WHITE PAPER

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TEXAS INSTRUMENTS

Designing a Cost-Effective System Management Controller for Industrial PCs

Introduction

The proliferation of PC infrastructure technology extends far beyond the traditional desktop PC or laptop, and the widespread availability of powerful, low-cost x86-based processors has led to the adoption of these controllers in a broad range of industrial applications. While perhaps not as common as other market segments such as consumer electronics or wireless applications, the increased drive toward energy-efficient processes has resulted in industrial electronics outpacing these other markets. Second in growth only to automotive electronics, industrial applications are becoming an increasingly important market segment.

This white paper explores the design of a platform-based system management controller for x86-based industrial PCs. These systems have stringent design requirements that exceed those of consumer and commercial PCs, including the need to support various industrial interfaces and the ability to operate in extreme environmental conditions. To design a reliable system management controller (SMC) that can be optimized to individual applications while minimizing cost, developers need a controller that provides flexibility both in software and hardware.

System management control

Industrial PCs can take a variety of forms, from rugged portables and embedded controllers to rack-form factors, mini-form factors and specialized human-machine interface (HMI) PCs. What makes these industrial PCs different from their consumer and commercial counterparts are the interfaces they use and the need to provide a high level of reliability even while operating in extreme environmental conditions.

To provide reliable operation, industrial PCs require an SMC to monitor and manage the operating health of the system. For example, the SMC tracks the temperature of the x86 processor and drives a cooling fan as required. However, industrial PCs have become extremely complex systems that support an increasing array of high-speed interfaces, and system management must extend beyond simple temperature monitoring and fan control. Today's SMCs must be able to monitor systems across a spectrum of characteristics with precision and be able to respond in real-time to ensure the PC is running in as ideal an operating environment as possible.

Traditionally, SMCs for industrial PCs have been based on 8-bit MCU architectures such as the 8051. However, the increasing complexity of PC-based systems has pushed these MCUs beyond their ability to provide sufficient monitoring and management capabilities. To support the necessary interfaces, an external FPGA or ASIC is often required. In addition to increasing board size and complexity, these devices typically require specialized programming that is both time-consuming and costly to develop. In older industrial PC systems, Super I/O chips were the forerunners to the modern SMC.

An additional key challenge that developers face is keeping system cost down. An FPGA, however, costs more than the MCU it supports and requires the use of a second development environment. Alternatively, moving to an ASIC can potentially reduce device cost but comes at the expense of limiting system flexibility by fixing the types, number and routing of interfaces. Alternatively, an ASIC typically has high up-front and non-recurring engineering costs (NRE) as well. Effectively matching the capabilities and cost of an SMC to a particular platform is extremely difficult.

Within the consumer market, specialized SMC devices are available that provide the processing performance, as well as peripheral and interface support required for these applications. These devices provide an integrated approach to system management that simplifies design and integrates functionality to reduce system cost and board space requirements (Figure 1). As devices targeted for consumer or commercial applications, however, these SMCs are restricted to a temperature range of 0°C to +70˚C and cannot provide either the interface/peripheral mix or environmental robustness required for the reliable operation of an industrial PC.

