MSP430 Ultra-Low Power MCUs

MCU Day 2009
One Day, Multiple Solutions
MSP430 Ultra-Low Power MCUs

MSP430 Agenda

• Architecture & Key Features
• Peripherals
• New Technologies
• Portfolio Overview
• Getting Started: Tools & Software
• Resources for You
MSP430 Ultra-Low Power MCUs

**Ultra-Low-Power + High Performance**

### Performance
- 16-bit RISC CPU up to 25MHz
- Industry leading code density
- Flexible clock system
- Single-cycle register operations
- 16 GP 16-bit Registers
- No accumulator bottleneck

### Integration
- 14 to 113 pin devices
- 1-256kB Flash/ROM
- 10-/12-/16-bit ADC
- 12-bit D/A, LCD Drivers, RTC, DMA
- Comparators and Op Amps
- Supply Voltage Supervisor & BOR
- 16-bit and 8-bit timers; WDT
- I2C, SPI, UART/LIN, IrDA
- USB & RF

### Low Power
- *Industry’s Lowest Power*
- Standby <1 µA
- Includes RTC and BOR
- Active 160 µA/MIPS
- Fast wake-up <1 µs
- Internal voltage regulator
- 4 Programmable voltage levels
- <50 nA pin leakage

### Ease of Use
- C friendly IDE and compiler
- One programmer for all devices
- Embedded emulation
- Trace, single-stepping, in-system debug
- Intelligent peripherals reduce overhead
- DTC, DMA, Autoscanning A/D
- Free & Low cost dev tools
# MSP430 Ultra-Low Power MCUs

## MSP430 Key Application Spaces

### Medical and Industrial Metering
- Glucose and cholesterol meters, thermometer, EKG, heart rate monitor, pulsoximeters
- Voltage, current, temperature, pressure, pH meters

### Sensoring
- Alarm system, smoke detector
- Home control and automation
- Wireless asset tracking
- Wireless sensors
- System supervisor

### Utility Metering
- Energy
- Water
- Gas
- Automated Meter Reading (AMR)
- Advanced Metering Infrastructure
- Heat Cost Allocation

### Portable Consumer
- Cell phone, digital camera, MP3
- Fitness monitors and sensors
- Toothbrush, shaver
- Remote control
- Wireless keyboard and mouse
- Battery charging
MSP430 Ultra-Low Power MCUs

Ultra-Low Power Is In Our DNA

- Every aspect of the MSP430 design for ULP
- Peripherals optimized to reduce power and minimize CPU usage
- Intelligent, low power peripherals can operate independently of CPU and let the system stay in a lower power mode longer

www.ti.com/ulp

- ✓ Multiple operating modes
  - 0.1 µA power down
  - 0.3 µA standby
  - 165 µA / MIPS
- ✓ Instant-on stable high-speed clock
- ✓ 1.8 - 3.6V single-supply operation
- ✓ Zero-power BOR
- ✓ <50nA pin leakage
- ✓ CPU that minimizes cycles per task
- ✓ Low-power intelligent peripherals
  - ADC that automatically transfers data
  - Timers that consume negligible power
  - 100 nA analog comparators
- ✓ Performance over required operating conditions
MSP430 Low Power Modes

- **LPM0**
  - CPU Off
  - DCO on
  - ACLK on
  - 45-65µA

- **LPM3**
  - RTC function
  - LCD driver
  - RAM/SFR retained

- **Stand-by**
  - DCO off
  - ACLK on
  - 1.0µA

- **Active**
  - DCO on
  - ACLK on
  - 165-500µA

- **Off All Clocks Off**
  - 0.1µA

Specific values vary by device
MSP430 Ultra-Low Power MCUs

**Ultra-Low Power Activity Profile**

- Extended *Ultra-Low Power* standby mode
- Minimum active duty cycle
- Interrupt driven performance on-demand
MSP430 Ultra-Low Power MCUs

16-bit Orthogonal RISC CPU

- Efficient, ultra-low power CPU
- C-compiler friendly
- RISC architecture
  - 27 core instructions
  - 24 emulated instructions
  - 7 addressing modes
  - Constant generator
- Single-cycle register operations
- Memory-to-memory atomic addressing
- Bit, byte and word processing
- 20-bit addressing on MSP430X for Flash >64KB
MSP430 Ultra-Low Power MCUs

Fast Flexible 10- and 12-bit ADCs

• 10-bit & 12-bit ADCs
• 200ksps+
• Autoscan
• Single Sequence Repeat-single Repeat-sequence
• Int/ext ref
• TA SOC triggers
• Data Transfer Controller (DTC)
• DMA Enabled
MSP430 Ultra-Low Power MCUs

High-Precision SD16

- 16-bit Sigma Delta ADC
- Differential inputs
- 4.096ksps
- 85dB SINAD
- 32x PGA
- 18ppm 1.2V ref
- Temp sensor
- Battery input
MSP430 Ultra-Low Power MCUs

**DAC12**

- 12-bit monotonic
- 8/12-bit voltage output
- Programmable settling time versus power
- Int/ext reference
- Binary or 2’s compliment
- Self-calibration
- Group sync load
- DMA enabled
MSP430 Ultra-Low Power MCUs

