Vehicle Electrification Solutions

Semiconductors for the next generation of electric vehicles
# Table of Contents

Introduction .............................................. 3
Why NXP for Electrification? ......................... 4
Battery Management Reference Platform Solution ...................................... 5
HEV/EV Power Inverter System Reference Platform ....................................... 6
Hybrid or Electric Vehicle Control Unit ............. 7
Development Platforms .................................. 8
Battery Management Systems ......................... 9
Motor Control: High Voltage Inverters ............... 10
Power Management: Functionally Safe System Basis Chip ................................. 11–12
Vehicle Dynamics and Safety MCUs .................. 13
Microcontroller Hybrid Control Unit .................. 14
Electrified General-Purpose Nodes ................. 15
Vehicle Network Protocols ............................... 16
NXP, Your Electrification Partner ...................... 17
SafeAssure Functional Safety Program .............. 18
NXP Product Summary ................................... 19
Available Resources ................................. 20
Introduction

Fueled by rising energy costs, environmental concerns, and the consequences of internal combustion engine (ICE) emissions, stricter vehicle emissions regulations are steadily driving and growing the demand for electrified vehicles (EVs).

Analysts predict a strong growth for all different electric vehicle platforms in the years ahead. By 2030, approximately 50% of all cars sold are predicted to contain powertrains containing electric propulsion. The market is highly dynamic, with a variety of new OEMs emerging focusing on purely electric vehicles. Legacy OEMs are restructuring their fleets to bridge the gap between the internal combustion engine (ICE) era and the future of electrified powertrains.

Regionally, China is a major driver due to local legislation and Europe is leading the way for 48 V technology-based mild hybrid architectures.

There are also health concerns regarding NOx emissions and particulate matter produced by diesel and high-performance petrol engines. Some urban areas have deemed these engines as unacceptable risks and have passed radical legislation to counter their effects. For example, London and Paris are banning certain vehicles from city centers, and several cities in China currently restrict vehicle usage during certain times of the calendar year.

With all these changes, it’s no surprise that traditional automakers and new market entrants alike are under increased pressure to roll out electric and hybrid vehicles quickly. At the same time, developers in this evolving ecosystem are searching for partners with the extensive automotive experience and product portfolios needed to build economical and efficient system solutions.
NXP is the number one global automotive semiconductor supplier with more than 30 years in the automotive space and an unrivaled product portfolio. NXP delivers the optimal performance, robust functional safety and power management that automakers and developers require for this next generation of electric and hybrid vehicles.

Our automotive electrification products feature:

- Scalable functional safety
- MCUs with associated power management ICs and system basis chips (SBCs)
- In-vehicle networking components for CAN, LIN, FlexRay™ and Ethernet
- Battery cell controller and battery management solutions
- Electric motor driver solutions, based on advanced functional safety IGBT gate drivers
- Enablement platforms, reference designs and evaluation boards
- Worldwide presence and support
- Automotive robustness

**Main Components of an EV Architecture**
Battery Management Reference Design with Functional Safety features up to ASIL C

The battery management reference design is an evaluation platform for 14 V Li-ion batteries, with cell monitoring, current sensing, passive cell balancing and battery breaker control. It is designed for systems with a high demand on reliability and safety in compliance with functional safety ISO 26262 ASIL C.

The reference design uses a two-board approach. The first is a functional safety system-on-module (Safety SoM) board with NXP’s S32K144 and KEA microcontrollers and FS4503C safety system basis chip. The second is a BMS application board based on the MC33772B battery cell controller IC.

Key features
- Integrated system diagnostic function up to ASIL C
- Under voltage
- Unintended relay close and open
- Crash detection

Reference design kit contents
- Evaluation board
- Schematic, layout and Gerber files
- Quick start guide
- Safety how-to guide for ASIL C
- Application software
- Complete safety documentation templates for certification

Supported devices
- FS4500: Grade 1 and Grade 0 safety power system basis chip with CAN flexible data transceiver
- FS6500: Grade 1 and Grade 0 safety power system basis chip with CAN flexible data transceiver
- S32K: 32-bit automotive general-purpose microcontrollers
- KEA: ultra-reliable KEA automotive microcontrollers (MCUs) based on Arm® Cortex®-M0+ Core
- MC33772: 6-Channel Li-ion battery cell controller IC
- Reference platform: NTBMS-FSNXP

Battery Management System Reference Platform Solution Block Diagrams
The xEV power inverter system solution is a small footprint 400 V ASIL-D 100 kW power inverter platform which includes:

- MPC5775E secure multi-core 32-bit lockstep MCU with software resolver
- FS6500 robust fail-silent SBC with operation from 36 V down to 2.7 V
- GD3100 isolated IGBT gate driver with < 2 μs overcurrent protection
- TJA1042 redundant CAN bus interface with low-power standby
- Enablement software with API and functional safety case

**Benefits**
- ASIL C/D compliancy with small, compact 9 IC system footprint
- Robust fail-silent SBC with operation from 36 V down to 2.7 V
- Secure multicore 32-bit lockstep MCU w/ eTPU & SW RDC
- Functional safety case and enablement software with API
- < 2μs iSense-compatible 2-level IGBT OC protection with soft shutdown

**Features**
- Efficiently drives 100 kW 3-phase motor from 400 V supply
- Integrated galvanic signal isolation in IGBT gate drivers
- Redundant CAN bus interface with low-power standby
- Primary and backup battery inputs with no negative gate driver supply
- Supported by S32DS SDK w/ MCAL drivers

**Hybrid & EV Powertrain Block Diagram**
The hybrid/electrical control unit is the brain of the powertrain control for hybrid or electric vehicles. It will control the power distribution, energy storage, engine and motor. As such, it is key for enhancing the efficiency of the xEV powertrain.

**Benefits**
- NXP S32S: leads the market for Automotive ASIL D compute performance
- Automotive virtual ECU development platform

**Features**
- Executes multiple applications, including hybrid electric control with advanced algorithms, all under Hypervisor
- Energy management
- Regenerative braking
- Battery states (charge, health, function) management
  - Advanced Algorithms (Torque Vectoring, A-ECMS, etc.)
  - Inter-domain communication, acts on ADAS domain messages (GLOSA)

**Supported devices**
- FS6600: functionally safe multi-output power supply integrated circuit
- S32S24: The S32S24 is an Arm-R52 based microcontroller for automotive vehicle dynamics, domain control and safety co-processor applications. It offers support for the highest levels of automotive safety and with more than 7x the performance of previous generation devices, provides the performance headroom to manage the transition to advanced HEV/EV and autonomous vehicles applications.

**Reference platform part number:**
S32PDEVL-KITC, S32SDEVPL-KITP

---

HEV Powertrain Control Block Diagram
In addition to our development platforms, evaluation boards and tools are available to accelerate your electrification designs.

<table>
<thead>
<tr>
<th>EVB Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATT-14EMULATOR</td>
<td>14-cell battery pack to supply MC33771 EVBs — emulates a multi-cell battery pack</td>
</tr>
<tr>
<td>BATT-6EMULATOR</td>
<td>6-cell battery pack to supply MC33772 EVBs — emulates a multi-cell battery pack</td>
</tr>
<tr>
<td>FRDM33771BTPLEVB</td>
<td>MC33771B, a 14-channel battery cell controller for automotive and industrial Li-ion battery applications; supports cell voltage measurement, passive cell balancing, GPIOs, external EEPROM, and fault detection pin report</td>
</tr>
<tr>
<td>FRDM33771BSPIEVB</td>
<td>MC33771, a 14-channel battery cell controller for automotive and industrial Li-ion battery applications; supports cell voltage measurement, passive cell balancing, GPIOs, external EEPROM, and fault detection pin report</td>
</tr>
<tr>
<td>FRDM33664BEVB</td>
<td>Evaluation board for MC33664ATL isolated network high-speed transceiver to interface a microcontroller with a high-speed isolated communication network</td>
</tr>
<tr>
<td>FRDMGD3100HBIEMVM</td>
<td>Half-bridge evaluation kit populated with two MC33GD3100 single channel IGBT gate drive devices on a half-bridge evaluation board</td>
</tr>
<tr>
<td>FRDM-GD3100EVB</td>
<td>Half-bridge evaluation board for GD3100</td>
</tr>
<tr>
<td>DEVKIT-MPC5744P</td>
<td>Offers dual e200z4 lockstep cores, motor control, safety and communication interfaces to facilitate a complete safety/chassis solution for motor control applications</td>
</tr>
<tr>
<td>S32PDEVL-KITC</td>
<td>GreenBox, advanced performance, peripherals and multicore Arm® environment for HEV and EV development with Peripheral Board for HEV and ICE applications</td>
</tr>
<tr>
<td>S32SDEVPL-KITP</td>
<td>GreenBox, advanced performance, peripherals and multicore Arm environment for HEV and EV development with peripheral board for motor control and BMS applications</td>
</tr>
<tr>
<td>MTRCKTDPS5643L</td>
<td>Dual 3-phase PMSM development kit with MPC5643L microcontroller ideal for applications requiring 2 PMSM motors, such as active suspension or electric powertrain</td>
</tr>
<tr>
<td>MPC5775E-416DS adapter</td>
<td>MPC5775E MCU targets industrial and automotive battery management systems (BMS) and the MPC5775E targets HEV/EV inverter control systems that require advanced performance, eTPU-based timer system and ISO26262/IEC61508 functional safety support up to ASIL D.</td>
</tr>
<tr>
<td>MPC5775E-516DS adapter</td>
<td>For automotive engine control applications that require advanced performance, timing systems and functional safety capabilities</td>
</tr>
</tbody>
</table>

