V, Vcell=1.5~4.3V -40~60°C
Functional Safety	Support up to ASIL-D at System Level	Support up to ASIL-D at System Level
Isolated communication Speed	2 Mbps	2 Mbps
Communication Isolation	Inductive, Capacitive	Inductive, Capacitive
Max Nodes per Daisy Chain	15	62
CRC Bit	8	8
Integrated Balancing	<300 mA	<300 mA
Balancing sleep mode	No	No
Deep sleep mode	No	No
GPIO / Analog measurement inputs	7	7
Current Channels	1	1
Coulomb counter	1	1
Package	64-pin LQFP-EP (-40~105°C)	64-pin LQFP-EP (-40~105°C)

MC33771B

In production

MC33771C

CES   July 2019

PPAP October 2019

NXP MC33771C Battery Cell Controller Solution
Differentiating Points

Battery Topology Flexibility

- Scalable SW & HW compatible BMS solution supporting 7 to 14[14] cells per daisy chain
- MC33771C (7 to 14 cells)
- 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 isolated differential communication
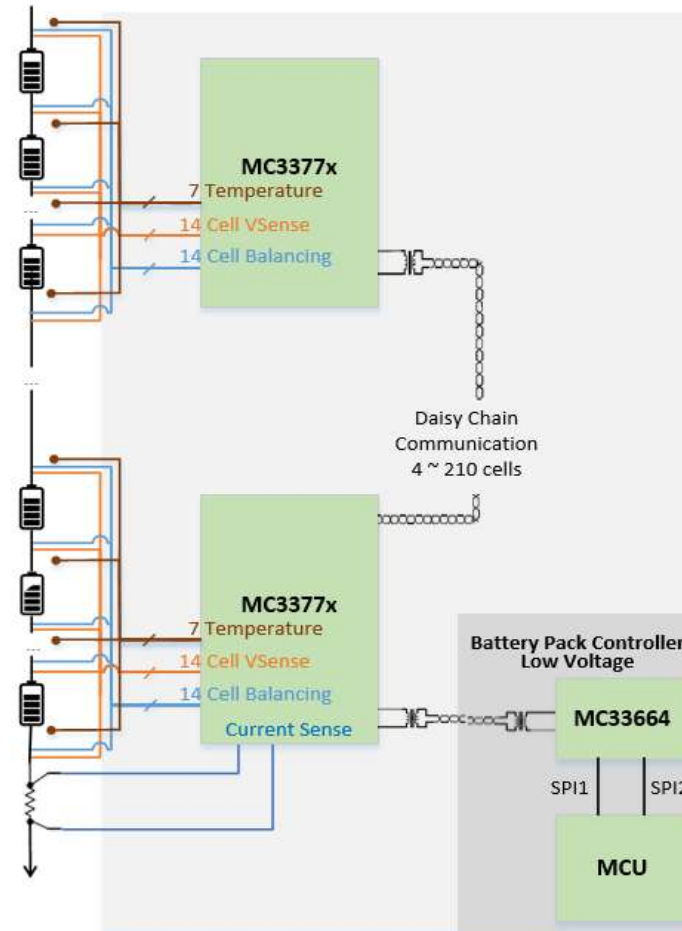
High measurement accuracy

- Voltage measurement accuracy after soldering and aging within full operation Voltage & Temperature range ± 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 ISO26262 w/ single chip

- Designed to support up to ASIL D safety system
- 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

MC33771C – 14 Cell Battery Cell Controller AFE

Key features

- ### High-performance integrated functions
  - Operating voltage: 9.6V ≤ VPWR ≤ 61.6 V operation, 75 V transient
  - Life-time guaranteed high accuracy 14 cell voltage measurement channels
  - 4.0 Mbps SPI or isolated 2.0 Mbps differential communication
  - Synchronized on-chip Current measurement with ±0.5% accuracy (±1500 A / 100 µΩ shunt)
  - Synchronized on-chip Coulomb Counter (also in low-power mode)
  - 7 ADC/GPIO/temperature sensor inputs

- ### Comprehensive integrated functional safety features
  - Designed to support ISO 26262, up to ASIL D safety system
  - Automatic OV/UV and temperature detection routable to fault pin
  - Integrated sleep mode OV/UV and temperature monitoring
  - OV/UV, over/under temperature fault verification
  - Detection of internal and external faults, i.e. open line, short, and leakage
  - Integrated Balancing Diagnostics

- ### Quality & robustness
  - AEC-Q100 automotive Qualified
  - Temp range: -40°C to 105°C
  - Operational low-power mode
 - Hot plug capable
  - EMC/ESD robustness

