Technical Article

How advanced current and voltage sensing enable ultra-precise robotics

Kia Rahbar

Imagine a humanoid robot attempting to thread a needle, or a collaborative robot (cobot) handling fragile items in a food processing plant. The slightest miscalculation will cause it to miss its mark.

Precision is everything in robotics. Advancements in current- and voltage-sensing technology are leading to significant improvements in a robot's ability to handle intricate tasks with faster torque response, resulting in smoother, human-like motions. And functionally isolated converters are giving robots more precise motor control in smaller designs, enabling them to be smarter, safer and more efficient.

As robots such as <60V autonomous mobile robots and humanoids take on increasingly complex roles, they need to operate longer and with improved power efficiency. Accurate current- and voltage-sensing measurements have a direct impact on precision and fast torque response times, in turn enabling robots reach their position and orientation faster and more precisely. Nanoseconds matter when it comes to enabling safe navigation and performing sudden tasks such as reacting to changes in load or environmental conditions. These measurements provide the robot's control system with real-time data, enabling the robot to instantly adjust its actions and maintain precision during ongoing tasks. Figure 1 shows how current- and voltage-sensing accuracy helps robots to be more precise.

Figure 1. Current- and voltage-sensing accuracy impacts how precise robotics can perform tasks

The need to improve sensing capabilities

Despite the benefits that voltage- and current-sensing solutions can bring to today's robotic systems, higher-performance sensing has many challenges. The most prevalent challenge is how to perform accurate, low-noise measurements of the current and voltages being provided to the motor. In robotics systems today, three-phase inverters operate at low current or voltage levels, and generate transient noise that can interfere with the accuracy of existing non-isolated sensor measurements.

Slower torque response and less precise motion can present significant challenges when designing robots with fine motor skills that are required to perform intricate tasks in a very smooth and controlled manner.

Another challenge facing design engineers is that many robots, including mobile robots, are battery-powered, making it difficult to optimize energy efficiency while maintaining performance. Insufficient power can additionally lead to system failures, limited task duration and higher operational costs.

Along with the performance challenges, there is limited space for additional sensing circuitry in compact humanoid robots. Integrating current- and voltage-sensing circuits without significantly increasing the size of the module or the weight of the system can be a big challenge.

Isolation between the power and control circuits in the high- and low-voltage domains is required when engaging in robotic design. Protection against short-circuit events or overvoltage conditions requires detection of these faults quickly and accurately to prevent damage to other components.

Achieving precise current and voltage measurements

To overcome the design challenges of traditional robotic designs, TI's functionally isolated converters enable designers to achieve smooth torque operation and precise motor control, while maintaining small size and low cost in compact <60V designs.

The AMC0106M05 and AMC0106M25 functionally isolated delta-sigma current-sensing modulators, as well as the AMC0136 functionally isolated voltage-sensing modulator, can achieve more precise current and voltage measurements. These devices have 12 to 14 effective number of bits (ENOB) as shown in Figure 2, compared to today's eight- to 11-bit analog solutions. This increase in measurement precision enables improved measurements of low current and voltage levels for delicate robot tasks and movements.

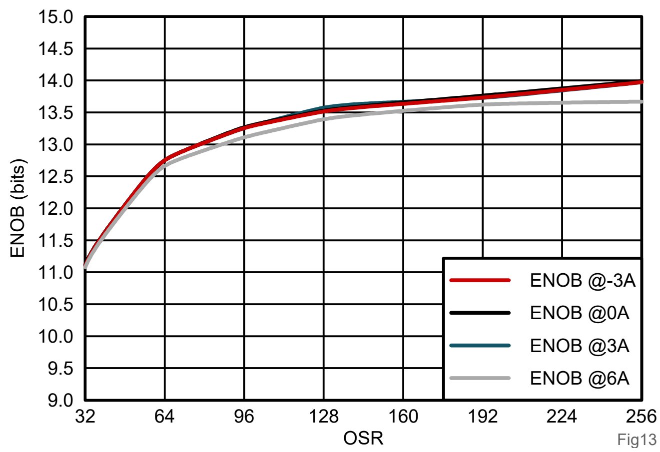

Figure 2. Increased ENOB and oversampling ratio help reduce noise and improve resolution