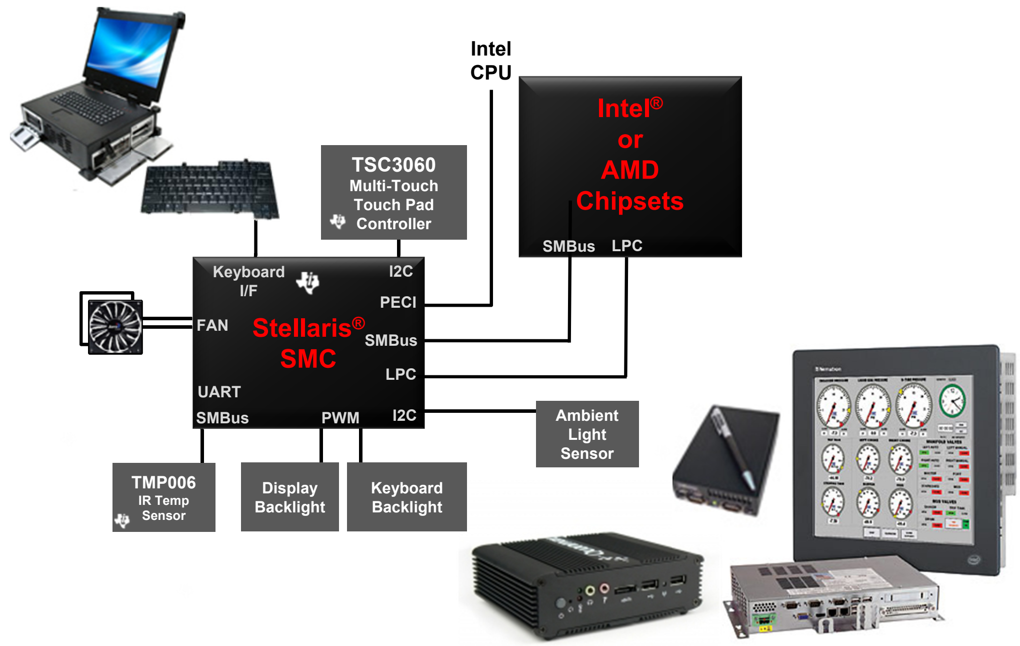

Figure 1. With the rising complexity of today's industrial PCs, a system management controller (SMC) must be able to flexibly support a wide range of types and number of interfaces across an extended temperature range that exceeds the capability of consumer and commercial SMCs.

The Stellaris® LM4FS SMC series

To meet the needs of the industrial market, TI has introduced the Stellaris LM4FS SMC series of system management controllers. The Stellaris LM4FS microcontroller is the first SMC available on the market designed to bring the capabilities of today's commercial technology to industrial applications. In addition to integrating the required industrial interfaces, the Stellaris LM4FS SMC is rated to operate reliably from –40°C to +85˚C, with optional support for extended temperature operation up to +105˚C.

Based on TI's industry-proven Stellaris MCU architecture with an ARM® Cortex™-M4F core operating at 80 MHz, the LM4FS SMC series provides powerful 32-bit processing performance to monitor and manage today's complex industrial PC architectures. Developers also have the system resources they need – 256 KB Flash, 32 KB SRAM and 2 KB EEPROM – to design robust SMC systems. By integrating the analog, digital and industrial interface peripherals required by a SMC, the Stellaris LM4FS device reduces both component count and cost to provide an overall lower cost implementation that offers higher performance, superior power efficiency and simplified design using a single development environment.

The Stellaris LM4FS SMC series provides complete system management control functionality (Figure 2), including a platform environment control interface (PECI), a low pin count (LPC) bus, advanced PWM fan control, software keyboard control and software PS2 and OneWire® interfaces. To ensure the highest accuracy and reliability, the architecture supports two high-performance 12-bit ADCs capable of 1 MSPS without the need for hardware averaging. Three analog comparators are also available to offload the CPU for tasks such as real-time threshold checking. An integrated LDO voltage regulator and temperature sensor further reduce component count, board size and system cost.

The Stellaris LM4FS SMC series has prolific connectivity: up to 3 UART, 6 I²C, and 4 SSI/SPI interfaces. For applications that require additional interfaces, the Stellaris LM4FS19 device also offers dual CAN, USB 2.0 Full Speed with support for Host, Device and On-the-Go (OTG), plus a motion-control PWM block with up to 16 PWM outputs.

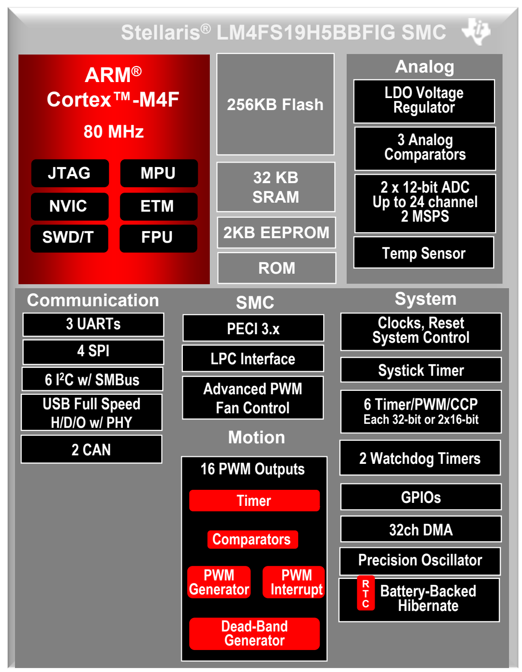

Figure 2. The Stellaris LM4FS SMC series provides complete system management control functionality, including two high-performance ADCs, a platform environment control interface, a low-pin-count bus and advanced PWM fan control. It also supports a wide range of industrial interfaces to further reduce component count, board size and system cost.

