

Simple interfacing to analog and digital position sensors for industrial drive control systems



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Introduction

In many respects, system designers of industrial drive control systems, such as robotics and other applications involving servo and brushless motors, have to expend considerable time and effort developing, integrating and testing many of the control and connectivity building blocks—those “glue” elements—that go into their systems. This can cause many challenges such as lengthier development cycles, a larger board area or a higher bill of materials (BOM) cost. Due to this, these developers are unable to concentrate on differentiating features like enhanced performance, greater precision and improved control loops.

A particular example of this is the task of interfacing microcontrollers (MCUs) to position sensors. These sensors can be linear, angular or multi-axis and typically are used to sense the relative or absolute position of a mechanical system in motion, propelled by a motor. The sensed position is then converted to an analog or digital electrical signal for transmission to the controlling circuit.

Historically, interfacing a position sensor to an MCU could be a time-consuming task that often involved the integration of the communication protocol into a field programmable gate array (FPGA) or the programming of an additional MCU with the decode protocols. In addition, this situation is exacerbated by the fact that there are multiple encoder protocols available, each suited to certain types of functionality and subsystems. The system design team might be forced to develop several protocol-specific FPGAs which would not scale effectively from one application to another. Of course, this type of FPGA implementation would add cost to the system by increasing the system’s electronic BOM, impacting the necessary board space and requiring lengthy development cycles. Moreover, developers also have to complete extensive compliance testing to certify conformance with industry standards.

This situation begs for a solution that would simplify the interfacing of position sensors to control elements in industrial drive systems and thereby free designers to concentrate on features and functionality that would make their systems truly distinctive, as well as more competitive, in the marketplace.

TMS320F2837xD		Temperatures		105C	125C	Q100
Sensing		Processing		Actuation		
ADC1: 16-bit, 1.1-MSPS. 12-bit, 3.5 MSPS		C28x™ DSP core		12x ePWM Modules (Type 4)		
ADC2: 16-bit, 1.1 MSPS. 12-bit, 3.5 MSPS		200 MHz		24x Outputs (16x High-Res)		
ADC3: 16-bit, 1.1 MSPS. 12-bit, 3.5 MSPS		FPU		Fault Trip Zones		
ADC4: 16-bit, 1.1 MSPS. 12-bit, 3.5 MSPS		TMU		3x 12-bit DAC		
8x Windowed Comparators w/Integrated 12-bit DAC		VCU-II		Connectivity		
8x Sigma Delta Interface		CLA DSP core		4x UART		
Temperature Sensor		200 MHz		2x I2C (w/true PMBus)		
3x eQEP		Floating-Point Math		3x SPI		
6x eCAP		6ch DMA		2x McBSP		
Configurable Logic Block		Memory		2x CAN 2.0		
4 Tiles		Up to 512 KB Flash		USB 2.0 OTG FS MAC & PHY		
Position Manager: Flexible Absolute Encoder Interface		Up to 102 KB SRAM		uPP		
System Modules		2x 128-bit Security Zones		Power & Clocking		
3x 32-bit CPU Timers		Boot ROM		2x 10 MHz OSC		
NMI Watchdog Timer		2x EMIF		4-20 MHz Ext OSC Input		
192 Interrupt PIE				Debug		
				Real-time JTAG		

Figure 1: A closer look at the C2000™ dual-core F28379D MCU with DesignDRIVE Position Manager technology

Integrating position feedback

Building on the C2000™ Delfino™ MCU portfolio, Texas Instruments provides a comprehensive platform for industrial drive and control systems. Starting with the processing capabilities required by sophisticated and precise control systems, the C2000 family of MCUs are equipped with a full complement of on-chip resources, including **DesignDRIVE Position Manager** technology supporting today's most popular off-the-shelf analog and digital position sensor interfaces. This relieves system designers from many of the more basic, repetitive tasks, saving design time.

TI has extensive expertise with interfacing position sensors to digital controllers. Beginning with standalone interface solutions for resolver-to-digital solutions, such as the **TMDSRSLVR**, TI has continued to add to its position feedback interface support. Expensive resolver-to-digital chipsets have been replaced by C2000 MCU on-chip capabilities, leveraging high-performance analog-to-digital

converters (ADCs) and digital-to-analog converters (DACs). Moreover, the powerful trigonometric math processing of C2000 MCUs is particularly well-suited to the additional processing needed to calculate the angle, and extract high-resolution speed information from a resolver's amplitude modulated sinusoidal signals.

