

# Application Brief

## Automotive Smart Actuators



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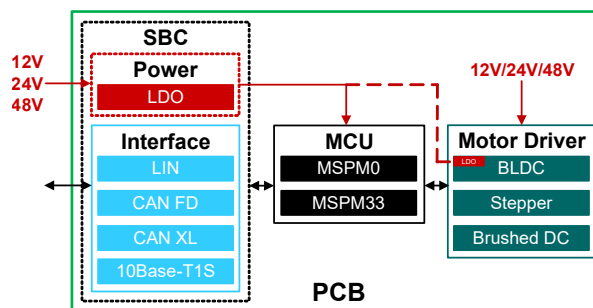
### Introduction

A smart actuator is defined as a locally controlled actuator with the PCB directly connected to the motor. A communication interface allows upper level ECUs to control the speed, position or torque of the motor. The smart actuator market continues to grow even as vehicle architectures evolve, due to wire harness optimization, scalability across vehicle platforms, and the need for local real-time motor control. In the automotive sector, these intelligent modules are helping to improve vehicle design by managing critical components such as [valves](#), [pumps](#), [fans](#), [windows](#), [wipers](#), and [roof motors](#), enhancing safety, comfort, and efficiency. [Figure 1](#) shows an exploded view of an smart oil pump with the PCB directly embedded into the housing of the pump.



**Figure 1. A2MAC1 exploded view of an oil pump**

With the industry's shift toward electrification, autonomous driving, and connected systems, the need for reliable, versatile, and future-ready actuator designs has become paramount. TI's smart motor designs, as shown in [Figure 2](#), are offering a comprehensive ecosystem tailored for next-generation low-voltage power networks and interfaces, supporting 48V, 24V, and 12V supplies. Compatible with industry standards like CAN FD, LIN, and the emerging 10BASE-T1S and CAN XL protocols, this design make sure there is seamless integration into modern vehicle architectures. Leveraging Arm-based microcontrollers with trapezoidal and field-oriented control (FOC) algorithms available in the [software development kit \(SDK\)](#), TI provides a robust foundation for motor control development. The inclusion of drivers for all applications — brushless DC (BLDC), stepper, and brushed DC (BDC) motors ranging from 1W to 1kW, along with integrated diagnostics and protection, makes this a versatile choice for diverse motor control applications. TI's design covers a wide array of needs with a scalable approach, addressing the challenges of this dynamic automotive market.



**Figure 2. Smart Actuator Block Diagram**

## Overview of Smart Actuator Applications in Today's Automotive Industry

The development of smart motors requires comprehensive evaluation of system-level parameters including cost optimization, form factor constraints, performance specifications, and reliability. TI currently provides system designs that address these fundamental requirements across a broad spectrum of applications as outlined in [Table 1](#) and [Table 2](#).

**Table 1. Thermal Management and HVAC Systems**

	Coolant/ Oil pump	Blower	Cooling Fan	Valve	Flaps	Grill Shutter
Motor Type	BLDC	BLDC, BDC	BLDC, BDC	Stepper, BLDC, BDC	Stepper, BDC	Stepper, BLDC
Power range	50W-500W	50W-350W	200-1000W	< 20W	< 20W	< 20W

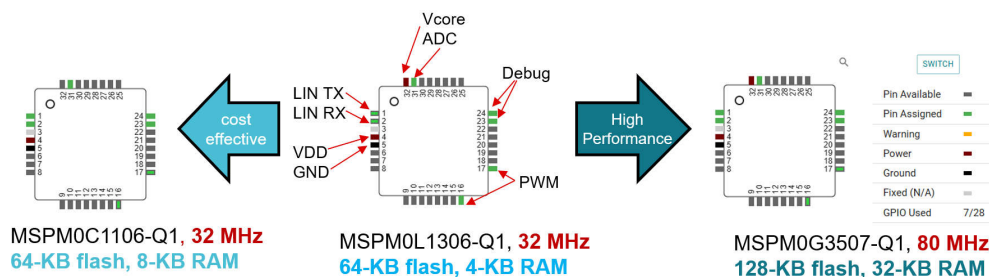
**Table 2. Body Motors Applications**

	Windshield Wiper	Window Lift	Sunroof Motor	Seat Fan
Motor Type	BLDC, BDC	BDC	BLDC, BDC	BLDC, 1ph BLDC
Power Range	50W-200W	50W-150W	20W-200W	<20W

