Powering the Future

Why 48V is Revolutionizing Robotics

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Introduction

Robotics is evolving at an incredible pace, with industrial automation demanding more powerful and efficient machines. This shift is driving a significant change in the electronics that power them, moving away from traditional 12V systems towards higher operating voltages, particularly 48V.

This transition brings a host of benefits that are crucial for modern robotics design, addressing the growing need for higher payloads, increased integration, and greater efficiencies to lower electricity bills and enhance productivity. It has become clear that the world of power in robotics and industrial automation is undergoing significant transformation. We are witnessing voltages change, and there's a growing presence of robotics in our daily lives, making it essential to understand the underlying technological shifts.

The Shift to 48V Power in Robotics

Meeting the Demand for Higher Power and Efficiency

The move to 48V offers compelling advantages for robotics designers, fundamentally impacting how manufacturers address solutions in the semiconductor world. A higher voltage translates directly to lower current for the same power output, which significantly reduces cable loss. This enables the use of lighter and thinner cables, leading to substantial savings on system costs and a notable improvement in overall efficiency.

Beyond just efficiency, 48V systems are inherently capable of supporting greater loads and achieving higher motor speeds, providing the necessary flexibility for demanding robotic applications that might require large payloads of up to 50 kilograms. This increased power and torque are vital for tasks where robots need to handle heavy objects or move with considerable speed. Furthermore, many modern 48V drivers are equipped with advanced features like adjustable gate current, empowering designers to fine-tune their systems to effectively minimize both radiated and conducted electromagnetic interference (EMI).

This fine-tuning capability is critical for ensuring compliance with regulatory standards and maintaining signal integrity in complex robotic systems. Crucially, integrated 48V solutions can lead to a lower overall Bill of Material (BOM) cost while simultaneously enhancing system reliability and robustness. These solutions are specifically designed to support functional safety and withstand harsh transients, making them ideal for rigorous industrial environments where reliability is paramount. The shift to 48V is a direct response to the macro trends in robotics, where the focus is on "smarter power," ensuring that the energy consumed is efficiently converted into useful work, thereby reducing electricity bills and minimizing thermal losses.

Higher voltage requirements for steady-state and transient operation

True 48V **voltage** drivers enable steady-state operation up to 80–100V and support negative transients down to -22V.

Large payloads from 1 kg to 50 kg

48V motor drivers deliver **power and torque**, increasing payload capacity by 4x for demanding tasks (P = IV).

Lower electricity bills

Improved **system efficiency** reduces current by 75%, cutting power loss by 16x ($P = I^2R$).

Minimal radiated and conductive EMI

Optimized **MOSFET switching** provides adjustable gate current, minimizing EMI for better performance.

System reliability & robustness

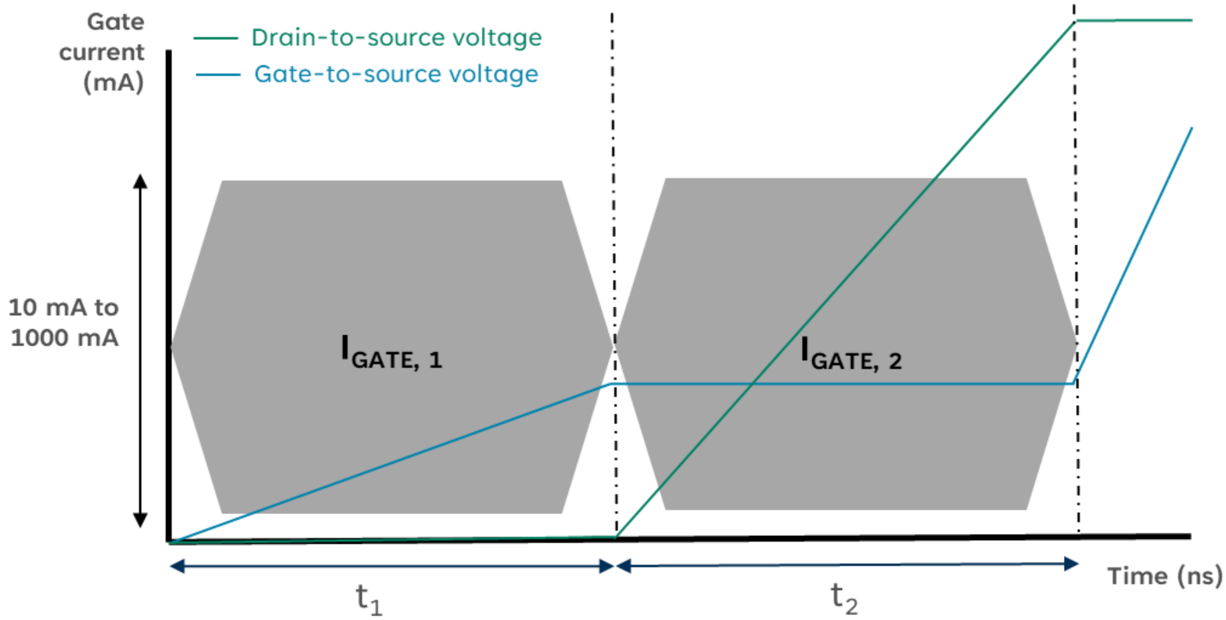
Designed for **functional safety**, supporting transients up to -18V with ISO/IEC diagnostics.