Many C2000 MCUs support enhanced quadrature encoder pulse (eQEP) modules that are capable of interfacing with linear or rotary incremental encoders. These encoders count pulses to obtain position (once an index is known), direction and speed information from rotating machines used in high-performance motion and position control systems. In addition, the eQEPs can be employed to interface to pulse train output (PTO) signals generally output by a programmable logic controller (PLC) in industrial automation for motion control. Also, eQEPs can interface to clockwise/counter clockwise (CW/CCW) signals. CW/CCW signals are typically used in conjunction with stepper or servo drives for controlling motors or other motion-based hardware. C2000 MCUs support up to three eQEP modules.

Resolver and QEP capabilities provide fast, efficient and integrated solutions for effectively interfacing position sensors with C2000 MCUs. The next step has been to extend that support with complementary solutions that would allow the MCU to connect directly to more advanced digital and analog position sensors.

DesignDRIVE Position Manager technology

Available through TI's DesignDRIVE platform, Position Manager technology takes advantage of the on-chip hardware resources of the C2000 MCUs to interface to the most popular digital and analog position sensors. Already incorporating support for incremental encoders (eQEP), CW/CCW communications and standalone resolver solutions, Position Manager adds solutions for analog position sensing, integrating both resolver excitation and sensing, as well as a SinCos transducer manager. Unique to C2000 MCUs, Position Manager combines the analog sensor support with popular digital absolute encoders, giving system designers a wide range of position sensor types to choose from.

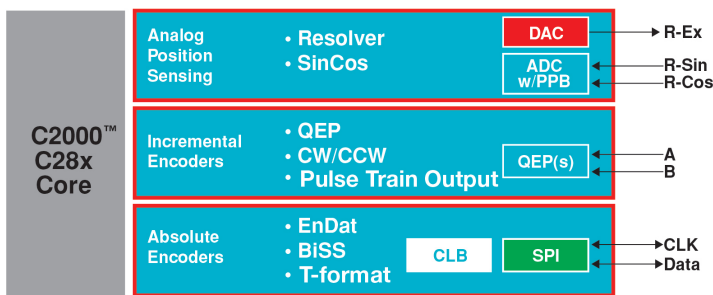


Figure 2: DesignDRIVE Position Manager technology supports the leading analog and digital position sensors

This integrated Position Manager technology offers system designers a real opportunity to accelerate development cycles and reduce BOM costs by eliminating the need for an FPGA to interface a specific encoder to the MCU or by drastically

reducing the size of the FPGA that may still be needed for other functions. The illustration below demonstrates how Position Manager technology relieves system designers from the burden of developing the high- and low-level software drivers, as well as any custom hardware and logic that previously may have been implemented on an external FPGA. In addition, example closed-loop, position-sensor-based control projects downloaded from **C2000WARE-MOTORCONTROL-SDK** can be modified for integration into customer projects. The lower system layers are provided on-chip or through reference designs and a ready-to-use library of application programming interface (API) modules.

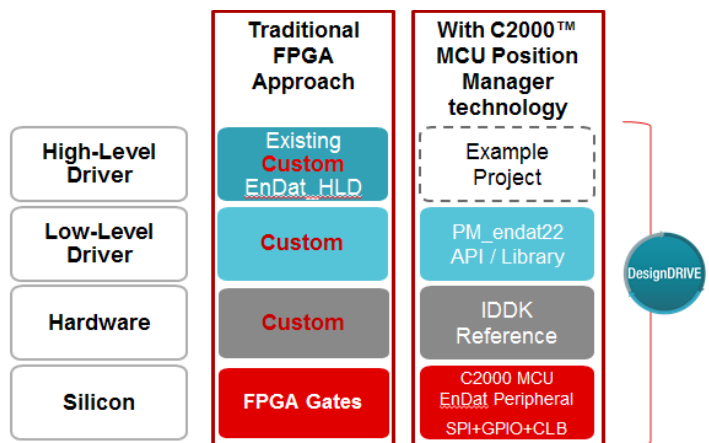


Figure 3: EnDat 2.2 solution example: Stackup vs. FPGA

Absolute encoder techniques are enabled by the Configurable Logic Block (CLB) peripheral. The **CLB** enables customization in a microcontroller based real-time control system while eliminating or reducing the size of the FPGA, CPLD, or external logic. Each CLB tile consists of look up tables, finite state machines, counters, output look up tables, and a high level controller (HLC). There are up to 8 of these CLB tiles on a given device and the tiles can be used independently or combined for more complex functions. The CLB is programmed through a free GUI based plug-in for TI's Code Composer Studio and includes logic simulation

and a visualization tool for verification. The CLB programming tool is available in C2000Ware and absolute encoder system examples that use functions created using this CLB configuration tool are released in the C2000Ware Motor Control Software Development Kit.

