Utilizing Sitara™ Processors for Industry 4.0 Servo Drives

TEXAS INSTRUMENTS

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The manufacturing and automation industries have used servo motor control for many years, but the rise of Industry 4.0 and smart factories has accelerated the adoption of automated systems, which in turn has led to increased demand for smarter servo drives with more functionality and the ability to control more axes.

Historically, high-end microcontrollers and large field-programmable gate arrays (FPGAs) performed the low-level control algorithms and provided peripherals to connect to the drive output and motor feedback. The requirements for what a servo drive must support are rapidly changing, however, as equipment gets smarter and higher in performance. Features like real-time industrial communications, functional safety, predictive maintenance and cloud connectivity are being brought into the servo control board to provide more services at the edge. This increased level of integration and need for higher performance are leading designers to look to heterogeneous processors, such as Sitara™ processors from Texas Instruments, to handle the processing needs for Industry 4.0 applications.

Performance

In servo motor-drive applications, motor control is typically separated into several control-loop layers: current/torque loop, speed loop, position loop and a higher-level motion-control loop. These loops are typically arranged in a cascade, each with their own "real-time" processing requirements. The current or torque loop is the tightest control loop. Each upstream loop runs at a multiple of the loop before it and provides input references to the downstream loops. **Figure 1** on the following page shows a typical cascaded control topology.

The blocks in **Figure 1** lend themselves well to logical partitioning across cores within a heterogeneous processor, or between a processor and a microcontroller. Spreading the various loops among the different cores in a multicore processor maximizes the processing bandwidth dedicated to each loop. When a processor core receives its control-loop input data, it can run the algorithm to completion as quickly as possible, provide the reference value for the downstream loop and then continue providing other services until the next set of input data is ready.

Processors with higher raw performance can finish the control processing faster and have more bandwidth available to provide more services and features. Fast processing is especially crucial when cycle times approach 31.25 µs in a 32-kHz control loop or when inputs from multiple axes must be processed practically simultaneously.

There are a few options for the strict real-time processing requirements of servo control, including digital signal processors (DSPs), FPGAs and standard Arm® processing cores. Choosing the right processing core can be difficult because there's a balance between flexibility and optimizing control algorithms. In the past, optimizing control algorithms was the No. 1 priority, so DSPs,

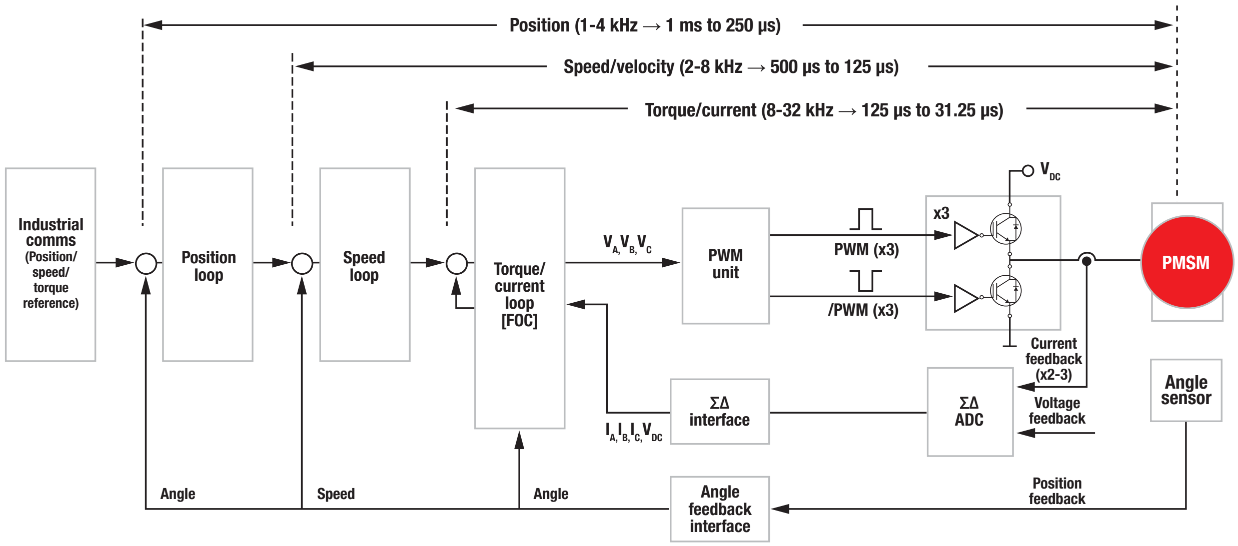

Figure 1 *Typical servo motor control loop topology.*

application-specific integrated circuits (ASICs) and FPGAs were the clear choice.

