

# How to Achieve Precise Motion Control in Industrial Drives

---



Zhenyu (Zhen) Yu

This article is part one of our motion control technical article series ([part two](#) | [part three](#))

When riding in an elevator, I'm sure you expect a smooth and safe ride from one floor to the next. In an elevator drive, precise motion control enables the elevator to stop at specified positions and to slow down to a full stop smoothly. A lack of precise motion control could result in the elevator stopping at misaligned positions versus building floors, causing those inside to feel dizzy or unsafe.

Robotics, computer numerical control machines and factory automation equipment all require precise position control (and in many cases precise speed control) from their servo drives in order to manufacture products correctly and maintain workflows.

Many aspects of an industrial drive are important to precise motion control, encompassing all three foundational subsystems of real-time control designs, from sensing to processing to actuation. In this article, I will discuss examples of enabling technologies for each subsystem.

---

## Motion control technical article series - Part two



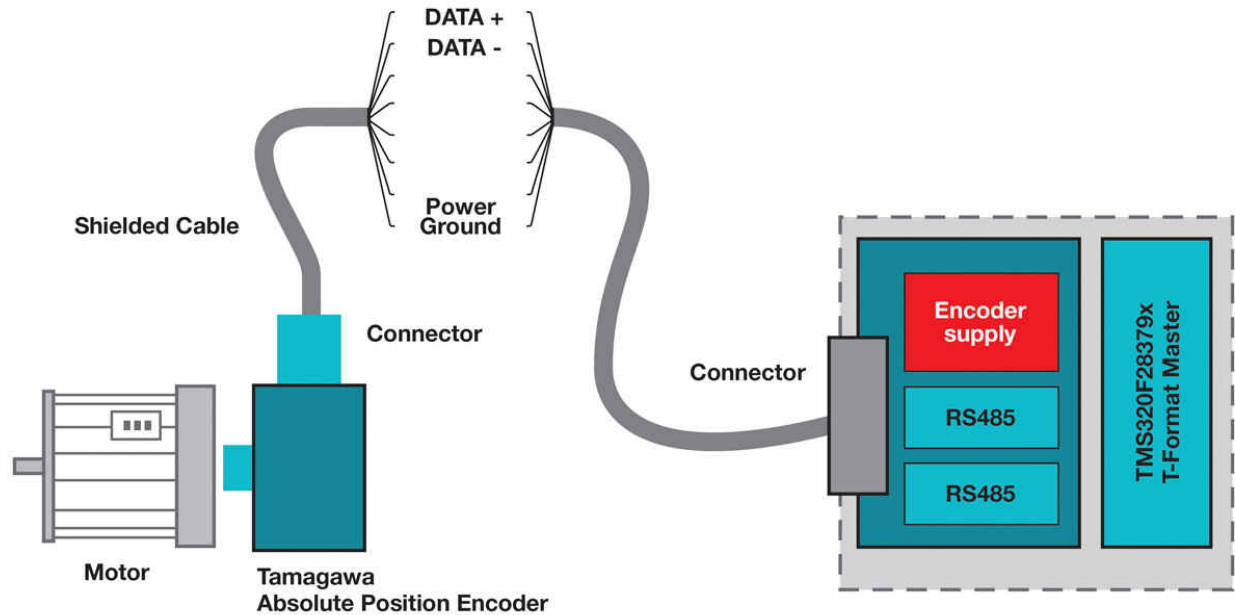
Read part two of our motion control technical article series, "[Top 3 ways to reduce audible noise in motion control applications.](#)"

---

## Sensing

It's not possible to achieve precise motion control without precise position and speed sensing. Sensing can include motor shaft angular position and speed sensing or conveyor linear position and speed sensing. Designers often implement incremental optical encoders, which have anywhere between a few hundred to a thousand slots per revolution, in order to sense position and speed. These encoders typically interface to a microcontroller (MCU) through quadrature encoded pulses (QEPs), and thus require QEP interface capabilities.

Significantly higher-precision absolute encoders typically have a much higher count of slots per revolution and are precision mounted to provide the absolute angular position. The sensed position is converted to a digital representation and encoded per standard protocols. Examples of such protocols are the T-format by Tamagawa and Bidirectional Serial Synchronous (BiSS) C by iC-Haus GmbH. Until recently, you would have needed field-programmable gate arrays (FPGAs) to interface to such encoders, but it's now becoming common for microcontrollers (MCUs) to have the same capability, as shown in [Figure 1](#). Since the T-format and BiSS C protocols are typically not the same as what's supported by popular communication ports or interfaces like Serial Peripheral Interface (SPI), universal asynchronous receiver transmitter (UART) or Controller Area Network (CAN), that are found on most MCUs, they often require customizable logic blocks or proprietary processing units.



**Figure 1. An Absolute Encoder Interfaced to a TI Control MCU**

Absolute encoders can also be based on electromagnetic- or resolver-like circuits, requiring accurate measurement of electrical sinusoidal signals. Therefore, precision operational amplifiers and voltage references are also important. Precision motor current and voltage sensing are always required for motor and motion control, particularly when adopting sensorless control. Inline and inverter leg low-side sensing using isolated or non-isolated amplifiers and drivers with integrated low-side current sensing are popular solutions.