Analog Comparators

- ~100nA operation (Comp_B)
- Hysteresis generator (B)
- Input multiplexer
- Reference generator
- Low-pass filter
- Battery detect
- Interrupt source
- Timer_A capture
- Multiplexer short for sample-and-hold
MSP430 Ultra-Low Power MCUs

USCI: Serial Communication I/F

**USCI_A**
- UART with IrDA/LIN support or SPI
- Baud-rate generator with auto-baud rate detect
- Double buffered TX/RX

**USCI_B**
- I2C master/slave up to 400kHz or SPI
- Bit clock generator
- Double buffered TX/RXs
LCD Controllers

- Ultra-low power
- Fully automatic
- 4/3/2/1 mux
- Up to 160-bit display
- Internal regulated voltage generator
- Internal or external bias generation
- Contrast control
- 1/2 bias for 3 or 4 mux
- Internal clock generation
- Auto segment blinking
New MSP430 Technologies

FRAM | RF | USB | Energy Harvesting
MSP430 Ultra-Low Power MCUs

FRAM: Future of Embedded Memory

- Universal Memory
- Fast write capability
- High write endurance
- Non-volatility
- Low power
- High radiation hardness
- High tamper resistance
MSP430 Ultra-Low Power MCUs

**Products Enabled by FRAM**

- **High Write Endurance (SRAM Replacement)**
  - Digital rights management (>10M write cycles)
  - Data logging, sensor applications

- **Low Power Electronics**
  - FRAM instead of SRAM to eliminate quiescent current
  - Increases battery life
  - Enables “energy harvesting” (i.e. with Low Power Wireless, RFID technologies)

- **Cost efficient Microcontroller SOCs**
  - Reduced masks / No charge pumps
  - Small die size (portable equipment control/security)
  - High volume potential
FRAM (Ferroelectric Random Access Memory)
Non-Volatile Memory – the search is over!

• Fast Write / Update
  – ~ 50ns/byte or word – which is
    ~1000x faster than
    Flash/EEPROM

• Low Power
  – Needs 1.5v to write/erase
    compared to > 10-14v for
    Flash/EEPROM

• Data Reliability
  – No data-tearing and 100 Trillion
    write/read cycles

FRAM realizes the Universal Memory concept!
MSP430 Ultra-Low Power MCUs

**FRAM: The future of MCU memory**

- **TI & FRAM**
  - ~9 years of experience with FRAM
  - Currently producing devices up to 4 Mbits

- **Applications:**
  - High Write Endurance (SRAM Replacement)
  - Digital rights management (>10M write cycles)
  - Data logging, sensor applications
  - Low Power Electronics
  - FRAM instead of SRAM to eliminate quiescent current
  - Increases battery life
  - Enables “energy harvesting” (i.e. with Low Power Wireless, RFID technologies)

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**MSP430FR1000**

- Targeting low end motor control
- 16kB FRAM / 1kB RAM
- <$1.50
- Available 4Q2009
MSP430 Ultra-Low Power MCUs

Enabling you with Full Speed USB

**Ultra-low power MCUs + USB for smarter connectivity**

- Embedded full-speed USB 2.0 (12 Mbps)
- High flexibility with configurable 2K data buffers that can be used as RAM
- Unused USB interface pins can function as high-current I/O (5v tolerant)

**Analog and peripheral integration reduces system cost**

- Multiple analog options with 10 or 12-bit ADC, DAC, comparator
- Integrated 3.3V LDO for use with 5V USB bus power
- Uses low-cost crystal for USB clock, with flexible, integrated PLL

**44 New USB devices within next 12 months**

- Wide range of memory configurations and package options, 8k-128k flash
- Diverse peripheral mix in the MSP430F55xx family
- Pricing as low a $0.96 in volume
MSP430 Ultra-Low Power MCUs

**USB Made Easy**

- **USB Bootstrap Loader (USB)**
  - Supporting device programming
  - Field Firmware updates
- **USB Descriptor Tool**
  - Configures stack functions
- **Free USB stacks available:**
  - Communication Device Class (CDC)
  - Human Interface Device (HID)
  - Mass Storage Class (MSC)
- **Additional stacks available from third parties**

FREE Vendor ID/ Product ID sharing program

MSP430F5529 Sample Kit

FREE Request for embedded USB products

Texas Instruments
Enabling you with RF

CC430

Lowest power RF SoC

Low Power RF Transceiver

- High sensitivity
- Low current consumption
- Excellent blocking performance
- Flexible data rate & modulation format
- Backwards compatible

MSP430 MCU

- Market’s lowest power MCU
- High analog performance
- High level of integration
- Ease of development
- Sensor interface

The Best of Both Worlds
CC430: Reduces complexity, lets designers do more with less

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<th>RF Transceiver</th>
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<td>Sub-1GHz Radio</td>
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<td>System Control/Watchdog</td>
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<td>JTAG Spy-Bi-Wire Interface</td>
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<td>ADC</td>
<td>Segment LCD Static, Muxed</td>
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</tr>
</tbody>
</table>

9.1 mm x 9.1 mm package
Global frequency bands

Supports 300–348MHz, 400–464MHz, 800–928MHz
MSP430 Ultra-Low Power MCUs

Wireless Made Easy

• **Free** RF libraries and stacks
• SimpliciTI <description>
• TIMAC – IEEE 802.15.4 Medium Access Control (MAC)
• Z-Stack – Free ZigBee Stack
  – Compliant with 2006 ZigBee™ spec
  – [www.ti.com/zigbee](http://www.ti.com/zigbee)
• Third party partners with mesh network stacks – coming soon!
• SmartRF® Studio
  – Automatically generates register values
TI Low Power RF at a glance...