The Stellaris architecture also offers the highest power efficiency for a processor of its class and capabilities. Built upon TI's proprietary 65-nm process technology, the Stellaris LM4FS SMC series achieves standby current as low as 1.6 µA and supports active real-time clock (RTC) modes operating down to 1.7 µA. In addition, the wakeup time of 500 µs or less allows the SMC controller to save additional power by spending idle time in sleep or hibernate modes, and wakes up quickly when the application requires full performance provided in active mode.

Flexibility for a single-platform design

When a system designer must develop their own IP in-house, there is a tendency to mandate its use in future designs. For example, given the high investment required to create an ASIC, developers will seek to minimize future investment by leveraging existing ASIC devices when they develop new products. However, while using a single SMC design across an entire product line is compelling in terms of lower cost, reduced development and faster time-to-market, such an approach can be extremely limiting given that existing implementations may not be optimized for a particular application.

With the Stellaris LM4FS SMC series, TI brings a new level of flexibility to SMC design. The high level of integration of the Stellaris LM4FS architecture makes it possible for a single platform to serve as the base hardware in multiple applications. Because certain key aspects of SMC functionality are configurable or implemented in software, developers can customize the SMC to meet the specific requirements of individual products to achieve an optimal implementation. For example, developers can turn off interfaces that are not required or in use for a specific application. In addition, the flexibility of software-based control enables developers to implement exceptional handling of peripherals and interfaces without having to redesign the entire platform.

By implementing configuration details in software, designs based on the Stellaris LM4FS SMCs can accommodate many changes with simple firmware changes that would require hardware-based modifications in FPGA- and ASIC-based designs. In addition, developers can create an entire SMC design using a single development environment.

From a hardware perspective, developers have the ability to easily reroute the device GPIOs to accommodate hardware constraints on interface placement and routing. Consider a late design change where an interface needs to be relocated to the other side of the controller. With the Stellaris LM4FS SMC, a simple firmware update will enable this. In contrast, with an FPGA-based approach, rerouting within the FPGA would have to be managed manually. For ASIC-based designs, accommodating even the simplest change requires an expensive re-spin.

To enhance the re-routable capabilities of Stellaris LM4FS devices, TI provides intuitive GPIO configuration tools that substantially simplify the customization of interface placement. ASICs, with their fixed implementation, cannot easily accommodate routing changes. Even though FPGAs offer flexible routing, the method with which they are configured is still extremely complex. Consider that any change to an FPGA configuration requires retesting of the device to ensure the new routing was implemented correctly. In addition, implementing an interface for the first time on an FPGA can be time-consuming if there are no existing libraries available. Even with libraries, the interface must be thoroughly tested to ensure it meets standard interface specifications.

With the multiple GPIO routing options and pin configuration tools of the Stellaris LM4FS SMC, TI has eliminated the need for interface integration and testing. All interfaces and firmware have been pretested across all I/O locations to which they can be routed. Thus, there is no need to qualify interfaces each time they are modified. In addition, GPIO configuration change is a simple point-and-click process, thus significantly reducing development time and engineering costs.

This approach can also substantially speed time to market. With the Stellaris LM4FS SMC series, developers can begin their designs immediately and leverage IP provided by TI to accelerate the design of industrial applications. In addition, the ability to customize the SMC for each application enables developers to quickly address new market opportunities by eliminating the need to build an in-house interface IP from scratch or wait the many months required to turn around an ASIC re-spin. The result is increased market agility with the ability to react to the market within weeks rather than several quarters.

The cost savings due to integration extend to future designs as well by enabling developers to easily optimize their base SMC platform to new applications. In this way, developers are able to use their software investment over the long-term with a single hardware design, avoiding the recurring expense and market delays associated with having to create one-off FPGA designs or re-spin an ASIC.