**GreenBox Platform**
Battery Management Systems

MC33771/2B Battery Cell Controller Solution

Battery topology flexibility
• Scalable software- and hardware-compatible BMS solution supporting 3 to 210 cells per daisy chain
• MC33771B (7 to 14 cells) and 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 up to 300 mA per channel (300 mA per channel)
• Integrated Power Supply

Fast and robust communication with DAQ
• 4.0 Mbit/s SPI or isolated 2.0 Mbit/s differential communication with transformer
• 3.6 ~ 4.1ms for sending command and read back 96 cell 16-bit voltage data

Lifetime guaranteed high accuracy
• ± 0.8 mV cell voltage measurement error
• ± 0.5% total stack voltage measurement
• ± 0.5% integrated current sensor gain error

Diagnosis and functional safety supporting ISO26262 w/ single chip
• Designed to support ISO 26262 up to ASIL D safety system
• Sleep mode OV/UV and temperature monitor
• Detection of internal and external faults, i.e., open lines, shorts, and leakages
• Integrated balancing diagnostics

Automotive robustness
• ESD, EMC; Hot Plug, AEC-Q 100
• Temp range: -40 °C to 105 °C
• Operational low power mode

[Diagram of MC33771 Battery Cell Controller Solution Block Diagram]
GD3100 IGBT GDIC With Integrated HV Isolation

The GD3100 is an advanced single-channel gate driver for high-voltage power IGBTs. Integrated high-voltage galvanic isolation and low on-resistance drive transistors provide high charging and discharging current, low dynamic saturation voltage, and rail-to-rail gate voltage control. New current sense features help minimize short circuit stress and reduce IGBT die size.

Features and benefits
- High level of integration and flexibility for any IGBT module:
  - Galvanic signal isolation
  - 10 A on/off power stage
  - Active Miller clamp
  - 3.3 or 5.0 V I/O
  - Compatible with 200 to 1700 V IGBT’s
  - SPI for programmability and diagnostics
  - Reduces BOM costs and PCB size
- Fast overcurrent or short-circuit protection
  - Both i-Sense or DESAT sense available
  - Two-level turn-off
  - Soft shutdown
- Compliant with ISO26262 ASIL C/D functional safety requirements
  - VGE monitoring verify communication between PWM input and gate output
  - Fail-safe pins allow redundant gate control
  - Secure SPI settings with cycle redundancy check (CRC)
  - Enforced deadtime protection
  - Built-in self-test (BIST) for analog and digital circuits

GD3100 Advanced IGBT Gate Driver Block Diagram
FS45 and FS65 Grade 1 and Grade 0 safety power system basis chip

The FS4500 and FS6500 are system basis chips (SBCs) that provide power to MCUs and optimize energy consumption through DC-DC switching regulators, linear regulators, and ultra-low-power saving modes.

Features and benefits

• Physical and electrical independence for ASIL D
• Power management monitoring unit (UV/OV)
• Analog and digital built-in self-test to minimize latent faults
• Own reference and supply to reduce common cause failure
• $V_{\text{CORE}}$ external monitoring
• FCCU: fault collection control unit
• Monitor dual-core lock-step MCUs
• Configurable RSTb activation provides more system availability
• Redundant system fail-safe enabler
• Second fail-safe pin to assert safety path with configurable delay after failure

FS6500 Functionally Safe System Basis Chip Block Diagram
The FS6600 is an automotive, functionally safe multi-output power supply integrated circuit. It’s focused on powertrain, safety and chassis applications and is the primary companion chip of the S32S2 microcontroller.

### Features
- 60 V DC maximum input voltage
- Multiple SMPS and LDO to supply S32S2 microcontroller and more
- Standby OFF mode with very low sleep current (10 uA)
- 32-bit SPI interface with CRC
- FIT for ASIL D with independent safety monitoring unit

![FS6600 Block Diagram](image-url)
MPC5744P, MPC5777C, MPC5775B and MPC5775E for Battery Management Systems and Inverter Applications

These microcontrollers target automotive and industrial battery management and inverter applications that require advanced performance, security and ASIL D support.