64-pin LQFP-EP
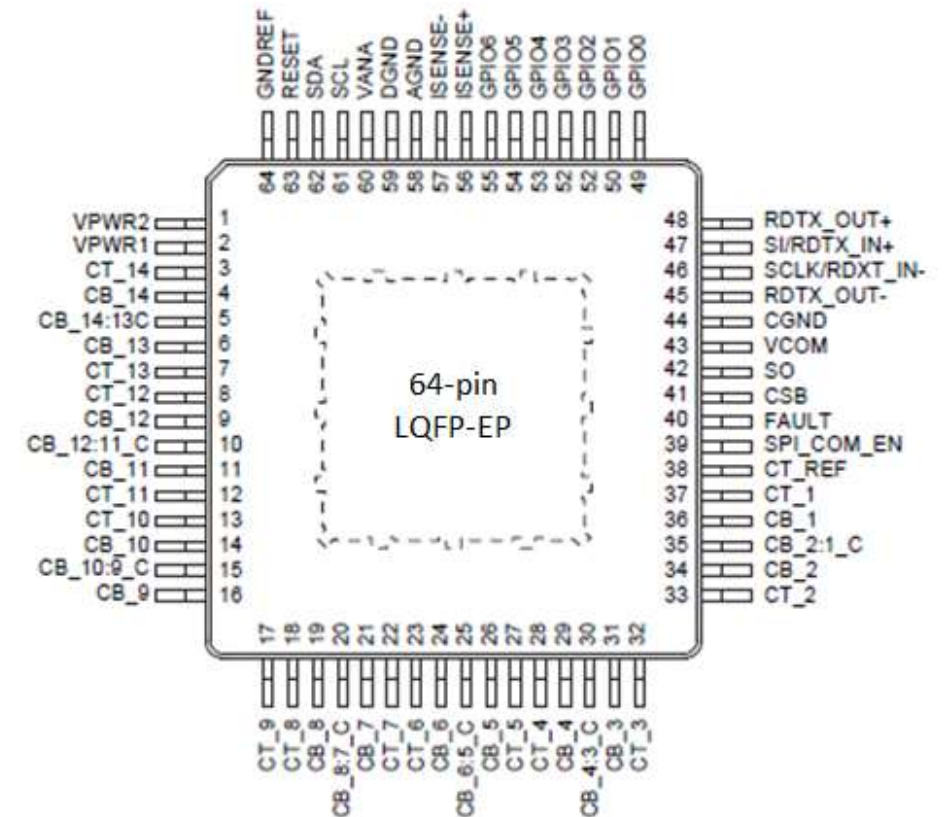
MC33771C – Benefits of Integrated Averaging Functionality

- MC33771C is offering an integrated averaging functionality for the cell terminal voltage measurements

- The integrated averaging avoids the need to transfer each measurement result
  Benefit 1: Less MCU load for communication and average computation

- Integrated averaging decouples the acquisition frequency from the communication. Higher acquisition frequencies are possible
  Benefit 2a: Smaller anti-aliasing filter capacitor needed (lower BOM cost)
  Benefit 2b: Smaller anti-aliasing filter capacitor speeds up settling time for safety mechanisms

- Internal accumulation allows higher sampling frequencies. More samples result in lower noise on measurement results
  Benefit 3: Improved noise performance

MC33771C – Improved Daisy Chain

MC33771C TPL2 improvements:

- Compatible with MC33664

- Inductive & capacitive coupling support (current transformers & current external components)

- TPL2 block consumption divided by 2 or 10 depending on configuration.

- Up to 62 nodes (48bit Protocol)

- Support 1 daisy chain, but several daisy chains can be managed by software.

- 2m between each node in LowPower configuration, 20m in HighPower

- Loopback support for 1 daisy chain.

- 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

- RevC introduces the new TPL2 communication

- Minor TPL protocol layer changes are required on the Battery Management Controller (BMC) when introducing the revC

