11 Experts Discuss Advanced Motor Control for Modern Electric Vehicles

Sponsored by

NXP | MOUSER ELECTRONICS

Mighty Guides

Table of Contents

Mighty Guides

Meet Our Experts

The electrification of systems, including industrial and automotive, relies heavily on advances and innovation in motor control technology. We interviewed eleven experts on the current state of motor control in modern electric vehicles, the industry's challenges, and the unique solutions empowering the future of transportation and automation.

We hope you enjoy their insights!

David Rogelberg

David Rogelberg
Publisher,
Mighty Guides Inc.
david@mightyguides.com
(516) 234 2969

in

Mighty Guides

Marius-Lucian Andrei
Technical Lead,
Model-Based Design Team,
NXP Semiconductors

Pedro Chavez Jr.
Principal Electrical
Engineering Manager,
FutureMotiv

Jérôme Dietsch
Senior Principal Functional Safety
Architect, Electrification Systems,
NXP Semiconductors

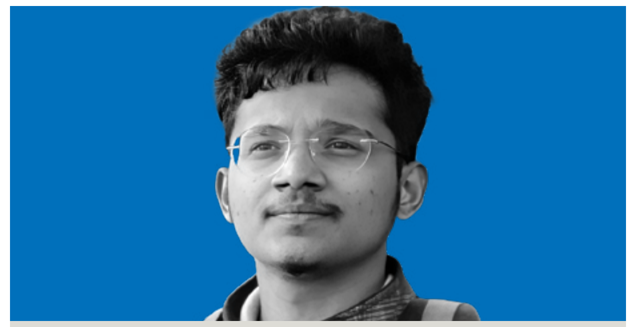
Lukas Gorel
Motor Control Application Engineer,
NXP Semiconductors

Manoj Kumar
Senior Engineer,
Valeo

Vincent Lagardelle
Automotive Electrification Systems
Marketing Manager,
NXP Semiconductors