In addition to reducing development time, Position Manager technology also decreases the compliance and interoperability testing that system manufacturers have undertaken in the past. The Position Manager technology is fully tested across a variety of sensors. Please see the **user's guides** for details on the testing results. Moreover, future revisions and updates to the applicable standards will also be supported by Position Manager technology.

New position sensor interfacing capabilities

With its rich heritage of position feedback technologies as a starting point, TI has been able to expand its position sensor interface solutions with enhanced capabilities and performance. The following are several recent additions to TI's capabilities through DesignDRIVE Position Manager technology.

SinCos

SinCos is a feedback methodology which is incorporated into encoder interfaces like Hiperface[®] as well as other proprietary interfaces. These so-called sinusoidal absolute encoders typically offer much higher position and speed resolutions than do resolver or incremental encoders. In conventional quadrature encoders, angle information is obtained by counting the edges of a pair of quadrature pulses. Angular resolution is fixed by the number of pulses

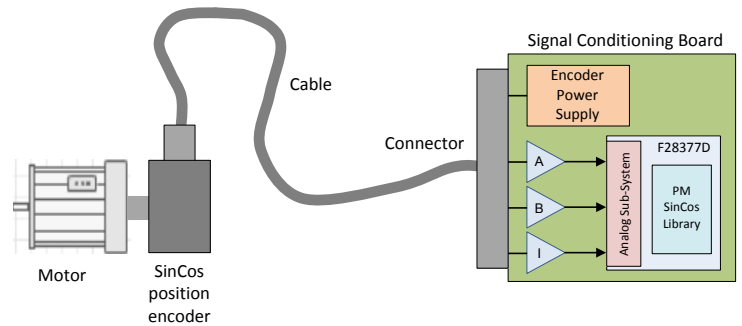


Figure 4: Industrial servo drive with SinCos position encoder interface

per mechanical revolution. However, in SinCos transducers, precision of the angular measurement is increased by computing the angle between edges using the relationship between a pair of sine and cosine outputs from the sensor. Effectively, an interpolation between edges is made to obtain a "fine" angle. The fine angle is computed using an arctangent of the two sinusoidal inputs. For this computation to be valid, both inputs must be sampled simultaneously. Typically, several thousand electrical revolutions of the sinusoidal signals occur during each mechanical revolution of the encoder shaft.

The internal analog sub-system of C2000 MCUs is ideal for interfacing to SinCos transducers. The presence of multiple ADCs, which can be triggered from the same source, allows simultaneous measurements of both input channels. In addition, the latest C2000 MCUs include a native ARCTAN instruction as part of the Trigonometry Math Unit (TMU) which means the angle calculation can be done in as little as 70 nanoseconds!

Another consideration is the high motor shaft speed state. In this case, there is no longer a need for precise angle information and the measurement algorithm only needs to count the number of complete sinusoidal revolutions to determine a "coarse" angle measurement. Typically, this is done using a pair of analog comparators which compare the incoming sinusoids with a threshold representing

the zero crossing point. The comparator outputs correspond to the sign of each sinusoid and the resulting digital signals are similar to those produced by a quadrature encoder. On the latest C2000 MCUs, there are up to eight pairs of analog comparators, each with its own programmable threshold voltage. These allow the quadrature pulses to be generated which are then fed *internally* to one of the on-chip quadrature encoder peripheral (QEP) modules for coarse angle and speed measurements.

EnDat

EnDat is a digital bi-directional four-wire interface developed by the German company, HEIDENHAIN. A sensor with an EnDat encoder can communicate position values, transmit and update information stored in the encoder, or save the information. Data is sent along with clock signals. The C2000 MCU can select the type of data the encoder will transmit, including position values, parameters, diagnostics and others.