Extending interface support and capacity

Capacity is another important consideration for developers. Today's industrial PCs, following in the technology wake of desktop PCs, continue to become increasingly complex with the need to support more interfaces and peripherals. With ASIC-based designs, adding an interface frequently requires a system design re-spin. Systems that use an FPGA can also encounter capacity issues as the rising number of interfaces and peripherals exceeds the available number of gates on the FPGA. Consequently, the need to support multiple sizes of FPGA makes it harder to standardize on an implementation while still enabling cost-effective scaling of capacity. In addition, FPGA companies typically deliver only the hardware interface IP; developers still have to develop and test their own software stacks, drivers and middleware.

The Stellaris LM4FS architecture gives developers a great deal of flexibility in matching capacity to each application using a single platform. To further optimize capacity to individual applications, TI will expand the Stellaris LM4FS roadmap to offer additional devices in 2013. The series will have solutions that range from lightweight versions of the Stellaris LM4F MCUs that provide reduced capacity for cost-optimized applications, up to configurations ideal for applications that need more interfaces and peripherals, such as board management controllers (BMC) used in servers and racks.

TI also provides its customers with all of the baseline software required to implement a complete SMC with a mature tool chain that helps manage the software development process and substantially speeds system design. The development process is built around the powerful Code Composer Studio™ tool suite, providing developers with a powerful integrated development environment (IDE) and debugger.

Traditionally, industrial development has been a niche market without the volumes to justify tool investment by silicon manufacturers. Because Code Composer Studio IDE supports the entire portfolio of TI processors, developers are able to leverage the same professional-level tools which developers of consumer and commercial applications have access to. In addition, many engineers are already familiar with the Code Composer Studio environment from other work they have completed. This leads to less upfront design investment in terms of tool cost and learning curve, enabling developers to spend more time on making their products easier to use or to implement more advanced functionality.

TI also offers a wide range of integrated software tools and libraries to jumpstart development. The StellarisWare® software library provides production-ready drivers for all of the peripherals and interfaces on Stellaris LM4FS devices. Software applications are also available to support incremental firmware development and in-field updates. TI also provides its SMC Library, offering a comprehensive collection of system management controller functionality.

The SMC Library has more than just the low-level drivers required to monitor and manage systems. It also includes a middleware layer to simplify application design. For example, the fan control algorithms include a lightweight API for directly driving the fan while abstracting all of the low-level implementation details such as managing the pulse width modulator (PWM) to drive the fan or tracking which I/O are used for this particular implementation.

The SMC Library offers a wide range of capabilities that can be easily implemented in an industrial PC design (Figure 3) including matrix keyboard support through GPIO, sensor management and power sequencing to bring up a system in the proper order.

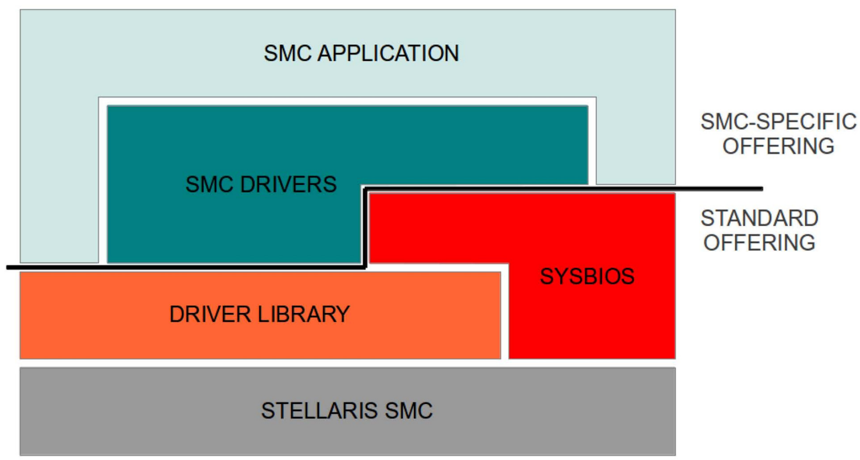

Figure 3. The system management controller (SMC) Library from TI provides a comprehensive collection of production-ready functions for accelerating the design of industrial PCs. It also offers a middleware layer with a lightweight API for simplifying application design while abstracting all low-level implementation details.