Marek Mušák
Motor Control Application Engineer,
NXP Semiconductors

Venkatesh Naidu
Senior Hardware Engineer,
Bosch Global Software Technologies



Saikrishna Rama
Motor Calibration Engineer,
Stellantis

Ufuk Saral
Team Leader, Engine, HVAC &
Electrical Validation,
TürkTraktör

Marek Stulrajter
Solution Engineering Team Manager,
NXP Semiconductors

Introduction

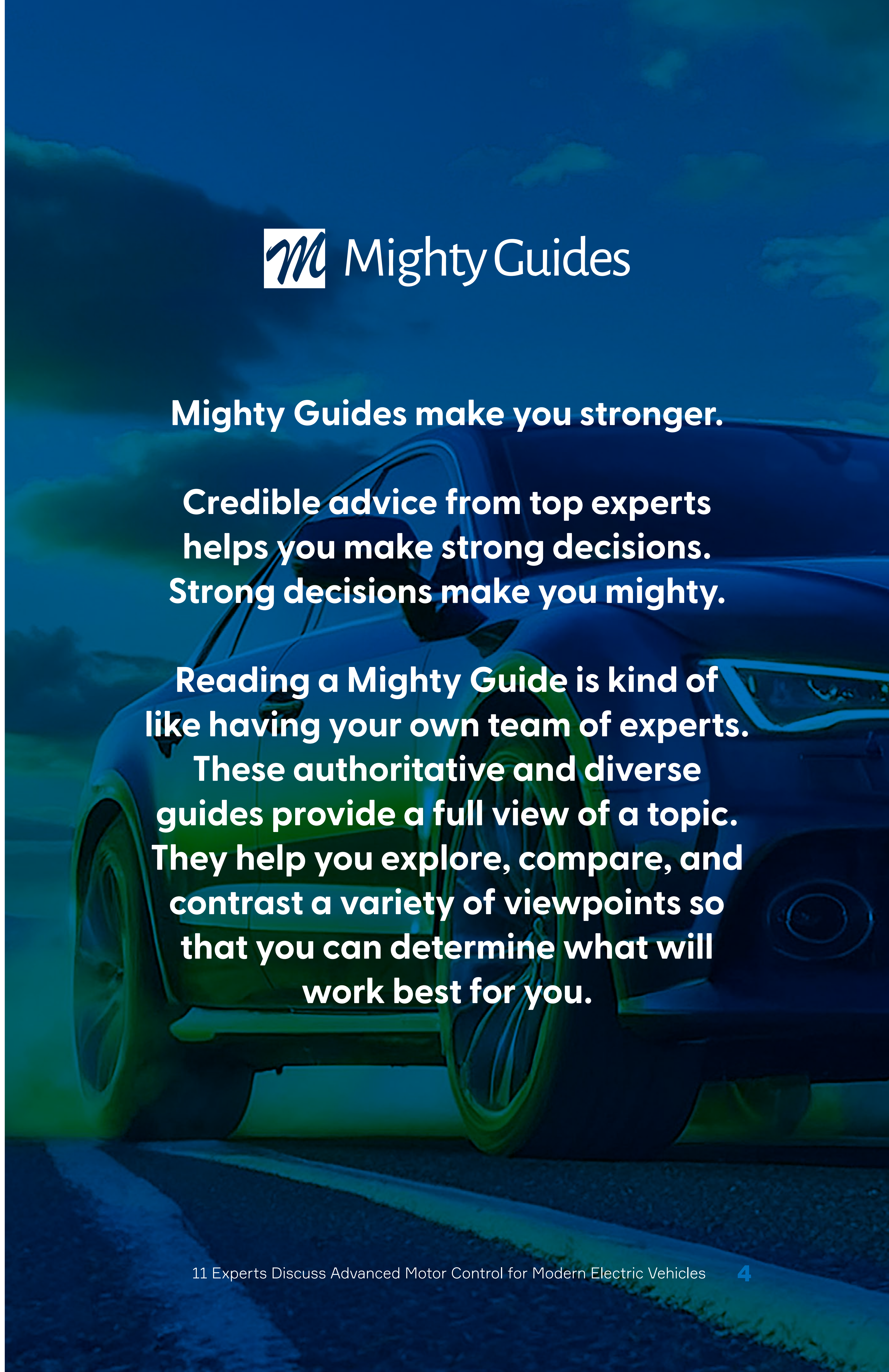
The modern transition from internal combustion engine vehicles to electric vehicles (EVs) represents one of the most significant shifts in the automotive industry's history. This shift is driven by the increasingly apparent effects of climate change and the global demand for a decrease in carbon emissions for a more sustainable transportation sector.

While EVs are already gaining widespread adoption by consumers, design engineers still face major technological challenges. Particularly, the switch to electric motors has placed major importance on motor control technologies.

In the context of EVs, motor control can be defined as the process of regulating the electric motor's speed, torque, and direction to optimize performance, enhance energy efficiency, and ensure smooth operation across different driving conditions. Motor control impacts everything from EV efficiency and range to functional safety and thermal management.

Achieving optimal motor control requires a combination of high-performance semiconductor devices and sophisticated control algorithms. Aware of this growing need, NXP Semiconductors is leveraging its expertise to build out a portfolio of motor control products and solutions for EV designers.

In this eBook, we will discuss the role of motor control systems in modern EVs, the impact of motor control on various vehicle aspects, and how NXP Semiconductors helps its customers design advanced motor control systems that ensure efficiency and safety.



Foreword

By **Manuel Alves Mendes**, SVP & GM, Product Line Automotive Microcontrollers, Business Line Automotive Embedded Systems, NXP Semiconductors

There's no denying that the electrification of vehicles is transforming the automotive industry and the future of transportation as we know it. Paramount to the success of the shift to electric vehicles (EVs) is the development of advanced motor control systems.

Engineers and designers developing these systems face significant challenges in bringing the energy efficient EVs to market, as motor control impacts nearly every aspect of a vehicle. NXP Semiconductors is helping customers navigate today's rapidly changing technical landscape and deliver high-performance solutions needed to drive the industry's future.

Using NXP's processor portfolio, tools and software, EV designers can deliver safe, energy efficient, and cost-effective motor control—innovations considered unachievable just a decade ago. To help automotive manufacturers unlock their fullest potential, we've assembled the most authoritative voices in motor control engineering to share their insights into key considerations to make when designing EVs. In this eBook, they share their unique perspectives from a broad range of experience in engineering smart actuators, body electronics, and traction inverter systems all for the purpose of attaining the highest degrees of efficiency and functional safety.