Simplified design & lower BOM cost

Integrated **power, control, sensing, and protections** reduce system complexity and component costs.

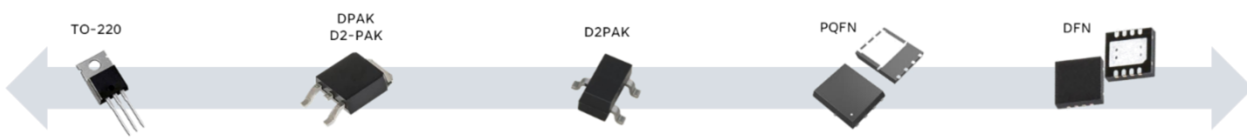
Optimizing Motor Control: The Slew Rate Balancing Act

Optimizing motor control is another critical aspect of modern robotics, and this involves careful consideration of the MOSFET slew rate and the chosen driver architectures. Controlling the MOSFET slew rate—which defines how fast the drain-source voltage switches—is absolutely vital for effectively managing EMI and optimizing power efficiency. When measuring the voltage across a MOSFET, it will transition from the battery voltage to zero volts, or vice versa, within a certain timeframe. This slew rate, if not properly managed, can lead to issues: switching too fast can cause higher EMI, while switching too slowly can result in significant thermal dissipation and power inefficiency. Therefore, precise control over the slew rate is optimal and depends heavily on the specific design requirements of the robotic system. The most effective way to control the slew rate is by managing how fast the MOSFETs switch, which is directly tied to the gate drive current.



The effect of adjustable gate current on MOSFET slew rate.

An adjustable gate drive current is a highly beneficial feature in modern driver ICs, whether they are half-bridge or three-phase drivers. This adjustability allows engineers to control the drive current, often through hardware settings or Serial Peripheral Interface (SPI), to precisely manage the MOSFET switching behavior and optimize the Miller Plateau. The Miller Plateau is a critical period during MOSFET switching when the drain-source voltage begins to slew. By controlling this plateau through adjustable gate drive current, designers can drive a wide variety of 48V MOSFETs, even those with varying QGD (gate-to-drain charge) values. While traditionally 48V MOSFETs had large QGD values, requiring significant gate drive current, advancements in 48V technology have led to smaller QGD values, reducing the need for excessive gate drive current. This flexibility allows for better optimization of efficiency and EMI performance across diverse MOSFET types.

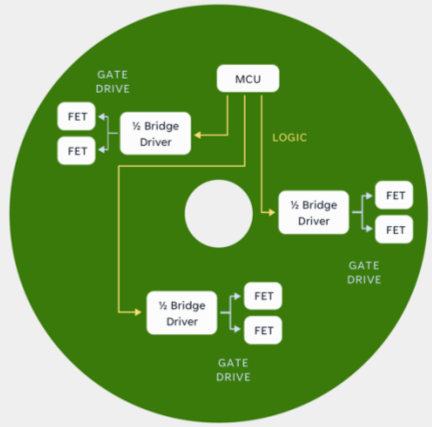


MOSFET packaging options require slew rate control for optimal efficiency.

