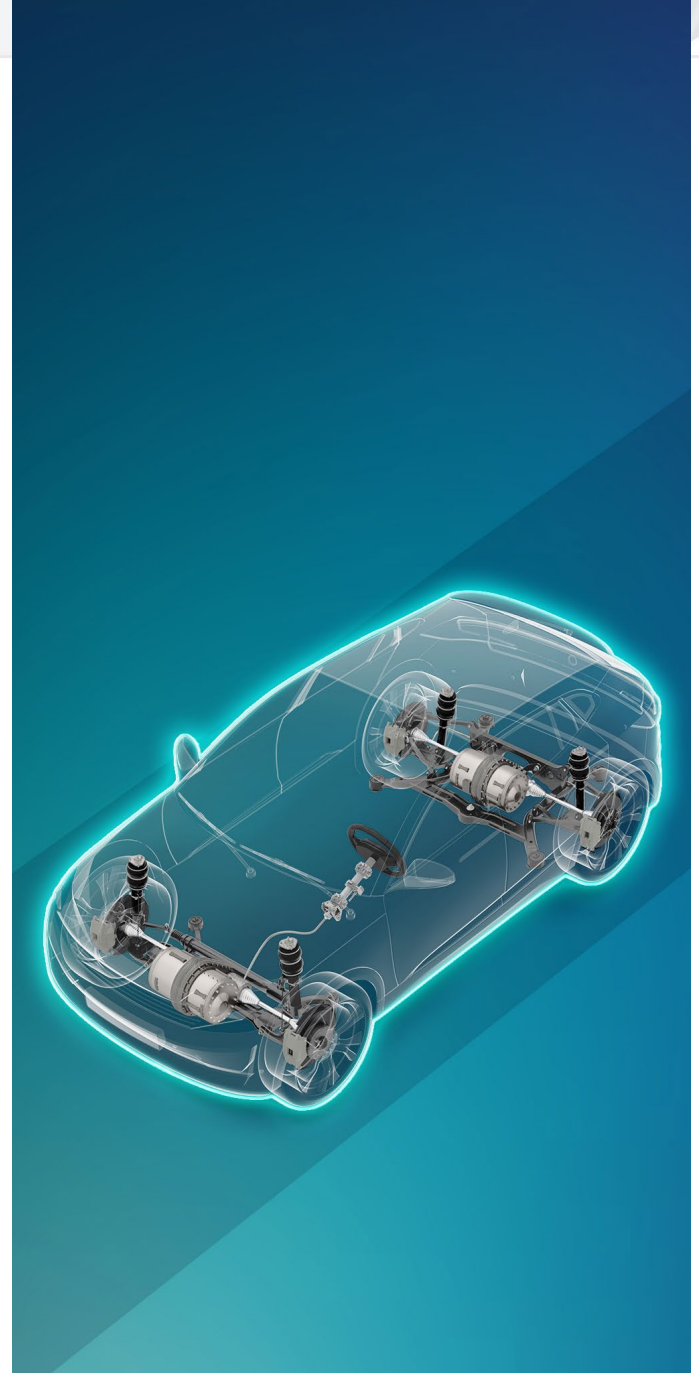


The intelligent chassis: How by-wire technology is reshaping steering, braking and suspension

By Jerry Shi, sector manager,
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At a glance

- 1** By-wire technologies deliver the precision and safety that intelligent chassis systems demand.
- 2** Real-time performance, functional safety and scalable integration are the engineering challenges that OEMs and Tier 1 suppliers must address for next-generation chassis.
- 3** Semiconductors and software spanning sensing, computation, actuation and power management are the building blocks that make intelligent chassis design possible.



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The chassis has always defined how a vehicle feels on the road. Now, electrification and control-by-wire technologies are driving the automotive industry toward the full realization of autonomous driving, while enabling a smoother, safer and more responsive driving experience. By rapidly replacing mechanical systems across steering, braking and suspension applications, these technologies are meeting the accuracy, performance and safety requirements of intelligent chassis design.