Mighty Guides

NXP

NXP Semiconductors N.V. (NASDAQ: NXPI) is the trusted partner for innovative solutions in the automotive, industrial & IoT, mobile, and communications infrastructure markets. NXP's "Brighter Together" approach combines leading-edge technology with pioneering people to develop system solutions that make the connected world better, safer, and more secure. The company has operations in more than 30 countries and posted revenue of $13.28 billion in 2023. Find out more at www.nxp.com.

MOUSER ELECTRONICS

Mouser Electronics is an authorized semiconductor and electronic component distributor focused on New Product Introductions from its leading manufacturer partners. Serving the global electronic design engineer and buyer community, the global distributor's website, www.mouser.com, is available in multiple languages and currencies and features more than 6.8 million products from over 1,200 manufacturer brands. Mouser offers 28 support locations worldwide to provide best-in-class customer service in local language, currency and time zone. The distributor ships to over 650,000 customers in 223 countries/territories from its 1 million-square-foot, state-of-the-art distribution facilities in the Dallas, Texas, metro area. For more information, visit www.mouser.com.

Chapter 1

ADVANCED ACTUATION SYSTEMS IN THE VEHICLE CHASSIS

One of the major advancements of the modern EV is advanced actuation systems, or smart actuators. Smart actuators are integrated systems that combine sensors, controllers, and actuators to perform precise and efficient control tasks. Today, the design of smart actuators is rapidly evolving as vehicles increase range and adopt trends like autonomous driving and additional actuators.

At the heart of these smart actuators is the microcontroller (MCU), which functions as the brains of the operation, handling mission-critical tasks such as real-time motor control, data processing, and communication management. In a smart actuator, the MCU and sensors work together to form a feedback loop that continuously monitors key parameters such as current, speed, and voltage applied to the motor phases. Sensors gather this information and send it back to the MCU. These real-time data allow the MCU to evaluate motor performance and make necessary adjustments to maintain optimal operation.

In this context, one of the most important computational specifications of an MCU is its sampling frequency. Higher sampling frequencies allow the MCU to capture more data points per second, leading to finer resolution and more precise control. In practical terms, by sampling current and speed at high frequencies, the MCU can immediately detect deviations from the desired

"By orchestrating the intricate movements of electric motors, motor control systems elevate comfort levels, enhance controllability, and ultimately instill a greater sense of confidence behind the wheel."

Manoj Kumar

Senior Engineer, Valeo

"A model-based design approach can help engineers identify performance changes and classify the severity of issues. Designers can then adjust the control structure to prevent failure, underperformance, or inefficiencies in the motor's operation."

Marius-Lucian Andrei

Technical Lead, Model-Based Design Team,
NXP Semiconductors

performance. For instance, if a sudden load change occurs, the MCU can rapidly adjust the voltage applied to the motor phases to compensate, ensuring stable and efficient operation.

Implementing such control systems in smart actuators presents several design challenges for engineers. For example, a tradeoff exists between low power consumption and precision control. High-precision control requires increased sampling and switching frequencies, which, in turn, demand more power. This behavior creates a balancing act where engineers must optimize the system to achieve the necessary precision without excessively increasing power consumption.

Additionally, the real-world limitations of switching devices, such as metal-oxide-semiconductor field-effect transistors (MOSFETs), further complicate this balance. These components are designed for specific frequency ranges; pushing them beyond these limits can lead to inefficiencies and potential failures. For these reasons, the industry is starting to adopt new materials like gallium nitride (GaN) and silicon carbide (SiC), which can offer higher efficiency and switching speeds but with the tradeoff of requiring new design approaches and validation processes to be effectively utilized.

Designing effective actuation systems and reducing long iteration cycles requires various tools and methodologies, including a model-based testing approach known as the Model-in-the-Loop (MIL) phase. In the MIL phase, engineers validate that the algorithm behaves as expected on controlling a virtual motor.

The design process normally starts at the model level, at which engineers extensively use tools like MATLAB and Simulink to simulate and model motor control systems. Such platforms allow engineers to design control algorithms and test them in a virtual environment before deploying them on hardware. Engineers can optimize control strategies by simulating various scenarios and ensuring that the system meets performance requirements under different conditions. Compared to hardware-based testing, MIL testing helps identify potential issues early in the design phase, thereby reducing the risk of later costly revisions.

Next, the Software-in-the-Loop (SIL) phase validates that the model can be translated into C code and that the compiled source code delivers the same result. The SIL phase is followed by the Processor-in-the-Loop (PIL) phase, where the algorithm's C code is cross-compiled and deployed to the MCU, where the algorithm's accuracy and performance are tested.