When it comes to motor driver architectures, designers have distinct choices, each with its own trade-offs that impact performance, cost, and ease of layout. In many robotics applications, three-phase brushless DC motors are preferred due to their efficiency, longevity, and versatile control options for speed, torque, or position. For driving these motors, two primary architectures are commonly employed. One approach involves using half-bridge gate drivers. These can be strategically placed close to each motor phase on the PCB, which is a significant advantage. This proximity substantially reduces the signal trace lengths for gate drive signals from the half-bridge driver to the high-side and low-side MOSFETs. This reduction in length directly minimizes parasitic effects like ringing and overshoot, phenomena that often plague hardware designers. Ringing, for instance, occurs when switching an inductive load like a motor phase, causing oscillations in the switch node between the MOSFETs and the motor phase due to rapid turning on and off of the MOSFETs. By shortening trace lengths, half-bridge drivers lead to superior signal integrity and achieve low propagation delays, resulting in better overall performance. However, this approach might lead to a higher Bill of Material (BOM) cost due to the need for multiple half-bridge drivers.

Half-bridge Gate Drivers

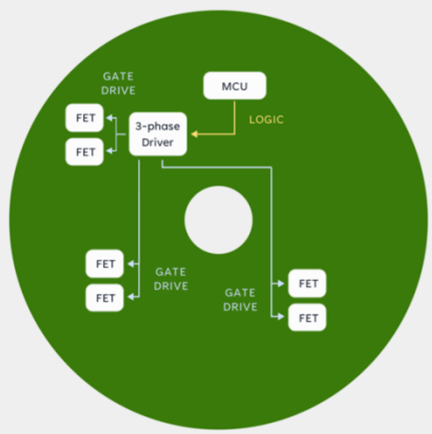
- Controls HS+LS MOSFET
- Reduces gate drive trace length, parasitics, and switch node ringing on donut-shaped PCBs
- Improves signal integrity & low propagation delay



On the other hand, a three-phase driver approach offers greater integration, typically consolidating the control for all three phases into a single IC, which can result in a potentially lower overall BOM cost. However, this architecture requires careful consideration of potential ringing and parasitics that may occur from longer gate traces, especially when the driver routes to three phases or six MOSFETs located across the PCB. The choice between half-bridge and three-phase drivers ultimately depends on the system designer's priorities, balancing factors like performance requirements, ease of PCB routing, and cost considerations. For instance, if minimizing ringing and achieving optimal signal integrity are paramount, a half-bridge solution might be preferred, even with a higher BOM. If cost and integration are the main drivers, a three-phase solution could be chosen, provided the designer can effectively manage the potential parasitic issues through careful layout and component selection.

3-phase BLDC Gate Driver

- Controls 6 MOSFETs
- Integrated power management & CSAs for lower BOM cost
- Phase-to-phase delay matching (<20 ns)



Regulations Driving Robotics Safety

Safety is paramount in robotics, and modern motor drivers integrate comprehensive diagnostics to address this critical aspect, ensuring both component protection and compliance with stringent industry standards. These diagnostics cover a wide range of conditions, such as overvoltage, undervoltage, and overtemperature, ensuring that all components in the system, including the MOSFETs and other external elements, are protected from potentially damaging conditions. The goal is to ensure that the entire system operates as intended, even under adverse circumstances. This integration of protection and diagnostics simplifies compliance with stringent safety standards such as UL 2595, ISO 13484, and IEC 61800. These standards provide robust guidelines for building safety into electronic devices, and by incorporating features that align with them, designers can significantly reduce the need for external components and complex safety circuits. This not only cuts down design time but also prevents costly field failures, such as shoot-through conditions where large currents can cause ICs to explode or PCBs to be severely damaged.

Regulations driving robotics safety

UL 2595 & UL 1740	ISO 13482 & ISO 10218	IEC 61508 & ANSI/RIA R15.08	IEC 61800-5-2
Battery-powered robots & robotic equipment	Industrial & personal robots	Functional safety & industrial mobile robots	Safe Torque Off (STO) for motor shutdown

Protecting Against Overvoltage, Shoot-Through, and Other System-Level Faults

A crucial aspect of these integrated diagnostics is their ability to self-check. This means the driver can verify that its own diagnostic and protection features are functioning correctly, eliminating the need for engineers to add external comparators and additional circuits to confirm the safety mechanisms.

For example, the driver can confirm that it will shut down correctly if an overvoltage condition is detected, providing an extra layer of assurance. Beyond just diagnostics, safety also involves rigorous verification and validation of the system's performance in real-world conditions. This includes testing against various noise sources, battery conditions, line voltage fluctuations, and motor-induced load dumps. Ensuring that the system meets its design requirements and operates safely in all these scenarios is critical for long-term reliability in harsh environments. While obtaining safety labels and certifications is important, it's equally vital to ensure that the system genuinely works as intended in the field, preventing dramatic failures. Examples from applications engineering experience highlight the dangers of shoot-through conditions in MOSFETs. These can occur when a sudden change in torque or force, such as a robot picking up a heavy package, causes a large amount of current spiking in the MOSFETs, leading to catastrophic failures like exploding ICs or damaged PCBs. The presence of robust internal diagnostics and protection features in the IC is therefore essential to avoid such field failures and ensure the longevity and safety of robotic applications.

