Designing the next generation of industrial drive and control systems

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Introduction

A typical industrial system requires control, application and connectivity capabilities. The control subsystem directly manages motor operation and feedback, the application directs the overall motion and the connectivity subsystem downloads application, control data and allows the system to be remotely managed.

In general, the core technology that makes up the foundation of each of these subsystems is clearly understood. At the high-end, developers continue to innovate new ways to improve overall performance and accuracy. As these technologies mature and the cost to implement them decreases, these solutions, which were available for high-end applications, work their way down the value chain.

The challenge that developers of next-generation systems face today is efficiently implementing incremental innovations to provide better performance with lower latency and greater precision for their target application. To expand market share, they need to be able to deliver better functionality such as new feedback algorithms or novel approaches that improve position accuracy and current sensing at lower costs.

To achieve this, processors offering higher performance and greater integration are required; however, this approach increases development costs and adds system complexities, which in turn delays time-to-market and ultimately reduces the competitive advantage of delivering next-generation designs. Implementing new technology must be seamless, simple and value added both to end users and developers.

A new architecture for next-generation industrial designs

Many original equipment manufacturers (OEMs) have traditionally relied upon field-programmable gate-array (FPGA) technology to augment their microcontrollers (MCUs) and push leading-edge performance of critical functions like torque-loop management. FPGAs, however, increase system cost and are difficult to program. In addition, FPGAs offer a relatively fixed implementation that lacks scalability across multiple applications without requiring a redesign.

The dual-core C2000™ Delfino™ F2837xD MCU from TI makes it easy to implement various mathematical transforms and trig-heavy computations that enable efficient torque-loop management in a programmable processor platform. The Delfino MCU's dual-core architecture is also designed to maximize hardware and software performance for industrial drive and control applications. For example, its fast torque-loop calculation can reach sub-2 microseconds, which is comparable to FPGA implementations.

The F2837xD MCUs are extending control-loop performance with their fast CPUs further boosted by tightly coupled accelerators. The dual-core MCU is based on TI's proven C28x CPU. Each CPU core provides 32-bit floating-point-processing capabilities at 200 MHz, and dual real-time control accelerators (CLAs) also running at 200 MHz each. Each C28x CPU is augmented by its own Trigonometric Math

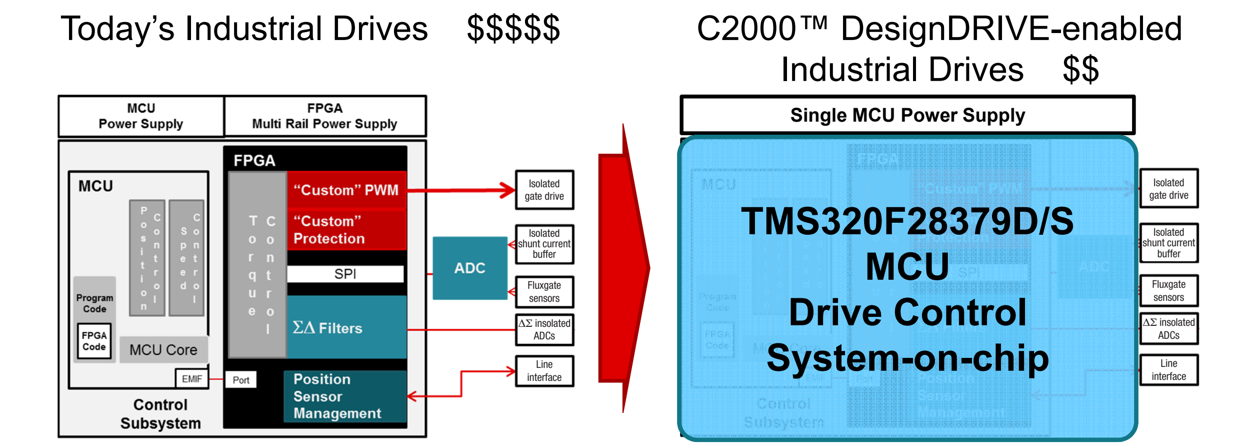

Figure 1: Before C2000™ Delfino™ F2837xD, industrial drive systems were complicated and expensive.

Unit (TMU) accelerator that provides hardware-based acceleration useful for control-based tasks. These four powerful engines are capable of pounding out the equivalent of 800 MIPS or 1600 MFLOPS of performance enabling consolidation of multi-processor architectures in control loop systems (Figure 1).

For example, in an industrial drive application one CPU + CLA + TMU can be used to implement control-side functionality; i.e., the torque loop. The other CPU + CLA + TMU can be used to implement the application side of the system; i.e., tracking speed and position, computing trajectories, comparing motion profiles and so on.

This division of the industrial drive system into control and application segments between CPUs provides developers with a clean partitioning to simplify design. Because only control code is running on one of the CPUs, it is isolated from application code, thus, developers

Processing	Processing
C28x DSP core 200 MHz	**C28x DSP core** 200 MHz
FPU	FPU
TMU	TMU
VCU-II	VCU-II
CLA core 200 MHz	**CLA core** 200 MHz
Floating point	Floating point

Figure 2: A closer look at the dual C28x cores and accompanying accelerators.

do not need to spend valuable development hours mitigating the potential impact of application code on the responsiveness and latency of real-time tasks (Figure 2).

