Industrial automation systems are getting smaller, yet require more performance and lower energy consumption

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Introduction

The complexity of the modern factory has brought intense demand for precision and efficiency in the machines, control systems and communications required for it to operate. The cost of error has driven more and more factories to automate as many of their processes as possible. With this push towards automation, microcontrollers (MCUs) play a key role – particularly in sensor communication networks, and equipment monitoring. Consider sensors and transmitters throughout a factory – a typical sensor system will consist of the sensor element, a control block for processing sensor data and a communications interface (Figure 1). The microcontroller in this system is often responsible for amplifying and reading the value from the sensor element. This data is then processed and used to either take an immediate action, such as turning on a cooling system as temperature rises, or is transmitted back to a central node for overall system monitoring. This communication handled on the MCU can take several forms. It could involve wired protocols such as IO-Link or 4–20mA current loops, or could leverage a wireless transceiver to pass information throughout a factory. Even a basic system such as this presents challenges that must be addressed by microcontrollers in the system.

The challenges

Factory automation and process control in industrial systems bring unique sets of requirements and challenges for engineers:

- Achieve more performance on a reduced power budget
- Collect more precise sensor data to make better decisions
- Operate in increasingly harsh environments
- Fit the entire design in a space-constrained location

From a power perspective, developers are often constrained by the energy available, whether that energy comes from a battery, where replacement could mean high labor costs across thousands of sensor nodes, or operating from a current loop, where each node must consume under 3mA of current to meet the overall specifications of the loop. While working to minimize energy consumption, these developers are often faced with a need to

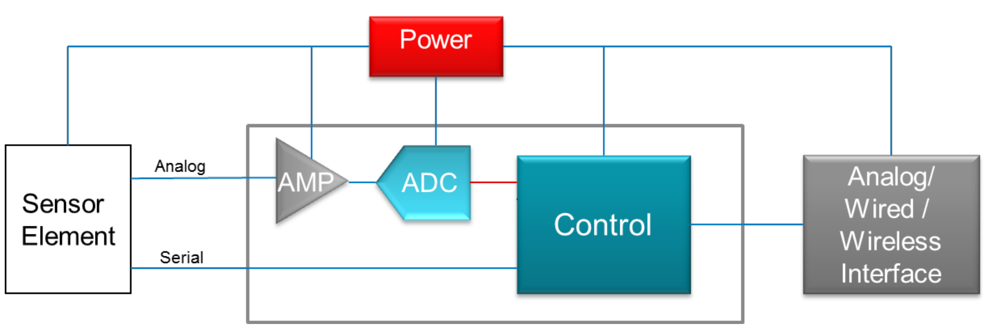

Figure 1: A typical industrial sensing system

capture above 16-bit resolution on sensor readings so that the system can distinguish between small changes in the environment and make the desired decisions. They also require high-performance analog for communicating on current loops. All of this is amplified by the need to operate at higher temperatures in cases such as those where sensors are located next to large motors. Finally the entire sensor node must fit within the communication wires connecting different parts of the overall automation system. These challenges are real, but the need to support multiple protocols such as IO-Link, 4–20mA and HART® creates software complexity as well. The MSP MCU portfolio offers chipsets to meet any and all of these challenges.

Protocol	Description
4-20mA Current Loop	All components communicate on a single loop, using current to represent a value (like water level) – 4mA represents min value (0 meters), 20mA represents max value (100 meters), 0mA represents system failure.
HART	Superimposes a small AC signal over the existing DC signal in a 4–20mA loop, and provides a "smart" digital interface, enables additional information (i.e., beyond just water level) to be transmitted, and allows for two-way communication in the system.
IO-Link	Point-to-point digital serial communication ideal for communicating with sensors and/or actuators. Allows two-way exchange of process data, service data and events.

Figure 2. Some of the common communication protocols with a brief description

Addressing the challenges of industrial automation systems

Low power + performance

There are prominent and recurring challenges across all market sectors that are just as prevalent in factory automation. At the forefront are the needs for a system to reduce power consumption. In our basic system, temperature sensors may be wireless and require batteries that last as long as possible (in some cases, over 20 years). In addition, when a factory uses a 4–20mA current loop for communication, there is a typical max current budget of less than 3.5mA on the loop. With such limited current, the MCU needs to consume as little energy as possible. MSP microcontrollers continue to lead the industry in power-optimized applications. The key to achieving the lowest power consumption is recognizing that **power is more than one number**. Some systems require the lowest standby current consumption, others require higher performance with low active current consumption, and many require a combination. Beyond the basics, there is a need to reduce energy consumption required to read and store sensor data as well as to optimize application software.