**Alarm and Security**
- **CC1110**
  - Sub 1 GHz SoC
  - 32KB Flash
  - 0.3 uA sleep current
- **CC1101**
  - Sub 1 GHz Transceiver
  - + MSP430 MCU, 500 Kbps
  - -112dBm sensitivity

**Smart Metering**
- **CC2530**
  - ZigBee
  - System on Chip
  - IEEE 802.15.4 compliant
  - + CC259x Range Extenders
- **CC1020**
  - Narrowband
  - 12.5 KHz channel spacing
  - -118dBm sensitivity
- **CC2431**
  - Location Tracking
  - System on Chip
  - Solutions

**Remote Controls**
- **CC2530**
  - RF4CE
  - IEEE 802.15.4 compliant
  - System on Chip
  - RemoTI SW
- **CC2505S**
  - PurePath™ Wireless
  - Coming Soon
  - CD Quality
  - Wireless Audio
- **CC2511**
  - 2.4 GHz Radio
  - 8051 MCU, 32 KB Flash, USB 2.0
  - Proprietary solution

**Wireless Audio**
- **CC2591**
  - 2.4 GHz Range Extender
  - +22dBm output power

**Sport & Gaming**
- **CC2540**
  - Bluetooth Low Energy
  - Coming Soon
  - Single-mode BTLE SoC
- **CC2500**
  - 2.4 GHz Transceiver
  - +MSP430 MCU

**Home Automation & Lighting**
- **CC430**
  - Network Processor
  - fully certified ZigBee 2006
  - Software Stack

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**Technology**
- **MSP430 Ultra2Low Power MCUs**
- **Smart Metering Alarm and Security**
- **Home Automation & Lighting**
- **Remote Controls**
- **Sport & Gaming**
- **Wireless Audio**
Enabling you with RF: Low Power Networking

**Consumer / personal networking**
- Watch/shoe combination for monitoring of miles and calories
- Enough processing for wireless networking and batteries that 10+ years

**Industrial remote monitoring**
- Low power sensor networks for innovative applications like remote monitoring for stress cracks
- Harvest energy from motion, vibration and heat

**Shipment monitoring**
- Information transmitted wirelessly is protected via encryption for more secure systems
- Location, tamper detection and temperature monitoring
New CC430 combines leading MCU and RF technology

Best of both worlds

Newest MSP430 MCU + leading low power RF IC = smarter, low power applications with more flexibility

Smaller is better

Leading integration means smaller products, easier manufacturing and lower system cost

Making RF easy

Complete ecosystem for MCU and RF ease of use and fast time to-market
MSP430 Ultra-Low Power MCUs

MSP430 Enables No-Power Apps

🌟 Energy harvesting is the process by which energy is captured and stored

🌟 Can substitute batteries that are costly to maintain and can extend system uptime

🌟 Only possible with ultra-low power components

🌟 Solar, kinetic, thermal, RF, salinity gradients, pH difference and other ambient sources available

- Body warm monitoring devices powered by body heat, movement
- Monitor environmental conditions on farm, winery, etc.
- Mesh networking for environmental monitoring (e.g. forest fire detection)
- Automotive monitoring (e.g. tire pressure gauges powered by vibration)
Energy Harvesting Made Easy

Ambient energy: light, heat, motion, RF, etc

Perpetually Powered Sensor

Energy Harvester
Energy Storage & Power Mgmt
Sensor(s)
Ultra Low Power Microcontroller
Low Power Transceiver

Environment: temperature, status, position, etc

Energy Harvesting Solutions:

AdaptivEnergy
CYMBET Corporation
Infinite Power Solutions
micropelt
PMG perpetuum
POWERCast
MSP430 Ultra-Low Power MCUs

Self-Powered Solar Energy Harvester

- Solar Energy Harvesting module
- Works in low ambient light
- Negligible self-discharge
- 400+ transmission with no light
- Adaptable to any sensor and RF network

Only $110 for MCU Day attendees
MSP430 Product Families

1xx | 2xx | 4xx | 5xx

Access | Performance
MSP430 Ultra-Low Power MCUs

MSP430 Portfolio

**Device**
- Performance
- Access

**2xx-Catalog**
- 16 MIPS
- 120 kB Flash
- 8 kB RAM
- 500 nA Standby
- 1.8 – 3.6 V

**1xx-Catalog**
- 8MIPS
- 60 kB Flash
- 10 kB RAM
- 1.8 – 3.6 V

**The New Generation**

**5xx-6xx**
- 25MIPS
- 256 kB Flash
- 16 kB RAM
- 1.8 – 3.6 V
- FRAM, USB, RF
- 6xx: LCD Controller
- 160 uA/MIPS

**4xx: LCD**
- 16 MIPS
- 120 kB Flash
- 8 kB RAM
- LCD Controller, 160 segments
- 1.8 – 3.6 V
MSP430 Access Portfolio

- MSP430 Ultra2Low Power MCUs
- MSP430 Access Portfolio

- 1kB: $0.75
- 2kB: $1.00
- 4kB: $1.25
- 8kB: $1.50
- 16kB: $1.75
- 32kB: $2.00

- 32kB: $2.25

- Models:
  - F2001
  - F2002
  - F2003
  - F2101
  - F2111
  - F2112
  - F2121
  - F2122
  - F2131
  - F2132
  - F2133
  - F2301
  - F2311
  - F2321
  - F2331
  - F2341
  - F2350
  - F2351
  - F2352
  - F2361
  - F2362
  - F2370