The Delfino F2837x MCUs enable developers to migrate high-end functionality down the value chain to mid- and low-range applications. It achieves this through a combination of innovative technologies, including:

- Greater processing capacity at a lower cost than the current solutions
- A streamlined, low-latency architecture that provides higher performance in a deterministic manner
- Advanced hardware-based engines that accelerate common but compute-intensive tasks
- Integration of essential functions into the processor's architecture to reduce external component count and cost
- Simplified new design migration and reuse of an OEM's existing code investment.
- Pin and software compatibility across devices offering multiple performance and Flash size options, including the Piccolo™ F2807x MCU family as well.

Boosting system performance

The F2837xD MCU is a powerhouse enabling 800 MIPS of total system performance. This is provided through dual C28x CPUs and dual CLAs. The CPUs also integrate hardware accelerators which enable swift execution of trigonometric-based control functions ideal for very fast current-loop execution and complex math operations common in vibration analysis and encoded communication applications. These hardware accelerators include:

- ***Trigonometric Math Unit (TMU):*** TI developed the TMU hardware accelerator to assist the main C28x CPU execute trigonometric functions like SIN, COS, ARCTAN and 1/X that are commonly used in applications such as robotic motion where hinged joints require linear to angular translation. These complex functions are computationally intensive and typically require 30 to 90 cycles to complete even when using a CPU with floating-point capabilities.
  The TMU can be used as an high-octane accelerator to perform floating-point-unit calculations in parallel to the CPU. With an average execution time of five cycles per instruction, the speed of math transforms requiring trigonometric calculations, can achieve 10× improvement in performance versus the competition when the TMU is used (Figure 3).

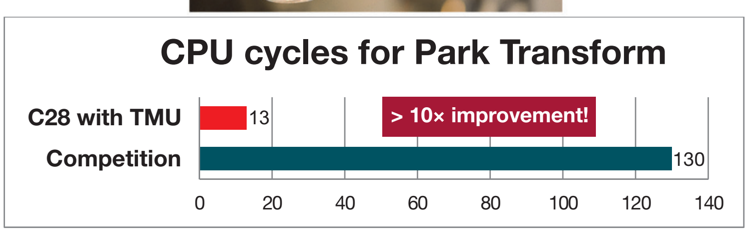

Figure 3: Enabling very fast system response in changing load conditions, the C28x MCU with the TMU challenges FPGA torque-loop performance.

- ***Viterbi Complex Math Unit (VCU II):*** This accelerator efficiently processes complex math functions (Figure 4). The VCU has been designed to be flexible in supporting various communication technologies. It can accelerate the performance of communications-based algorithms by as much as 10 times, thus enabling C2000 MCUs to operate at a lower MHz, reducing system cost and power consumption. The VCU II with acceleration is ideal for OFDM interleaving and de-interleaving, Viterbi decoding, CRC calculations and more.

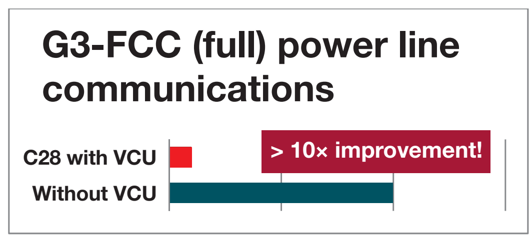

Figure 4: Viterbi Complex Unit (VCU II) is ideal for OFDM.

For the typical MCU, key signal-processing operations can consume much of the processing power when performing complex Fast Fourier Transforms (FFT/iFFT) and complex filters. Besides communications, the VCU is very useful for general-purpose DSP applications such as filtering and spectral analysis.
From an industrial motor drives perspective, spectral analysis can be used to process motor vibration noise to determine the impact of vibration on a system, estimate the motor operating life and calibrate the control loop to improve efficiency, thus increasing operational efficiency and reducing system downtime.

Using the hardware capabilities of the VCU, drives applications will significantly benefit from the increased performance over a software implementation (Figure 5).

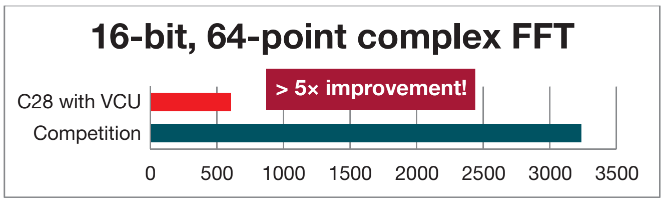

Figure 5: Viterbi Complex Unit (VCU II) performs efficient complex math and signal processing functions.

Along with the TMU and VCU II hardware accelerators, the F2837xD MCUs include two real-time CLAs, thus enabling processing optimizations through intelligent partitioning of critical control tasks in a drives system.

- ***Real-time control accelerator (CLA):*** The CLAs are standalone, floating-point processors which are tied to the main CPUs. CLAs are dedicated low-latency CPU-like architectures with direct access to control peripherals. They are pure mathematical engines that operate independently of the main CPU.

The CLAs can be used in a variety of ways to completely offload intensive signal-processing tasks from the CPU (Figure 6 below). For example, the CLA can serve as part of the analog-to-digital conversion by post processing the incoming signals to filter noise and then buffer data in its own random access memory (RAM). In this way, the CPU is involved only when there is an entire block of preprocessed data ready for it to work. Another way to use the CLA is by performing Fast Fourier analysis on incoming current wave forms, the CLA can then profile a motor's real-time performance. The profile can be continuously compared to a "golden signature" based on the type of motor. As the profile begins to deviate from the expected signature, indicating a potential fault, the industrial drive system can alert the operator to take preemptive action before failure occurs. Other tasks the CLA can perform are feedback preprocessing, feed-forward control and special signal analysis or packet processing.