### Scalable, Safe, and Secure MSPM0 MCU for Smart Actuators

The MSPM0 microcontroller series represents a balanced architecture built around the 32-bit Arm® Cortex®-M0+ core. Manufactured on a 65nm technology node, the platform achieves integration of analog and digital peripherals while maintaining a competitive cost-performance ratio. TI provides engineers with an easy and fast way to get started with motor control software through comprehensive resources available on ti.com, including detailed guides such as [MSPM0 Motor Control](#) and [MSPM0 MCU Advantages in Automotive Applications](#). These resources offer step-by-step implementation guidance, best practices, and application-specific insights to accelerate development cycles and reduce time-to-market for motor control designs.

A defining characteristic of the MSPM0 family is the hardware and software scalability through complete pin-to-pin (P2P) compatibility, allowing for scalable and flexible smart motor architectures. This platform-level design verifies consistent peripheral mapping and package footprint across devices with varying flash memory sizes and operating frequencies. As demonstrated in the implementation below, this architecture facilitates seamless performance scaling within a unified hardware platform, enabling adaptation across diverse motor configurations and interface specifications. For instance, when implementing a cost-optimized, LIN-based scale down of a CAN-based smart brushed DC actuator, the MSPM0C1106-Q1 can serve as a direct replacement for the MSPM0G3507-Q1, maintaining functional compatibility while achieving significant cost reduction. This scalable approach allows engineers to leverage a common design foundation across multiple product variants, reducing development time and maintaining design consistency while optimizing for specific performance and cost targets.



**Figure 3. Scalable MSPM0 Platform Example**

## MSPM0 Motor Control for Smart Actuators

For automotive smart motor applications, the MSPM0 platform delivers exceptional computational efficiency through its high-performance CPU and integrated Math Accelerator (MATHACL). This dedicated hardware unit offloads complex mathematical operations from the main CPU, enabling high-precision field-oriented control (FOC) algorithms while preserving processing bandwidth.

The MATHACL is fully programmable through the optimized IQMATH library, providing developers with a seamless interface for implementing advanced motor control algorithms. Benchmark data demonstrates significant CPU bandwidth optimization when executing FOC routines, as illustrated in the performance comparison, as listed in [Table 3](#)

**Table 3. MSPM0 FOC Performance**

FOC Algorithm	Product	CPU	Clock	PWM Freq.	FOC Rate	FOC Time	CPU Bandwidth
Sensorless	MSPM0G3507*	M0+ MathACL	80MHz	20kHz	10kHz	60.8us	60.8%
	MSPM0G3107**	M0+ <b>Without</b> MathACL	80MHz	20kHz	10kHz	79.9us	79.9%
	MSPM0C1106**	M0+ <b>Without</b> MathACL	32MHz	15kHz	5kHz	199us	99.5%
Hall sensed	MSPM0G3507*	M0+ MathACL	80MHz	16kHz	16kHz	43.9us	70.3%

\* The Benchmark is tested with SDK FOC design ([MSPM0-SDK](#))

\*\* The benchmark is estimated with SDK FOC design.

