MSP430 Agenda

Why the MSP430? Solving your MCU needs

- MSP430-Enabled applications
- MSP430 Core Values

Features, Technologies, and Benefits

- Ultra-Low Power + Performance
- Integrated solutions
- Extensive Portfolio with low cost options

Development

- MSP430 is easy to get started
- Resources, support, code examples. Start here!

Products & Roadmap

- The future of the MSP430 product line
MSP430-Enabled Solutions at a Glance

- Portable Medical
- Utility Metering
  AMI & AMR
- Wireless Applications
- Consumer Electronics
- Energy Harvesting & Building Automation
- Personal Health & Fitness
- Intelligent Sensors & Security
- Consumer Electronics
- Portable Medical

AND 1000's MORE...
MSP430 Overview

Ultra-Low Power + Performance

World’s Lowest Power MCU Family
- Optimized Low Power Modes & Instant Wake-up
- 230μA/MIPS | 0.7 μA RTC | 0.1 μA RAM

Do More with MSP430
- Industry leading code density
- Increase speed and flexibility with advanced clocking, hardware acceleration, and up to 25 MIPS

System Integration

Intelligent Analog & Digital Peripherals
- Autonomous operation in low power modes
- 16-bit ADCs, DACs, DMA, MPY, Comparators, LCD, USB, RF, high-res timers, power management

COMING SOON
- FRAM memory technology
- Capacitive touch I/Os

Extensive Portfolio

Find the right MCU for you
- 200+ Devices with one consistent architecture
  Flash: 0.5 – 256 kB  Pins: 14 - 113
  RAM: 128 B – 16 kB

NEW: MSP430 Value Line
- Don’t Settle | 16-bit Performance, 8-bit Price
- Starting @ $0.25 USD

Easy to Get Started

Consistent Development Environment
- One development tool for all MSP430 devices
- Code compatibility throughout portfolio

Get started now!
- Complete development kits @ $4.30 USD
- eZ430-Chronos development watch @ $49 USD
- Free code-limited IDEs
MSP430 is Ultra-Low Power + Performance
**Ultra-Low Power Activity Profile**

- Minimize active time
- Maximize time in **Low Power Modes**
- Interrupt driven performance on-demand with **<1μs wakeup time**
- Always-On, Zero-Power **Brownout Reset (BOR)**
Ultra-Low Power is in Our DNA

- MSP430 designed for ULP from ground up
- 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
  - 100 nA power down (RAM retained)
  - 0.3 µA standby
  - 110 µA / MIPS from RAM
  - 220 µA / MIPS from Flash

- Instant-on stable high-speed clock
- 1.8 - 3.6V single-supply operation
- Zero-power, always-on 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
  - 45µA

- **Active**
  - DCO on
  - ACLK on
  - 220µA

- **Off**
  - All Clocks Off
  - 100nA

- **LPM3**
  - RTC function
  - LCD driver
  - RAM/SFR retained
  - 0.3µA

- **LPM4**
  - RAM/SFR retained
  - <1µs

**BOR is enabled in all modes**

See all LPMs...
Specific values vary by device
Always-on Brownout Reset

- Brown-out reset (BOR) forces the MCU to reset both on power-up/down
  - When $V_{CC}$ rises and when $V_{CC}$ falls below normal operating range, a POR is triggered.
  - Zero-power Brown Out Reset
  - Always-on and active in all modes of operation.
Average Current Consumption & Battery Life @ 1% Active (~14.4 Minutes)

- MSP430G20xx: 6.34 years (3.6uA)
- MSP430F26xx: 4 years (5.8uA)
- PIC24F XLP: 1.9 years (11.9uA)

Example: Portable measurement system
- Active power consumption is important in this example
- Average = Standby*(99%) + Active*(1%)
- Used peripherals will impact total current consumption
Average Current Consumption & Battery Life @ 0.1% Active (1.4 Minutes)

<table>
<thead>
<tr>
<th>Device</th>
<th>Life</th>
<th>Current Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP430G20xx</td>
<td>25 years</td>
<td>0.9uA</td>
</tr>
<tr>
<td>MSP430F26xx</td>
<td>21 years</td>
<td>1.1uA</td>
</tr>
<tr>
<td>PIC24F XLP</td>
<td>12 years</td>
<td>1.9uA</td>
</tr>
</tbody>
</table>

Example: Wireless sensor network
• Standby & Active power are equally important
• Average = Standby*(99.9%) + Active*(0.1%)
• Used peripherals will impact total current consumption
Which MCU? MSP430x2xx vs MSP430F5xx

The crossover is at ~0.04% Active
Or about 35 seconds/day

This means that if the CPU is Active >0.04% of the time (or >35 seconds per day), the lower Active Mode power of the F5xx outweighs the lower LPM3 current advantage of the F2xx device.

- MSP430x2xx has lower LPM3 consumption
- MSP430F5xx has lower active power consumption
ULP is Easy!