- Texas Instruments
# MSP430 Ultra-Low Power MCUs

## MSP430 Generations

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<th>4xx</th>
<th>5xx</th>
</tr>
</thead>
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<tr>
<td><strong>CPU Clock (Max)</strong></td>
<td>16MHz</td>
<td>8 &amp; 16 MHz</td>
<td>25MHz</td>
</tr>
<tr>
<td><strong>Flash/RAM (Largest comparable device)</strong></td>
<td>120KB / 4KB (F24xx)</td>
<td>120KB / 4KB (FG46xx)</td>
<td>256KB / 16KB (F54xx)</td>
</tr>
<tr>
<td><strong>Active Current (3.0V) µA/MIPS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1MHz</td>
<td>515 µA</td>
<td>600 µA</td>
<td>220µA</td>
</tr>
<tr>
<td>8MHz</td>
<td>525 µA/MIPS</td>
<td>600 µA/MIPS</td>
<td>165 µA/MIPS</td>
</tr>
<tr>
<td>16MHz</td>
<td>569 µA/MIPS</td>
<td>N/A</td>
<td>188 µA/MIPS</td>
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<tr>
<td>25MHz</td>
<td>N/A</td>
<td>N/A</td>
<td>224 µA/MIPS</td>
</tr>
<tr>
<td><strong>Standby Current (LPM3)</strong></td>
<td>0.3 – 1.1µA</td>
<td>0.7 – 1.3µA</td>
<td>2.6µA (w/ active true RTC)</td>
</tr>
<tr>
<td><strong>Power Down Current (LPM4/5)</strong></td>
<td>0.1µA</td>
<td>0.1µA</td>
<td>1.6µA (LPM4) / 0.1µA (LPM5)</td>
</tr>
<tr>
<td><strong>Wake-up Time From LPM3</strong></td>
<td>1µs</td>
<td>6µs</td>
<td>5µs</td>
</tr>
<tr>
<td><strong>Flash ISP Minimum DV&lt;sub&gt;cc&lt;/sub&gt;</strong></td>
<td>2.2V</td>
<td>2.7V</td>
<td>1.8V</td>
</tr>
<tr>
<td><strong>Port I/O Interrupt Capability</strong></td>
<td>P1/P2</td>
<td>P1/P2</td>
<td>P1/P2 (F5438)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Add’l pins in future devices</td>
</tr>
<tr>
<td><strong>Prog. Port Pin Drive Strength</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>All port pins</td>
</tr>
<tr>
<td><strong>Prog. Pull-ups/-downs</strong></td>
<td>All port pins</td>
<td>N/A</td>
<td>All port pins</td>
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<tr>
<td><strong>Available MCLK Sources</strong></td>
<td>DCO, VLO, LFXT1, XT2</td>
<td>FLL, LFXT1, XT2</td>
<td>FLL, VLO, REFO, XT1, XT2</td>
</tr>
<tr>
<td><strong>FLL Reference Clocks</strong></td>
<td>N/A</td>
<td>LFXT1</td>
<td>REFO, XT1, XT2</td>
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</table>

- **Lowest active power in the industry**
- **Lowest stand-by and fastest wakeup**
- **Write to Flash at min Vcc**
## MSP430 Peripheral Overview

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<td>Basic Clock System</td>
<td>Basic Clock System +</td>
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<td>Unified Clock System</td>
<td>Programmable core voltage with integrated PMM (1.8-3.6V)</td>
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<td>Core voltage same as supply voltage (1.8-3.6V)</td>
<td>Core voltage same as supply voltage (1.8-3.6V)</td>
<td>Core voltage same as supply voltage (1.8-3.6V)</td>
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<tr>
<td>16-bit CPU</td>
<td>16-bit CPU, CPUX</td>
<td>16-bit CPU, CPUX</td>
<td>16-bit CPU, CPUX</td>
<td>16-bit CPUXv2</td>
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<td>GPIO w/ pull-up and pull-down</td>
<td>GPIO, LCD Controller</td>
<td>GPIO w/pull-up and pull-down, drive strength</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>CRC16</td>
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<td>Software RTC</td>
<td>Software RTC</td>
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<td>USCI, USI</td>
<td>USART, USCI</td>
<td>USART, USCI, USB, RF</td>
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<td>DMA up to 3-ch</td>
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<td>4-wire JTAG, 2-wire Spy Bi-Wire (Some devices)</td>
<td>4-wire JTAG</td>
<td>4-wire JTAG, 2-wire Spy Bi-Wire</td>
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*Texas Instruments*
MSP430 Ultra-Low Power MCUs