Following the PIL phase, development moves into the Hardware-in-the-Loop (HIL) phase, in which control algorithms are deployed on actual hardware and tested under real-world conditions. The HIL phase allows engineers to verify that the control algorithms work as

Smart actuators offer faster, precise, and efficient motor control while ensuring safety by meeting Automotive Safety Integrity Levels (ASIL). For example, ASIL D represents the maximum safety standards for vehicle applications such as braking."

Venkatesh Naidu

Senior Hardware Engineer, Bosch Global Software Technologies

"Smart actuators are structures developed to control and optimize vehicle dynamics in modern vehicles. The fundamental design components of these structures include mechanisms, sensor groups, electronic circuits, and communication interfaces. They are particularly used in applications prioritizing comfort and safety, such as collision avoidance systems."

Ufuk Saral

Team Leader, Engine, HVAC & Electrical Validation, TürkTraktör

intended when integrated with physical components. By simulating real-world operating conditions, HIL testing validates that the system can handle various scenarios and maintain stability and efficiency.

NXP helps its customers develop performant, efficient, and reliable smart actuation systems by

- Offering a range of high-frequency MCUs designed specifically for automotive applications
- Providing motor control libraries, such as the Automotive Math and Motor Control Library (AMMCLib)
- Offering the Model-Based Design Toolbox (MBDT), which integrates the NXP tools ecosystem with MATLAB and Simulink to allow engineers to generate code directly from simulation models and deploy the code on NXP MCUs
- Offering FreeMASTER as a real-time debug monitor and data visualization tool that enables runtime configuration and tuning of embedded software applications

“

Key factors in designing smart actuators in the chassis are safety, efficiency, and comfort. If the microcontroller is the brain of the actuator, then it must be enhanced by safety features and have enough processing power to handle real-time motor control tasks.”

Marek Mušák

Motor Control Application Engineer, NXP Semiconductors

S32K3

Learn More

S32M2

Learn More

Mighty Guides

Key Points

- **Smart actuators in EVs combine sensors, controllers, and actuators for precise and efficient control.**
- **High-frequency MCUs in smart actuators ensure precise control by capturing more data points per second.**
- **Model-based design, using tools like MATLAB and Simulink, allows engineers to optimize motor control systems in a virtual environment.**
- **NXP supports smart actuation system development with high-frequency MCUs, motor control libraries, model-based design tools, and real-time debug monitors like FreeMASTER.**

Chapter 2

MOTOR CONTROL IN BODY ELECTRONICS AND VEHICLE DYNAMICS

Motor control also plays a key role in the vehicle's body electronics and traction systems. Body electronics and vehicle dynamics encompass various systems related to the vehicle's starting, stopping, and steering. These systems include auxiliary drives, electric power steering (EPS), and braking systems. On the other hand, traction inverter systems focus on transforming electric power from the battery into mechanical power for the wheels. In both cases, the integration of advanced motor control technologies significantly enhances vehicle performance, comfort, and safety.

One way that motor control technologies impact these systems is by enhancing driving comfort and efficiency. Modern automotive body electronics systems employ electric motors to replace traditional mechanical components, leading to smoother and more precise operations. For example, EPS systems utilize motor control to provide variable steering assistance, which improves handling and reduces driver effort, especially at low speeds. Unlike conventional steering systems, which rely on an engine-driven pump, EPS systems use an electric motor to assist the driver's steering input.

“

By providing precise and real-time control over vehicle dynamics, motor control systems lay the groundwork for a transportation landscape that prioritizes safety, efficiency, and a fundamental transformation in how we interact with our vehicles.”

Manoj Kumar

Senior Engineer, Valeo

> ***In automotive motor control systems, safety is critical across all components—as any malfunction could directly endanger the driver, especially during crucial operations like acceleration, braking, and overtaking."***

Vincent Lagardelle

Automotive Electrification Systems Marketing Manager, NXP Semiconductors

This electric motor is controlled by an MCU that adjusts the level of assistance on the basis of vehicle speed, steering angle, and other parameters. At low speeds, the MCU increases assistance, making it easier for the driver to turn the wheel—a particularly useful feature in parking scenarios. Assistance is reduced at higher speeds to provide a better road feel and stability.