Figure 3. Simplified internal block diagram
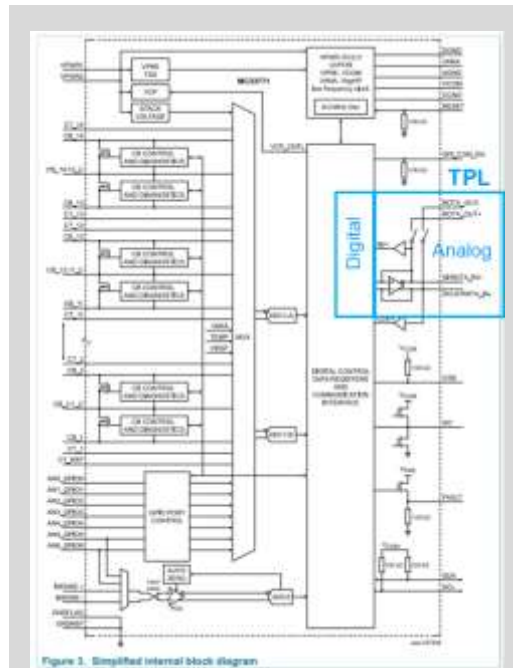
updated blocks on MC33771C compared to MC33771B
Other blocks are identical btw MC33771B and MC33771C
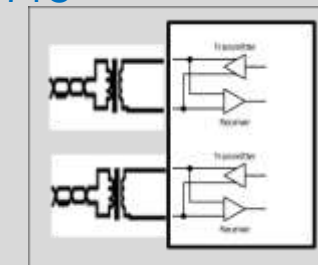
MC33771B
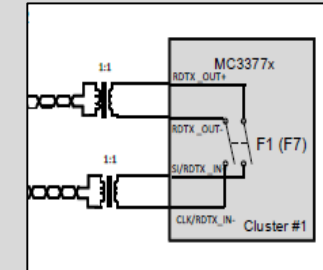
- TPL PHY is a bus which is cut by internal switches
- Each wire segment, bus switch, and transformer contribute to signal attenuation and limit the number of nodes
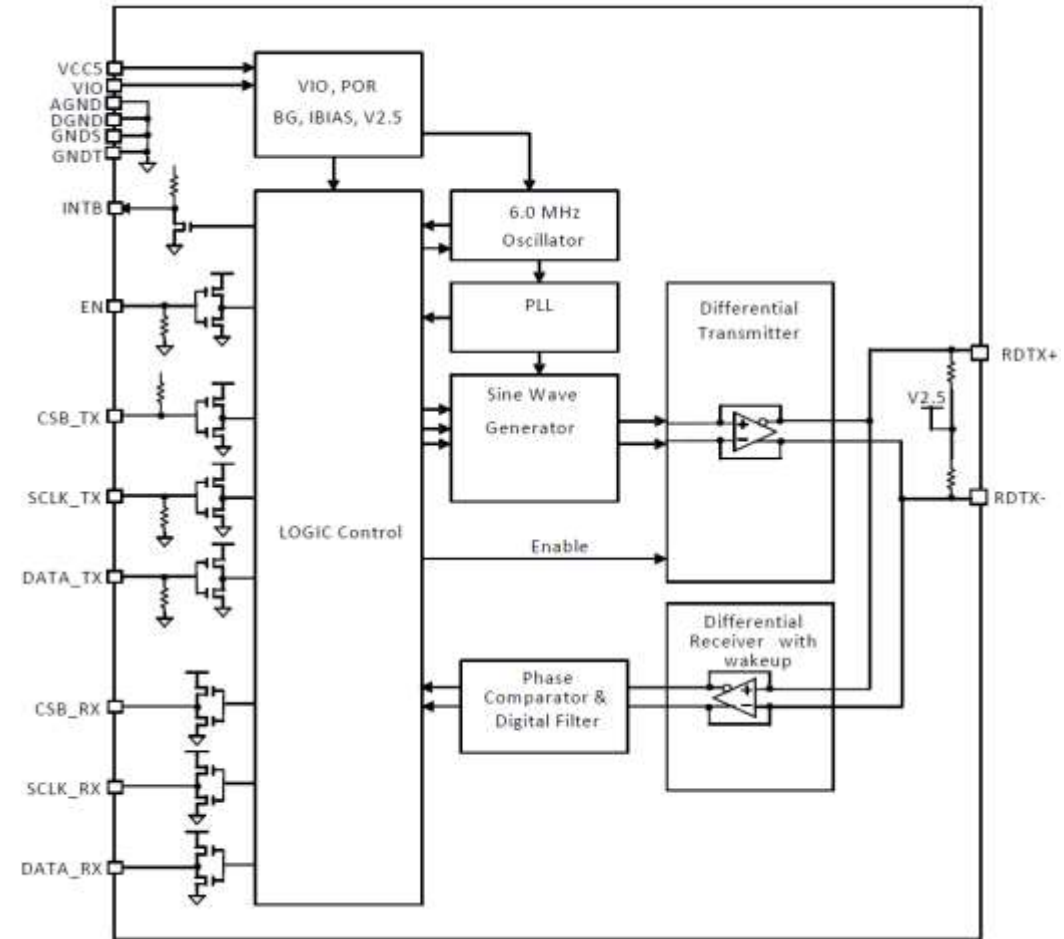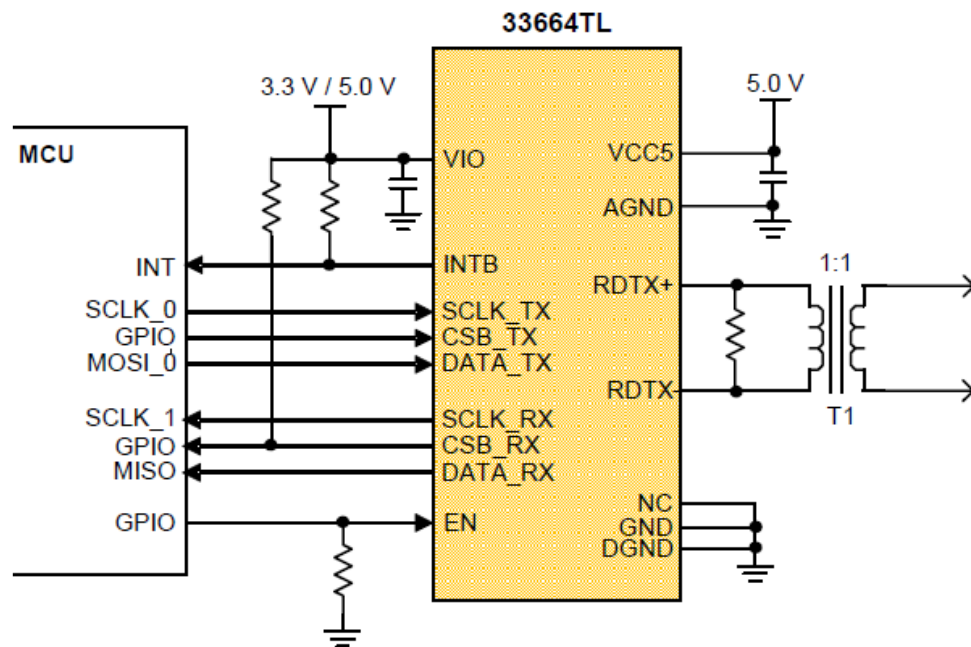- TPL is compatible with the MC33664