TI's ultra-low-power MSP MCUs with **Ferroelectric Random Access Memory (FRAM)** are perfect for applications that spend the majority of time in standby or need to log data. They consume as little as 350nA of current with the real-time clock enabled and are able to write 13 KB of data to nonvolatile storage in milliseconds, not seconds. They even provide more computational performance with optimized math libraries that can be leveraged in combination with the 100µA/MHz active mode current for efficient operation. If 32-bit performance is needed, the **MSP432™ MCU series** offers up to 48-MHz operating frequency and an ARM® Cortex®-M4F core that still delivers best-in-class active-mode current consumption of 90µA/MHz. Moreover, unique optimization utilities including **EnergyTrace™ technology** are available to deliver unmatched real-time power profiling for MSP MCUs.

Making smarter designs

Once power concerns are addressed, system integration becomes a key priority. High-performance analog does not need to be integrated in the microcontroller (MCUs usually have serial communication ports including SPI, I^2C or UART for communication to external interfaces), but **doing so can simplify development and help to reduce overall system power consumption and size**. The MSP MCU portfolio contains chipsets with a high degree of on-chip analog integration, perfect for quick and easy implementation of factory automation applications. Many MSP MCUs contain 10-, 12-, and 14-bit ADCs and DACs, operational amplifiers and comparators. In particular, the **MSP430i2x** MCU family features four on-chip 24-bit Sigma-Delta ADCs. Specialized peripherals are also available. The extended scan interface, available in the FRAM MCU series, is an analog front end that enables flow measurements that consume less than 9nA per sample in a two-sensor system using induction, magnetic or optical sensors.

Using FRAM-based microcontrollers in a system can improve system efficiency in other ways as well. FRAM offers a unified location to store application and data with the flexibility to adjust the allocated proportions as development needs change. What's more, on-the-fly, bit-level data writes that do not require buffering or pre-erase means that wireless transmissions can be shorter. This is critical to battery-powered systems, where wireless communication often consumes the most energy in the system. This also means that over-the-air updates will consume less power and be simpler to handle in software. Finally, if power does fail, the **Compute Through Power Loss FRAM utility** enables your system to restore system state after power failure with two lines of code and no backup power source required.

These features all come together on MSP MCUs to create system-on-chip solutions that can handle analog sensor inputs, output directly on 4–20mA current loops and run communication protocols.

High operating temperature

High temperatures are common in many aspects of a factory's production line. Sensor nodes are often placed close to processes that generate a lot of heat and need to withstand high temperatures. One example is a sensor node used for **equipment monitoring**. Rather than use a handheld meter to ensure motors in a factory are operating correctly, remote sensor nodes can run calculations on vibration data and transmit that data to a central hub. In cases, where that equipment runs hot, the MSP MCU portfolio offers wide operating temperature ranges across Flash and FRAM products. The MSP430F2xx MCU family in particular, contains MCUs that operate at temperatures up to **105°C, 125°C and even 150°C**.

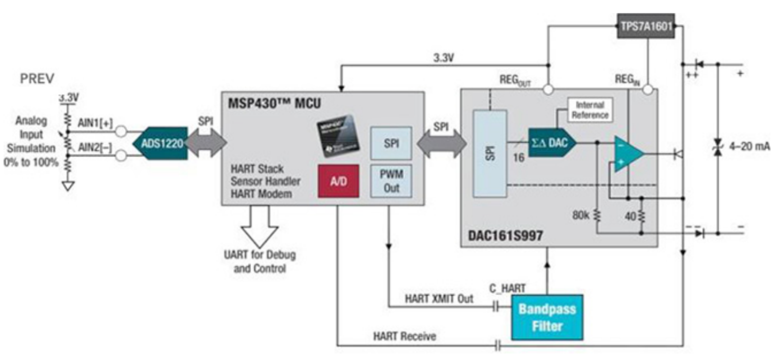

Figure 3: ***Field transmitter featuring HART® communications***

Small package size

When package size is the primary concern, MSP MCUs deliver a wide range of options as well. The