Motor control can also impact user experience in terms of noise reduction. Inherently, EVs produce less noise than their internal combustion engine counterparts, but noise sources still need to be managed for an optimal user experience. These sources include the electric motor itself, inverter switching, mechanical components like gears, and road-tire interactions.

For example, torque ripple is a common source of noise and vibration that arises from variations in the torque produced by the motor. Based on field-oriented control (FOC), sophisticated motor control algorithms are designed to minimize torque ripples by delivering smooth and continuous torque. By precisely regulating the motor's current and voltage, these algorithms reduce the fluctuations that cause noise and vibration.

Similarly, the inverter's switching frequency, which converts DC power to AC power for the motor, is another significant noise source. Higher switching frequencies can reduce audible noise but may increase electromagnetic interference and power losses. Advanced motor control technologies optimize these switching frequencies to balance noise reduction with efficiency and thermal management. Techniques like spread spectrum modulation can further help distribute the noise energy over a wider frequency range, making it less perceptible.

The underlying MCU must, therefore, offer a unique combination of high-frequency support, advanced noise-reduction techniques, substantial computational power, and versatile input/output capabilities for motor control in body electronics, vehicle dynamics, and traction systems.

Like the development of advanced actuation systems, the development of motor control systems for body electronics and traction systems relies heavily on advanced tools and simulation software. Simulation and modeling, real-time data analysis, and HIL testing are integral to this process. Combining these techniques allows engineers to optimize performance, enhance reliability, and reduce time to market.

NXP helps its customers meet the challenges of body electronics and traction inverter systems by

- Providing development kits and reference designs that include hardware and software components necessary for developing and testing motor control systems

"Motor controls play an important role in overall driving comfort. A finely tuned motor control strategy prevents unnecessary movement and excitation, ensuring smooth, efficient, and quiet operation."

Pedro Chavez Jr.

Principal Electrical Engineering Manager, FutureMotiv

> ***Motor control operates with a logic that provides optimization possibilities through various algorithms and offers multiple solutions. Efficient motor control optimizes the energy consumption of electric motors, reducing the overall power demand from the vehicle's electrical system and increasing fuel efficiency."***

Ufuk Saral

Team Leader, Engine, HVAC & Electrical Validation, TürkTraktör

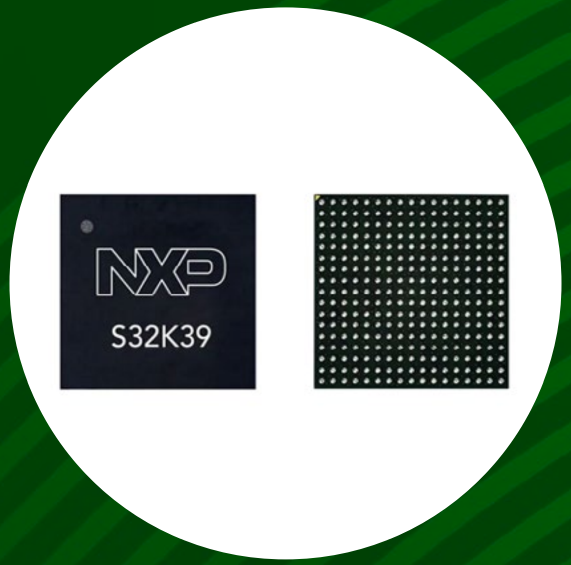
- Offering solutions for every part of the EV traction inverter, including functional safety integrated circuits (ICs) such as high-voltage gate drivers, MCUs, power management ICs, and communication interfaces
- Providing extended documentation at the device level, as well as at the system level, to facilitate the implementation of functional safety approaches
- Partnering with power electronics experts like Nexperia and Wolfspeed to support advanced SiC and GaN power solutions

“

Every single advanced system that helps you drive electric vehicles more safely and comfortably relies on electric machine assistance. Motor control is the underlying secret, controlling the machine’s speed or torque to get the effects you want.”

