

# Cost Optimized High Voltage Battery Management System (HVBMS) based on MC33771C

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SECURE CONNECTIONS  
FOR A SMARTER WORLD

# Agenda

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- Vehicle Electrification
- Battery Management System
- MC33771C
- MC33664
- BMS System Architectures



# Automotive Global Megatrends

Driving the Need for Next-generation Silicon Capabilities



Autonomy



Electrification



Connectivity

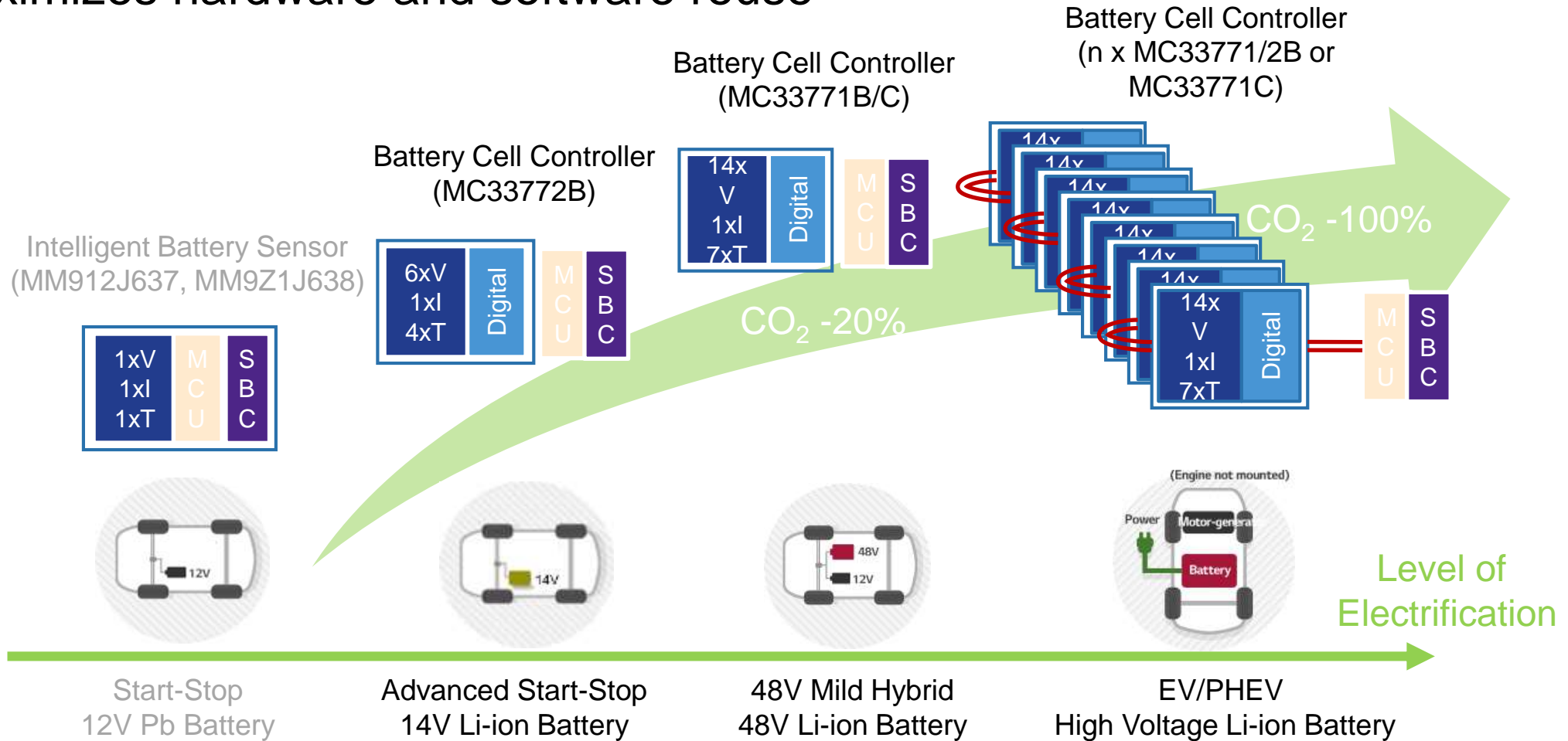
Target: Zero Emission

# Vehicle Electrification: Diversity of Approaches

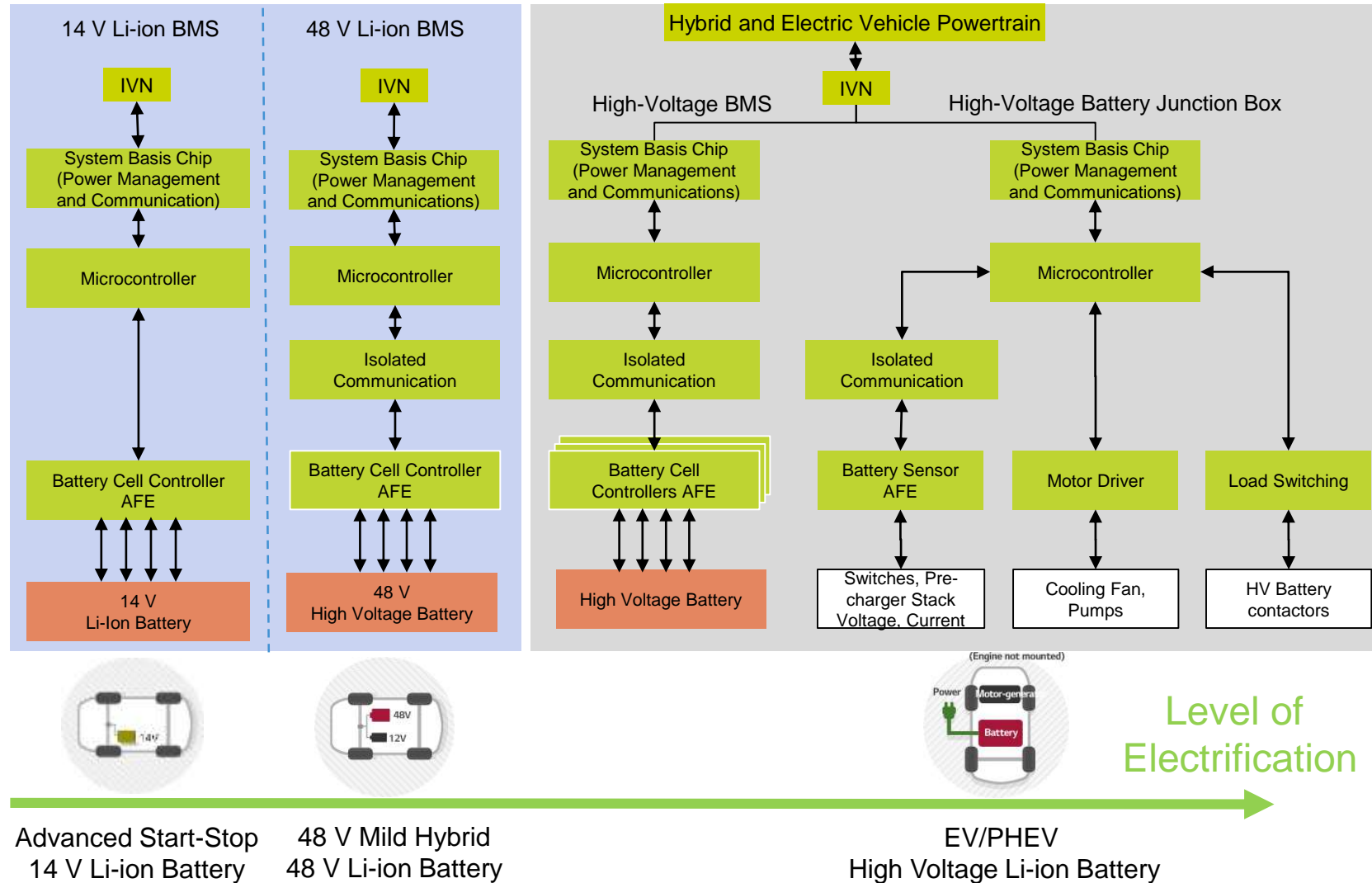