Meeting these demands requires precise sensing, real-time computation and high-performance actuation, anchored by deterministic control, proven compliance with functional safety requirements and scalable integration across the entire architecture. Together, these capabilities eliminate mechanical delays and vibration, enabling a smoother and more responsive driving experience and scaling toward autonomy levels beyond Society of Automotive Engineers (SAE) J3016 Level 3. If advanced driver assistance systems (ADAS) sensors act as the eyes and ears of a vehicle, computation the brain, and communication the nervous system, the intelligent chassis acts as the body, where every decision is followed by a physical response.

In this white paper, I'll examine the transition to intelligent chassis systems; the associated engineering challenges; and the enabling technologies that help original equipment manufacturers (OEMs) and Tier 1 suppliers accelerate development, achieve International Organization for Standardization (ISO) 26262 Automotive Safety Integrity Level D compliance with confidence, and bring next-generation chassis systems to market faster.

What makes a chassis intelligent?

Mechanical chassis systems have defined vehicle dynamics for over a century. Today, electronic control – especially by-wire technology – is transforming that legacy. An intelligent chassis combines software, sensors and by-wire actuators to optimize steering, braking, ride comfort and stability in real time. Three core technologies are enabling this transition: steer-by-wire, brake-by-wire and active suspension systems.

In steer-by-wire systems, electronics interpret steering input rather than transmitting it through a mechanical link. One electronic control unit (ECU) captures driver intent and generates steering feedback, while a second controls the steering rack actuator to move the wheel precisely.

Within the broader autonomous vehicle architecture, the intelligent chassis, delivers the final layer of perception, computation, communication and response. It translates data-driven decisions into precise vehicle motion.

In brake-by-wire systems, braking commands from the pedal or ADAS controller are processed electronically. Depending on the architecture, the system generates brake force through electrohydraulic systems (electrohydraulic braking [EHB]) or electromechanical actuators (electromechanical braking [EMB]) at each wheel.

Active suspension systems continuously adapt damping, ride height and body motion using electronically controlled dampers, air springs or other actuators, improving both comfort and vehicle stability. Forward-looking cameras paired with the suspension system feed road surface data to the suspension controller, enabling real-time, preemptive adjustment of chassis and body dynamics.

Together, these technologies turn the chassis into an intelligent motion control platform, which is essential for driving performance, ride quality and future autonomous driving.

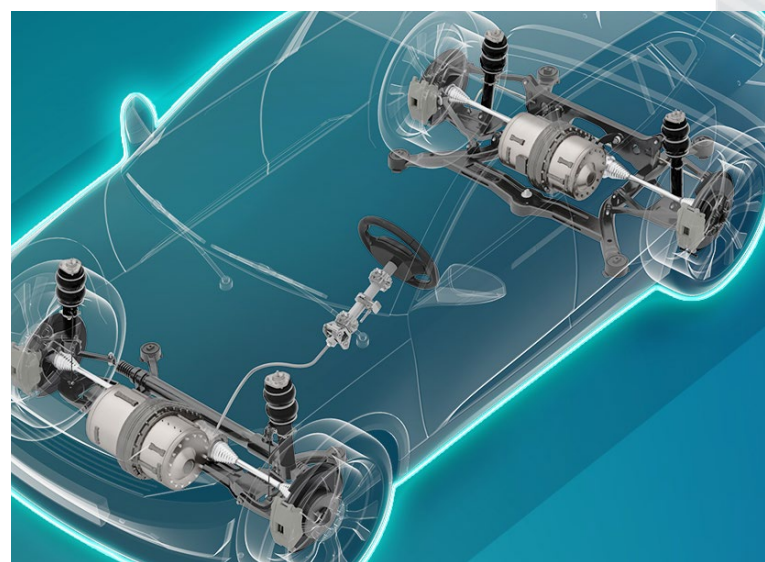


Figure 1. Full-vehicle chassis rendering shows an integrated steering, braking and suspension architecture of an intelligent chassis system.