These are just a few examples of the many possible features that can be implemented using the CLA.

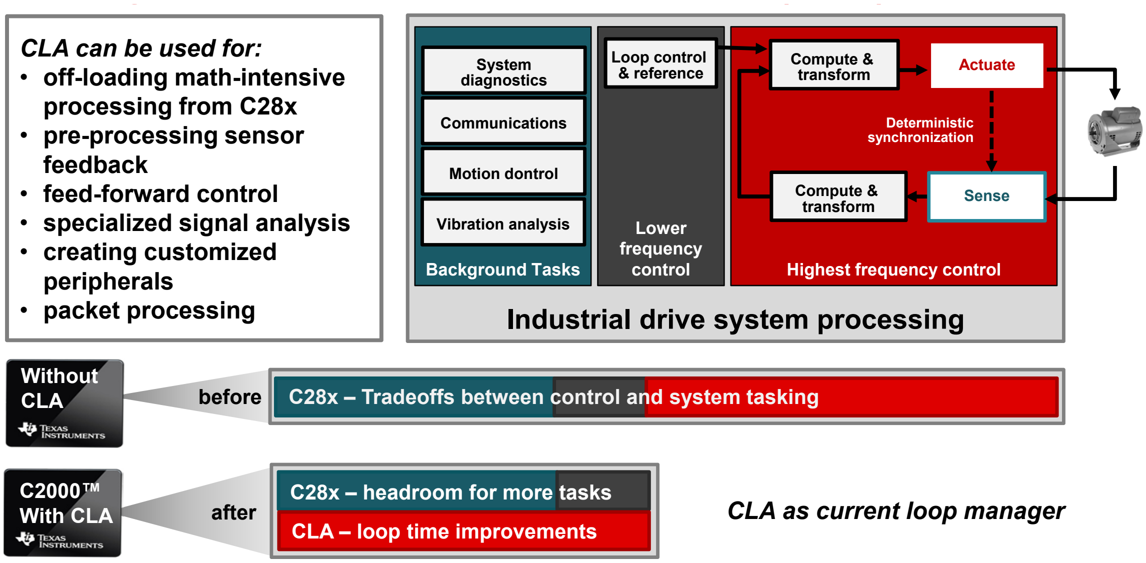

Figure 6: The CLA can increase frequency or number of control loops, offloading the C28x to perform more background control and system tasking.

Low-latency and deterministic architecture

Although performance is required for industrial drives, system design also needs to be simplified. When enhancements increase design complexity, this in turn could increase the development time. For example, determinism is essential for control-based applications. Determinism in essence means how feedback signals are sampled, processed accurately and arrive in time for control-loop actuation using the PWM signals.

With the loosely coupled memory architecture, like those with caches and/or memory management units (MMUs), accounting for the unpredictable timing of cache misses or MMU lookups makes the determination of ***worst-case responsiveness*** a very difficult calculation. Typically designers must rely on profiling real-time execution of the system to confirm worst-case operation—*the largest possible number of cycles possible*—wasted performance. This means that modifications to system code may require the system to be profiled multiple times to ensure the deterministic limits of the system have not been exceeded.

This C28x CPU core architecture determinism also carries over to the Delfino F2837x MCU's peripherals. The latency of ADC conversions is small and consistent for every sample. CPU reads and writes to ADC and PWM registers, respectively, are zero wait-state every time. This greatly simplifies overall system design because there is no need to guess what the worst-case execution path is.

The Delfino F2837xD MCU architecture is built upon a deterministic foundation that allows