	Combustion Engine (ICE)	Mild Hybrid (M-HEV)	Full Hybrid (F-HEV)	Plug-in Hybrid (P-HEV)	Range Extended EV (RE-BEV)	Pure Electric Vehicle (BEV)
Combustion Engine						
Battery System						
Mains Charging	-	-	-			
Electric Traction	-	 10 – 20 kW	 15 – 60 kW	 40 – 80 kW	 40 – 80 kW	 > 80 kW
CO <sub>2</sub> 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

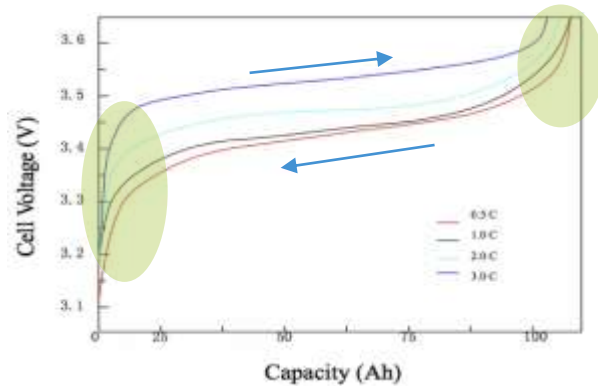


# Automotive Li-ion BMS Application Overview



# Main Functions of BMS Systems

## Safety



### Danger:

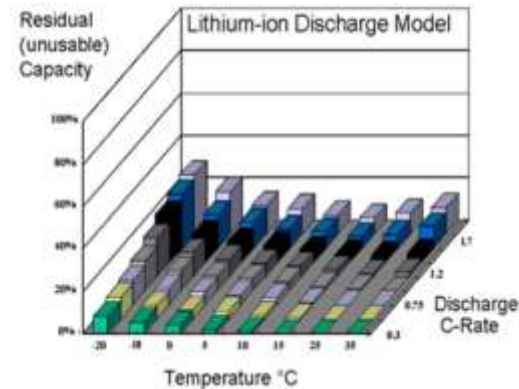
- Over Voltage
- Extra Heat
- Unstable Chemical Stage
- Thermal Runaway
- Low Temperature Charge

Key BMS Functions

V/I/T Measurement

Insure Safety

## Performance



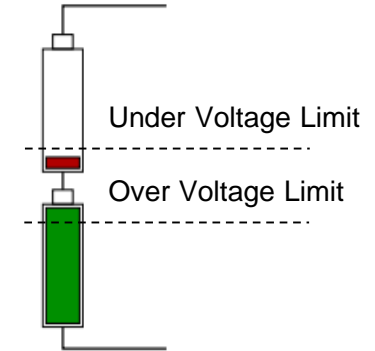
### Requirements:

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

V/I/T Measurement  
Coulomb Counting  
Internal Resistance Calculation

Monitor Available Energy  
Monitor Ageing

## Multi-Cell function



### Challenges:

- Up to hundreds of Cells
- Manufacture Mismatch
- Capacity Degradation
- Lifetime Degradation

Cell Balancing

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	± 3.9 mV
	Vpwr=9.6~61.6V, Vcell=1.5~4.3V -40~60°C	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

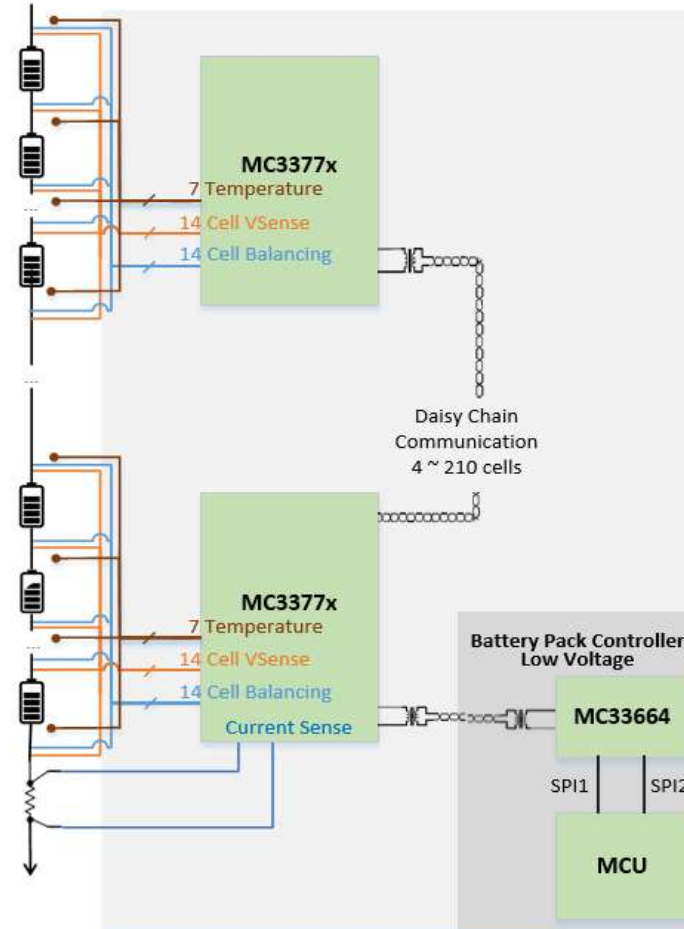
- Scalable SW & HW compatible BMS solution supporting 7 to 14[14] cells per **daisy chain**
- MC33771C (7 to 14 cells)
- Supporting Centralized, Distributed Daisy Chain, Distributed CAN

### 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**  $\pm 0.8$  mV total voltage measurement error (after soldering & 1000 hrs HTOL aging)
- $\pm 0.5\%$  total stack voltage measurement
- $\pm 0.5\%$  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

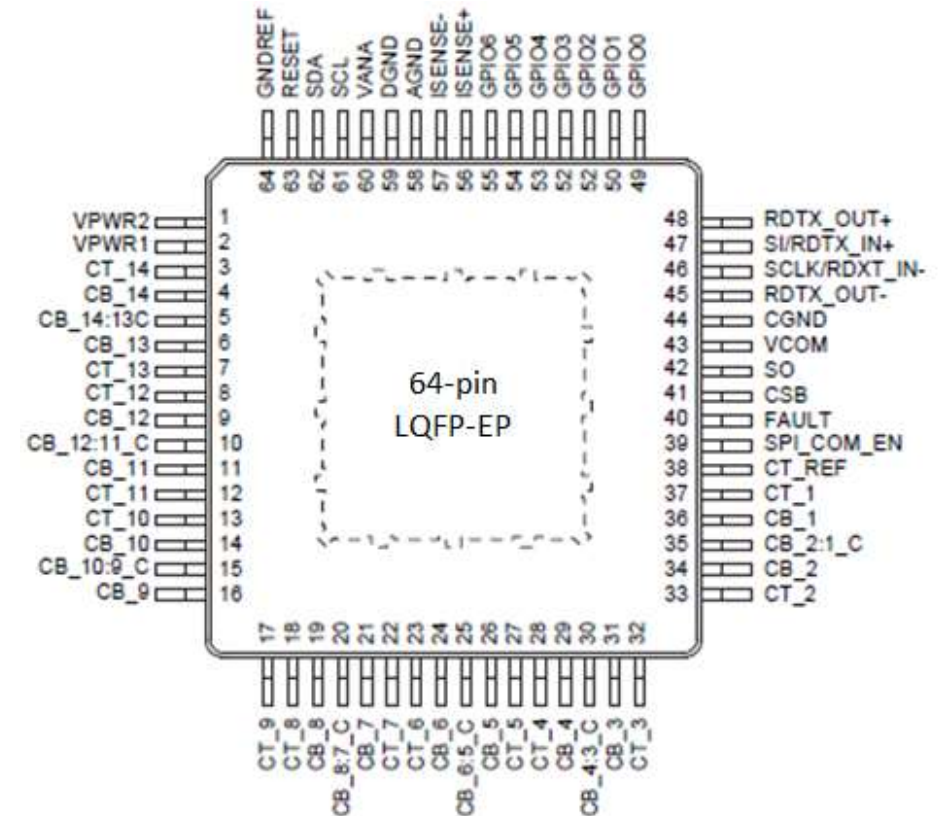
### Automotive robustness

- ESD, EMC; Hot Plug, AEC-Q 100
- Temp range:  $-40^{\circ}\text{C}$  to  $105^{\circ}\text{C}$
- Operational Low Power Mode