Developers can also quickly implement pretested and robust implementations of numerous interfaces important for industrial PC designs, including:

- **Advanced Configuration and Power Interface (ACPI):** Enables control of the power state of the x86 processor
- **Intel Low Pin Count (LPC) Bus:** A motherboard-only (no connector) bus used for communication between I/O functions and peripherals
- **Intel Platform Environment Control Interface (PECI) version 3.0:** PECI is a standard for thermal management using on-die digital thermal sensors (DTS) to provide processor-specific operating temperature information that is more accurate than alternative thermal monitoring methods

- **System Management Bus (SMBus):** An I^2C-based protocol promoting robustness and interoperability between devices such as power chips, fans and voltage sensors

The Stellaris LM4FS SMC series is also architected to support a real-time operating system (RTOS) or kernel. The SMC for an industrial PC must be able to guarantee and prioritize multiple real-time tasks while still supporting efficient application processing. Robustly managing real-time tasks and interrupts is greatly simplified when an RTOS is used to configure and service real-time tasks.

For example, with the TI-RTOS™, developers can add new functionality without having to re-time the system to ensure every interrupt is serviced and that the priority of tasks is not accidentally inverted. The TI-RTOS achieves this by abstracting the complexity of real-time scheduling. The TI-RTOS is open source and royalty free.

TI also has SMC reference designs available that provide developers with a base design utilizing the key system management controller capabilities of the Stellaris LM4FS SMC series. Developers can also utilize TI's extensive technical support network to accelerate design.

Industry leadership and expertise

TI is a world-leading supplier to vendors of PC-compute platforms across notebooks, desktops and servers. TI works with both Intel and AMD to develop reference designs and brings intimate knowledge of these platforms to the design of its industrial controllers.

For several years, TI has also been the lead supplier of semiconductor electronics to the industrial market, according to IHS iSuppli[1]. With the ability to leverage its expertise from both of these industries, TI is uniquely positioned to support its customers with real-world engineering and market experience for industrial applications.

As a design partner, TI is also able to offer more of the system solution than any other vendor. In addition to providing integrated system management controllers, TI provides a complete array of other components developers need, including sensors, multi-touch touchpad controllers, analog signaling and analog power technology. Many industrial developers already rely upon TI for their analog components. With the introduction of the Stellaris LM4FS SMC series, these companies can now source the controller for their SMC designs as well.

As one of the few companies in the world with extensive knowledge of both PC compute and industrial platforms, TI is able to provide world-class support and design services to its customers to accelerate their development cycles, help cost-reduce designs and minimize risk.

Developers can also have confidence that their designs will be able to keep pace with advances in PC technology. As a technology leader, TI is continuously investing in innovation, and every breakthrough, whether in tools, silicon, or software, is one TI's customers can leverage immediately without having to redesign their existing hardware or software IP.

With the release of the Stellaris LM4FS SMC series, TI continues to demonstrate its leadership in the industrial market. The Stellaris LM4FS SMC series is the first that supports industrial interfaces, integrated Flash and a large SRAM plus optional USB, CAN and motion-control peripherals for those applications that need these capabilities. Now developers can get a controller that has been designed for use in industrial environments, eliminating many of the reliability concerns associated with consumer and commercial devices.

The Stellaris LM4FS SMC series provides a cost-effective, low-power foundation for designing a single SMC platform that can be customized to meet even the exceptional requirements of industrial PC applications. Its' highly integrated architecture consolidates the functionality of multiple chips into a single controller while providing flexibility through software programmability and hardware-based mapping of interfaces to GPIO to reduce routing challenges.

Based on the proven, mature and robust Stellaris architecture, the Stellaris LM4FS SMC series offers a full hardware and software solution backed by professional design tools that cannot be matched when using proprietary or in-house controllers. Developers are able to provide an optimal implementation for different industrial PC product lines while lowering cost, achieving better power efficiency, reducing board space requirements and accelerating time to market.

If you are interested in learning more about TI's solutions for the industrial PC market, please contact your local TI sales representative or the Stellaris industrial PC team (**IndustrialPC@list.ti.com**) for samples and pricing information.

References

[1] The HIS iSuppli Industrial Electronics Market Tracker report.

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