Lukas Gorel

Motor Control Application Engineer, NXP Semiconductors



S32K39

Learn More

GD3162

Learn More

Key Points

- **Advanced motor control technologies in body electronics and traction systems enhance vehicle performance, comfort, and safety.**
- **Systems for EPS utilize motor control to adjust assistance on the basis of vehicle speed and steering angle, improving vehicle handling and reducing driver effort.**
- **Motor control algorithms like FOC minimize noise and vibration by reducing torque ripples and optimizing inverter switching frequencies.**
- **NXP supports motor control development with comprehensive development kits, solutions for EV traction inverters, and extensive functional safety documentation.**

Chapter 3

FUNCTIONAL SAFETY IN AUTOMOTIVE MOTOR CONTROL

Functional safety is arguably the most important consideration for an engineer when designing automotive motor control systems. These systems must be designed to prevent catastrophic failures that could lead to unintended acceleration or braking.

Ultimately, three main safety goals drive the design of these systems.

The first goal is preventing over-acceleration and unintended braking, both of which can result from faults within the motor control system. For instance, if the system misinterprets sensor data because of a fault, it could inadvertently increase the torque, leading to sudden and unexpected acceleration. To mitigate this scenario, safety mechanisms

“

A robust safety system includes redundancy, fault detection and diagnosis, fail-safe and fail-operational mechanisms, safety-critical software, safety architectures, monitoring and control, reliable communication protocols, comprehensive safety analysis, and adherence to standards such as ISO 26262 (Road Vehicles – Functional Safety).”

Ufuk Saral

Team Leader, Engine, HVAC & Electrical Validation, TürkTraktör

"Fail-safe modes are designed to bring the motor control system, in the case of a failure, to a predefined safe state, such as opening all phases to avoid current circulation or shorting specific sides of the inverter to stop potential uncontrollable accelerating or braking motor torque."

Jérôme Dietsch

Senior Principal Functional Safety Architect, Electrification Systems, NXP Semiconductors

continuously monitor sensor inputs by cross-checking measurements with expected behavior to detect and counteract any anomalies.

Secondly, designers should consider energy discharge in crash situations. In such situations, ensuring that no stored energy remains in the system is paramount. Mechanisms that safely discharge energy from the inverter and other high-voltage components must be implemented to prevent additional hazards.

Designers must also account for human errors during maintenance. Such considerations include ensuring that the system is safe to handle even when maintenance personnel might inadvertently create fault conditions or dangerous work situations. For example, built-in safety interlocks allow the discharge of the high-voltage bus to avoid inadvertent short circuits caused by technician work. Clear diagnostic messages and guided troubleshooting procedures embedded within the system's software help technicians identify and resolve issues without introducing new faults.

Finally, gate drivers, which control the power transistors in the motor inverter, can come equipped with safety features that can transition the motor control system to a safe state on request by the external monitoring system if abnormal conditions are detected. For example, if an overcurrent or overvoltage condition is detected, gate drivers can shut down the power transistors, preventing damage to the motor and other components.

To further improve safety, fail-safe modes are integrated into the design of motor control systems. Fail-safe modes are predefined states to which motor control systems can transition in the case of a fault. These modes include:

- **Three-phase open state:** This mode avoids current circulation by opening all phases of the motor control system at low motor speed.
- **Shorting specific sides of the inverter:** Depending on the speed of the motor, this mode safely discharges energy by shorting either the low or high side of the inverter.
- **Zero-torque control:** This mode is used when the system can still control the motor but must ensure that no torque is generated.

Designing a motor control system to reach the appropriate fail-safe modes requires meticulous planning and advanced engineering techniques. Engineers must integrate robust hardware components and sophisticated software algorithms to detect faults and transition the system to safe states seamlessly. This effort can be supported by developing precise models and simulations to predict system behavior under various fault conditions and by ensuring that at least one path permits the safe reaction of the system.

> ***Implementing fault detection and operational modes such as Fail Safe and Fail Operational, based on the type of fault detected, is fundamental for ensuring the vehicle's reliable operation and the safety of its occupants."***

Saikrishna Rama

Motor Calibration Engineer, Stellantis

> ***"Designing for functional safety in automotive motor control systems requires a complex balance of foresight and precision. Engineers must anticipate every potential failure and incorporate robust safety mechanisms that can swiftly transition the system into a fail-safe state."***

Marek Stulrajter

Solution Engineering Team Manager,
NXP Semiconductors

Additionally, thorough testing and validation are crucial to verify that the system responds correctly to faults and that fail-safe mechanisms operate as intended, minimizing risks and enhancing overall vehicle safety.

