Automating the industry with low power microcontrollers

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What you will learn today

• Trends in the industrial market
• An example system and the place of low-power microcontrollers
• The latest from the MSP family of microcontrollers: FRAM and MSP432™ MCUs
• Related reference designs from TI for
  • Industrial Communications
  • Flow Metering
  • Equipment Monitoring
  • Compute Through Power Loss (CTPL)
Challenges in Industrial Automation Systems

- Lower Power
- Higher Resolution Analog
- Wider Operating Temperatures
- Reduced System Size
Field transmitters facilitate automation and process control:
- Temperature
- Pressure
- Flow
- Vibration
Industrial Sensing and Communications
TI’s Low-Power Microcontroller Solutions

16-bit MSP430™ MCUs
• The industry leader in ultra-low-power, rich peripherals and analog integration.
• World’s only portfolio of ultra-low-power embedded FRAM MCUs.
• Growing portfolio of more than 500 ultra-low-power MCUs across 13,000+ customers.

32-bit MSP432™ MCUs
• Industry’s lowest power ARM® Cortex®-M4F MCUs. Period.
• High performance MCUs without sacrificing power consumption.
• Pin-for-pin platform planned; sampling 256KB today.

Wireless MCUs
• Focused on ease of use and low power.
• Support for 14 standards including Bluetooth® Smart, Wi-Fi®, Sub-1 GHz, 6LoWPAN, ZigBee® and more.
• Portfolio includes SimpleLink™ Wi-Fi, SimpleLink ultra-low power and CC430 platforms.
Challenges in Industrial Automation Systems

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MSP MCUs: Continued Low-Power Leadership

Leverage the EnergyMonitor tool to evaluate MCU power using your application code.

See for yourself: ULPBench Scores

MSP MCUs: Industry’s lowest power
16-bit MCUs and 32-bit Cortex-M4F MCUs.
Introducing the FRAM Advantage

The lowest power

• Because you spend so much time in standby, current consumption as low as 350 nA

• When your application wakes up, 100µA/MHz active mode current for efficient operation

• Write quicker to save power; 13 KB in milliseconds, not seconds

The smartest designs

• Adjust to changing memory requirements with flexible non-volatile FRAM; store your application, data or both

• Restore your system state after power failure with two lines of code and no backup power source

• Update your system over the air with on-the-fly, bit level data writes and no buffering or pre-erase required

The highest reliability

• Log data continuously with $10^{15}$ write endurance and proven 10 year data retention at 85°C

• Prevent unauthorized memory and data communication access with IP encapsulation and hardware AES

• Diminish data loss with undetectable soft error rates and other inherent security advantages of FRAM
Compute Through Power Loss (CTPL)

System counter implementation on startup

Context save on power failure

Application resume on power restore

MSP-EXP430FR6989 LaunchPad Development Kit
CTPL | Makes LPMx.5 Easy to Use

• Reduces the complexity and makes it easier to use LPMx.5

```c
// Check if a wakeup from LPMx.5 was detected and use a dedicated dev.
// previous program execution in that case.
if (SYSSTIV == SYSSTIV_LPMX5U) {
    mode = APP_ULP_ADC;
    select = SEL_ADC_LPM3S_MODE;
    setClock = 1;  // After exiting from LPM3.5, set up date and time
    SystemInitFromLPM35();
} else {    // Start up normally
    SystemInit();  // Initialize board
    // Display TI Logo
    LCD_drawPicture(1);
    TA1_sleep(8192);        // 2s
    // Display Wolverine Slash
    LCD_drawPicture(2);
    TA1_sleep(8192);        // 2s
    // Write "Wolverine User Experience" on LCD
    LCD_introWrite();
    TA1_sleep(8192);        // 2s
}
```

One simple function call saves state of your system…

```c
void ctpl_enterLpm35(bool restoreOnReset);
```

Similarly, one function call restores the state upon waking up!
CTPL | Save Processor State on Power Loss

- Gracefully enter and exit shutdown on power loss using VCC monitoring
- Ensure enough energy through system capacitance

![Diagram showing VCC, VCC Monitor TH ~ 2.6V, SVS TH, and 0V levels with application runs and shutdown phases, indicating ctpl_enterShutdown() and state transitions on power-up and power-down.](diagram.png)
Ultra-Low-Power MSP FRAM MCU Portfolio

Broad portfolio
- 100s of device options
- 4 – 128 KB FRAM
- More than 10 packages
- Integrated smart analog

MSP430FR5x
- Up to 64 KB FRAM
- ADC12
- 256-bit AES accelerator
- 40-48 pins

MSP430FR6x
- Up to 128 KB FRAM
- ADC12
- 256-bit AES accelerator
- Scan interface
- Integrated LCD
- 64-100 pins