**MSP430x1xx Series: 31 Unique MCUs**

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<td>128B</td>
<td>14</td>
<td>A3, WDT</td>
<td>Slope</td>
<td>-</td>
<td>Comp</td>
<td>$1.00 – $1.40</td>
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<td>256B</td>
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<td>A3, WDT</td>
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<td>-</td>
<td>Temp Sensor</td>
<td>$1.65 – $2.00</td>
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<tr>
<td>F12x</td>
<td>4-8KB</td>
<td>256B</td>
<td>22</td>
<td>A3, WDT</td>
<td>Slope</td>
<td>USART</td>
<td>Comp</td>
<td>$1.65 – $1.80</td>
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<tr>
<td>F12x2</td>
<td>4-8KB</td>
<td>256B</td>
<td>22</td>
<td>A3, WDT</td>
<td>ADC10</td>
<td>USART</td>
<td>Temp Sensor</td>
<td>$1.80 – $2.05</td>
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<td>48</td>
<td>A3, B3, WDT</td>
<td>ADC12</td>
<td>USART</td>
<td>Comp, Temp Sensor</td>
<td>$2.65 – $2.85</td>
</tr>
<tr>
<td>C13x1</td>
<td>8-16KB</td>
<td>256-512B</td>
<td>48</td>
<td>A3, B3, WDT</td>
<td>Slope</td>
<td>USART</td>
<td>Mask ROM, Comp</td>
<td>$2.00 – $2.30</td>
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<tr>
<td>F14x1</td>
<td>32-60KB</td>
<td>1-2KB</td>
<td>48</td>
<td>A3, B7, WDT</td>
<td>Slope</td>
<td>2 USART</td>
<td>Comp, MPY</td>
<td>$3.50 – $4.30</td>
</tr>
<tr>
<td>F14x</td>
<td>32-60KB</td>
<td>1-2KB</td>
<td>48</td>
<td>A3, B7, WDT</td>
<td>ADC12</td>
<td>2 USART</td>
<td>Comp, MPY, Temp Sensor</td>
<td>$3.85 – $4.65</td>
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<td>F15x</td>
<td>16-32KB</td>
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<td>48</td>
<td>A3, B3, WDT</td>
<td>ADC12</td>
<td>2 USART w/I2C</td>
<td>BOR, SVS, Comp, MPY</td>
<td>$4.25 – $4.75</td>
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<td>F16xx</td>
<td>32-60KB</td>
<td>1-10KB</td>
<td>48</td>
<td>A3, B7, WDT</td>
<td>ADC12</td>
<td>2 USART w/I2C</td>
<td>BOR, SVS, Comp, MPY</td>
<td>$5.60 – $7.95</td>
</tr>
</tbody>
</table>

**USART: SPI + UART**

[Texas Instruments Logo]
MSP430 Ultra-Low Power MCUs

F2xx Key Features

• <1µA standby LPM3
• <1µs 0-16MHz
• Zero-power BOR
• Failsafe oscillator
• Enhanced watchdog
• Pull-up / down resistors
• Hack proof boot loader
• 2.2V Flash ISP
• Extended temp 105°C
• *Same instruction set architecture*
## MSP430F2xx Series: 39 Unique MCUs

<table>
<thead>
<tr>
<th>Family</th>
<th>Flash</th>
<th>RAM</th>
<th>I/O</th>
<th>16-bit Timers</th>
<th>ADC</th>
<th>Comm.</th>
<th>Other Integrated Peripherals</th>
<th>Price USD 1kU</th>
</tr>
</thead>
<tbody>
<tr>
<td>F20x1</td>
<td>2 KB</td>
<td>128 B</td>
<td>10</td>
<td>A2, WDT</td>
<td>Slope</td>
<td>Comp</td>
<td></td>
<td>$0.55 – $0.80</td>
</tr>
<tr>
<td>F20x2</td>
<td>2 KB</td>
<td>128 B</td>
<td>10</td>
<td>A2, WDT</td>
<td>ADC10</td>
<td>USI</td>
<td></td>
<td>$0.80 – $0.95</td>
</tr>
<tr>
<td>F20x3</td>
<td>2 KB</td>
<td>128 B</td>
<td>10</td>
<td>A2, WDT</td>
<td>SD16</td>
<td>USI</td>
<td></td>
<td>$1.20 – $1.30</td>
</tr>
<tr>
<td>F21x1</td>
<td>8 KB</td>
<td>256 B</td>
<td>10</td>
<td>A2, A3, WDT</td>
<td>Slope</td>
<td>Comp</td>
<td></td>
<td>$0.65 – $0.95</td>
</tr>
<tr>
<td>F21x2</td>
<td>8 KB</td>
<td>512 B</td>
<td>10</td>
<td>A2, A3, WDT</td>
<td>ADC10</td>
<td>USCI</td>
<td></td>
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<tr>
<td>F22x2</td>
<td>32 KB</td>
<td>1 KB</td>
<td>10</td>
<td>B3, A3, WDT</td>
<td>ADC10</td>
<td>USCI</td>
<td></td>
<td>$1.75 – $2.20</td>
</tr>
<tr>
<td>F22x4</td>
<td>32 KB</td>
<td>1 KB</td>
<td>10</td>
<td>B3, A3, WDT</td>
<td>ADC10</td>
<td>USCI</td>
<td>2 Op Amp</td>
<td>$2.00 – $2.65</td>
</tr>
<tr>
<td>F23x0</td>
<td>32 KB</td>
<td>2 KB</td>
<td>10</td>
<td>B3, A3, WDT</td>
<td>Slope</td>
<td>USCI</td>
<td>Comp, MPY</td>
<td>$1.80 – $2.25</td>
</tr>
<tr>
<td>F23x</td>
<td>16 KB</td>
<td>2 KB</td>
<td>10</td>
<td>B3, A3, WDT</td>
<td>ADC12</td>
<td>USCI</td>
<td>SVS, Comp, MPY</td>
<td>$2.15 – $2.45</td>
</tr>
<tr>
<td>F241x</td>
<td>120 KB</td>
<td>4 KB</td>
<td>48</td>
<td>B7, A3, WDT</td>
<td>ADC12</td>
<td>USCI</td>
<td>2 USCI SVS, Comp, MPY</td>
<td>$4.70 – $5.30</td>
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<tr>
<td>F24x</td>
<td>56 KB</td>
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<td>10</td>
<td>B7, A3, WDT</td>
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<td>USCI</td>
<td>2 USCI SVS, Comp, MPY</td>
<td>$3.40 – $4.60</td>
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<tr>
<td>F24x1</td>
<td>60 KB</td>
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<td>10</td>
<td>B7, A3, WDT</td>
<td>Slope</td>
<td>USCI</td>
<td>2 USCI SVS, Comp, MPY</td>
<td>$3.15 – $3.80</td>
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<tr>
<td>F261x</td>
<td>120 KB</td>
<td>4 KB</td>
<td>48</td>
<td>B7, A3, WDT</td>
<td>ADC12</td>
<td>USCI</td>
<td>2 USCI SVS, Comp, MPY, 2 DAC12, 3 DMA</td>
<td>$5.85 – $6.65</td>
</tr>
</tbody>
</table>