NXP helps its customers design motor control systems with high degrees of functional safety by

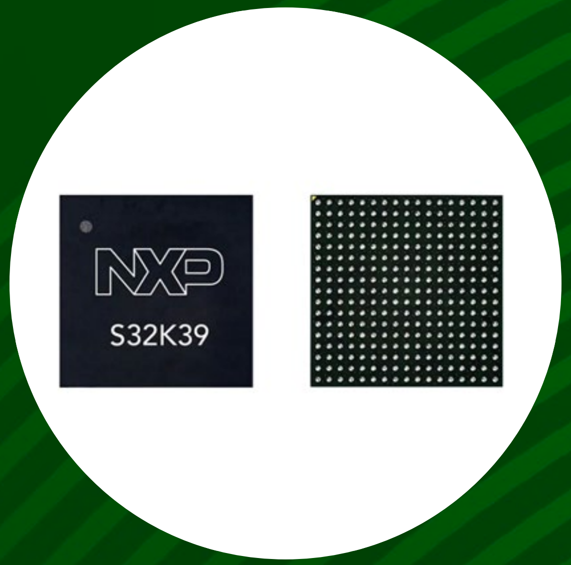
- Providing advanced MCUs with dual-core lockstep functionality to ensure reliable processing of safety-critical tasks
- Offering comprehensive safety documentation and configurable safety software to reduce development risks and accelerate time to market
- Utilizing model-based design and simulation tools like MATLAB and Simulink for safety software development in a system environment
- Integrating robust safety mechanisms in power management ICs and gate drivers to maintain system integrity under fault conditions

“

Motor control systems are designed to detect faults in real time and respond appropriately—whether that means putting the hardware into a safe state, derating it, or sometimes even shutting it down.”

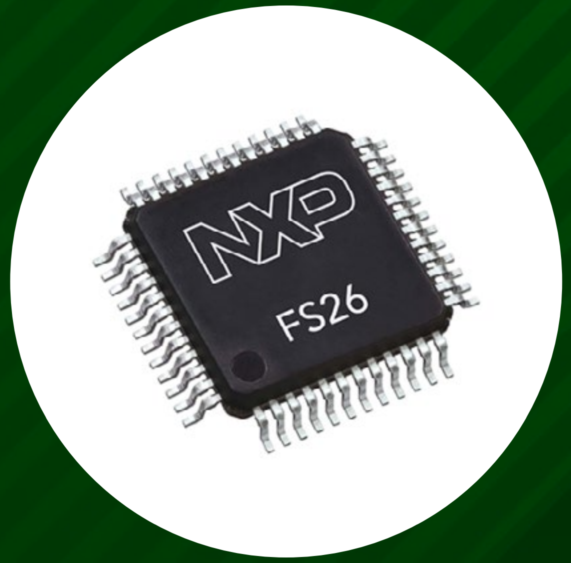
Saikrishna Rama

Motor Calibration Engineer, Stellantis



S32K39

Learn More



FS26

Learn More

S32M2

Learn More

Key Points

- **Functional safety in automotive motor control systems prevents catastrophic failures like unintended acceleration or braking.**
- **Designers must implement safety mechanisms to monitor system parameters like sensor inputs, safely discharge energy during crashes, and account for human errors during maintenance.**
- **Fail-safe modes, such as three-phase open state, short fail, and zero-torque control, help motor control systems transition to safe states during faults.**
- **NXP supports functional safety with advanced MCUs, comprehensive safety documentation, model-based design tools, and robust safety mechanisms in power management ICs.**

Learn More About Our Experts

Marius-Lucian Andrei

Technical Lead, Model-Based Design Team, NXP Semiconductors

Marius-Lucian Andrei is a Technical Lead for the Model-Based Design Team at NXP Semiconductors in Bucharest, Romania. He holds a master's degree in Advanced Computer Architecture and a bachelor's degree in Computer Science from Politehnica University. Marius joined NXP in 2017 and contributed to Model-Based Design software solutions for Automotive Products. He works closely with customers, offering training and support in areas including battery management systems, motor control, and data acquisition.

Pedro Chavez Jr.

Principal Electrical Engineering Manager, FutureMotiv

Pedro Chavez Jr. is a seasoned Electrical Engineering Manager with 19 years of experience in systems engineering, EV systems, and EE architecture. He holds a graduate certificate in Systems Engineering from Purdue University Global and a BS in Electrical and Electronics Engineering Technology from ECPI University. Pedro is a respected mentor and public speaker, actively involved in SAE and IEEE, and an expert in EV charging standards.