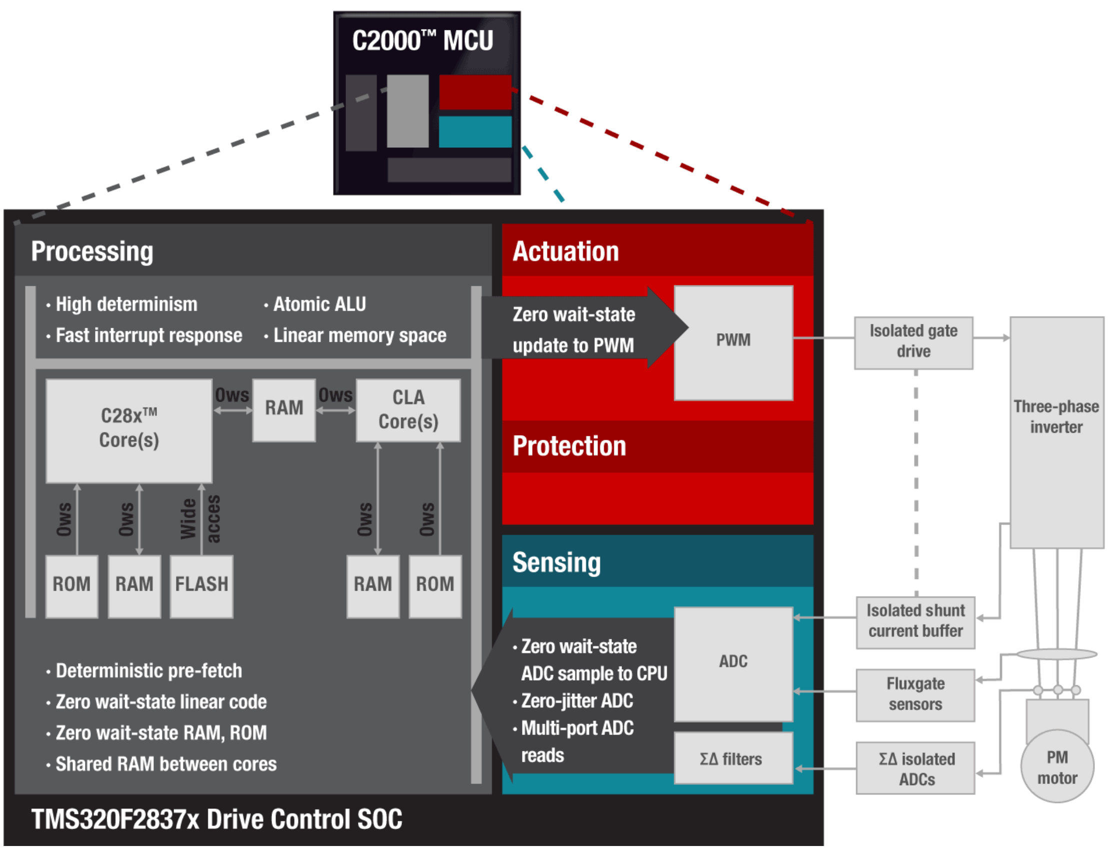

Figure 7: A differentiated architecture; built for industrial drive control

developers to ensure reliability without increasing design complexity (Figure 7 below). With its tightly coupled memory architecture, there is no need for a cache, thus eliminating the arbitrary delays that arise from cache misses. All memory transactions to static random-access memory (SRAM), Flash and peripherals are designed to fit within finite and consistent busing cycle counts, thus providing highly deterministic throughput. The dual six-channel direct memory access (DMA) peripheral augments an efficient memory management to ensure data is always available when the CPU or the accelerators need them.

To facilitate efficient communication between cores, the Delfino F2837x MCU uses shared memory where both cores have full read/write access to data. Developers also have access to two message RAMs. Each core has write privileges to one of the message RAMs and read-only privileges to the other. In this way, code on one core cannot accidentally corrupt critical data belonging to the other core. This greatly simplifies messaging, especially for developers new to dual-core design.

Of special note, there are several error-check functionalities that are spread across the subsystems in Delfino F2837x MCU architecture. Non-volatile memory and SRAM offer ECC and parity capabilities. Device-level diagnostics are collated to generate flags, interrupts and external error signal. This can be enabled during power up and run time of the applications.

System consolidation with integrated control and analog peripherals

The hallmark of the Delfino F2837x MCU is its control peripherals. These are the powerful industry-proven PWM timers, 32-bit enhanced capture units (ECAP) and quadrature encoder peripherals. Each of the PWM modules is enhanced to support high-resolution capabilities on both A and B channels. These high-resolution channels extend 150-ps PWM step resolution to enable high-frequency PWM modulation techniques and advanced control topologies.

Performance is directly impacted by the precision of the PWM control feedback loop. Integrated analog peripherals reduce latency and cost compared to the use of external components. In higher-end control applications such as servo drives, high-resolution feedback is required to provide precise phase-current measurements for low torque ripple and precision positioning; however, for some measurements, precise sample rates are more important than higher resolution, such as when making high-speed, low-side shunt current measurements.

To support different sensing accuracy requirements, the Delfino F2837xD MCU architecture offers flexible ADCs that can support two resolution modes: 16-bit resolution at 1.1 MSPS and 12-bit resolution at 3.5 MSPS. The F2837xD MCU features four independently integrated ADCs which provide simultaneous conversions, thereby enabling industrial systems to accurately monitor multiple signals in real-time (Figure 8 on the following page). For example, in a servo drive, designers can monitor the phase voltages and currents of a three-phase motor while simultaneously sampling the DC link voltage.

Delfino F2837x MCU offers three 12-bit buffered digital-to-analog converters (DACs) to provide analog actuation signals, including resolver excitation, that are very useful for tracking engineering parameters at the system level. Further increasing integration is the availability of