USCI_A : UART + SPI  
USCI_B : I2C + SPI  
USI : I2C + SPI  
USART: SPI + UART
MSP430 Ultra-Low Power MCUs

F4xx Key Features

• <1µA standby LPM3
• <1µs 0-16MHz
• 4-120 KB Flash
• Built-in LCD Driver
• Zero-power BOR
• Pull-up / down resistors
• 2.7V Flash ISP
• Same instruction set architecture
## MSP430 Ultra-Low Power MCUs

### MSP430x4xx w/ LCD: 94 Unique MCUs

<table>
<thead>
<tr>
<th>Family</th>
<th>Flash</th>
<th>RAM</th>
<th>I/O</th>
<th>LCD Seg.</th>
<th>16-bit Timers</th>
<th>ADC</th>
<th>Comm.</th>
<th>Other Integrated Peripherals</th>
<th>Price USD 1kU</th>
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<tbody>
<tr>
<td>x41x</td>
<td>4-32KB</td>
<td>256B-1KB</td>
<td>48</td>
<td>96</td>
<td>A3,A5, WDT</td>
<td>Slope</td>
<td>-</td>
<td>Comp, SVS</td>
<td>$1.60 – $2.10</td>
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<tr>
<td>F41x2</td>
<td>8-16kB</td>
<td>512B</td>
<td>56</td>
<td>144</td>
<td>A2, WDT</td>
<td>ADC10</td>
<td>1 USCI</td>
<td>SVS, Comp</td>
<td>$1.70 – $1.90</td>
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<tr>
<td>F42x</td>
<td>8-32KB</td>
<td>256B-1KB</td>
<td>14</td>
<td>128</td>
<td>A3, WDT</td>
<td>SD16</td>
<td>USART</td>
<td>MPY(16 X16), SVS</td>
<td>$2.40 – $2.90</td>
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<tr>
<td>FW42x</td>
<td>8-32KB</td>
<td>128B-1KB</td>
<td>48</td>
<td>96</td>
<td>A2, WDT</td>
<td>Slope</td>
<td>-</td>
<td>Flow-meter</td>
<td>$2.50 – $3.10</td>
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<tr>
<td>FE42xx</td>
<td>8-32KB</td>
<td>256B-1KB</td>
<td>14</td>
<td>128</td>
<td>A2, A3, WDT</td>
<td>SD16</td>
<td>USART</td>
<td>E-meter</td>
<td>$2.35 – $2.75</td>
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<td>F42x0</td>
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<td>256B</td>
<td>32</td>
<td>56</td>
<td>A2, A3, WDT</td>
<td>SD16</td>
<td>-</td>
<td>DAC12</td>
<td>$3.10 – $3.65</td>
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<tr>
<td>FG42x0</td>
<td>16-32KB</td>
<td>256B</td>
<td>32</td>
<td>56</td>
<td>B3, A3, WDT</td>
<td>SD16</td>
<td>-</td>
<td>DAC12, OPAMP</td>
<td>$3.30 – $4.00</td>
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<td>F43x</td>
<td>16-32KB</td>
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<td>160</td>
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<td>ADC12</td>
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<td>SVS, Comp</td>
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<td>F43x1</td>
<td>16-32KB</td>
<td>512B-1KB</td>
<td>48</td>
<td>160</td>
<td>B3, A3, WDT</td>
<td>Slope</td>
<td>USART</td>
<td>SVS, Comp</td>
<td>$2.90 – $3.95</td>
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<tr>
<td>FG43x</td>
<td>32-60KB</td>
<td>1-2KB</td>
<td>48</td>
<td>128</td>
<td>B3, A3, WDT</td>
<td>ADC12</td>
<td>USART</td>
<td>DAC12, OPAMP</td>
<td>$5.15 – $6.60</td>
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<tr>
<td>F44x</td>
<td>32-60KB</td>
<td>1-2KB</td>
<td>48</td>
<td>160</td>
<td>B7, A3, WDT</td>
<td>ADC12</td>
<td>2 USART</td>
<td>SVS, Comp, MPY</td>
<td>$4.60 – $5.15</td>
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<tr>
<td>xG461x</td>
<td>48-120KB</td>
<td>4-8KB</td>
<td>80</td>
<td>160</td>
<td>B7, A3, WDT</td>
<td>ADC12</td>
<td>2 USART</td>
<td>DAC12, OP-AMP, MPY (32 x32)</td>
<td>$7.45 – $8.35</td>
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<td>FG47x</td>
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<td>2kB</td>
<td>48</td>
<td>128</td>
<td>A1, B1, WDT</td>
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<td>2 USCI</td>
<td>DAC12, Op-Amp,</td>
<td>$4.75 – $6.20</td>
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<tr>
<td>F47x</td>
<td>32-60kB</td>
<td>2kB</td>
<td>48</td>
<td>128</td>
<td>A1, B1, WDT</td>
<td>(1)SD16</td>
<td>2 USCI</td>
<td>DAC12</td>
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<td>F471xx</td>
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<td>4-8KB</td>
<td>72</td>
<td>160</td>
<td>B3, A3, WDT</td>
<td>(7)SD16</td>
<td>2 USCI</td>
<td>RTC, MPY (32x32), DMA, Comp</td>
<td>TBD</td>
</tr>
</tbody>
</table>
MSP430 Ultra-Low Power MCUs