The galvanically isolated modulators improve noise immunity and system-level offset drift with a high common-mode transient immunity (CMTI) of 150V/ns. A digital interface ensures that pulse-width modulation switching does not impact measurement accuracy. These features enable robotic designers to use fast switching speeds of 50V/ns or more for high-efficiency gallium-nitride motor designs. The high CMTI additionally prevents data corruption and performance degradation by reducing the risk that noise from power ground will interfere with the microcontroller when switching the gates.

Along with the performance benefits enabled by functionally isolated modulators, these devices enable a >50% reduction in sensing solution size compared to other reinforced isolated modulator solutions, thanks to a 3.5-mm-by-2.7-mm package (see Figure 3). This smaller form factor also allows for smaller printed circuit boards (PCBs) to enable smaller robots.

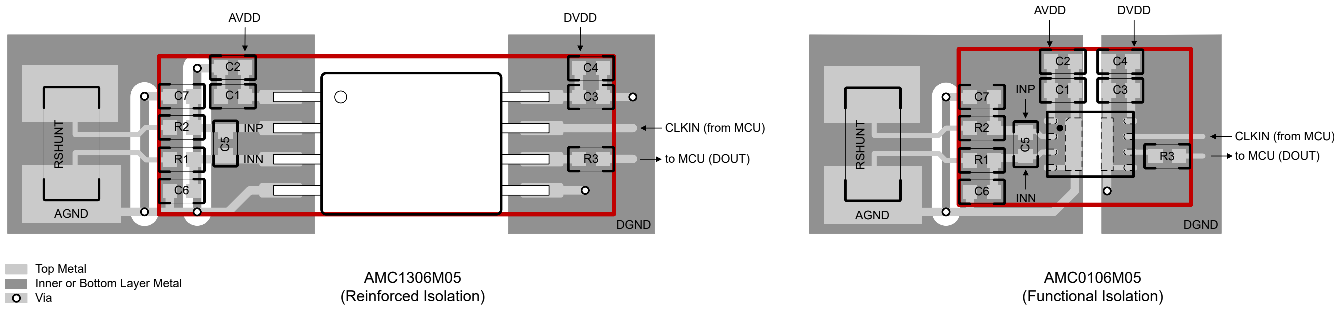

Figure 3. The AMC0106M05 reduces PCB solution size by 50%

For protection against faults such as short-circuit events or overvoltage conditions, the AMC21C12 functionally isolated comparator helps enable a 290ns response time. This speed of fault detection can help prevent damage to other components in the system by shutting down the gate drivers quickly.

Conclusion

With expected advancements in functionally isolated sensing and high-speed torque response, one can only imagine the future possibilities for robots. They may perform advanced microsurgeries or assemble tiny electronics at high speeds. Autonomous mobile robots could navigate more efficiently in complex environments; cobots could work more safely in assembly lines; and humanoid robots might conduct complex repairs, or even do laundry.

Additional resources

- The application note, *High-Resolution, Small-Form-Factor Phase Current Sensing for 48V Robotics and Servo Drives* explains how to design an accurate and reliable shunt-based current-sensing subsystem
- Check out our latest GaN-based robotic reference design: 48V/16A Small-Form-Factor Three-Phase GaN Inverter Reference Design for Integrated Motor Drives (TIDA-010936)
- See our new high-power robotic reference design: 48V, 4kW Small-Form-Factor Three-Phase Inverter Reference Design for Integrated Motor Drives (TIDA-010956)
- Learn more about our portfolio of isolated amplifiers, modulators, and comparators with *An Engineer's Guide to Isolated Signal Chain Solutions*
- Purchase our DIYAMC-0-EVM Universal Do-It-Yourself (DIY) Isolated Amplifier and Modulator Evaluation Module to evaluate these new devices

Trademarks

All trademarks are the property of their respective owners.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265