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
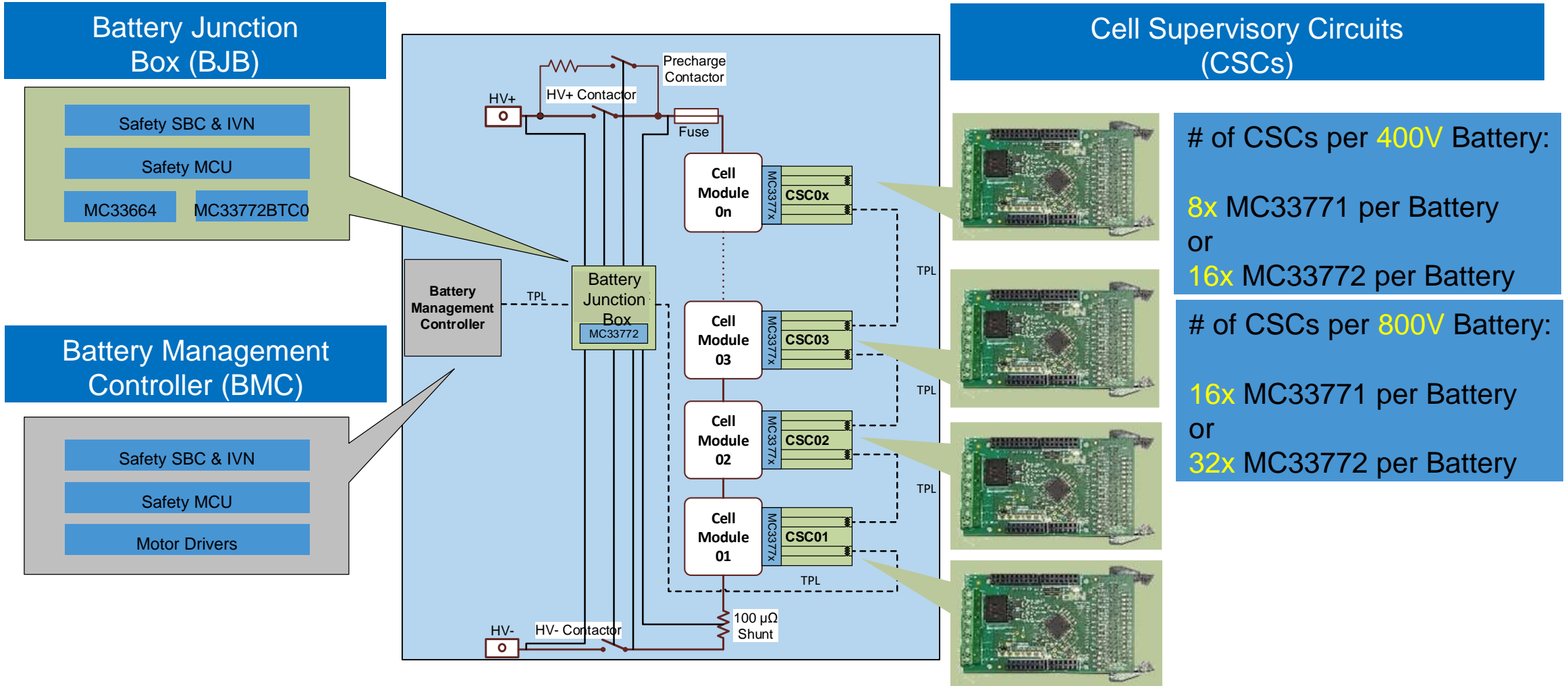- TPL2 is compatible with the MC33664