Features and benefits

- High-performance cores with advanced programmable motor control times and analog modules
- Functional Safety ISO 26262 targeting ASIL D with lockstep cores, ECC, temperature and voltage sensors, clock monitoring, fault collection unit
- Hardware module (CSE) with encryption and decryption, secure boot and key storage; pre-programmed firmware simplifies production
- Communication peripherals via CAN FD, Ethernet, SPI, LIN
- Software enablement with AUTOSAR MCAL, S32 Design Studio
The hybrid control unit (HCU) is a core control component for hybrid and electric vehicles. It uses input signals to calculate and manage output parameters such as engine power or motor torque.

**S32S24 Safety Microcontroller**

The S32S24 is an Arm-R52 based microcontroller for automotive vehicle dynamics, domain control and safety coprocessor applications. It offers support for the highest levels of automotive safety and with more than seven times the performance of previous generation devices, provides the performance headroom to manage the transition to advanced HEV/EV and autonomous vehicles applications.

**Features and benefits**

- 4 x Arm-R52 cores in lockstep (8 cores total), operating at 800 MHz
- Large integrated flash memory (up to 64 MB)
- On-the-Fly, over-the-air update capability with zero processor downtime
- Advanced safety functionality and fault recovery to support ASIL D applications
- Hardware security engine supporting public and private key encryption
- AEC-Q100 Grade 1 device with support from -40 to 150°C (junction)
The Scalable S32K1 Family: Accelerated Design Time, Low-Power Performance

- Performance and integration with future-proof designs
- Automotive-grade software with minimized complexity
- Broad portfolio allows maximized reuse

S32K functional safety software

- Cortex-M Core Self-Test Library: Structural Core Self-Test Library (SCST) is a safety measure against permanent faults in the cores
- Developed for detecting hardware permanent faults in a core by means of executing machine op-codes with fixed set of operands and comparing their execution results
- This library is considered as Safety Element out of Context and was developed according to ASIL B
- SCST library provides tests to achieve the claimed diagnostic coverage (analytically estimated)

Hardware platform

- Low-cost development board compatible to Arduino™ shields
- Onboard debugger and system basis chip

Runtime software

- Automotive-grade NXP Software Development Kit (SDK)
- NXP middleware e.g., Core Self Test, LIN stack
- AUTOSAR 4.0 and 4.2 MCAL
- FreeRTOS
- Bootloader

Software development tools

- IAR, GHS and GNU toolchains
- Full-featured, no-cost development platform (S32 DS)
- FreeMASTER

Application specific

- Motor control
- Touch sensing
- Secure communication
- Wireless charging
- Near field communication

---

S32K General-Purpose Microcontroller Common Features

<table>
<thead>
<tr>
<th>S32K11x MCUs</th>
<th>Common Features</th>
<th>S32K14x MCUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>S32K116 MCU</td>
<td>AEC-Q100</td>
<td>S32K142 MCU</td>
</tr>
<tr>
<td>S32K118 MCU</td>
<td></td>
<td>S32K144 MCU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S32K146 MCU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S32K148 MCU</td>
</tr>
<tr>
<td>Arm®Cortex®-M0+ core @ 48 MHz</td>
<td></td>
<td>Arm Cortex-M4F core @ 112 MHz</td>
</tr>
<tr>
<td>128 KB Flash</td>
<td></td>
<td>256 KB Flash</td>
</tr>
<tr>
<td>16 KB SRAM</td>
<td></td>
<td>256 KB Flash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 KB SRAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 KB SRAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>128 KB SRAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>256 KB SRAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>up to 42 I/Os</td>
<td></td>
<td>up to 128 I/Os</td>
</tr>
<tr>
<td>up to 58 I/Os</td>
<td></td>
<td>up to 156 I/Os</td>
</tr>
<tr>
<td>4-ch. eDMA</td>
<td></td>
<td>16-ch. eDMA</td>
</tr>
<tr>
<td>1 x FlexCAN with 1x FD</td>
<td></td>
<td>2 x FlexCAN with 1x FD</td>
</tr>
<tr>
<td>1 x 13-ch. 12-bit ADC</td>
<td></td>
<td>3 x FlexCAN with 1x FD</td>
</tr>
<tr>
<td>QFN-32</td>
<td></td>
<td>3 x FlexCAN with 2x FD</td>
</tr>
<tr>
<td>LQFP-48</td>
<td></td>
<td>3 x FlexCAN with 3x FD</td>
</tr>
<tr>
<td>LQFP-64</td>
<td></td>
<td>2 x 16-ch. 12-bit ADC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 24-ch. 12-bit ADC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 32-ch. 12-bit ADC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LQFP-64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LQFP-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAPBGA-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LQFP-176</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LQFP-144</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENET</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QuadSPI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ETM Trace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAI</td>
</tr>
</tbody>
</table>

