

Revolutionizing eBike and Personal Mobility Motor Control with the A89212 System-on-Chip

Christoph Stangl
Product Marketing Manager
Allegro Microsystems



Introduction

As the world embraces sustainable transportation, eBikes/Pedelecs and personal mobility devices are experiencing unprecedented growth. It is projected that by 2028 the eBike market value will approach 50 billion USD¹. Allegro MicroSystems is at the forefront of this revolution, providing innovative semiconductor solutions that drive efficiency, reliability, and performance in these applications.

With increasing consumer demand for longer range, enhanced driving experience, and more compact designs, the need for advanced motor control solutions is continuously increasing. This white paper introduces the A89212 system-on-chip (SoC) motor controller, a highly integrated and robust solution designed to meet the evolving needs of mobility devices – ranging from pedal-assisted eBikes/Pedelecs to purely electrically driven e-Scooters or other personal mobility devices.

¹ <https://www.statista.com/statistics/1261084/global-e-bike-market-forecast/>

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The A89212: A Versatile System-on-Chip Motor Controller

The A89212 is a high-performance processor with an integrated three-phase gate drive unit and related peripherals. Designed for use with advanced stand-alone three-phase BLDC and PMSM motor control applications, the A89212 integrates an ARM Cortex-M4 CPU core running at 40 MHz, giving up to 50 MIPS performance. This capability is further enhanced by peripheral functions specifically designed for motor control applications, including a PWM generator and sense current capture systems capable of providing up to 12-bit control precision at up to 20 kHz PWM frequency.

Key Advantages of the A89212

The A89212 boasts a wide operating voltage range of 5.5V to 90V, providing exceptional flexibility for different battery cell configurations. This is particularly beneficial for eBike and personal mobility device manufacturers who need to support a variety of battery voltages in their product lines. By accommodating a broad range of battery cell configurations, the A89212 enables manufacturers to:

- **Reduce Development Costs:** A single motor control solution can be used across multiple platforms, minimizing the need for separate designs and reducing development time and resources.
- **Optimize System Performance:** The A89212's ability to operate at higher voltages allows for more efficient power delivery, improved motor performance and enhances mileage per battery charge.
- **Simplify Inventory Management:** A single device can support multiple product lines, streamlining inventory management and reducing the complexity of the supply chain.

High Integration for Miniaturization and BOM Savings

The A89212 is a highly integrated SoC that combines a microcontroller unit (MCU) equipped with a powerful ARM Cortex-M4 core and a gate driver unit (GDU) for voltage source inverter power switching. This high level of integration allows for significant miniaturization and BOM cost savings.

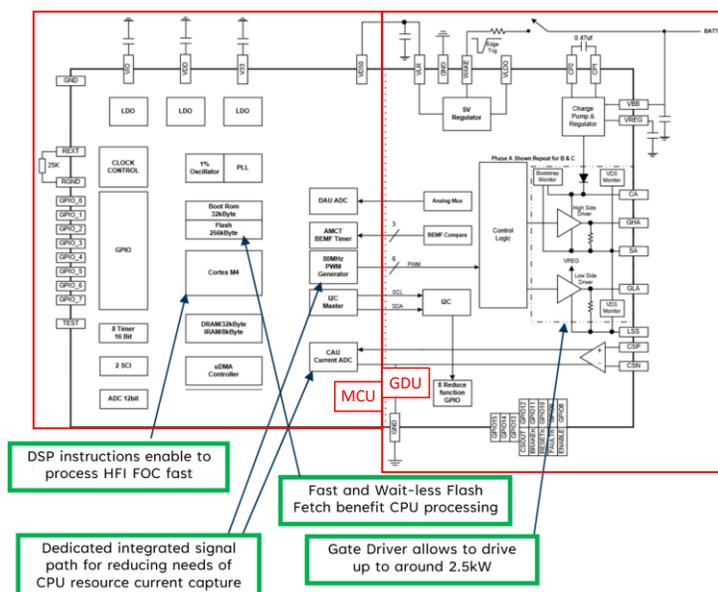


Figure 1. High level functionality blocks view

Key integrated components include:

- 40 MHz ARM Cortex-M4 CPU Core with FPU: Provides ample processing power and memory for advanced motor control algorithms. The Cortex-M4 processor core also offers a Single-precision Floating Point Unit (FPU) and DSP instruction set which accelerates math calculations, further enhancing motor control algorithm processing with minimal overhead.
- Integrated 3-phase Gate Driver unit (GDU) enables area savings on PCB and more compact overall Hardware design
- Leveraging from the expertise of Allegro in Power solutions, the GDU is designed as an N-channel power MOSFET driver capable of controlling MOSFETs connected on a three-phase bridge arrangement. It is specifically designed for power applications with high-power inductive loads, such as BLDC motors, which are becoming increasingly common across all industrial applications.
- To increase the functionality that the system may require, the GDU features 8 additional general purposes Input Output pins, allowing a versatility for their configuration, from analog input signals for sensor fusion/communication or for digital input/output command transmission/reception. Five of them have also default specific functionality spanning from fault flag detection to power-stage driver direct control to full power stage reset and brake mode for immediate motor stops (brake). This enhances the versatility and deployment of intelligent solutions for eBike powertrains.
- The GDU allows a power saving mode via a SLEEP mode, which will allow the MCU to stay active only, while the power stage is dormant, hence allowing additional power savings in the long run for battery powered systems. The GDU can be intelligently brought back to full active state by a dedicated I/O pin.
- By employing a single shunt resistor for the current sensing line of sampling, the A89212 minimizes the external component count, reducing both BOM costs and PCB area requirements. This streamlined approach simplifies design and enhances system reliability.
- Programmable high performance current sensing amplifier, located in the GDU, unlocks flexibility for difference current sensing range. The A89212's high-speed current acquisition, achieved in less than 1 μ s, enables precise, real-time motor control and minimizes the impact of PWM switching noise, resulting in smoother operation and improved performance. coupled with the current sensing amplifier delivers accurate current measurements for efficient motor control and protection with up to 12 bits resolution, employing up to 3 ADCs blocks.

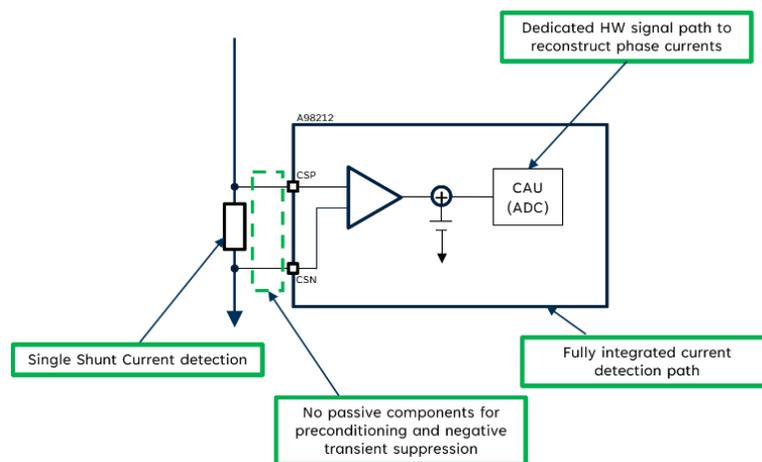


Figure 2. Single shunt and CAU sensing integration

- The Advanced Motor Control peripheral block in the microcontroller sub-unit offers specific HW features which enable the development of both sensed (Hall sensors reading) and sensorless solutions, dead-time compensation

via current direction detection and line voltage estimation in real time for further motor control performance enhancement. This latest feature helps greatly in detecting windmill or reverse windmilling conditions of the BLDC, allowing a speed/voltage estimation and an effective restart on-the-fly.

- PWM Generator: Enables precise control of motor speed and torque via dead time and two different options for inverter switches duty cycles updates, to maximize efficiency and smoothness of operation.
- Dual Serial Communication interfaces (SCI) via both UART and SPI facilitate seamless communication with other system components. This high level of integration reduces the bill of materials (BOM) cost, simplifies PCB layout, and enables compact designs.
- Versatility in functionality due to up to 8 General Purpose Input/Output Terminals
- Ample memory storage for SW deployment:
 - Up to 256kB Flash
 - 32kB DRAM
 - 8kB IRAM
 - 32kB Boot ROM

By integrating these essential components into a single chip, the A89212 enables manufacturers to create more compact and cost-effective motor control solutions.

The features of the full SoC guarantee an extremely efficient and high performing success in the implementation of standard FOC closed loop speed sensorless control, as well as more advanced techniques such as HFI (High-Frequency-Injection) speed and position detection. The latter are particularly useful for high-torque, low speed operational motor conditions. The A89212, coming into the market alongside with the optional Allegro proprietary motor control software enables unmatched control performance with very low overhead computational cost for the MCU.