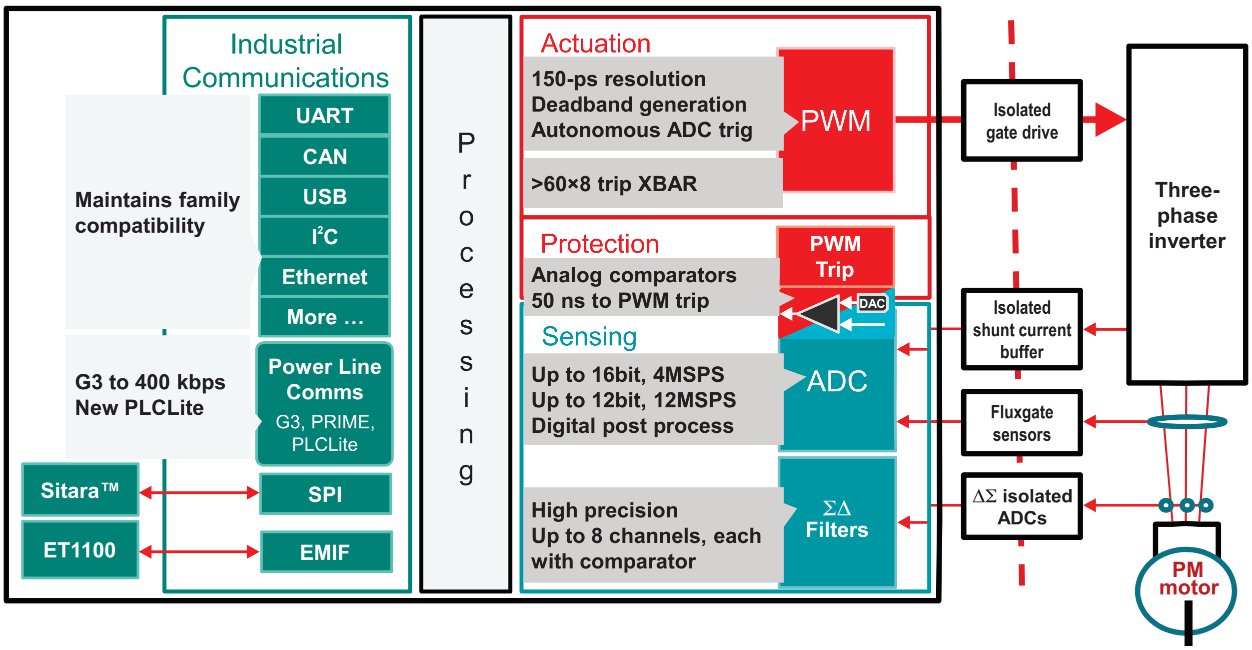

Figure 8: System integration is enabled with high-integrity analog and control peripherals incorporated on chip.

eight sigma-delta demodulators/filters. Because of the high voltages associated with industrial motor control, isolation is required when measuring feedback signals. Developers can use TI's AMC130x delta-sigma converter, for example, to convert analog values into a digital bit stream that feeds directly into Delfino F2837xD MCU's Sigma-Delta interface and is reconstructed by the filter. This enables hot-side/high-side current sensing of motor phases, providing the required feedback fidelity, which is essential in high-performance industrial drives.

Eight windowed comparators are integrated into the Delfino F2837xD MCU architecture, providing over-voltage or under-voltage "trip points" and operate independently from the CPU so there is no additional CPU loading. The comparators are also fast acting and minimize latency with trip signals so the system can react quickly to any abnormal events or over/under limit conditions. The comparator trip events can be configured to help provide a full shut down action in the case of a catastrophic event in *fifty nanoseconds*, making the system more resilient in industrial drive and power systems.

Position Manager

Historically, interfacing a position sensor to an MCU could be a time-consuming task that often involves the integration of the communication protocol into an 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. System design teams 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 component bill of materials (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.

Integrating position feedback

Starting with the processing capabilities required by sophisticated and precise control systems, the C2000 Delfino **F28379D** and **F28379S** 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 (Figure 9). 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 stand-alone 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 ADCs and 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.

C2000 F28379 MCUs support up to three enhanced quadrature encoder pulse (eQEP) modules. The eQEP modules interface directly with linear or rotary incremental encoders that are counting 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, C2000 MCU 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.

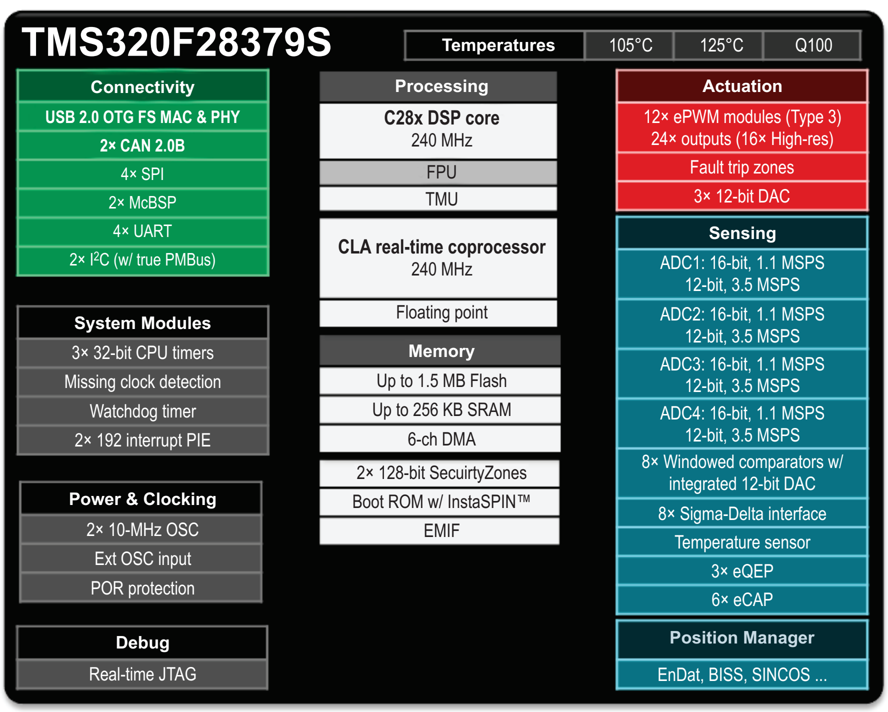

Figure 9: A closer look at the C2000 single-core F28379S MCU with DesignDRIVE Position Manager.

Resolver and QEP capabilities provide fast, efficient and integrated solutions for effectively interfacing position sensors with C2000 Delfino 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 Delfino F28379S and F28379D 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 interface/manager (Figure 10). Unique to C2000 MCUs, Position Manager combines the analog sensor support with the popular digital absolute encoders, EnDat 2.2 and BiSS-C, giving system designers a wide range of position sensor types to choose from.