- **Advanced sensing:** High-precision current sensing is fundamental to achieving optimal performance in advanced motor control applications. MSPM0 addresses this critical requirement through a fully integrated analog signal chain designed to maximize measurement accuracy while minimizing external component count. The platform features:
  - **High-Resolution Data Acquisition:** Dual 12-bit SAR ADC supporting max 4 MSPS sampling rate with 11.2 ENOB, enabling simultaneous multi-channel current sampling for accurate real-time motor parameter monitoring
  - **Precision Signal Conditioning:** Two integrated zero-drift operational amplifiers (OPAs) providing high CMRR and low offset drift, supporting PGA mode and ensuring stable and accurate current sensing across extended temperature ranges. These OPAs enable FOC BLDC motor operation with cost-optimized motor drivers that lack integrated current sense amplifiers. The integrated OPAs can be leveraged for current sensing functionality without requiring additional external components, reducing system cost and complexity.
  - **Real-Time Hardware Protection:** Configurable high-speed comparators with programmable reference thresholds (8-bit DAC) enable immediate fault response without CPU intervention
  - **Enhanced System Integration:** On-chip voltage reference generation and signal routing eliminate external buffering and conditioning components
- **AEC-Q100 qualified:** MSPM0 fully applies to the AEC-Q100 Grade 1 standard and strictly follows the testing protocols that qualify ICs for automotive use, ensuring ICs can perform reliably in harsh environments.
- **Functional safety - Achieves ISO26262 ASIL-B standards:** Tailored for medium- to low-risk scenarios QM and ASIL-B, MSPM0 provides a comprehensive report analysis, including functional safety manual, FIT rate, FMEDA documentation, and diagnostic library to help identify and avoid system failure.
- **Cybersecurity:** To enhance automotive on-board network resilience and address the evolving Cyber Resilience Act (CRA) framework emerging across Europe, MSPM0 provides enhanced security enablers, including AES acceleration with key storage, TRNG, and IP firewall, to help customers address Evita-Light and PSA-L1 requirements. Including debug security, secure boot, hardware acceleration, and attack resistance.

See [Table 4](#) for MSPM0 feature comparison for quick selection.

**Table 4. MSPM0 Feature Comparison**

	MSPM0C1106	MSPM0G3107	MSPM0G3507	MSPM0G3519
Recommended motor control	Stepper, BDC, MCF-based BLDC, trapezoidal control	BDC, Trapezoidal and low speed FOC control	FOC control	FOC control
Frequency	32MHz	80MHz	80MHz	80MHz
MATHACL	No	No	Yes	Yes
Flash	64KB	128KB	128KB	512KB (Dual bank)
CAN-FD	-	1	1	2
LIN	1	1	1	2
Analog Peripherals	1*12bit SAR ADC (up to 27ch)	2*12bit SAR ADC (up to 17ch)	2*12bit SAR ADC (up to 17ch)	2*12bit SAR ADC (up to 27ch)
Op-Amp	-	-	2	-
Gp-Amp	-	-	1	-
Advanced Timer	1	2	2	2
Total timer	5	7	7	9
Functional Safety	FS-QM	ASIL-B	ASIL-B	ASIL-B

### Communication and Power Supply Requirements of Smart Actuators: Bus Fault Voltage and Loss of GND

The LIN and CAN bus fault voltage protection is crucial across 12V, 24V, and 48V automotive systems due to the inherent risks of short-circuit faults. These faults can introduce spurious signals or, worse, create a direct path to ground or power rails, potentially damaging ECUs and disrupting communication. TI's broad portfolio of robust transceivers and system basis chips (SBCs) is listed in [Table 5](#) and enables smart motors applications to achieve high-performance, reliable communication within the LIN and CAN bus networks, particularly in demanding automotive environments.

**Table 5. TI Interface Options Overview**

	12V	24V	48V
LIN	TLIN102x-Q1 family ( $\pm 45V$ bus fault protection)	TLIN202x-Q1 family ( $\pm 60V$ bus fault protection)	TLIN402x-Q1 family ( $\pm 70V$ bus fault protection)
CAN FD	TCAN1473A-Q1 ( $\pm 58V$ bus fault protection)	TCAN1473A-Q1 ( $\pm 58V$ bus fault protection)	TCAN1043HG-Q1 ( $\pm 70V$ bus fault protection)
LIN SBC (1x LDO, 3.3V/5V at 125mA) CAN SBC (1x LDO, 5V at 100mA)	TLIN1028-Q1 ( $\pm 58V$ bus fault protection) TCAN11625-Q1 ( $\pm 58V$ bus fault protection)	TLIN1028-Q1 ( $\pm 58V$ bus fault protection) TCAN11625-Q1 ( $\pm 58V$ bus fault protection)	-

### Advanced Motor Drivers for Smart Actuators

TI's motor driver portfolio addresses smart actuator applications through product families spanning 12V to 48V automotive systems. For BLDC applications, designs range from cost-optimized gate drivers like the DRV8311-Q1 for 12V systems to advanced drivers such as the DRV8363-Q1 for 24V/48V domains. The integrated FET motor drivers, including DRV8316-Q1 and MCx8316-Q1 families, eliminate external MOSFETs while supporting currents up to 8A, making them valuable for space-constrained applications.