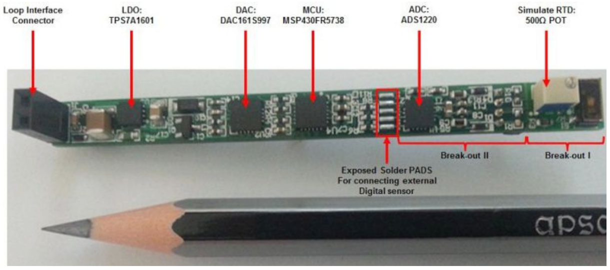

Figure 4: ***Current loop TI Design using the MSP430FR5738 MCU***

portfolio includes many chips in a 4-mm × 4-mm configuration. But in some factory automation applications this may not be small enough. In our system, some sensor nodes may need to be as thin as the communication wires on which they communicate. The MSP430FRx FRAM MCU series includes a packaged device as small as 2 mm × 2 mm to accommodate these types of communication and control applications. Combined with analog integration and the ability to take over the functionality of external EEPROM with FRAM, MSP MCUs can offer the perfect fit for small form-factor designs.

Full solutions

Reference Designs

TI offers many resources for using MSP MCUs in industrial automation environments. There are many TI Design reference designs available that offer holistic and detailed solutions, many of which would help implement the systems described earlier. In fact, many designs are geared toward industrial communication solutions for various protocols or sensing solutions of various types. View a summarized list of designs in Figure 5 on the following page.

Conclusion

The system we used to demonstrate the ability of MSP MCUs to meet the prevalent challenges in factory automation is a very simple example. Especially with the latest trends toward full automation in factories, systems that require MCUs are growing larger and more complex. As they grow, they demand more and more from microcontrollers. Texas Instruments' MSP MCU portfolio offers ultra-low-power and high-performance options that can meet the application demands of lower power, increased performance and integration, higher operating temperatures and smaller system size. Beyond having the right MCU to meet any of these needs, TI also offers tools and solutions to simplify implementation for developers. To find resources for a particular application, head over to **ti.com/MSPApps**.

TI Design	Reference #	Application	Details	Featured MCU
Data isolation for loop-powered applications	TIDA-00245	Communications	4–20mA	MSP430FR5969
NFC logger with FRAM	TIDA-00230	Communications and data logging	NFC	MSP430FR5969
Low-power micro-stepper motor driver using FRAM MCU	TIDM-LPSM	Motor control	CTPL utility	MSP430FR5969
Termocouple AFE with RTD CJC	TIDA-00168	Sensors	RTD	MSP430FR5949
Inductive proximity BoosterPack (LDC1101)	TIDA-00460	Sensors	Proximity	MSP430F5528
Turnkey IO-Link sensor transmitter	TIDA-00188	Sensors & communication	RTD & IO-Link	MSP430FR5738
RTD temperature transmitter for 2-wire, 4- to 20-mA current loop systems	TIDA-00095	Sensors & communication	RTD & 4–20mA	MSP430G2513
Isolated thermocouple transmitter 4–20mA	TIDA-00189	Sensors & communication	RTD & 4–20mA	MSP430F5172
Small form factor RTD sensor, 4–20mA	TIDA-00165	Sensors & communication	RTD & 4–20mA	MSP430FR5738
Single-chip temperature transmitter	TIDA-00247	Sensors & communication	RTD & 4–20mA	MSP430F2274
Hall-based proximity switch sensor with SIO interface	TIDA-00244	Sensors & communication	Proximity & SIO	MSP430FR5738
Linear Hall-based proximity sensor with SIO interface	TIDA-00286	Sensors & communication	Proximity & SIO	MSP430FR5738
Proximity and temperature multi-variable sensor IO-Link	TIDA-00341	Sensors & communication	Proximity/Temp & IO-Link	MSP430FR5738
Hall-Effect proximity sensor with IO-Link	TIDA-00340	Sensors & communication	Proximity & IO-Link	MSP430FR5738
IO-Link device with SPI sensor interface	TIDA-00339	Sensors & communication	Any sensor w/ SPI & IO-Link	N/A
HART field transmitter for RTD temperature	TIDM-HRTTRANSMITTER	Sensors & communication	RTD & HART	MSP430FR5969
Water meter reference design for two LC sensors	TIDM-LC-WATERMTR	Flow metering	LC sensors	MSP430FR6989
Water meter reference design for optical sensors	TIDM-OPTICALWATERMTR	Flow metering	Optical sensors	MSP430FR6989
Water meter reference design for GMR sensors	TIDM-GMR-WATERMTR	Flow metering	GMR sensors	MSP430FR6989
Ultrasonic flow meter design	TIDM-ULTRASONIC-FLOW-TDC	Flow metering	Ultrasonic sensors	MSP430FR6989
Intelligent system state restoration after power failure	TIDM-FRAM-CTPL	Control systems	N/A	MSP430FR6989

Figure 5: TI Designs for factory automation and control applications

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