# MC33771C – 14 Cell Battery Cell Controller AFE

## Key features

- **High-performance integrated functions**
  - Operating voltage:  $9.6\text{V} \leq \text{VPWR} \leq 61.6\text{V}$  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  $\pm 0.5\%$  accuracy ( $\pm 1500\text{ A} / 100\ \mu\Omega$  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:  $-40^\circ\text{C}$  to  $105^\circ\text{C}$
  - Operational low-power mode
  - Hot plug capable
  - EMC/ESD robustness



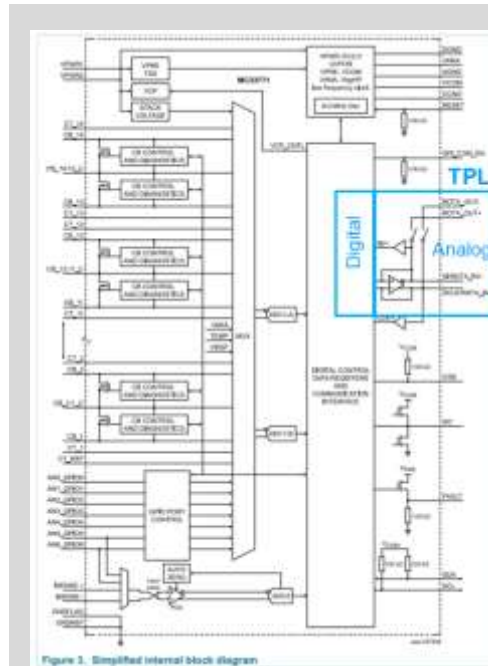
# MC33771C – Benefits of Integrated Averaging Functionality

- 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

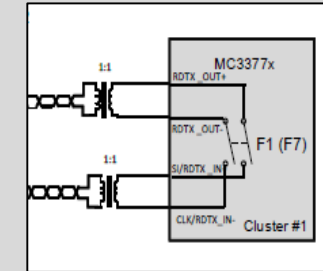
## MC33771C TPL2 improvements:

- 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



updated blocks on MC33771C compared to MC33771B  
Other blocks are identical btw MC33771B and MC33771C

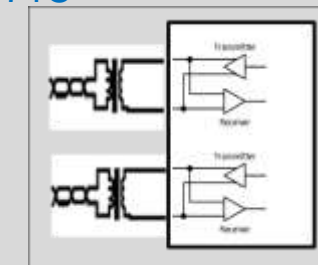
## MC33771B



- 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

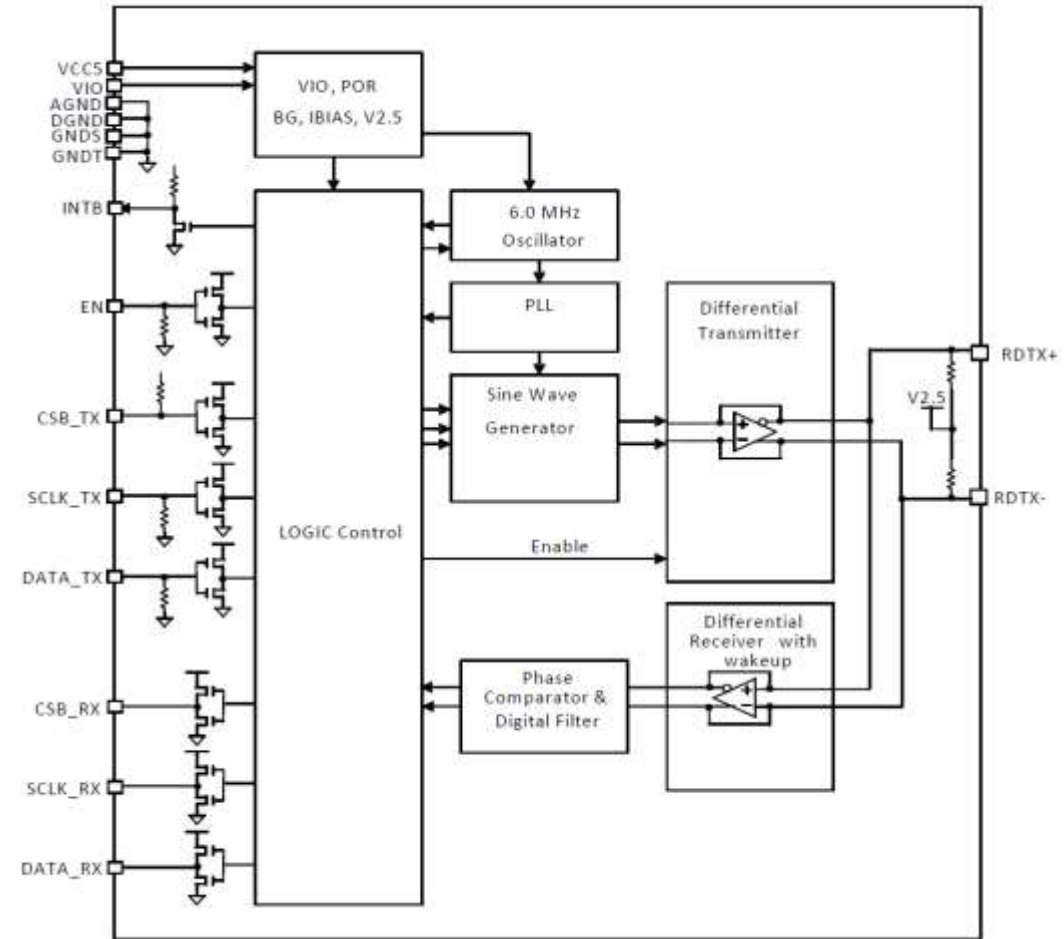
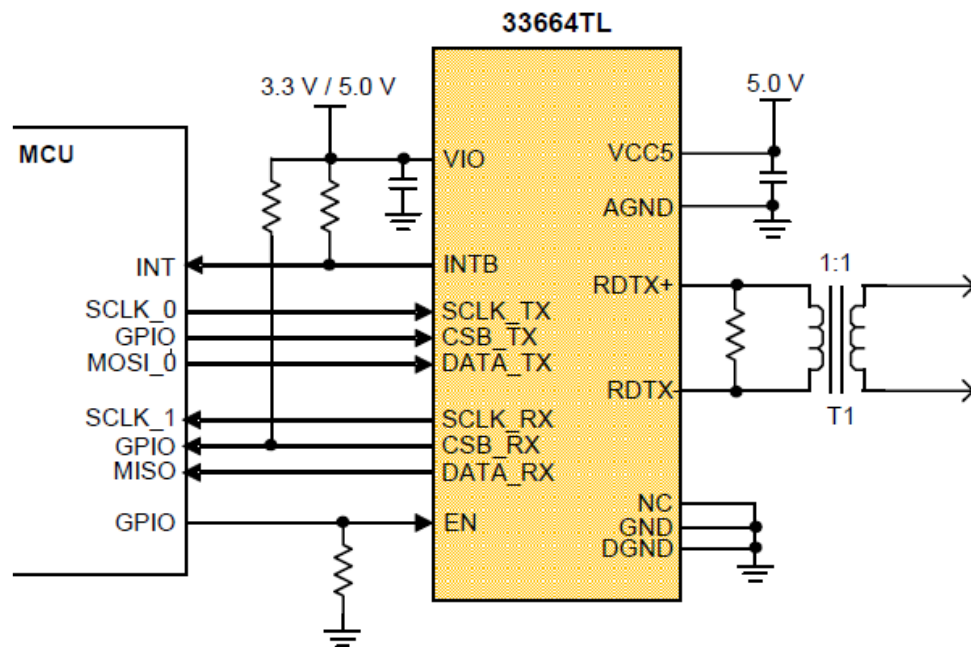