MC33664ATL Transformer Physical Layer

Features:

- 2 Mpbs Isolated Network Communication rate
- Dual SPI architecture for message confirmation
- Robust conducted and radiated immunity with wake-up
- 3.3 V and 5.0 V compatible logic thresholds
- Low current sleep mode with automatic wake-up
- Sine wave transmission for low radiated emission

NXP's Solution Proposal for Distributed HV-BMS

Battery Junction Box (BJB)
- Safety SBC & IVN
- Safety MCU
- MC33664
- MC33772BTC0

Battery Management Controller (BMC)
- Safety SBC & IVN
- Safety MCU
- Motor Drivers

Cell Supervisory Circuits (CSCs)

# of CSCs per 400V Battery:

8x MC33771 per Battery
or
16x MC33772 per Battery

# of CSCs per 800V Battery:

16x MC33771 per Battery
or
32x MC33772 per Battery

Diagram labels: HV+, HV+ Contactor, Precharge Contactor, Fuse, Cell Module 0n, Cell Module 03, Cell Module 02, Cell Module 01, CSC0x, CSC03, CSC02, CSC01, MC337x, Battery Management Controller, Battery Junction Box MC33772, TPL, 100 µΩ Shunt, HV-, HV- Contactor
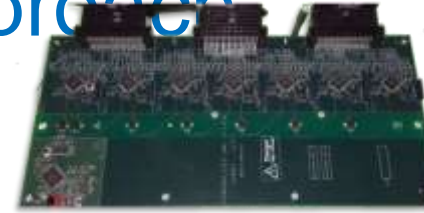
High Voltage BMS Distributed Approach

Main advantages:

- Short connections between AFE and battery cells

- Reduce EMI on measurement cables

- Saving space, weight and in assembly

- Modular battery design

- Usable for multiple battery pack configurations

Production proven, EVBs available for TPL solution prototyping
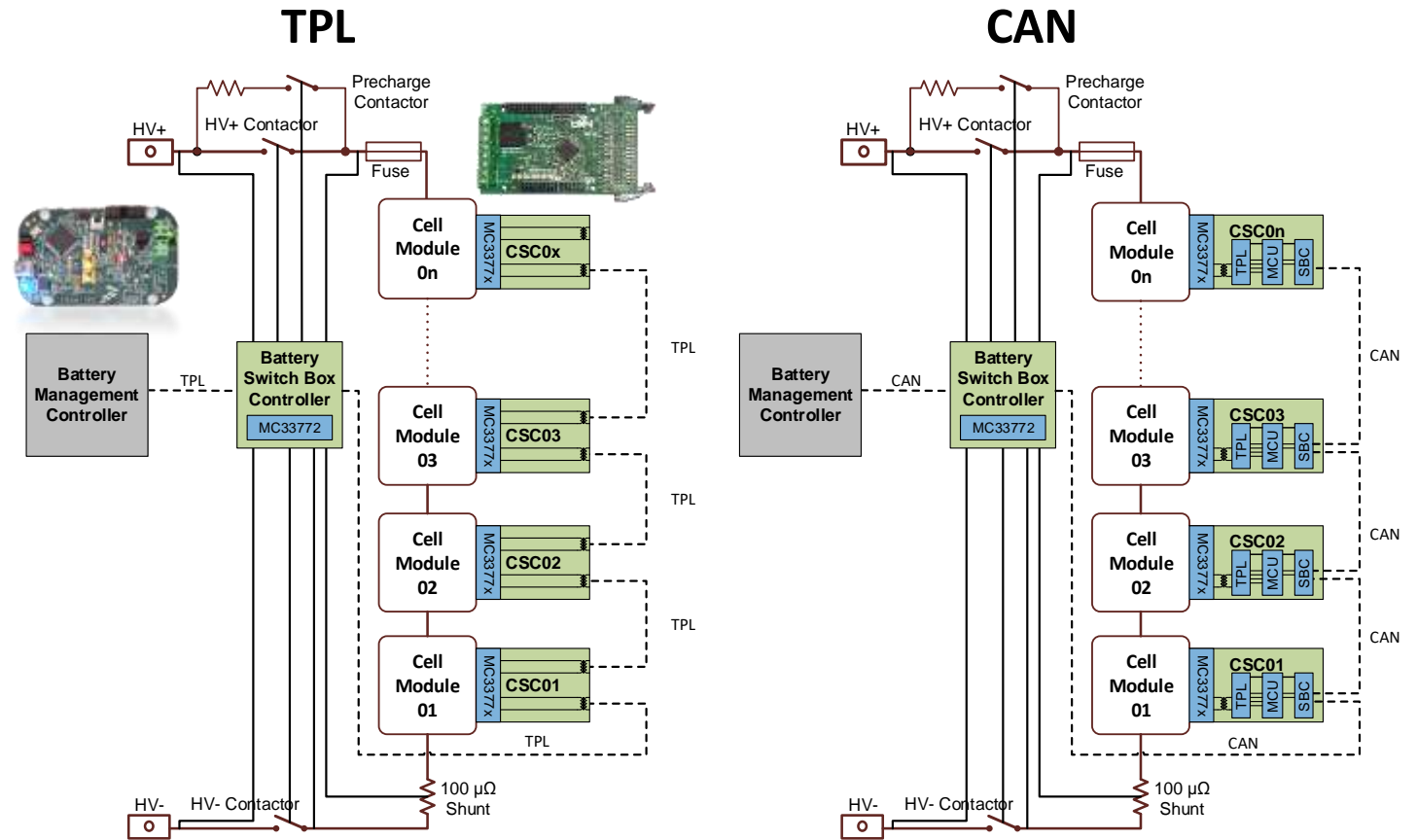
High Voltage BMS Centralized Approach