## Processing

The execution of motion control profiles and algorithms in a precise motion control system requires MCUs with high computational power. In order to deliver the necessary precision and accuracy, such MCUs are typically 32 bits in word length, with native 64-bit floating-point support. Because algorithms heavily rely on trigonometric, logarithm and exponential math, many MCUs have hardware accelerators.

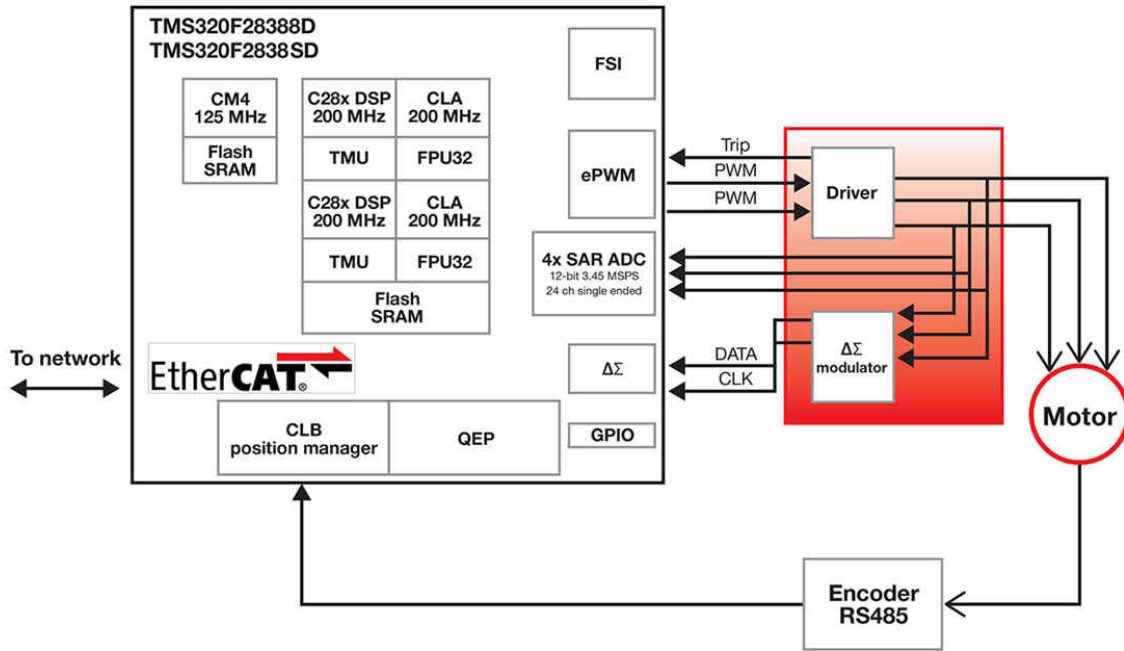
Given the number of motion axes controlled or the number of control loops, designers frequently adopt a multiple central processing unit (CPU) architecture or parallel, CPU-like accelerators. Additional supervisory and communication tasks can also be a good reason to implement multiple CPUs.

Being a real-time control application, the total latency of the whole signal chain – from the collection of current, voltage, position and speed measurements to the updating of control outputs – directly affects the control performance, which can in turn impact precision. Some MCUs have on-chip analog comparators to directly generate control actions, greatly reducing latency and CPU burdens. Fast interrupt response and context saving and restore are also important.

Just having high processing power is not enough. Motion control MCUs must also have common control peripherals such as 12- and 16-bit analog-to-digital converters, QEP interfaces, high-resolution edge and pulse capture, and pulse-width modulated (PWM) outputs. The ability to implement custom logics and timing sequences is also a requirement.

To help designers get started and tune their designs faster, MCU and motor-driver vendors provide motor and motion control algorithms, including core algorithms such as sensorless observers and software libraries and full control code with GUI configurability.

[Figure 2](#) is a conceptual illustration of a control MCU for an industrial drive.



**Figure 2. An MCU for an Industrial Drive**

### Actuation

Delivering the intended control action requires power devices and [drivers](#), typically in the form of PWM with the duty ratio representing the action. It's important to precisely control the PWM pulses, which means that drivers must deliver the necessary drive strength with minimal timing skew; power devices must turn on and off at the exact intended time. Such drivers are widely available today, with additional features such as overcurrent and overtemperature protection. The latest wide-bandgap power devices can ensure fast and precise turn-on and turn-off timing. The fast switching speed and low switching loss of wide-bandgap devices also allow fast control loop speeds for increased stability and performance.

In addition to precision, many applications require compact motor control designs, necessitating drivers with integrated current sensing and power modules.

### Conclusion

Precision motion control is critical for industrial drives. Technological solutions encompassing all three fundamental subsystems of a real-time control design, from sensing to processing to actuation, are employed to enable precision motion control.

### Additional Resources

- Learn more in the e-book, [“C2000™ MCU DesignDRIVE Solutions for Industrial Motor Drives.”](#)
- Download the [Distributed Multi-Axis Servo Drive Over Fast Serial Interface \(FSI\) Reference Design](#).
- Read the application note, [“FSI Bandwidth-Optimization for Multi-axis Servo Control.”](#)
- Read the application note, [“Optimized Trigonometric Functions on TI Arm Cores.”](#)
- Check out the technical article, [“Factory automation design made simple with multiprotocol industrial Ethernet systems.”](#)
- Read the application note, [“Industrial Communication Protocols Supported on Sitara™ Processors and MCUs.”](#)

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2023, Texas Instruments Incorporated