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. Figure 11 on the following page 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. Example

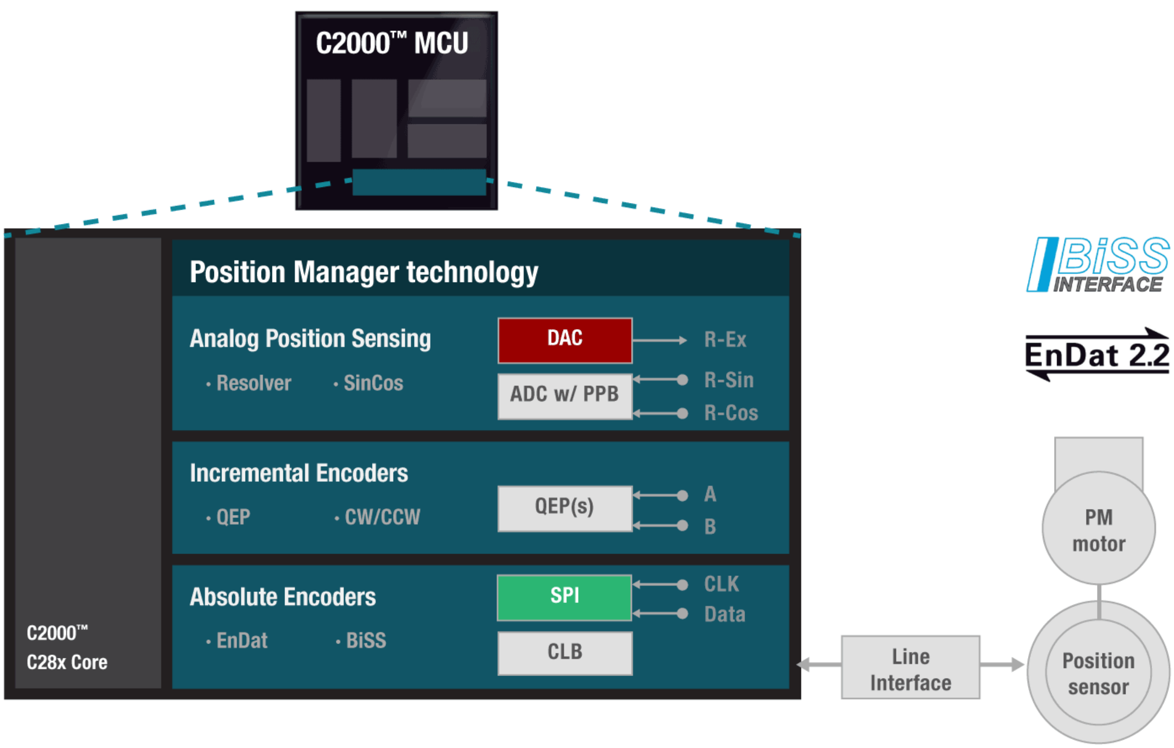

Figure 10: Position Manager utilizes C2000 MCU on-chip resources

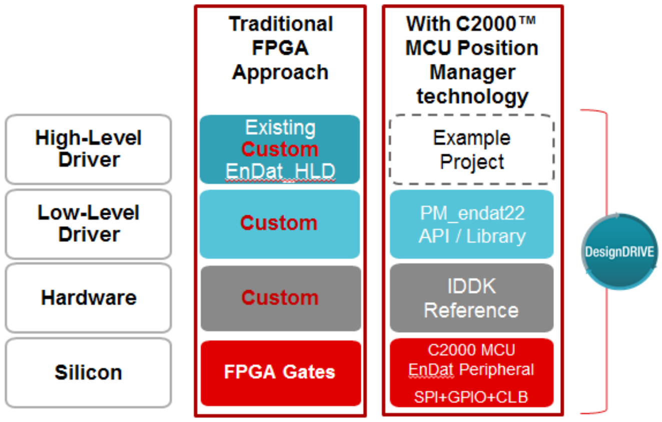

Figure 11: EnDat 2.2 solution example: Stackup vs. FPGA

closed-loop, position-sensor-based control projects downloaded from **DesignDRIVE** 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.

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. Table 1 shows some of the solutions available through DesignDRIVE 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.

For more information on Position Manager, please refer to the **Position Manager White Paper**, the Position Manager solutions User's Guides and the DesignDRIVE applications page.

DesignDRIVE software examples optimize the evaluation of the latest C2000 MCU innovations

With DesignDRIVE, the example software is built to illustrate how to use the new architectural,

Sensor type	Speed	Tested length	Resolution	C2000 MCU supported devices
Incremental	~ 12,000 rpm	N/A	Encoder dependent	F2803x, F2806x, F2807x, F2837xS, F2837xD[1]
EnDat 2.2 / 2.1	8 MHz	100 m	Up to 35 bits	F28379S, F28379D
BiSS-C	5 MHz	100 m	Up to 26 bits	F28379S, F28379D
t-format (Tamagawa)	2.5 MHz	100 m	–	F28379S, F28379D
SIN/COS	~ 12,000 rpm	70 m	± 4.5 arcsecs	F2807x, F2837xS, F2837xD
Resolver	> 3,000 rpm	~1 m	> 13.47 ENOB	F2802x, F2807x, F2837xS, F2837xD

Note 1: This project can be ported to other C2000 MCU families but has not been released via controlSUITE at this time