- TPL2 PHY bus is a series of lower power communication links
- Each node has a bidirectional repeater with transceivers for up and down communication
- TPL2 is compatible with the MC33664

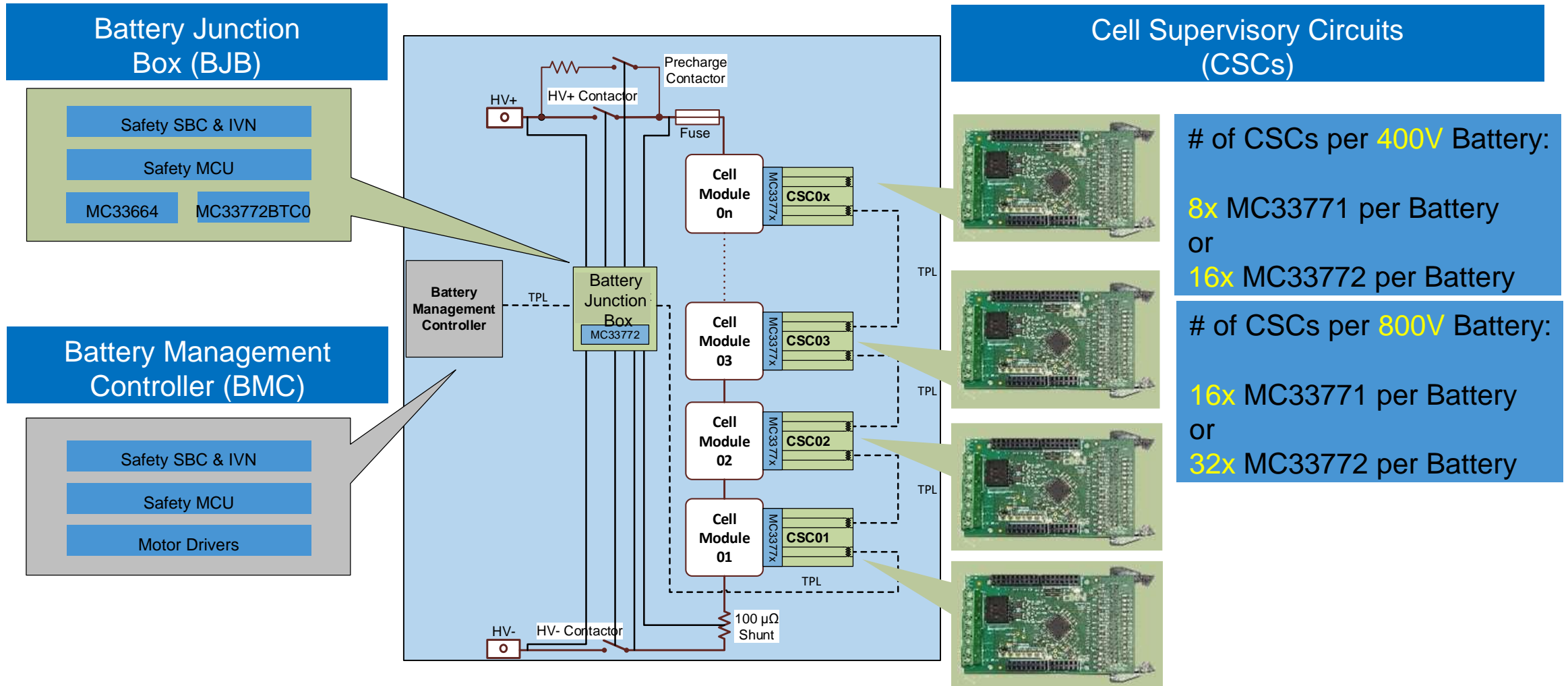