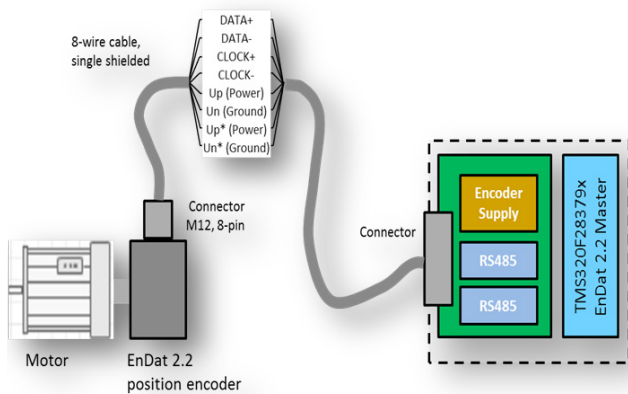


Figure 5: Industrial servo drive with EnDat 2.2 position encoder interface

Position Manager technology interfaces the C2000 MCU directly to the EnDat encoder (Figure 5). The only components external to the MCU are two RS-485 transceivers and the encoder power supply circuit. The EnDat Master is implemented using the C2000 MCU's configurable logic block, where the communication protocol is handled. Position Manager technology has been tested against a range of rotary, linear and multi-turn encoders from HEIDENHAIN and across resolutions from 13 bits to 35 bits at distances of 70 meters or more.

BiSS-C

The open source BiSS (bi-directional/serial/synchronous) digital interface is based on a real-time communications protocol. The original specification was developed by iC-Haus GmbH of Germany. BiSS-continuous mode (BiSS-C) is employed in industrial applications. The specification has its roots in the Synchronous Serial Interface (SSI). The BiSS-C interface consists of two uni-directional or bi-directional lines for the clock and data.

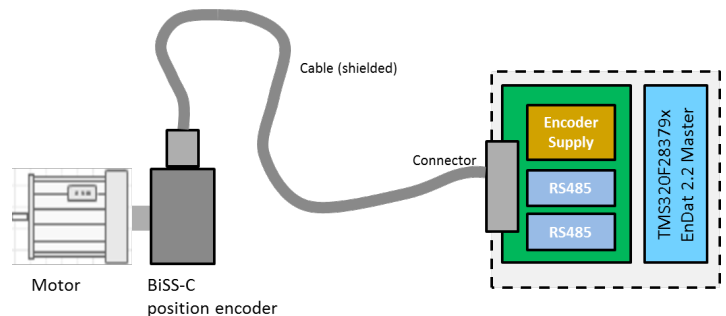


Figure 6: Industrial servo drive with BiSS-C position encoder interface

As with all interfaces supported by Position Manager technology, a BiSS-C master running on a C2000 MCU can connect directly to a BiSS-C encoder slave on a position sensor (Figure 6). The interface transmits position values and additional information directly from the encoder to the MCU. The MCU is able to read and write directly to the encoder's

internal memory. TI's Position Manager technology includes a feature-rich BiSS-C library of capabilities, which system developers can readily draw on for their development projects. For example, clock frequencies of 8 MHz are supported on cables up to 100 meters long. In addition, the C2000 MCU BiSS interface can be adjusted to feature improved control of modular functions and timing by transmitting position information from encoders every control cycle.

T-Format

From Tamagawa, T-Format is designed for serial transfer of digital data between linear, rotary, or angle encoders, touch probes, accelerometers, and the subsequent electronics, such as numerical controls, servo amplifiers, and programmable-logic controllers. T-Format is a pure-serial, digital interface based on the RS-485 standard. The interface transmits position values or additional physical quantities and also allows reading and writing of the internal memory of the encoder. The transmitted-data types include absolute position, turns, temperature, parameters, and diagnostics. Mode commands - that the electronics, often referred to as the T-Format master - send to the encoder select the transmitted-data types.

Industrial drive control systems-on-chip

Powerful and programmable MCUs like TI's C2000 MCUs represent the next step toward industrial drive control systems-on-chip (SoC). They empower more effective and efficient system architectures by eliminating the need for an external FPGA for ancillary processing requirements or by reducing the size of the FPGA significantly.

Now, TI has taken the next step to help industrial drives system developers deliver highly differentiated products including lower latencies, higher resolution and more powerful processing resources. That step involves simplifying the interfacing of MCUs to position sensors with Position Manager technology. By enabling a direct connection between a C2000 MCU and a position sensor, Position Manager technology frees developers from the more mundane tasks of device connectivity so they can focus on the features and capabilities that will make their system solutions truly distinctive in the marketplace with significant competitive advantages.

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