Table 1. Position Manager solutions by sensor type

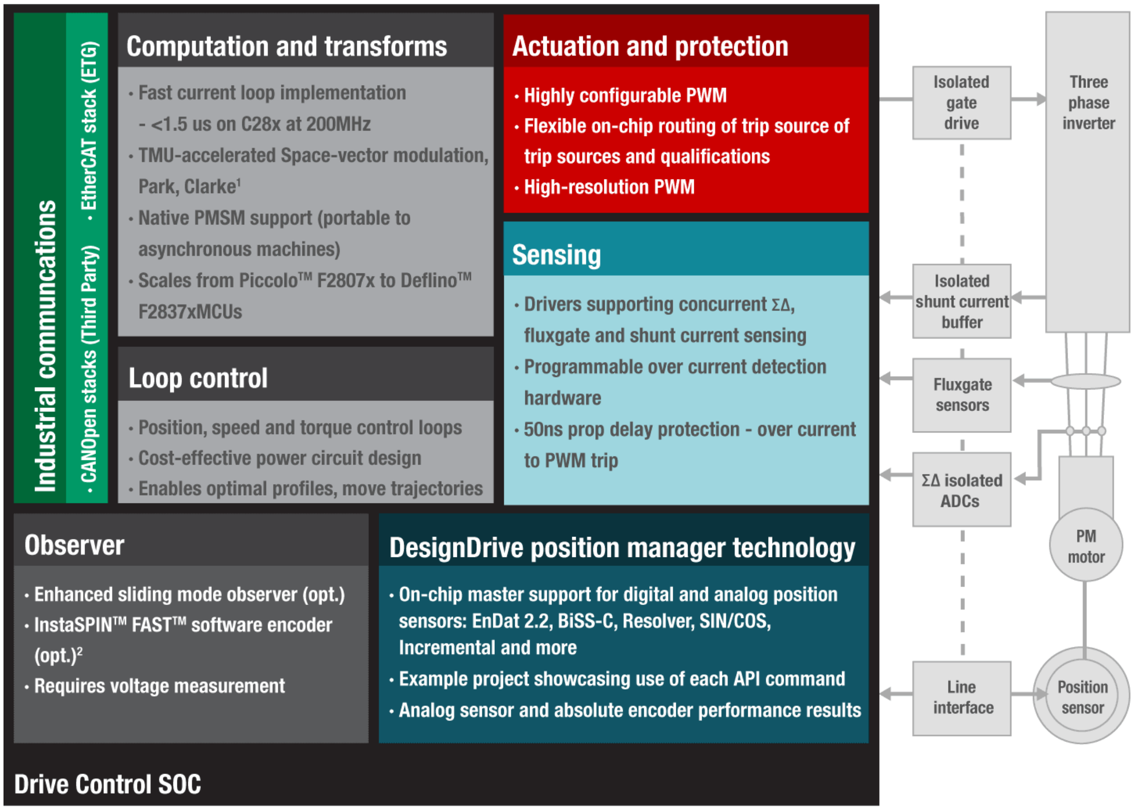

Figure 12: DesignDRIVE field-oriented control example block diagram.

peripheral and CPU innovations (Figure 12). The project(s) show:

- How to improve your current-loop timing without impacting your control bandwidth by off-loading computations to the CLA
- The benefit of the Trigonometric Math Unit on current-loop timing
- How to interface with many different position sensors
- How to configure the on-chip over-current protection circuits
- How to communicate with isolated Delta-Sigma ADC modulators
- How to use shunt resistors and fluxgate sensors for current sensing
- How to use (and replace as needed) simple P-I control loops for current, speed and position

Seamless migration and development

Multiple processing units and accelerators can substantially improve system performance. However, many OEMs are building on existing designs and have made a significant investment in developing a code base with Delfino and other MCUs.

TI understands that developers need to be able to exploit architectural enhancements seamlessly with simplified partitioning in the firmware. Use of the TMU, for example, is managed by the C compiler. When a native TMU function is available for use, the compiler will automatically utilize the TMU instead of calling a function from the math library. Thus, existing C28x CPU-based designs can take immediate advantage of the TMU's 5× performance boost without any code needing to be rewritten. The TMU can boost the performance of MathLAB®/SIMULINK®-based application code, as well. This also improves portability of intellectual property (IP) since the same code can be used with TI MCUs with and without TMU capabilities. The memory subsystem offers a very flexible code protection mechanism to help vendors and developers to exchange valued-added IPs.

To accelerate development, TI and its partners offer a **wide variety of software libraries, tools, development kits and technical support** as part of its extensive development ecosystem. For example, math libraries are available for both the CPU and CLA to assist developers in getting the highest performance from the Delfino F2837x MCU. TI also provides a wide range of low-level and application-specific libraries to accelerate design of control applications, as well as development boards that provide developers with easy access to all of Delfino's control-based functionality.

For applications that require communications, the Delfino F2837x MCU provides several options of serial ports: USB, UART, SPI, CAN and I^2C. High-speed serial peripheral interface (SPI) is also available for inter-processor connectivity and network connectivity.

For applications that require Ethernet and real-time Ethernet connectivity and protocol, TI's **Sitara™ AM335x processors** are available as companion communications processors. The Sitara AM335x processors are built around ARM® Cortex®-A8 cores with differentiated peripherals and certified industrial communication stacks/protocols, such as PROFINET®, EtherCAT® and more. These devices are fully featured to support the ARM ecosystem for extended application processing, if required.

Delfino F2837x dual-core devices offer scalable derivatives to meet several value points. This enables applications from low-end industrial drives to energy conversion across the industry. Furthermore, to support a wider breadth of industrial drive applications, while maintaining code and pinout compatibility, single-core versions of the Delfino F2837x and Piccolo F2807xMCUs are also available.

Conclusion

Powerful and programmable MCUs like TI's C2000 **Delfino F28379 MCUs** represent the next step toward industrial drive control systems-on-chip (SoC). They empower more effective and efficient system architectures for ancillary processing or auxiliary drive peripherals by eliminating the need for an external FPGA or by reducing the size of the FPGA significantly.