# MC33664ATL Transformer Physical Layer

## Features:

- 2 Mbps 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

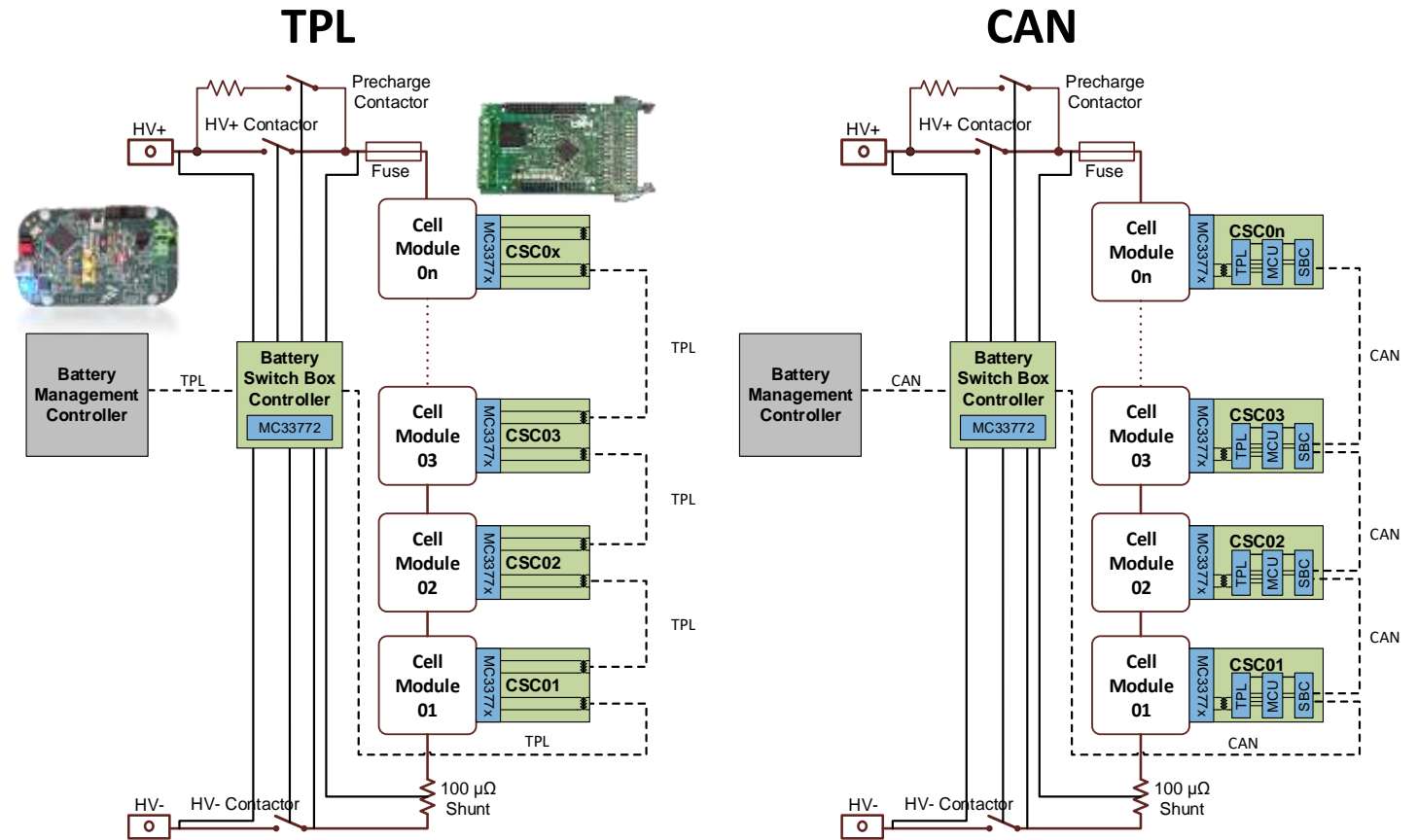


# High Voltage BMS Distributed Approach

## 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