BDC motor drivers such as the DRV8263-Q1 and DRV8163-Q1 support all three voltage domains with modern safety features, enabling platform scalability across vehicle architectures. For precision positioning, stepper motor drivers such as DRV8899-Q1 and DRV8434-Q1 provide precise current control and microstepping capabilities for valve positioning and HVAC dampers.

Key integration features include 3.3V LDO functionality that directly powers MSPM0 microcontrollers, reducing system cost and complexity while maintaining automotive reliability standards. ASIL-B rated options provide functional safety compliance for safety-critical applications. These designs integrate seamlessly with the MSPM0 platform to deliver a full control systems with optimized cost.

Table 6 summarizes and provides an overview of TI motor driver designs for smart actuators across all motor types.

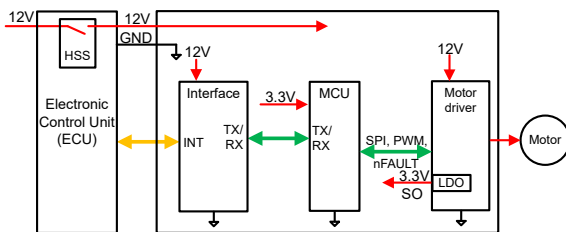
**Table 6. TI Motor Driver Overview**

	BLDC	BDC	Stepper
Gate driver	<a href="#">DRV8311-Q1</a> (12V) <a href="#">DRV8329-Q1</a> (12V/24V) <a href="#">MCF8329HS-Q1</a> (12V/24V) <a href="#">DRV8343-Q1</a> (12V/24V) <a href="#">DRV8300-Q1</a> (12V/24V/48V) <a href="#">DRV8363-Q1</a> (24V/48V)	<a href="#">DRV8705-Q1</a> (12V) <a href="#">DRV8706-Q1</a> (12V) <a href="#">DRV8714-Q1</a> (12V)	-
Internal FET motor driver	<a href="#">DRV8316-Q1</a> (12V) <a href="#">MCx8316-Q1</a> (12V) <a href="#">MCx8315-Q1</a> (12V) <a href="#">DRV8376-Q1</a> (12V/24V/48V) <a href="#">MCT8376Z-Q1</a> (12V/24V/48V)	<a href="#">DRV824x-Q1</a> (12V) <a href="#">DRV814x-Q1</a> (12V) <a href="#">DRV8263-Q1</a> (12V, 24V,48V) <a href="#">DRV8163-Q1</a> (12V, 24V,48V)	<a href="#">DRV8889-Q1</a> (12V) <a href="#">DRV8899-Q1</a> (12V) <a href="#">DRV8434-Q1</a> (12V)
Integrated 3.3V LDO	<a href="#">DRV8311-Q1</a> (12V) <a href="#">DRV8316-Q1</a> (12V) <a href="#">MCx8316-Q1</a> (12V) <a href="#">MCx8315-Q1</a> (12V) <a href="#">DRV8329-Q1</a> (12V/24V) <a href="#">DRV8376-Q1</a> (12V/24V/48V) <a href="#">MCT8376Z-Q1</a> (12V/24V/48V) <a href="#">DRV8363-Q1</a> (24V/48V)	<a href="#">DRV8163-Q1</a> (12V, 24V,48V)	-
ASIL B	<a href="#">DRV8334-Q1</a> (12V/24V) <a href="#">DRV8363-Q1</a> (24V/48V)	<a href="#">DRV8263-Q1</a> (ASIL B)	-

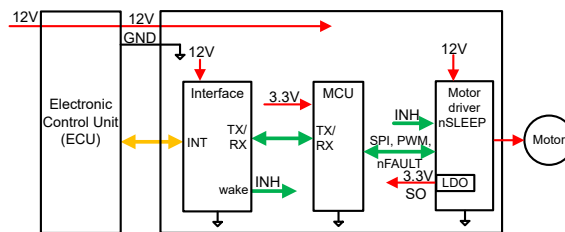
**Communication and Power Supply Requirements of Smart Actuators: Low Power Mode**