With the Delfino F2837x MCU, TI has redefined how industrial drives are designed. With its focus on performance, integration, simplicity and transparency, the Delfino F2837xD MCU architecture enables developers to implement classical and proven control systems with next-generation capabilities. Its advanced hardware-based engines and high level of subsystem integration provide greater performance at a lower cost and smaller system footprint. Developers can also speed time-to-market through simplified design based on its low-latency and deterministic architecture, as well as using the DesignDRIVE IDDK and software examples seamlessly implement Delfino F2837x MCU's architectural enhancements in new and existing industrial drive applications.

Get started with DesignDRIVE—a single hardware and software platform that makes it easy to develop and evaluate solutions for many industrial drive, motor control and servo topologies. DesignDRIVE offers support for a wide variety of motor types, sensing technologies, encoder standards and communications networks, as well as easy expansion to develop with industrial communications and functional safety topologies, thus enabling more comprehensive, integrated drive system solutions. Based on the real-time control architecture of TI's C2000 MCUs, DesignDRIVE is ideal for the development of industrial inverter and servo drives used in robotics, computer numerical control machinery (CNC), elevators, materials conveyance and other industrial manufacturing applications.

DesignDRIVE Industrial Drive Development Kit (IDDK)

Jump start your industrial drives and servo control evaluation and development with the DesignDRIVE Development Kit, or IDDK, which includes:

- Examples of vector control of motors, incorporating torque, speed and position
- Multiple current-sense topologies
  - Supports reinforced, isolated Delta-Sigma modulator ADCs, Hall / Fluxgate sensors and shunt-resistor current sensing
- Analog and digital position sensor interfaces
  - Supports Position Manager Technology—EnDat2.2, BiSS-C, SIN/COS, Resolver and incremental encoders

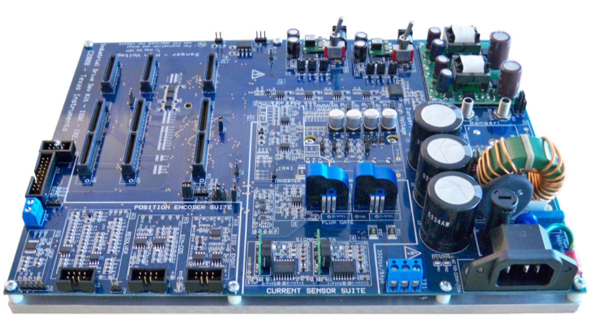

Figure 13: ***IDDK (TMDXIDDK28379D)*** *– U.S. $999*

- Integrated power module and DC Link supply as well as DC Bias supplies for control circuits—operates from a single AC Main connection
- Flexible real-time connectivity
  - Expansion support for multiple real-time Ethernet protocols
- Configurable power plane location (hot-side or cold-side) for the control circuit

Delfino F28379D controlCARD

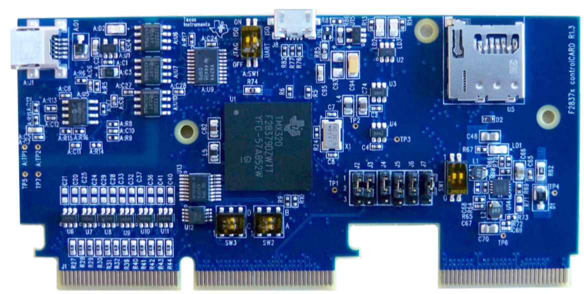

Figure 14: ***Delfino F28379D controlCARD (TMDSCNCD28379D)*** *– U.S. $159*

The **Delfino F28379D controlCARD** from Texas Instruments is Position Manager-ready and an ideal product for initial software development and short-run builds for system prototypes, test stands and many other projects that require easy access to high-performance controllers. All C2000 MCU controlCARDs are complete board-level modules that utilize a HSEC180 or DIMM100 form factor to provide a low-profile single-board controller solution. The host system needs to provide only a single 5-V power rail to the controlCARD for it to be fully functional.

C2000 MCU Experimenter Kits

C2000 MCU Experimenter Kits provide a robust hardware prototyping platform for real-time, closed-loop control development with Texas Instruments

C2000 32-bit microcontroller family. This platform is a great tool to customize and prove-out solutions for many common power electronics applications, including **industrial drives**, **motor control**, **digital power supplies**, **solar inverters**, **digital LED lighting** and **more**.

The C2000 MCU Experimenter Kit board hardware includes isolated XDS100 USB JTAG emulation facilitating easy programming and debugging, header pins access to key microcontroller signals, breadboard area for customizable routing, HSEC controlCARD plug-in slot, included controlCARD based on the Delfino TMS320F28379D microcontroller, and more.

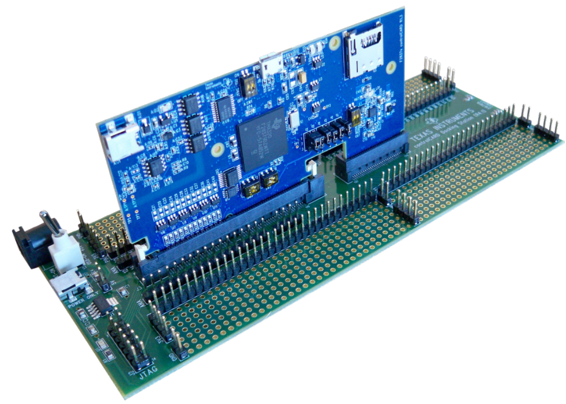

Figure 15: ***Delfino F28379D Experimenter's Kit (TMDSDOCK28379D)*** *– U.S. $219*