MSP430FR2x
- Up to 16 KB FRAM
- ADC10
- Up to 60 I/O
- 48-64 pins

MSP430FR4x
- Up to 16 KB FRAM
- Integrated LCD
- ADC10
- Up to 60 I/O
- 48-64 pins

Integration

Texas Instruments
MSP432 – Low-power + Performance

MORE PERFORMANCE FOR MSP430™ MCU DEVELOPERS
Advance to higher levels of computing and analog performance, while maximizing your ultra-low-power MSP430 MCU investment and expertise

LOWER POWER FOR ARM® DEVELOPERS
Slash power consumption and boost performance with the world’s lowest power Cortex®-M microcontroller

NO COMPROMISES
Get low-power and performance with a scalable portfolio of 16-bit and 32-bit MSP microcontrollers in a variety of applications
MSP432 MCU: PERFORMANCE AT ITS CORE

Selecting the high-performance ARM® Cortex®-M4F core

Highest Coremark score: 3.41/MHz

48MHz ARM® Cortex®-M4F
• Full ARM instruction set
• DSP extensions
• FPU engine

Industry-leading ultra-low-power
• Active power: 95 µA per MHz
• Sleep mode: 850 nA (with RTC)
• ULPBench score: 167.4

Incorporating high-performance peripherals and features
• Simultaneously read and erase from flash
• Execute up to 200% faster with DriverLib in ROM vs. Flash
• 14-bit 1MSPS ADC with 13.2ENOB, differential mode & 2 window comparators
MSP432 MCU: LOW-POWER AT ITS BEST

48MHz ARM® Cortex®-M4F
- Full ARM instruction set
- DSP extensions
- FPU engine

Industry-leading ultra-low-power
- Active power: 95 μA per MHz
- Sleep mode: 850 nA (with RTC)
- ULPBench score: 167.4

Optimizing peripherals for ultra-low power
- Save 40% more power with the integrated DC/DC vs. LDO
- Save 30nA per RAM bank with selectable RAM retention
- Consume minimal power (375uA) when sampling sensors at 1MSPS with 14-bit ADC
- DriverLib in ROM consumes up to 35% less power than Flash
Challenges in Industrial Automation Systems

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- Reduced System Size
Analog Integration Highlight

- High degree of analog integration makes system design simpler and easier
- Many MSP MCUs have on-chip integrated ADCs, DACs, and Op Amps
- MSP430i2xx family features on-chip 24-bit Sigma Delta ADC
- MSP432P401R features a high resolution 14-bit SAR ADC

24-bit Sigma-Delta Benefits

- Differential inputs - good for AC measurements and eliminates need for level shifting
- Simultaneous conversions - no inherent delay between voltage and current samples means SW compensation not required
- Built-in PGA - when shunt resistors or Rogowski coils are used, complete dynamic range can be used with any external gain amplifiers
Smart Peripheral Highlight

Extended Scan Interface (ESI) – MSP430FR69x

- Standalone module, operational in LPM3
- Measures rotation with 4 input channels
- Two unique analog front ends ensure parallel rotation measurement and calibration
- Dedicated 12-bit DAC, RAM and internal connections to 32kHz clock and timer output
- Orders of magnitude lower power than software-based approach
- Suitable for water, gas and heat meter flow measurement (induction, magnetic, or optical sensors)

- FR69x current per sample for 2 Sensors < 9nA
- FW42x current per sample for 2 Sensors < 17nA
Flow Metering Solutions

- **Challenge**: Continuously measure flow while consuming as little energy as possible
- **MSP430FR6989 MCU**
  - Ultra-low-power flow sensing with Extended Scan Interface
  - 320 Segment LCD Display Driver
  - 128kB of Unified FRAM

LC Water Meter TI Design
Ultrasonic Flow Meter Reference Design
Challenges in Industrial Automation Systems

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Extended Operating Temperatures

- System processes often require an MCU to operate at temperatures beyond the standard 85°C
- MSP430F2xx and MSP430i2xx MCU families offer chipsets with operating temperatures up to 105°C

- MSP430F2xx: 150°C -
- MSP430F2xx: 125°C -
- MSP430F2xx: 105°C -
- MSP430i2xx: -40°C -
- MSP430i2xx: -55°C -
- MSP430F5xx: -40°C -
- MSP430F5xx: -55°C -
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Small Package Size Options

- Often sensors on com links need to be as thin as wires that link them
- Some sensors require a package size that is less than 3mm wide
- **MSP430FR57xx** MCU family includes packages as small as 2mm x 2mm

<table>
<thead>
<tr>
<th>NVM Package Size (in mm)</th>
<th>2x2 (24DSBGA)</th>
<th>4x4 (24QFN)</th>
<th>5x5 (32QFN)</th>
<th>6x6 (40QFN)</th>
<th>7x7 (48QFN, 113BGA)</th>
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<tbody>
<tr>
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<td>MSP430FR5738</td>
<td>MSP430FR5738</td>
<td>MSP430i204x*</td>
<td>MSP430FR5969*</td>
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</table>

* 105°C
Single Chip HART Protocol and Modem Solution

Benefits
• Saves board space and cost by integrating dedicated HART IC (ASIC) and sensor MCU into a single MSP430 device.