Now, the need to add Industry 4.0 services to servo drives has resulted in the adoption of standard Arm Cortex®-A and Cortex-R cores. Cortex-A cores can achieve very high bandwidths, which is good for rapid processing, but they lack the real-time component of the Cortex-R, which is why Cortex-R is a better fit than the Cortex-A for servo control. On the other hand, the Cortex-A is much better suited than the Cortex-R for many other services, such as networking or predictive maintenance. Fortunately, multicore devices like Sitara AM6x processors can contain all of the processing elements mentioned here, enabling all necessary elements in a single chip.

Industrial communication

Industry 4.0 brings many new and exciting things to the factory, but the rapid adoption of multiprotocol industrial Ethernet is among the most noticeable in the industrial servo drives sector. There are over a dozen different communication protocols on the market for industrial Ethernet, field-bus and position encoders, each with its own pros and cons. EtherCAT®, PROFINET® and EtherNet/IP are the most popular Ethernet-based protocols in the servo drives market, and Hiperface® Digital Servo Link (DSL), EnDat 2.2 and Bidirectional Interface for Serial/Synchronous C (BiSS C) are among the more popular position-encoder protocols.

Many of these protocols have ASICs that you can attach to host processors to support that specific communication protocol. In some cases, with a multichip solution, the protocol's stack runs on the host processor and the ASIC performs the media access control layer. Manufacturers who only plan to support a single protocol prefer this distributed architecture, since ASICs are typically optimized for that specific communication standard. Once the need to support multiple protocols arises, a multichip solution loses its attractiveness for multiple reasons. Each new protocol requires that you familiarize yourself with a new device (which adds development effort and cost) and manufacturers must maintain several versions of their boards for each of the different protocols.

Solutions such as Sitara processors have integrated multiprotocol support onto the host processor, helping save costs, board space and development effort, while also minimizing the latency associated with communication between external components and the host. A single platform supporting multiple standards enables you to maintain a single board for the different versions of your end product.

If you need to future-proof your products, you must also take into account the need to support Time Sensitive Networking (TSN). The platform chosen for industrial communication must be flexible enough to adapt to evolving TSN standards, or risk being outdated once the standards are finally set. The Sitara AM6x processor family provides a solution through its flexible programmable real-time unit-industrial communications subsystem (PRU-ICSS), which enables gigabit TSN as well as traditional 100-Mb protocols like EtherCAT

Functional safety

The trend toward autonomous machine decision-making and operation, as well as increased human-machine interaction in potentially dangerous factory environments, means that functional safety is becoming more important for many applications in the smart factory, including servo drives. For a detailed description of functional safety standards and how Sitara processors play in the industrial environment, read our white paper titled, "The state of functional safety in Industry 4.0" for more information

System partitions

The cascaded control loops in a servo drive typically span at least two circuit boards, separated by a reinforced isolation boundary. This isolation boundary creates what's referred to as a "hot side" and a "cold side." The hot side is closest to the motor and includes the high-voltage components that supply power to the motor. The cold side is on the other side of the isolation and typically holds the control units.

The modular nature of the various control loops in a motor drive give you many possibilities when partitioning your system across the isolation boundary. **Figures 2, 3** and **4** show a few possible partitions of a servo drive.

Figure 2 shows a two-chip solution, with the two system on chips (SoCs) separated by the isolation boundary. This partition is often referred to as a decentralized control architecture. The benefit of