5xx Key Features

- **Ultra-Low Power**
  - 165 µA/MIPS
  - 2.5 µA standby mode
  - Integrated LDO, BOR, WDT+, RTC
  - 12 MHz @ 1.8V
  - Wake up from standby in <5 µs

- **Increased Performance**
  - Up to 25 MHz
  - 1.8V ISP Flash erase and write
  - Fail-safe, flexible clocking system
  - User-defined Bootstrap Loader
  - Up to 1MB linear memory addressing

- **Innovative Features**
  - Multi-channel DMA supports data movement in standby mode
  - Industry leading code density
  - More design options including USB, RF, encryption, LCD interface
# MSP430F5xx Series Summary

<table>
<thead>
<tr>
<th>Family</th>
<th>Flash</th>
<th>RAM</th>
<th>IO</th>
<th>16-bit Timers</th>
<th>ADC</th>
<th>Comm.</th>
<th>Other Integrated Peripherals</th>
<th>Price USD 1kU</th>
</tr>
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<tbody>
<tr>
<td>F541x</td>
<td>128 KB</td>
<td>16 KB</td>
<td>67,87</td>
<td>A5,3,B7, WDT</td>
<td>ADC12</td>
<td>2,4 USCI</td>
<td>DMA, UCS, MPY(32X32)</td>
<td>$3.30 - $3.65</td>
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<tr>
<td>F543x</td>
<td>192-256 KB</td>
<td>16 KB</td>
<td>67,87</td>
<td>A5,3, B7</td>
<td>ADC12</td>
<td>2,4 USCI</td>
<td>DMA, UCS, MPY(32X32)</td>
<td>$3.90 - $4.85</td>
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<tr>
<td>F551x</td>
<td>64 KB</td>
<td>6-8 KB</td>
<td>48,60</td>
<td>A5,3,3, B7</td>
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<td>USCI</td>
<td>USB, DMA, UCS, MPY(32X32)</td>
<td>$3.25 - $3.35</td>
</tr>
<tr>
<td>F552x</td>
<td>64-128 KB</td>
<td>6-8 KB</td>
<td>48,60</td>
<td>A5,3,3, B7</td>
<td>ADC12</td>
<td>2 USCI</td>
<td>USB, DMA, UCS, MPY(32X32)</td>
<td>$3.55 - $4.10</td>
</tr>
</tbody>
</table>

USCI_A : UART + SPI

USCI_B: I2C + SPI
MSP430 Ultra-Low Power MCUs

MSP430F5xx Operating Range

• 25MHz peak performance
• More performance across $V_{CC}$ range
  – Flash ISP @ 1.8V
  – 12MHz @ 1.8V
  – 25MHz @ 2.4V-3.6V
MSP430 Ultra-Low Power MCUs

F5xx: Power Management Module

- Integrated LDO
- $V_{\text{CORE}}$ level programmable
- Flexibility in processing performance vs. power
- Integrated *supervision* & *monitoring*
- Zero-power BOR
- Five integrated supervisors
  - SVSH, SVSL, SVMH, SVML & BOR
MSP430 Ultra-Low Power MCUs

**F5xx: Unified Clock System**

- **Orthogonal clock system**
  - Any source can drive any clock signal
- **2 Integrated clock sources:**
  - REFO: 32kHz, trimmed osc.
  - VLO: 12kHz, ultra-low power
- **DCO & FLL provide high frequency accurate timing**
- **MODOSC provides bullet proof timing for Flash**
- **Crystal pins muxed with I/O function**
MSP430 Ultra-Low Power MCUs