The engineering challenges of control by wire?

Designing an intelligent chassis with by-wire actuation introduces a new set of engineering challenges. Unlike traditional mechanical systems, intelligent steering, braking and suspension functions increasingly rely on sensors, software, power electronics and real-time control algorithms, requiring designers to balance dynamic performance, system integration, thermal constraints, and compliance with functional safety requirements.

By-wire systems must respond quickly and predictably to driver inputs and road conditions. Actuators – including electric motors, electrohydraulic systems or air-based systems – each require tightly controlled feedback loops. Some inner control loops operate in microseconds, while higher-level motion control loops may run in milliseconds. Across all layers, low latency and minimal jitter are essential to deliver precise, stable and smooth vehicle behavior.

Chassis systems must coordinate with vehicle control units (VCUs), ADAS, powertrain controllers, body electronics and increasingly, zone architectures. OEMs may choose stand-alone chassis ECUs, domain controllers or centralized compute platforms, so semiconductor and software solutions need scalable architectures that designers can reuse across multiple vehicle platforms and electrical and electronic topologies.

Many chassis actuators require high peak current and substantial power in compact packaging. Steering motors, brake actuators and active suspension systems generate significant heat, often in harsh environmental locations. Thermal management directly affects long-term performance, derating behavior and system reliability, requiring careful optimization of power semiconductors, printed circuit board layout, cooling paths, electromagnetic compatibility (EMC) shielding and diagnostics.

For steering and braking applications, safety requirements typically rank among the highest in the vehicle, often targeting ISO 26262 ASIL D at the system level. In steer-by-wire and brake-by-wire systems, design engineers must analyze every critical fault path, including sensors, power supplies, communication links, microcontrollers (MCUs), gate drivers and actuators. To meet safety goals, system designs may require redundant sensing, dual power paths, backup communication channels or secondary control units capable

of maintaining limited operation after a fault. Suspension systems may carry different safety targets depending on function and automaker goals (Figure 2).

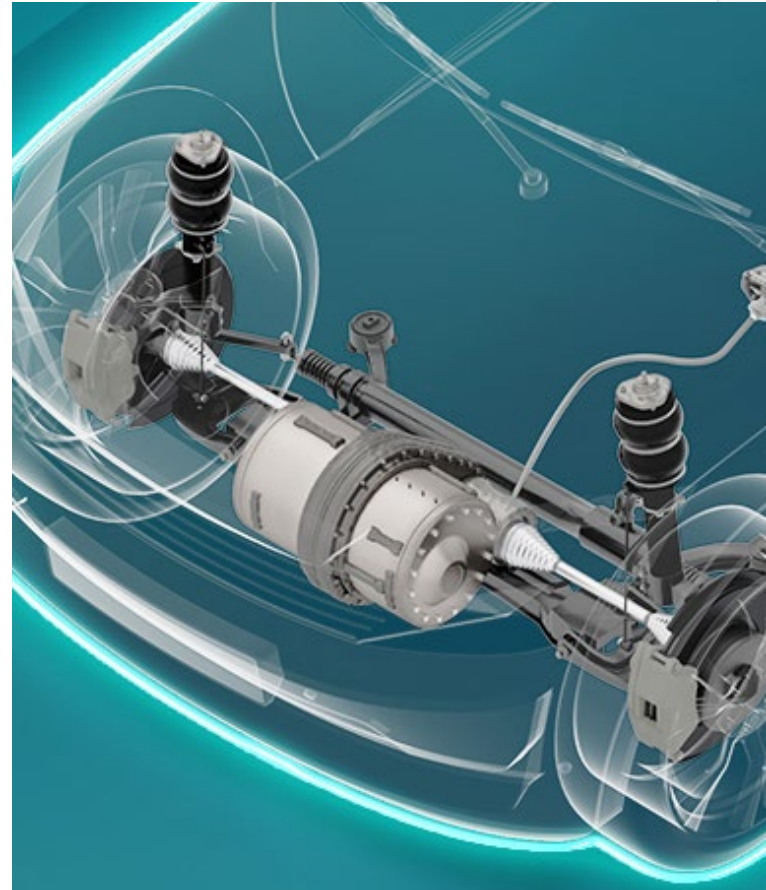


Figure 2. *The by-wire control loop integrated with a powertrain ECU in a zone architecture to address safety requirements.*