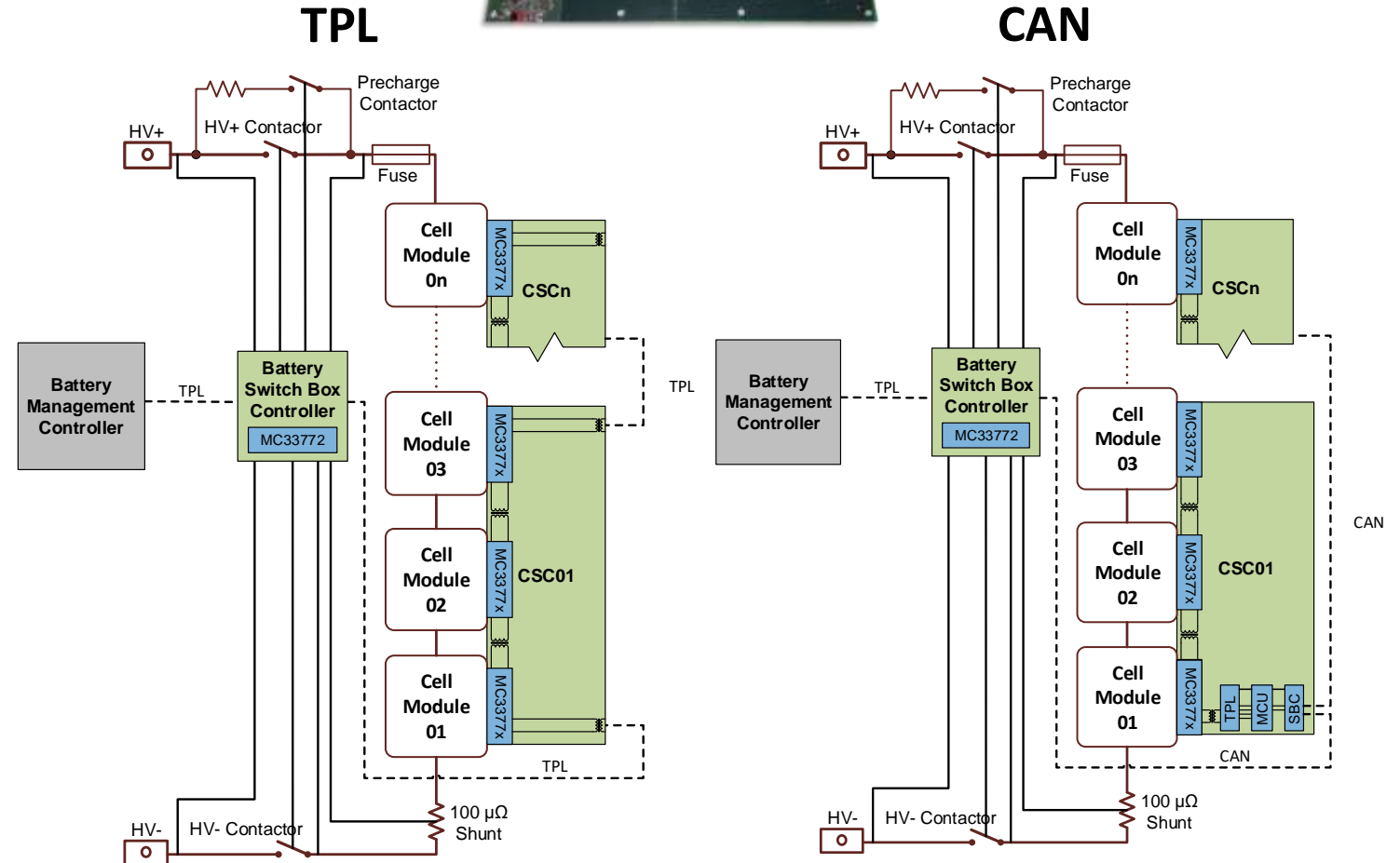
# High Voltage BMS Centralized Approach



## 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

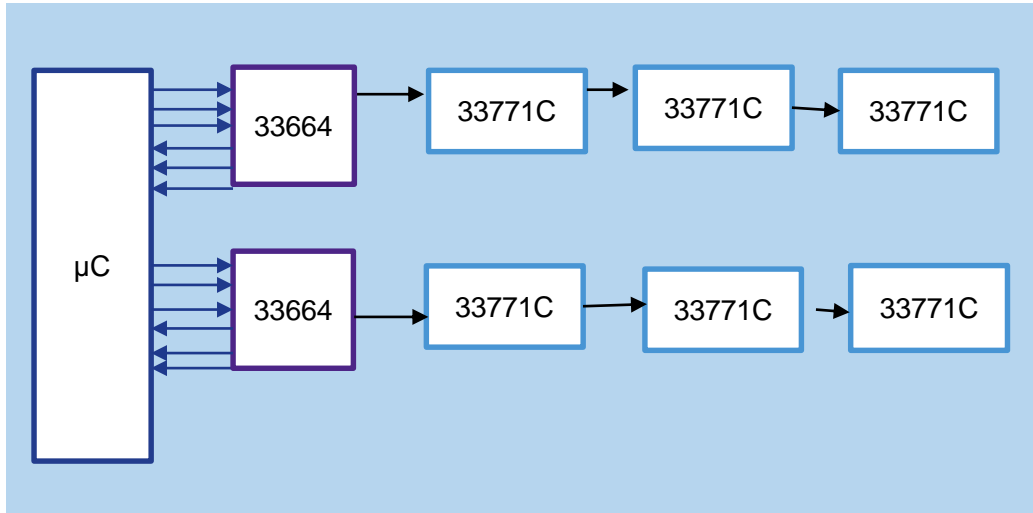
Production proven, reference design available