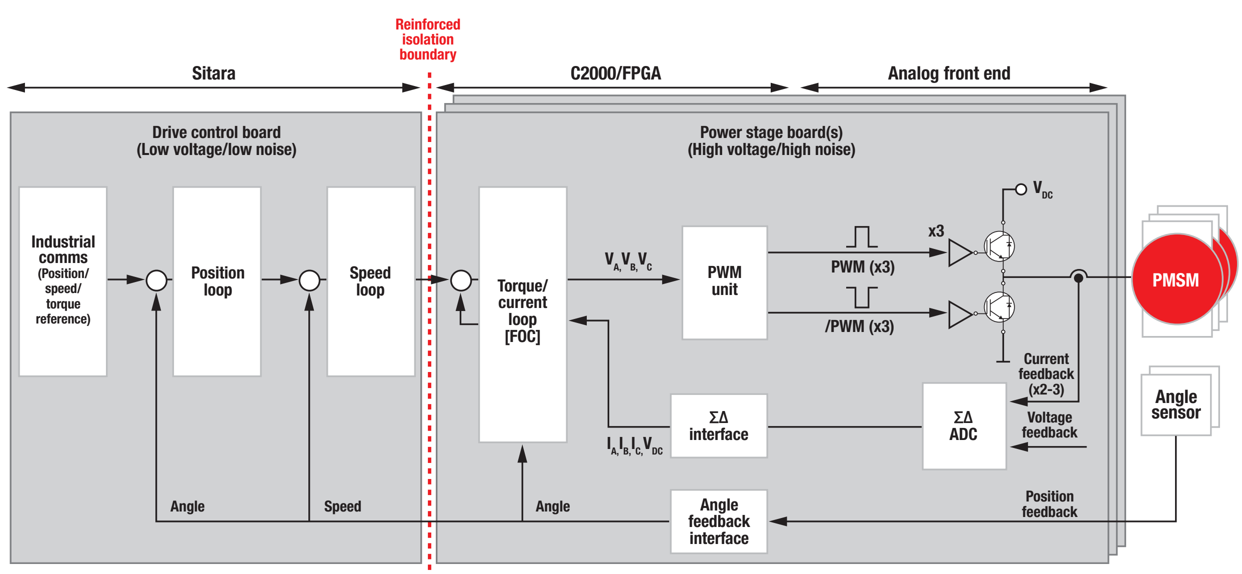

Figure 2 *Example of using a Sitara processor to communicate across the isolation boundary to a separate control unit on the hot side of the system.*

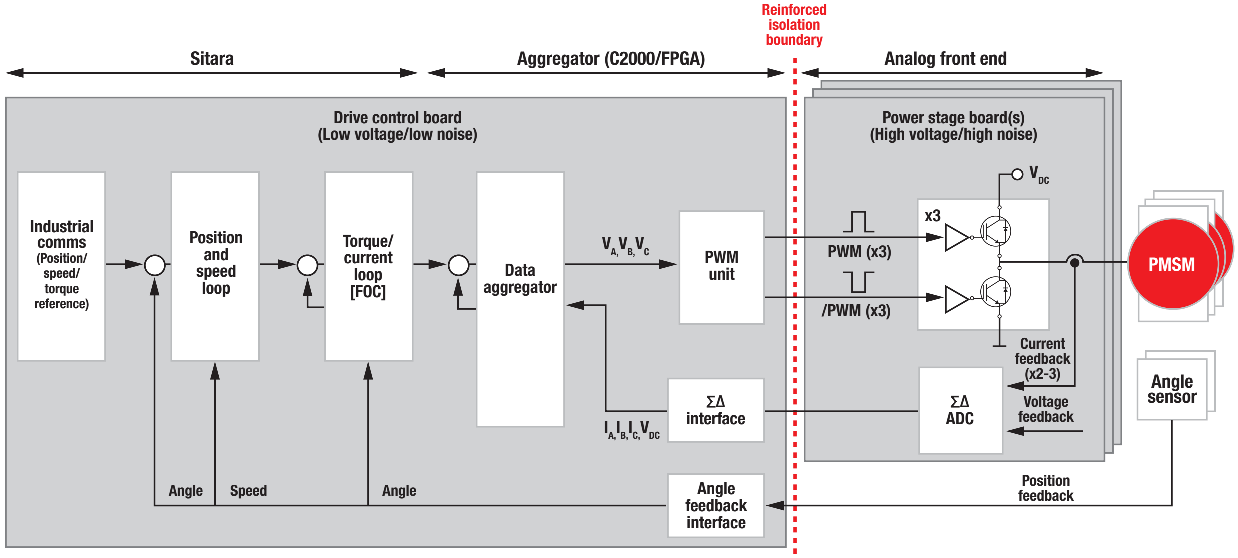

Figure 3 *Example of using a Sitara processor as a servo processer with control function offloaded to a C2000™ microcontroller or an FPGA on the cold side of the system.*

this architecture is that the total time for the field-oriented control loop to get inputs from the motor and return a current is short, because the entire loop runs on the power-stage board.