Main advantages:

- Short connections between nodes (usually less than 0.5m)

- Very limited signal attenuation/distortion allowing 100% reliable communication up to 62 nodes on all temp range→ excellent S/N and less attenuation

- Only one low cost single channel HM2103NL transformer or capacitive isolation between nodes

- Loopback capability
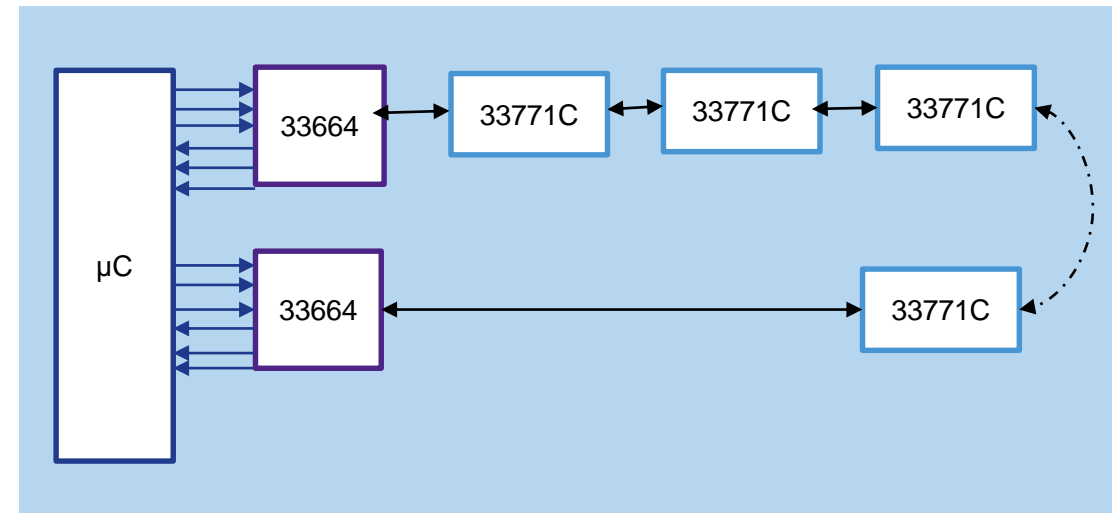
Production proven, reference design available
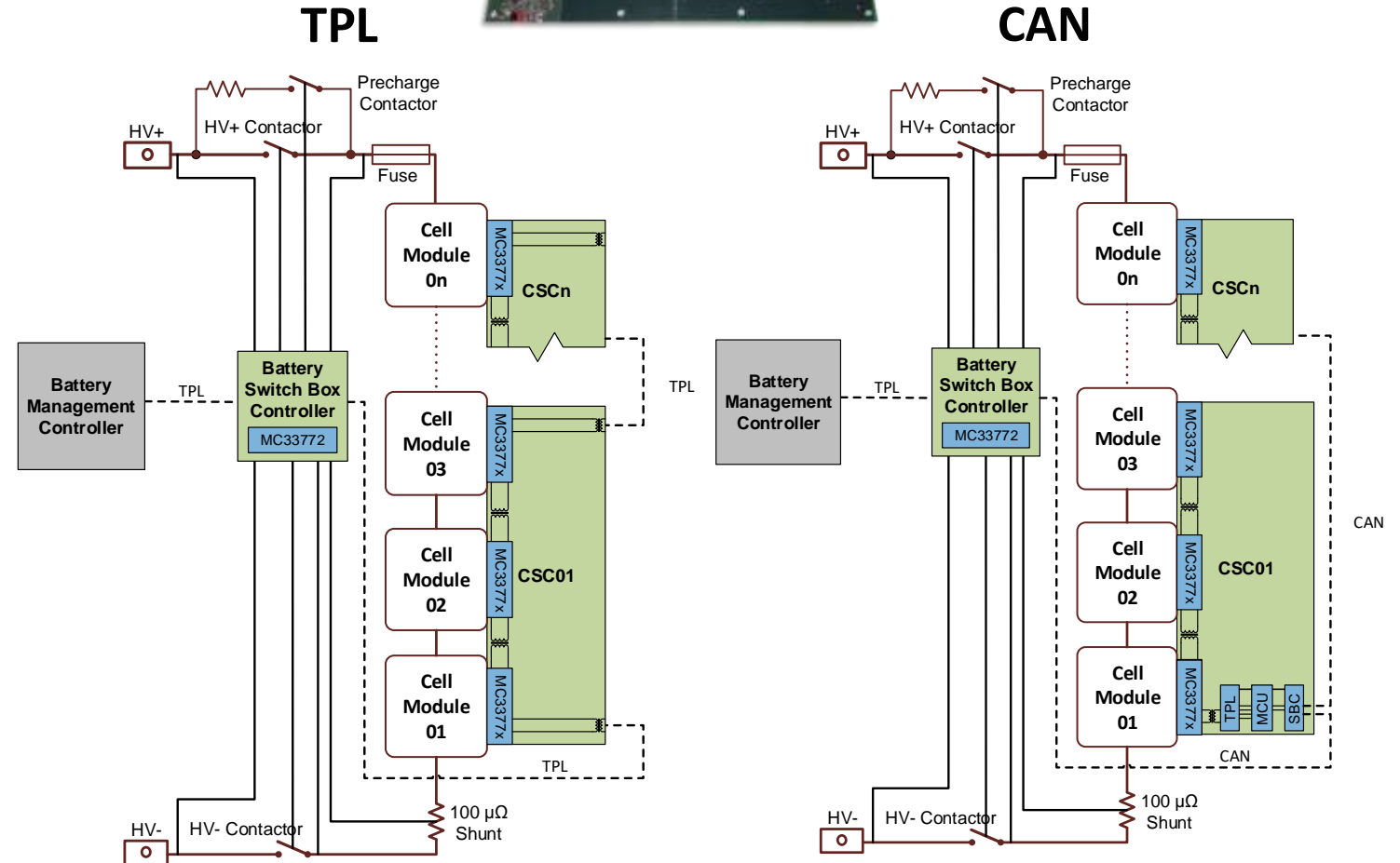
MC33771C – Typical Use Cases