Jérôme Dietsch

Senior Principal Functional Safety Architect, Electrification Systems, NXP Semiconductors

Jérôme Dietsch leads the technical functional safety architecture on various electrification system solutions with a focus on defining and developing functional safety collaterals documentation to ease the integration of ICs into customer architecture. He holds an MS in Power Electronic Engineering from Polytech Tours and has almost 20 years of experience as power electronic engineer in automotive industry mainly in hardware and system development on powertrain and chassis/safety systems.

Lukas Gorel

Motor Control Application Engineer, NXP Semiconductors

Lukas Gorel is an Application Engineer at NXP Semiconductors, developing and supporting real-time control solutions. He holds a PhD in Electrical Engineering, specializing in electrical drives and power electronics. His focus is on the automotive chassis segment, providing support for general-purpose microcontrollers and helping customers integrate microcontrollers into final applications. Lukas is involved in innovative projects targeting upcoming market trends, has published and peer-reviewed several journal articles, and holds several patents.

Learn More About Our Experts

Manoj Kumar

Senior Engineer,
Valeo

in

Manoj Kumar is a dynamic and seasoned professional in the automotive industry, with expertise on planning, executing, debugging, and overseeing complex projects in ADAS and autonomous systems. Currently, as a Senior Engineer at Valeo, Manoj spearheads comprehensive software development and project management initiatives. He has a proven track record in validating functional safety requirements, ensuring ASPICE standards, and maintaining compliance with cybersecurity norms.

Vincent Lagardelle

Automotive Electrification
Systems Marketing Manager,
NXP Semiconductors

in

Vincent focuses on enabling NXP's customers by providing complete system solutions that allow scalable, fast, and de-risked system development based on NXP's portfolio. He graduated from the INSA-Toulouse School (France) as an engineer in 2001. He has an MBA from Toulouse Business School and has worked in different product engineering, team management, technical marketing, and business development positions in the automotive division at Motorola, Freescale, and NXP.

Marek Mušák

Motor Control
Application Engineer,
NXP Semiconductors

in

Marek Mušák is an Application Engineer responsible for motor control solution development and support at NXP Semiconductors. He holds a PhD in electrical engineering with special focus on electrical machines and drives. He joined NXP Semiconductors in 2015 where he focuses on body segment, supports general purpose microcontrollers, and provides customer support for optimizing motor control design. He is involved in many innovative projects and contributes to the NXP motor control library.

Venkatesh Naidu

Senior Hardware Engineer,
Bosch Global Software
Technologies

in

Venkatesh Naidu is a Senior Hardware Engineer at Bosch Global Software Technologies, where he specializes in designing ECUs for motor control applications. His expertise includes electrical design, simulations, and quality assurance. In his previous position at Electrotherm Limited, Venkatesh developed products like motor controllers, battery chargers, and wiring harnesses. Known for his remarkable understanding of electronics, Venkatesh delivers innovative solutions that make him a valuable asset to any team.

Learn More About Our Experts

Saikrishna Rama

Motor Calibration Engineer, Stellantis

Saikrishna is a Motor Calibration Engineer experienced in developing and testing motor control strategies on dynamometers and prototype vehicles. He holds a master's degree in Mechanical Engineering from Michigan Technological University, specializing in Embedded Control Systems and Hybrid Electric Vehicles.

Ufuk Saral

Team Leader, Engine, HVAC & Electrical Validation, TürkTraktör

Ufuk has over nine years' experience at TürkTraktör, one of the leading manufacturers in Turkey. At TürkTraktör he has advanced from Production Maintenance Engineer to Team Leader in Engine, HVAC, and Electrical Validation. His strong technical leadership expertise spans test engineering, test execution, and vehicle testing. Ufuk has a degree in Mechanical Engineering from Baskent University in Turkey.

Marek Stulrajter

Solution Engineering Team Manager, NXP Semiconductors

Marek Stulrajter is the Automotive Solution and Application Engineering Team Manager at NXP Semiconductors. He drives the solution development for variety of applications in the automotive segment. He holds a PhD in Electric Drives and Machines and has worked at NXP since 2010, actively participating in and supporting research and innovation activities mainly in the motor control domain. Marek has published or peer-reviewed several IEEE journal articles and owns several patents.