Numerous automotive applications operate in periodic or intermittent cycles rather than continuous operation modes. To optimize power consumption and maximize electric vehicle operational range, low-power management strategies are systematically implemented. Two predominant architectural approaches have emerged:

- **Figure 4** shows an implementation of a high side switch (HSS) or electronic fuses (eFuses) within an upper ECU to achieve a low power mode. This configuration reduces edge node power consumption to zero, facilitated by TI's comprehensive portfolio of high-side switch designs, available with optional I<sup>2</sup>T wire protection mechanisms for enhanced system reliability.
- **Figure 5** shows a continuous power supply to the smart actuator with wake over communication interface capability, enabling both sleep mode and remote wake up via the bus. The architecture delivers robust performance with sleep current consumption below 100µA while maintaining autonomous operation independent of upper ECU.



**Figure 4. Upper Level High Side Switch Based Low Power Mode**



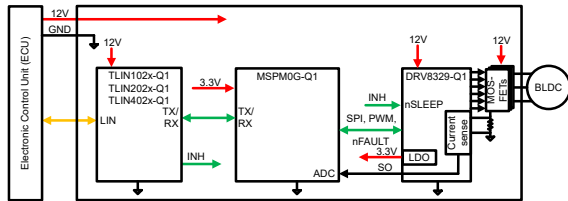
**Figure 5. Wake Over Communication Interface Based Low Power Mode**

## Smart Actuator BLDC Application Block Diagram Examples

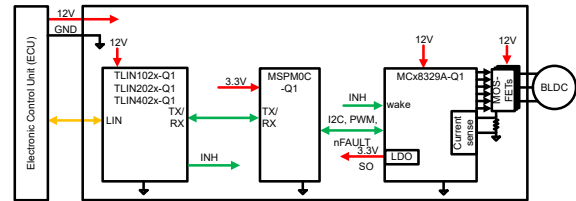
For BLDC based applications, TI strategically invests in two distinct technological approaches:

- External Control Drivers (DRV-based): Control algorithm is running on host MCU
- Integrated Control Drivers (MCF-, MCT-based): Control algorithm is running on motor driver

While the gate driver and integrated FET motor driver allow for maximum control over the motor control algorithm (Figure 6), the integrated control driver allows for quick system bring-up due to preprogrammed FOC algorithm (MCF) and trapezoidal algorithm (MCT) motor control which can both be configured by a low-cost host MCU (Figure 7). Both approaches are leveraging the integrated LDO inside the gate driver to supply the MSPM0 microcontroller to save system cost and design size. In case of currents less than 8A, MCx8316x-Q1 or DRV8316-Q1 can be used to simplify the system due to integrated FETs.



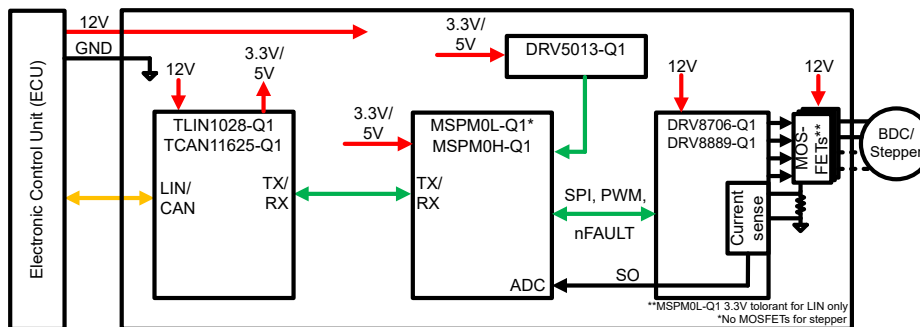
**Figure 6. DRV-Based Block Diagram for BLDC Motors**