Figure 3 also shows a two-chip solution, but this time both SoCs are on the control board on the cold side. The control loop is split between two SoCs: one handles the algorithm processing and the other acts as an aggregator and provides the pulse-width modulators (PWMs) across the isolation boundary. A system partition with all of the control logic combined on a a single board is often referred to as a centralized control architecture. The benefit of this architecture is that it enables lower-cost power-stage boards, but maintaining the same performance levels as the partition shown in **Figure 2** requires a high-speed interface between the two SoCs.

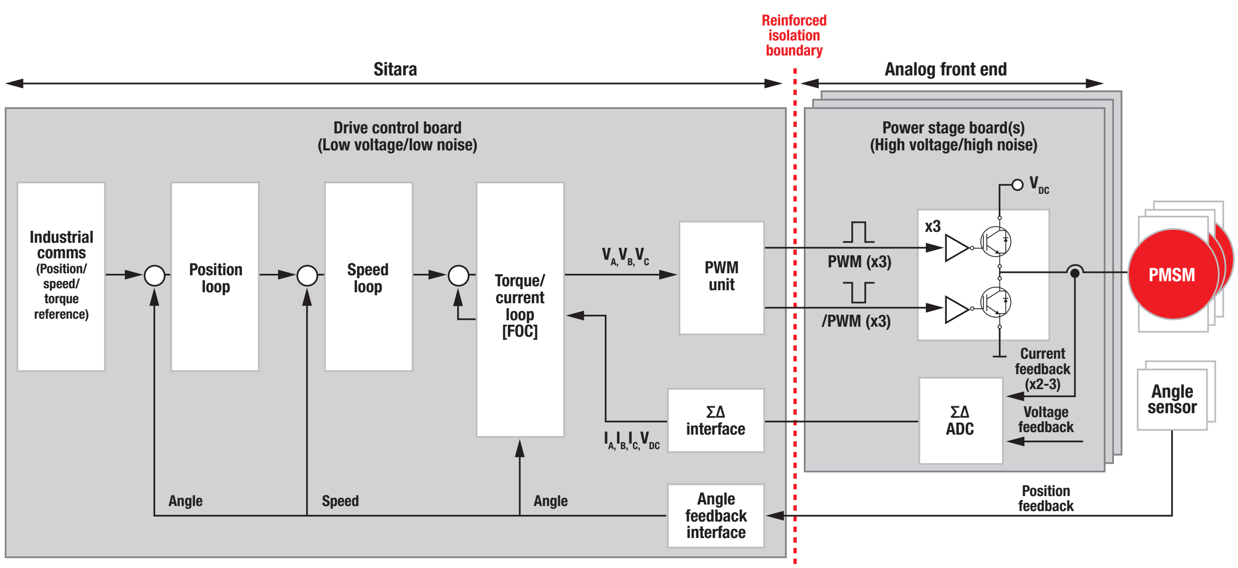

Figure 4 *Example of using a Sitara processor to implement full servo control on the cold side.*

In **Figure 4**, the entire control loop including the PWM and motion profile generation—typically handled by a programmable logic controller (PLC)—is integrated into a single SoC on the cold side. This architecture enables even more cost savings through integration and eliminates the latency associated with the interface between SoCs.

Solutions from Texas Instruments

The Sitara processor family has SoCs to handle everything from standalone industrial communications modules to fully featured multi-axis servo drives for any of the system partitions discussed in this paper. Sitara AMIC processors contain the PRU-ICSS subsystem and have been optimized for stand-alone multiprotocol industrial communications modules. The AM64x family takes integration to the next level by offering a single-chip solution for multiprotocol industrial communications, real-time motor control, cloud connectivity, and other Industry 4.0 services.

Conclusion

New guidelines and system requirements for servo drives are being introduced with Industry 4.0, making it important for designers to select a solution that fits the needs of current and future servo drives. Devices like Sitara AM64x processors, which include both Cortex-A and Cortex-R cores and support 100-Mb and 1-Gb industrial networking, are capable of supporting existing and future servo drives. TI also offers a variety of products, including other Sitara processors and C2000™ microcontrollers, to serve the changing needs of the industrial market.

Additional resources

- Read our white paper titled, "The state of functional safety in Industry 4.0."
- Check out our demo for multiprotocol industrial communications on Sitara AMIC110.
- Read our app note titled, "Industrial communication protocols supported on Sitara™ processors."