Careful semiconductor selection establishes the groundwork for real-time performance, system integration and scalability, reliability, and functional safety compliance across intelligent chassis applications.

Steer-by-wire: Architecture and design considerations for functional safety compliance?

The steer-by-wire architecture removes the permanent mechanical link between the steering wheel and the tires. Electronics interpret driver steering inputs and transmit them to a steering actuator, while a dedicated feedback unit at the steering wheel artificially creates steering resistance, road feedback and steering feel to the driver.

A typical steer-by-wire architecture contains two primary subsystems: the steering wheel unit and the rack actuator unit. The steering wheel unit measures handwheel angle, torque and driver intent using magnetic or torque sensors. A real-time MCU processes these inputs and controls a compact motor to generate the appropriate steering resistance, centering forces and dynamic road feel based on vehicle speed, road surface conditions and steering wheel angle and torque.

The steering actuator unit, typically located at the steering rack, receives commands through a deterministic communication link such as Controller Area Network Flexible Data-Rate (CAN FD) or Automotive Ethernet (for example, 10BASE-T1S or higher-bandwidth variants, depending on architecture). A second real-time MCU combines the steering command with position, current and torque sensor feedback, then drives a high-power brushless DC or permanent magnet synchronous motor to generate the required wheel steering torque.

Because steer-by-wire directly controls vehicle direction, its functional safety requirements rank among the highest in the vehicle.

Many architectures target ISO 26262 ASIL D and require redundancy in sensors, power supplies, communication paths and computing processors. Some designs also require backup actuation capability to support fail-operational behavior after a fault. This redundancy increases safety but also introduces system complexity and places additional constraints on packaging, thermal management, EMC and power consumption, making semiconductor integration, real-time control performance and diagnostic coverage significant design differentiators.

Brake-by-wire: Electronic braking control, ASIL D and actuator design?

Brake-by-wire systems replace traditional mechanical or hydraulic brake command paths with electronically controlled braking architectures, typically comprising a brake control ECU, pedal sensing or pedal simulator hardware, communication networks, and wheel-end brake actuators. Designers can implement the brake

ECU as a dedicated stand-alone controller with hardware redundancy or integrate the ECU into a zone or domain controller. The controller receives braking requests from the driver pedal, ADAS functions, regenerative braking coordinator and VCU; calculates the appropriate brake force distribution; and sends commands to the actuator systems.

There are two major actuator approaches:

- Electro-hydraulic braking uses electric motors, pumps, boosters and valves to generate and modulate hydraulic pressure to the calipers, building on conventional hydraulic braking while enabling brake blending, automation and pedal decoupling.
- Electromechanical braking (EMB) removes hydraulic lines entirely, with each wheel using a local motor-driven actuator to apply clamp force directly at the brake caliper. Local MCUs, current sensing, position sensing and motor drivers precisely control the braking torque. Brake-by-wire systems commonly target ISO 26262 ASIL D at the system level. OEM safety goals may require redundant sensing, backup power, fault diagnostics and fail-operational strategies. Thermal design also presents a major challenge for EMB wheel-end actuators located near the brake rotor, where electronics must tolerate vibration, contamination and elevated temperatures. Designers may consider magnetic, inductive or resolver-based position sensing depending on temperature and reliability requirements.

In advanced brake-by-wire systems, the brake pedal functions primarily as a driver input device with artificial pedal feel generation, while electronics command actual braking force, enabling seamless integration of friction braking, regenerative braking and automated driving functions.