Use case: Single-ended daisy chain
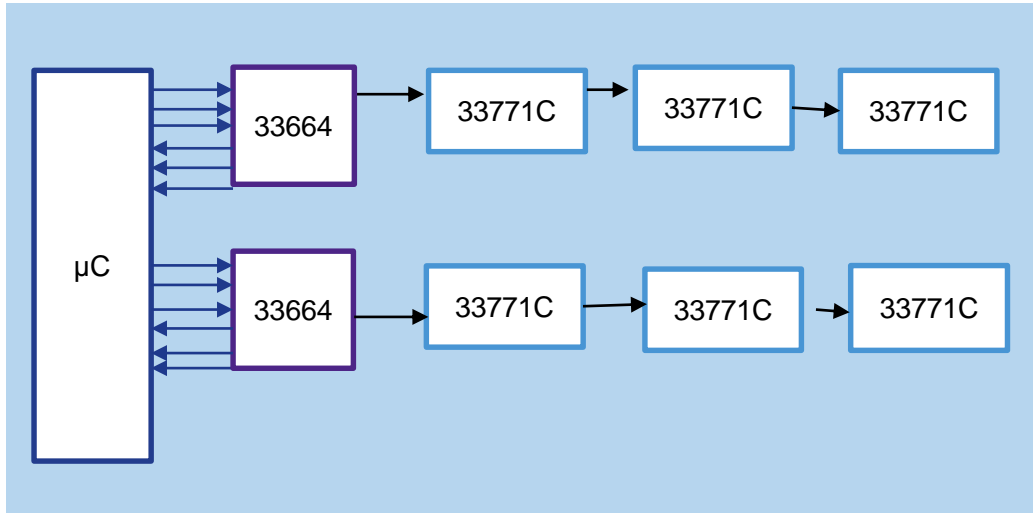
## Use case: Loopback daisy chain

- The TPL drivers are connected physically at different SPI ports. Each TPL driver is capable of driving one single ended daisy chain.

- **In single ended daisy chain configuration:**
  The MCU can support several daisy chain through software by internally assigning each SPI port as one chain.

- **In loopback configuration:**
  Two TPL drivers form one chain. Thus, MCU has to assign two physical SPI ports as one chain and write the chain address on internal config register of devices.