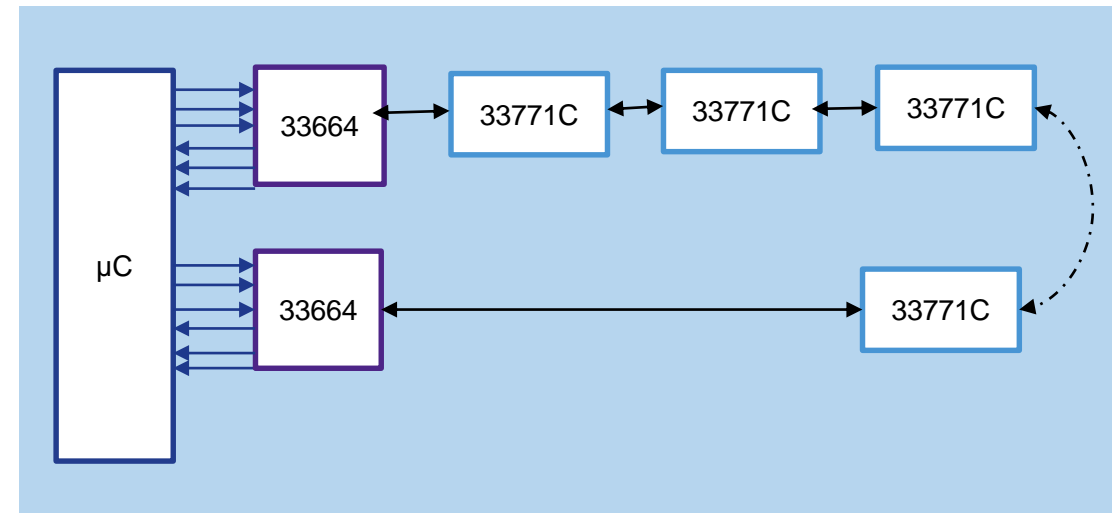


# MC33771C – Typical Use Cases

## Use case: Single-ended daisy chain



## Use case: Loopback daisy chain

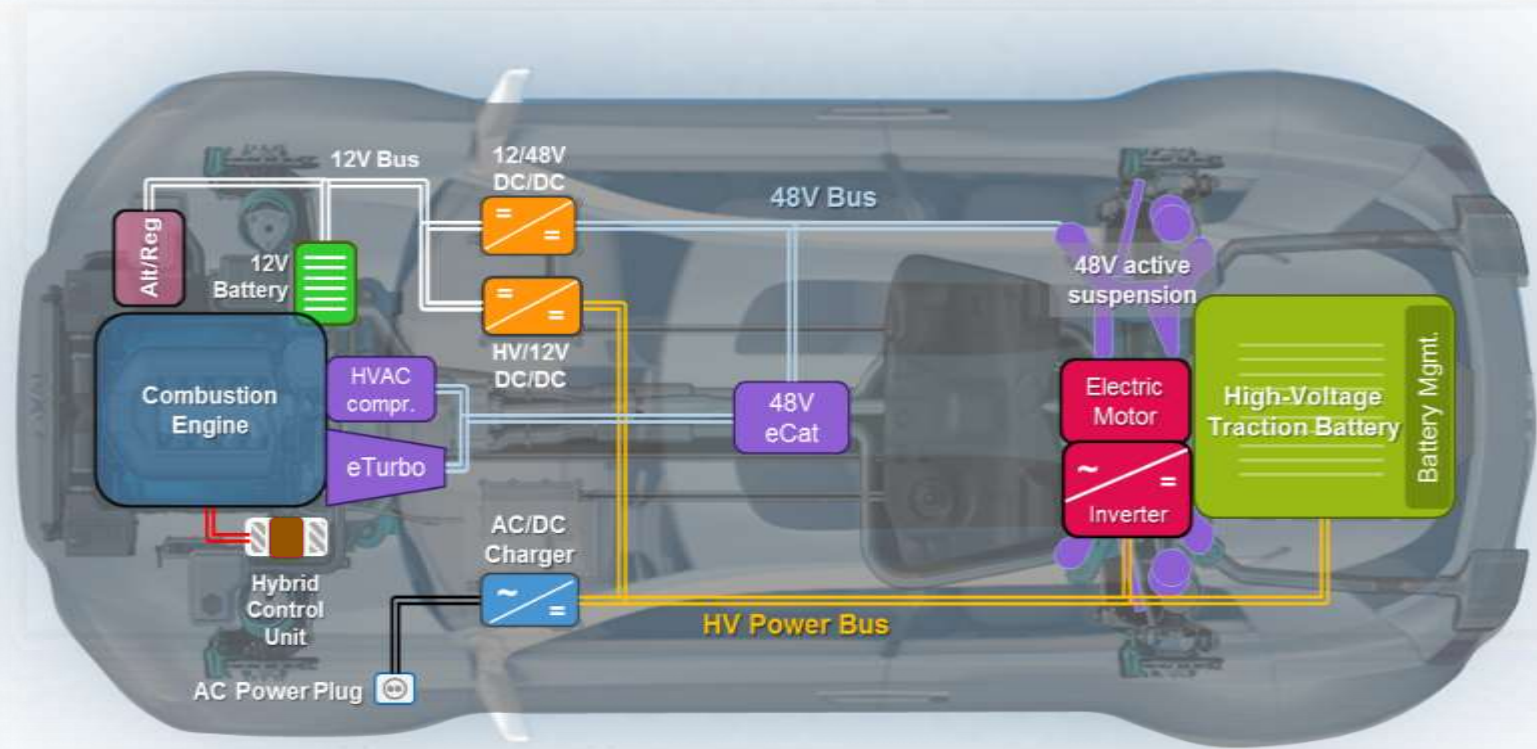


- The TPL drivers are connected physically at different SPI ports. Each TPL driver is capable of driving one single ended daisy chain.
- **In single ended daisy chain configuration:**  
The MCU can support several daisy chain through software by internally assigning each SPI port as one chain.
- **In 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**



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