Allegro MicroSystems offers a comprehensive range of true 48V half-bridge and three-phase brushless DC gate drivers specifically designed to meet the demands of these evolving robotic applications. Our portfolio includes half-bridge drivers like the AMT49502 and A89503, which are true 48V drivers with an impressive 80V absolute maximum rating. These devices are capable of controlling high-power MOSFETs, even those configured in parallel, to effectively drive large payloads. They come equipped with extensive diagnostics tailored for harsh environments, support challenging -18V transients, and offer a wide variety of integration features, including charge pumps and monitoring pins, simplifying overall system design. For smaller, more robust applications such as robotic joints and arms, Allegro offers the A89500, a compact solution in a 3x3mm footprint. Despite its small size, this driver can control powerful MOSFETs and includes functional safety quality management protection, making it suitable for applications that require a very small form factor without compromising on safety.

	AMT49502	A89503	A89500
Voltage	• True 48V capability (80V abs max)		• True 48V capability (100V abs max)
Power & Torque	• Up to 900nC MOSFETs		• Up to 1500nC MOSFETs
System Efficiency	• Higher motor speeds and torque, lighter cabling, and reduced conduction losses		• Low sleep current, lighter cabling
MOSFET Switching	• Adjustable gate current up to 1A peak		• Resistor-settable up to 5A peak
Functional Safety	• Functional Safety Compliant • Extensive diagnostics in harsh environments • Transients up to -18V		• Quality Managed (QM) • Transients up to -18V
Integration	• Charge pump regulator • 24 TSSOP package	• Charge pump regulator • Drain monitoring pin • 24 TSSOP package	• Int. Bootstrap diode • 10 DFN package (3x3mm)
Demo Boards	APEK49502KLP-03-T (3.3V I/O) APEK49502KLP-05-T (5.0V I/O)	APEK89503KLP-03-T (3.3V I/O) APEK89503KLP-05-T (5.0V I/O)	APEK89500GEJ-01-T

On the three-phase side, Allegro provides the AMT49100 and AMT49101, which are true 48V brushless DC drivers with high gate drive current capabilities. This allows them to manage a wide range of MOSFETs, ensuring versatility across different motor and load requirements. These integrated drivers are functional safety compliant, which are crucial for robust robotic systems demanding high levels of functional safety. They also support transients up to -18V, ensuring resilience against voltage fluctuations common in industrial settings. Furthermore, these three-phase drivers offer significant integration, including a buck regulator, a charge pump, and three low-side current sense amplifiers, all housed within a compact 7x7mm package. This high level of integration helps reduce BOM cost and simplifies PCB layout. Allegro's commitment extends beyond just providing components; we offer comprehensive support resources, including evaluation boards and documentation available on our product pages to assist engineers in their 48V designs. Our goal is to empower designers to build efficient, reliable, and safe robotic systems, providing the tools and support needed to embrace the future of 48V robotics with confidence.

	AMT49100	AMT49101
Voltage	True 48V capability (80V abs max)	
Power & Torque	Up to 300nC MOSFETs (FOC) Up to 900nC MOSFETs (Trapezoidal)	
System Efficiency	Higher motor speeds and torque, lighter cabling, and reduced conduction losses	
MOSFET Switching	Adjustable gate current up to 2A peak	
Functional Safety	Functional safety compliant Extensive diagnostics in harsh environments Transients up to -18V	
Integration	100mA DC/DC regulator Charge pump 3 low-offset CSAs with 7x7mm package	100mA DC/DC regulator Charge pump 2 low-offset CSAs 3.3V/5V LDO regulator 7x7mm package
Demo Boards	APEK49100JP-01-T	APEK49101KJP-A-03-T

Therefore, don't be afraid to embrace the future of robotics with 48V systems. While there might be pressure to save costs with traditional 12V systems, considering the long-term benefits of efficiency, power, and safety offered by 48V is crucial for future-proof designs. The necessary tools and support are already available to help you design for long-term efficiency, power, and safety, making the transition to higher voltage systems a strategic advantage in the rapidly evolving world of industrial automation and robotics.

To learn more about Allegro's 48V solutions and how they can power your next robotic design, visit our Robotics or 48V systems page.