Features
• Physical media: Same as 4-20 mA wiring (no terminators needed)
• Max devices: Point-to-point to multi-drop up to 15 devices.
• Max distance: 3000 meters (can use repeaters)
• Communication method: Analog 4-20 mA, plus two-way digital master/slave
• Cycle time: 500 ms for digital
• Data Packet size: Four process variables in IEEE floating point values.

Learn more at: HART Transmitter TI Design
Equipment Monitoring

• **A pervasive ULP vibration and temperature monitoring solution**
  – No wired power
  – Hourly to daily measurements
  – Local data processing

• 10+ Year Coin Cell Battery Life (100mAh Coin Cell)

• **Wireless Communication**
  – Bluetooth Smart (BLE) Communication

• **Temperature & Vibration Sensing**
  – Investigate precision piezoelectric vibration sensor
  – Co-packaged modular solution (sensor + AFE)

• **Small form factor**
  – Target final solution size similar to a matchbox

**Motor Condition Monitor TI Design**
<table>
<thead>
<tr>
<th>TI Design</th>
<th>Reference #</th>
<th>Application</th>
<th>Details</th>
<th>Featured MCU</th>
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<tr>
<td>Data Isolation for loop powered applications</td>
<td>TIDA-00245</td>
<td>Communications</td>
<td>4-20mA</td>
<td>MSP430FR5969</td>
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<td>NFC logger with FRAM</td>
<td>TIDA-00230</td>
<td>Communications and Data Logging</td>
<td>NFC</td>
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<td>Low Power Micro Stepper Motor Driver using FRAM MCU</td>
<td>TIDM-LPSM</td>
<td>Motor Control</td>
<td>CTPL utility</td>
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<td>Thermocouple AFE with RTD CJC</td>
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<td>RTD</td>
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<td>Inductive Proximity BoosterPack (LDC1101)</td>
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<td>Proximity</td>
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<td>Turnkey IO-Link Sensor Transmitter</td>
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<td>Sensors &amp; Communications</td>
<td>RTD &amp; IO-Link</td>
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<td>RTD Temperature Transmitter for 2-wire, 4 to 20-mA Current Loop Systems</td>
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<td>Isolated Thermocouple Transmitter 4-20mA</td>
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<td>Sensors &amp; Communications</td>
<td>RTD &amp; 4-20mA</td>
<td>MSP430FR5969</td>
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<td>Small Form Factor RTD Sensor , 4-20mA</td>
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<td>Sensors &amp; Communications</td>
<td>RTD &amp; 4-20mA</td>
<td>MSP430FR5969</td>
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<tr>
<td>Single Chip Temperature Transmitter</td>
<td>TIDA-00247</td>
<td>Sensors &amp; Communication</td>
<td>RTD &amp; 4-20mA</td>
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<td>Hall based Proximity Switch Sensor with SIO Interface</td>
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<td>Sensors &amp; Communication</td>
<td>Proximity &amp; SIO</td>
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<td>HART Field Transmitter for RTD Temperature</td>
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<td>RTD &amp; HART</td>
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<td>Water Meter Reference Design for two LC Sensors</td>
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<td>Flow Metering</td>
<td>LC Sensors</td>
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<tr>
<td>Water Meter Reference Design for Optical Sensors</td>
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<td>Ultrasonic Flow Meter Design</td>
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<td>Intelligent System State Restoration after Power Failure</td>
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<td>Control Systems</td>
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</tbody>
</table>

www.ti.com/tool/reference#
Summary in Industrial Automation Systems

- Lower Power
- Higher Resolution Analog
- Wider Operating Temperatures
- Reduced System Size
Answer the quiz and get a LaunchPad

Answer all 5 quiz questions correctly to get the chance to win a free coupon code to be exchanged for a MSP430FR6989 LaunchPad Development Kit

1. Go to www.ti.com/automatingwithmsp
2. Login
3. Answer all questions correctly
4. Wait for your confirmation (5 winners will be selected randomly)
5. Go to TI Store and redeem your coupon code!

www.ti.com/automatingwithmsp
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