F543x: Real World Power Comparison

- Assume a generic real-world application: active + stand-by operation
- A 1MHz clock cycle task occurs every second (1 MIPS)
- ~3x lower power than F24xx (largest 2xx device)
- F5438 Advantages
  - 12MHz over Vcc: 1.8-3.6V
  - ~150uA/MHz @ 12MHz
  - <2mA active current @ 12MHz
  - 2.6uA standby current

Lower average power than F20xx, the smallest MSP430 device!
  - 256K vs. 2K Flash, 16K vs. 128B RAM
Getting Started:
MSP430 Tools & Software
MSP430 Ultra-Low Power MCUs

Embedded Emulation

• Real-time, in-system debug
  – No application resources used
  – Full speed execution
  – H/W breakpoints
  – Single stepping
  – Complex triggering
  – Trace capability

• Powerful, easy to use tools

• Spy Bi-Wire
  – 2-wire debug interface
  – No pin function impact

• Only 1 tool required for all devices
MSP430 Ultra-Low Power MCUs

Easy To Use, Innovative Tools

Flash Emulation Tools
- Compatible with all devices
- Universal USB JTAG interface
- Target boards available
- $99 ($149 w/ target board)
- Free IDEs included

MSP430 Experimenter Boards
- Fully features prototyping system
- Available for FG4618 & F5438
- Starting at $99

eZ430 Tools
- Complete development system in USB stick
- Available for wireless and energy harvesting
- Starting at $20
MSP430 Ultra-Low Power MCUs

eZ430-Chronos: CC430 Watch

• CC430-based wireless development tool in a watch
• 915/868/433 MHz versions available
• Custom LCD driven directly by CC430

• Features:
  – 3-axis accelerometer
  – Altimeter
  – Temperature sensor
  – Buzzer

• Only $49!
  – $30 for MCU Day Attendees

USB RF access point

Updated eZ430 emulator for programming
CCE is now Code Composer Studio v4

- Code Composer Studio v4: A single development platform for all TI processors
- CCE users will feel at home
- Enhancements since CCE:
  - Usability enhancements
  - Speed
  - Code size improvements
  - Auto-updating
  - License manager
- Only $495 for MCU Edition
  - $249 for MCU Day attendees
- Site licenses available
MSP430 Ultra-Low Power MCUs

TI and IAR Systems: Deep and Evolving Partnership

- **1990’s**: TI and IAR Systems partners on MSP430
- **2005**: TI and IAR partners on ARM MCU’s
- **2006**: TI acquires Chipcon, partner to IAR Systems
- **2009**: TI acquires Luminary Micro, partner to IAR Systems

TI and IAR Systems Product Integration and Support

- IAR Embedded Workbench: C/C++ compiler and debugger tool set
- IAR PowerPac: RTOS, File System, USB Device Stack, TCP/IP stack
- IAR visualSTATE: design, test and verification tools using state machines
- IAR KickStart Kits: Completely integrated kits

- TI Stellaris microcontrollers
- TI MSP430 microcontrollers
- RF/IF and ZigBee Solutions
MSP430 Ultra-Low Power MCUs

Third Party Development Resources

- **Rowley CrossWorks**
  - Complete IDE solution
  - High code density
  - Simulator
  - Windows, Linux, Mac
  [www.rowley.co.uk](http://www.rowley.co.uk)

- **MSPGCC Tool Chain**
  - Free
  - Open Source
  - GNU C Compiler, Assembler / Linker, GDB Debugger
  - Windows, Linux, Unix
  [http://mspgcc.sourceforge.net](http://mspgcc.sourceforge.net)

- **Elprotronic**
  - MSP430, CC Chipcon, C2000 Programmers
  - Fastest download speed
  - Production programmers

- **Amber Wireless**
  - Drop in wireless modules
  - <1GHZ eZ430-RF target boards
  - CC430 Development boards

- **RTOS Options**
  - µC/OS-II™
  - CMX-Tiny+™
  - embOS
  - FreeRTOS™
  - IAR PowerPac
  - QP™
  - Salvo™
  - TinyOS

- **USB Stacks**
  - IAR
  - HCC

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Texas Instruments™
MSP430 Ultra-Low Power MCUs

www.ti.com/msp430

- User’s Guides
- Datasheets
- TI Community Forum
- 100+ Application Reports
- 1000+ Code Examples
- Product Brochure
- MCU Selection Tool
- Latest Tool Software
- 3rd Party Listing
- Silicon Errata
MSP430 Ultra-Low Power MCUs

Extensive Community Support

E2E Community
- Videos, Blogs, Forums
- Extensive community support and idea exchange
- Global customer support
- [http://e2e.ti.com](http://e2e.ti.com)

Processor Wiki
- Growing collection of technical wiki articles
- Tips & tricks, common pitfalls, and design ideas
- [http://wiki.msp430.com](http://wiki.msp430.com)
MSP430 Ultra-Low Power MCUs

MSP430 Summary

• ULP

• Broad portfolio
  – Access for size and cost constraints
  – Performance for precision and speed

• Enabling Technologies
  – FRAM, USB, RF, energy harvesting

• Ease of Use
  – HW and SW Tools
  – Community
  – Order a tool with your discount code!
Thank you.
Backup