Active suspension: Predictive damping control and electronically controlled actuation

Active suspension is the application most commonly associated with ride comfort, but its value extends far beyond comfort alone. Modern active suspension systems improve vehicle stability, handling precision, body control and the passenger experience, while enabling premium differentiation for electric and software-defined vehicle platforms.

Rather than simply replacing conventional springs or dampers, active suspension adds electronically controlled actuation to traditional suspension architectures. Depending on vehicle segment and cost targets, these systems may include semiactive dampers, air suspension, adaptive dampers, electrohydraulic actuators, active antiroll systems or fully active motor-driven suspension designs.

Some platforms use magnetorheological damping technologies, where an applied magnetic field changes fluid characteristics to continuously vary the damping force.

By actively controlling wheel and body motion in real time, the vehicle can reduce pitch during braking, limit roll during cornering, improve stability over rough roads, and maintain a smoother ride, giving occupants better comfort and drivers improved confidence and control.

More advanced systems add predictive suspension control (see Figure 3). When paired with forward-looking cameras, radar, lidar or other road-preview sensors and navigation data, the suspension controller can anticipate bumps, curves or road transitions before the vehicle reaches them. The system can then preadjust damping force, ride height or body posture for a smoother driving experience.

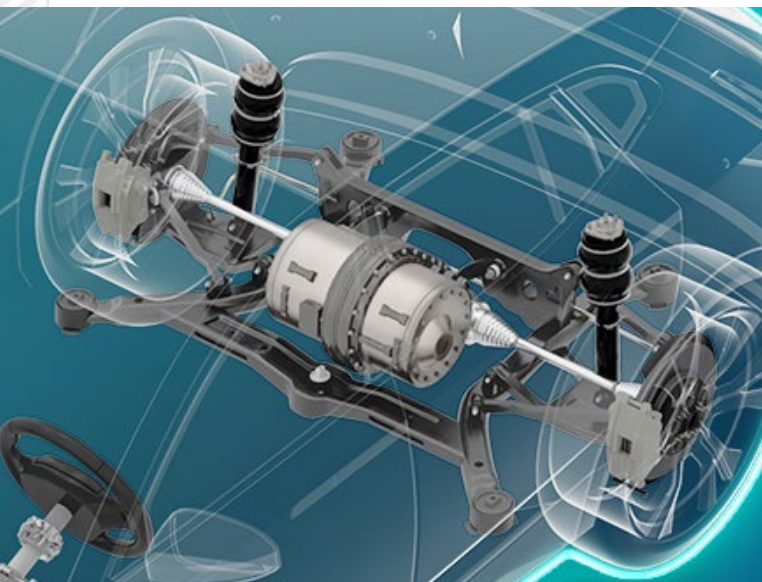


Figure 3. Active suspension systems can pre-adjust damping force or body posture for a smoother ride.

A typical architecture connects ride-height sensors, accelerometers, wheel-speed inputs and body-motion sensors to a real-time MCU or domain controller, which commands motors, valves, pumps or dampers through dedicated power stages

and communication networks. Functional safety requirements vary depending on system authority and failure impact, but reliability, diagnostics, thermal performance and fail-safe behavior remain important design considerations.

The intelligent chassis building blocks

Real-time motion-control systems, steer-by-wire, brake-by-wire and active suspension platforms share these five core technology building blocks, which must work together with deterministic timing, high reliability and functional safety:

- **Sensing.** Accurate and reliable sensing is fundamental to intelligent chassis control. Position, angle, torque and current sensing are widely used in steering and braking actuators, while wheel-speed sensing remains essential for brake control and vehicle stability functions. Pressure, temperature, acceleration and ride-height sensors may also be required, depending on the application. Because many chassis functions are safety-critical, sensor diagnostics, redundancy and environmental reliability are often design priorities. A portfolio of magnetic sensing, current sensing and precision analog technologies from Texas Instruments (TI) enables scalable sensing architectures across chassis applications.
- **Computation.** The generation of precise actuator responses requires real-time processing of sensor inputs, network data and control commands. Depending on the vehicle architecture, this processing may occur in local MCUs, zone controllers or centralized domain processors. Real-time performance is critical: some inner control loops operate in microseconds, while supervisory motion-control loops run in milliseconds. TI's real-time MCU portfolio, including C2000™ and Arm®-based automotive processors, help designers meet low-latency control, motor drive and functional safety requirements.
- **Actuation.** Intelligent chassis systems depend on efficient and precise actuation: motor drives for steering and braking, solenoid or valve drivers for hydraulic systems, and suspension actuators for ride and body control. As electric vehicle architectures evolve from 12V toward 48V and higher-power distributed systems, actuator electronics must deliver greater power density, thermal performance and diagnostic coverage. TI's motor drivers, gate drivers and power-stage technologies support compact and safety-capable actuator designs.

- **Power management.** Modern chassis ECUs require multiple regulated power rails for processors, sensors, networking integrated circuits and actuator drivers. Power devices also support startup sequencing, voltage monitoring, transient protection and fault reporting. TI's automotive power-management integrated circuits, DC/DC converters and power protection devices simplify power architecture designs while improving system reliability.
- **Communications.** Low-latency and reliable communications are essential for coordinating intelligent chassis functions across the vehicle. Common interfaces include CAN, CAN FD, Local Interconnect Network and Automotive Ethernet, depending on bandwidth and determinism requirements. As architectures become more centralized and software-defined, secure communication, network diagnostics and over-the-air update readiness are becoming increasingly important. TI's interface, networking and isolation solutions enable reliable in-vehicle communication architectures.

Together, these five building blocks form the complete signal chain that underpins every intelligent chassis application. Figure 4 shows a system diagram of an EMB actuator.

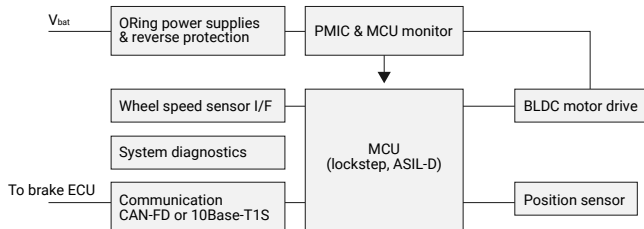


Figure 4. Simplified block diagram of an electromechanical braking actuator.

Conclusion

Intelligent chassis systems are rapidly defining the next-generation of vehicles. As steering, braking and suspension functions transition from mechanical systems to software-controlled, by-wire architectures, the chassis evolves from a passive structure into an active motion-control platform, improving comfort, responsiveness and safety while enabling higher levels of driving automation in the future.

The engineering challenges are significant – real-time control, compliance with functional safety requirements, thermal constraints and system integration – but it's possible to overcome these with the right combination of sensing, processing, power and communication technologies. Getting the building blocks right today will accelerate the path toward scalable SAE J3016 Level 4 autonomy and beyond, built on tomorrow's intelligent chassis hardware.

Additional resources

- Check out our [chassis control and safety page](#).
- Read the company blog, "[The intelligent chassis: The silent upgrade that's changing how cars move.](#)"
- For a deeper look at how ADAS perception, computation and communication feed into chassis actuation, read the white paper, "[From Detection to Decision: An Inside Look at Next-Generation ADAS.](#)"

About the author



Jerry Shi is the sector general manager for powertrain and chassis systems in automotive systems at Texas Instruments. With 25 years in the semiconductor industry and nearly a decade in automotive-electronics customer and market roles,

he brings a strong system-level perspective to traction inverters, onboard charging, DC-DC converters, brake- and steer-by-wire, and active-chassis technologies. Jerry works closely with OEMs and Tier-1 suppliers to enable scalable, production-ready vehicle platforms.

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