**Figure 7. MCx-Based Block Diagram for BLDC Motors**

## Smart Actuator Brushed DC and Stepper Application Examples

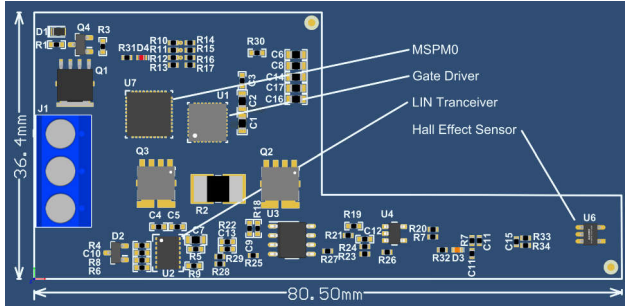
TI offers developers a comprehensive and seamless portfolio of gate drivers and integrated FET drivers for BDC and stepper based smart motor applications. Optional hall sensors can be used to support position control in BDC based systems. By leveraging TI's extensive range of LIN/CAN System Basis Chips (SBCs), developers can achieve cost-effective and compact designs that are preferred for space-constrained systems as shown in Figure 8.



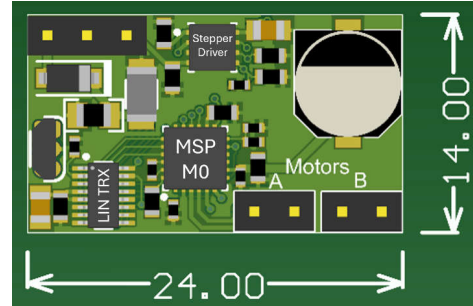
**Figure 8. DRV-Based Block Diagram for BDC and Stepper Motors**

## System Requirements of Smart Actuators: Design Size

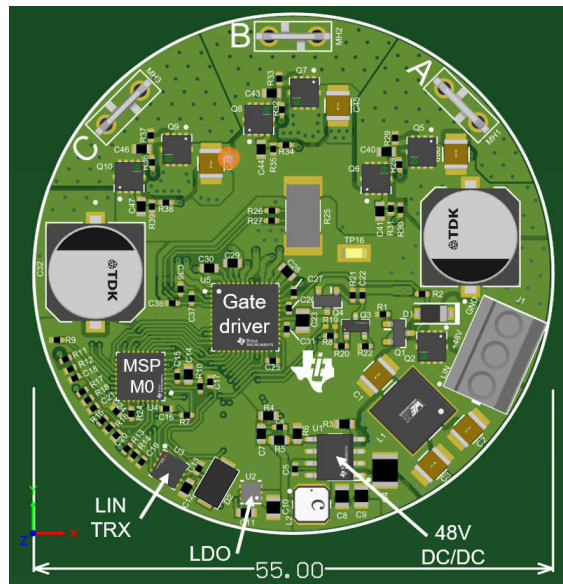
Smart motor architectures employ direct PCB-to-motor phase integration through soldered interconnections, thereby eliminating intermediate cable assemblies. This integrated architecture requires a protective enclosure encompassing both the motor assembly and control electronics. This demands small PCBs which typically have multiple constraints regarding placement of components. TI's system designs meet the stringent spatial constraints inherent in these applications through highly optimized form factors and pinout. [Figure 9](#) highlights how TI enables complex PCB geometries - such as L-shaped geometrics - that maximize available space utilization while maintaining critical electrical performance parameters. Similarly, TI's miniaturized driver designs for stepper-based precision valves as shown in [Figure 10](#) delivers designs without compromising control accuracy or reliability. Latest market trends are also demanding 48V smart actuators which can be addressed with TI designs while maintaining a small form factor as shown in [Figure 11](#).



**Figure 9. Size Constraint L-shaped Smart Actuator PCB for Window Lift Applications**



**Figure 10. Size Constraint Smart Actuator PCB for HVAC Valve Applications**



**Figure 11. Size Constraint Smart Actuator PCB for Pump and Blower Applications**

**Conclusion**

Texas Instruments provides a comprehensive system design for automotive smart actuators, covering a wide range of applications from grill shutters and valves to cooling pumps, fans, and window lifts. The scalable MSPM0 MCU platform, combined with TI's motor driver portfolio supporting BLDC, brushed DC, and stepper motors across 12V, 24V, and 48V systems, enables space-optimized PCB designs that meet tight form factor requirements. Safety and security demands are addressed through ISO26262 ASIL-B compliance and integrated cybersecurity features, verifying alignment with current automotive regulatory standards.

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