- On system level several looped daisy chain can be supported by writing a daisy chain address in the node. Thus, the node can always decode the chain address from command and know if the message was intended for it.

- To support loopback, two TPL drivers (master nodes) are connected physically at different SPI ports of MCU at different ends of daisy chain.

- The MCU through these Master nodes can reach a node from both direction. Also, in case of broken link a node can always be addressable from other side.

NXP xEV Energy Management Portfolio

	MCU	SBC	COMM	Driver	AFE
Battery Management Systems	●	●	●		●
Motor Control (HV inverters)	●	●	●	●	●
Hybrid Control Unit	●	●	●		
48V eMachine (BSG, ISG, HVAC)	●	●	●		
DC/DC Voltage Domain Converter	●	●	●		
On-board Charger AC/DC Converter	●	●	●		
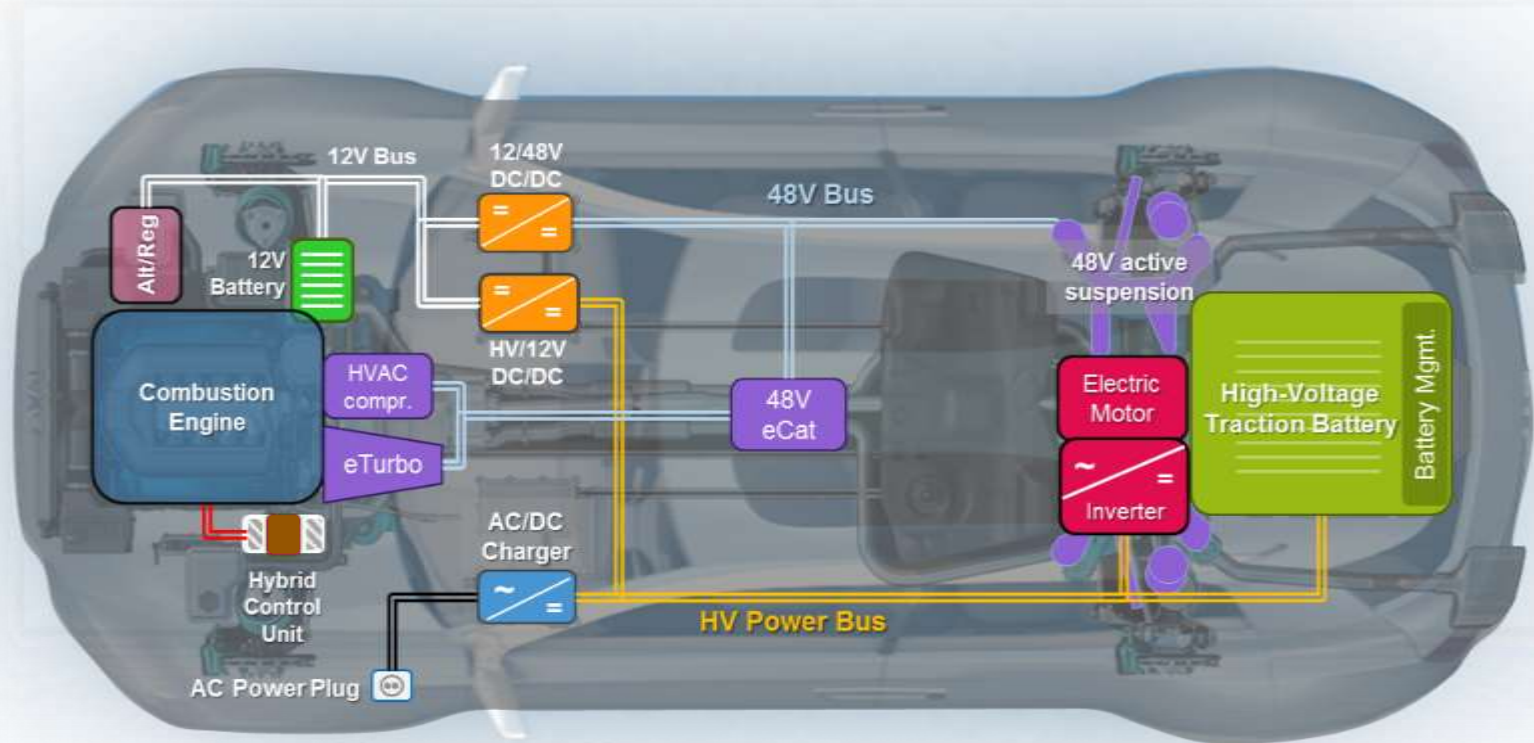
Summary

NXP Solutions are designed to address:

- Main BMS applications with comprehensive and scalable SW/HW solutions

- System Solution (MCU,SBC,Analog, IVN) 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

- NXP, your Electrification Partner

SECURE CONNECTIONS
FOR A SMARTER WORLD