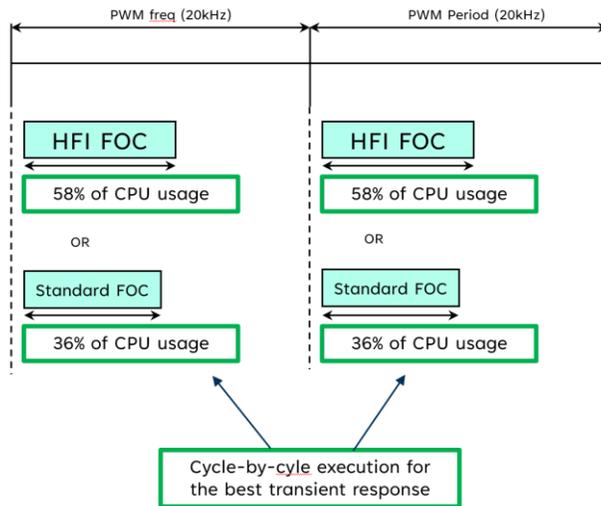


Figure 3. Allegro proprietary motor control SW performance on A89224 Soc

Robustness and Protection Features for Enhanced Reliability

The A89212 is designed to withstand the harsh environments common in eBike/Pedelec and personal mobility applications. Amongst others it boasts best-in-class negative transient protection down to -18V, built directly into the circuitry. This is crucial for eBikes, where large transient pulses can be common when switching MOSFETs controlling high-power motors, especially at start-up transients. This built-in protection can minimize the need for external components like additional snubber circuitry, saving board space and BOM costs. The gate driver is capable to provide functionality and operation down to a minimum of 6.5V. Furthermore, the A89212 incorporates a comprehensive suite of protection features and real-time diagnostic capability via communication between the gate-driver-unit and the microcontroller unit, safeguarding the system against potential faults and ensuring reliable operation even in harsh power tool environments. Some of the protection features include:

- **Overtemperature Protection (OTP):** The OTP circuit monitors the junction temperature of the A89212. If the temperature exceeds a predefined threshold, the OTP is triggered to prevent a thermal runaway and potential damage to the part and its surrounding components.
- **Overcurrent Protection (OCP):** OCP safeguards the A89212 and protects the system from damage due to excessive current, preventing component failures and ensuring safe operation.
- **Overvoltage Protection (OVP):** OVP protects the A89212 and the external MOSFETs from excessive voltage levels, which can occur due to voltage spikes, load dumps, or other transient events.
- **VDS Monitoring:** VDS monitoring detects faults on the external MOSFETs by monitoring their drain-source voltage (VDS). This allows for the detection of short circuits, open circuits, and other MOSFET failures.
- **Bootstrap undervoltage (BU):** boot – strap undervoltage is detected in case of bootstrap capacitors not reaching a sufficient charging state.

In addition to these integrated protection features, the A89212's wide supply voltage range (up to 90V) and transient support (down to -18V on motor terminals) further enhance system reliability by providing tolerance to voltage fluctuations and transient events.

Applications in eBikes and Personal Mobility Devices

The A89212 is ideally suited for a wide range of eBike and personal mobility device applications, including:

- **eBikes / Pedelecs:** The A89212 can be used to control the motor in eBikes – typically in a pedal-assisted operation mode - providing precise torque control, efficient power delivery, and robust protection. Its wide operating voltage range makes it compatible with various eBike battery systems. **A single A89212 based design can be scaled across multiple e-bike classes from Class 1 to Class 3. Engineers must navigate distinct platform requirements including:**
 - **Hub-Drive Platforms:** These platforms are common in commuter bikes and require ultra-compact electronics that can fit inside the front or rear wheel hub itself, demanding high thermal efficiency and minimal component count.
 - **Mid-Drive Platforms:** Used in high-performance bikes, these leverage the bike's gears for high torque and efficiency. They require sophisticated control algorithms to manage high RPMs and seamless torque delivery.

- **e-Scooters:** The A89212 is also well-suited for a range of e-scooters including **performance, three-wheel, offroad and seated e-scooters** - typically fully electrically driven - offering similar benefits as in eBikes. Its compact size and high integration make it ideal for the space-constrained designs of e-scooters.
- **Other Personal Mobility Devices:** Thanks to its flexibility, the A89212 can be used in a variety of other personal mobility devices, such as electric skateboards, mobility scooters, and electric wheelchairs.

In these applications, the A89212 enables manufacturers to achieve:

- **Increased Range:** By optimizing motor control and power delivery for greater efficiency, the A89212 helps to maximize the range of eBikes and personal mobility devices.
- **Enhanced Safety:** The A89212's integrated protection features ensure safe and reliable operation, protecting both the device and the user.
- **Improved Performance:** The A89212's precise motor control capabilities enable smooth and responsive performance, enhancing the overall riding experience.
- **Transient Protection:** This device features protection against negative transients down to **-18V. This is critical for preventing driver failure during high-current switching events common in high-torque climbs or regenerative braking.**

Competitive Advantages

While several motor control solutions are available on the market, the A89212 offers a unique combination of features and benefits that set it apart from the competition. Key competitive advantages include:

- **Wider Operating Voltage Range:** The A89212's 5.5V to 90V operating range is wider than many competing solutions, providing greater flexibility in battery cell configuration.
- **Higher Integration:** The A89212 integrates more components than many competing solutions, reducing the need for external components and minimizing BOM costs.
- **Robust Protection Features:** The A89212's comprehensive suite of protection features ensures reliable operation in harsh environments.

Conclusion

The A89212 system-on-chip motor controller is an ideal solution for eBike and personal mobility device manufacturers who are looking for a high-performance, highly integrated, and robust motor control solution. With its wide operating voltage range, integrated protection features, and automotive-grade quality, the A89212 enables manufacturers to create more efficient, reliable, and cost-effective eBikes and personal mobility devices.