Electrified General-Purpose Nodes
Vehicle Network Protocols

As vehicles become more connected, the need for reliable and secure communication within the car is clear. New isolated CAN for electric vehicles, hybrids and 48 V networks use unique wake-up functions to maximize efficiency and bridge voltage domains. In a distributed car network, central ECUs need to exchange data or configuration with each other within a critical time frame. Automotive Ethernet can be used to build a time-sensitive network (TSN) that connects microcontrollers directly in an Ethernet backbone.

For further information on the complete in-vehicle networking portfolio, please visit www.nxp.com/ivn
At NXP, we're leveraging our commitment to quality and security, our broad product portfolio and our application leadership in automotive power control to provide system solutions that deliver the optimal performance, functional safety and power management required for the next generation of electric and hybrid vehicles. When you explore NXP, you’ll find that we’re more than the products we create — we’re a dedicated partner committed to automakers and developers in their quest to accelerate EV system development and meet the ever-growing demand for vehicle electrification.
SafeAssure Functional Safety Program

The NXP SafeAssure program does more than align our development process to ISO 26262 across our business lines. It affirms our corporate commitment to supporting functional safety through safety-conscious culture, discipline and collaboration.

The SafeAssure program:
- Simplifies the process of system compliance, with solutions designed to address the requirements of automotive and industrial functional safety standards
- Reduces the time and complexity required to develop safety systems that comply with ISO 26262 and IEC 61508 standards
- Supports the most stringent safety integrity levels (SILs), enabling designers to build with confidence
- Adheres to a zero-defect methodology from design to manufacturing and helps ensure that our products meet the stringent demands of safety applications

NXP SafeAssure Products

Products within our SafeAssure program are delivered with quality certificates, safety manuals, reference manuals and data sheets following the ISO 26262 development process. In addition, further information such as safety plans, ISO 26262 safety cases, safety analyses and reports are available under NDA.

NXP’s Safety Strategy Evolution Visual
# NXP Product Summary

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC33771/2B</td>
<td>The MC33771/2B are battery cell controllers designed to address safety risks related to Li-ion batteries by accurately controlling critical Li-ion cell characteristics (voltages, temperatures, current) and by providing embedded balancing functions along with extensive system diagnostics.</td>
</tr>
<tr>
<td>GD3100</td>
<td>The GD3100 is an advanced single-channel gate driver for IGBTs. Integrated Galvanic isolation and low on-resistance drive transistors provide high charging and discharging current, low dynamic saturation voltage and rail-to-rail gate voltage control.</td>
</tr>
<tr>
<td>FS45/FS65</td>
<td>The FS4500 and FS6500 are system basis chips (SBCs) that provide power to MCUs and optimize energy consumption through DC-DC switching regulators, linear regulators and ultra-low-power saving modes.</td>
</tr>
<tr>
<td>FS6600</td>
<td>The FS6600 is an automotive, functionally safe multi-output power supply integrated circuit. It includes a multiple switch mode, linear voltage regulators and enhanced safety features with fail-safe outputs.</td>
</tr>
<tr>
<td>MPC5744P, MPC5777C, MPC5775B/E</td>
<td>The microcontrollers target automotive and industrial battery management and inverter applications that require advanced performance, security and ASIL D support.</td>
</tr>
<tr>
<td>S32S24</td>
<td>The S32S24 is an Arm®-R52 based microcontroller for automotive vehicle dynamics, domain control and safety coprocessor applications. It offers support for the highest levels of automotive safety and with more than seven times the performance of previous generation devices, provides the performance headroom to manage the transition to advanced HEV/EV and autonomous vehicles applications.</td>
</tr>
<tr>
<td>S32K1</td>
<td>S32K is a scalable family of AEC-Q100 qualified 32-bit Arm Cortex®-M4F and Cortex-M0+ based MCUs targeted for general-purpose automotive and high-reliability industrial applications.</td>
</tr>
<tr>
<td>IVN</td>
<td>IVN is a broad NXP portfolio of In-Vehicle Networking solutions for LIN, CAN, FlexRay™ and Ethernet.</td>
</tr>
</tbody>
</table>
Available Resources

For more information, please visit
nxp.com/electrification