- Using our Low Power Modes are easy
- Enter low power mode with 1 line of code!

```c
void main(void)
{
    WDT_init(); // initialize Watchdog Timer
    while(1)
    {
        __bis_SR_register(LPM3_bits + GIE); // Enter LPM3, enable interrupts
        activeMode(); // in active mode. Do stuff!
    }
}

#pragma vector=WDT_VECTOR
__interrupt void watchdog_timer (void)
{
    __bic_SR_register_on_exit(LPM3_bits); // Clear LPM3 bits from 0(SR), Leave LPM3, enter active mode
}
MSP430 for Energy Harvesting
“Self or Perpetual - 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 worn monitoring devices powered by body heat, movement
- Monitor 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)

- Ambient energy: light, heat, motion, RF, etc
- Environment: temperature, status, position, etc

Energy Harvesting Made Easy – MSP430 Solutions
Native 0.9V Operation

- **Native Means…**
  - The device, including peripherals operates at specified $V_{cc}$
  - Additional components such as charge pump are **NOT** needed to support the full $V_{cc}$ range
  - Full functionality of the device is maintained within $V_{cc}$ range
  - The microcontroller and application are supplied from one common supply that goes down to min $V_{cc}$

![Diagram showing Microcontroller (CPU, RAM, ROM, Peri, ... all operated from 0.9 – 1.65 V)](image)
Native 0.9V Target Applications

- General purpose low-cost MCU
- Consumer
  - Electric tooth brush, shavers, etc.
  - Toys
  - Games
- Security devices (door sensors, passive I/R)
- Sports applications
- Sensors (motion, pressure)
Don’t Compromise: ULP and Performance

PERFORMANCE
- 16-bit RISC architecture → Leading code efficiency
- Flexible and unified clocking system
- Up to 25 MIPS
**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**

<table>
<thead>
<tr>
<th>Register</th>
<th>Register</th>
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<th>Register</th>
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<th>Register</th>
<th>Register</th>
<th>Register</th>
<th>Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0/PC</td>
<td>R1/SP</td>
<td>R2</td>
<td>R3</td>
<td>R4</td>
<td>R5</td>
<td>R6</td>
<td>R7</td>
<td>R8</td>
<td>R9</td>
</tr>
<tr>
<td>R10</td>
<td>R11</td>
<td>R12</td>
<td>R13</td>
<td>R14</td>
<td>R15</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Notes:***
Higher Performance and Code Effectiveness

MSP430 MCU Day

Competitor A

; Competitor A (AN556)
movlw LOW Tab
addwf offset,F
movlw HIGH Tab
btfsc status,c
addlw 1
movwf PCLATH
movwf Data,W
call Tab
movwf PORTB
Tab DW 0063Fh
DW 04F5Bh
DW 06E66h
DW 0077Ch
DW 0677Fh
DW 00111111'
retlw B’01100110’
retlw B’01101101’
retlw B’01111111’
retlw B’01111101’
retlw B’00000111’
retlw B’01111111’
retlw B’01111111’
280 bits / 52 cycles

MSP430

; MSP430
; mov.b Tab(Data),P1OUT
Tab DW 0063Fh
DW 04F5Bh
DW 06E66h
DW 0077Ch
DW 0677Fh
DW B’01101111’
8X reduction in Cycles/Task

128 bits / 6 cycles

Total code size for simple math
8-bit vs 16-bit processing

Microcontroller

Arrow Electronics and Texas Instruments
Maximize Speed & Flexibility | Unified Clock System

Features

• 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

Benefits

• Ultra-Low Power functionality

• Best balance of performance and low power

• Enables flexible and capable Low Power Modes

• Instant on with fast oscillator wakeup
MSP430F5xx Speed and Flexible Operation

- 25MHz peak performance
- More performance across $V_{CC}$ range
  - Flash ISP @ 1.8V
  - 12MHz @ 1.8V
  - 25MHz @ 2.4V-3.6V

Wide Max MCLK

Flash Programmable Across Entire Range

vs. F2xx
MSP430 is Integrated
Performance Through Integration

- The 200+ MSP430 devices offer high-performance integration
  
  **Snapshot of Integrated Peripherals**
  
<table>
<thead>
<tr>
<th>MSP430 Devices</th>
<th>Power Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC10, ADC12</td>
<td>WDT</td>
</tr>
<tr>
<td>SD16</td>
<td>Basic Timer</td>
</tr>
<tr>
<td>Comparator</td>
<td>RTC</td>
</tr>
<tr>
<td>DAC12</td>
<td>PMM</td>
</tr>
<tr>
<td>DMA</td>
<td>BOR</td>
</tr>
<tr>
<td>Multiplier</td>
<td>SVS</td>
</tr>
<tr>
<td>OpAmp</td>
<td>EDI</td>
</tr>
<tr>
<td>Timer</td>
<td>RF Front End</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AES</td>
</tr>
<tr>
<td></td>
<td>USB</td>
</tr>
<tr>
<td></td>
<td>SPI</td>
</tr>
<tr>
<td></td>
<td>I²C</td>
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<tr>
<td></td>
<td>LIN/IrDA</td>
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<tr>
<td></td>
<td>SCAN_IF</td>
</tr>
<tr>
<td></td>
<td>ESP430</td>
</tr>
<tr>
<td></td>
<td>LCD</td>
</tr>
</tbody>
</table>

- Various levels of integration allows designers to find the right MSP430

- Integration enables smaller physical footprints and minimizes system costs
Even at Low Power Modes, intelligent peripherals allow many activities *without* the CPU

- Sampling the ADC
- Transfer data between entire memory range
- Generate PWM signals
- BOR is always enabled
- Use Hardware multiplier
- Includes Full RAM retention (LPM0, 1, 2, 3, 4)
- More…
Fast Flexible 10- and 12-Bit ADCs

**Features**

- 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

**Benefits**

- Fast sample/conversions for greater accuracy
- Sample data autonomously, lowering CPU load
- Stay in Low Power Modes, minimizing current consumption
**SD16_A Overview**

**Features**

- 2nd order 16-bit sigma-delta architecture
- Multiple channels
- 30kHz to 1.1MHz modulation frequency
- Modulation frequency divider
- Up to 1024 OSR
- Temperature sensor
- AVCC measure
- Up to 4096 samples/sec
- Gain amplifier to support wide range of current measurements
- SW selectable internal/external reference

**Benefits**

- Achieves <0.1% accuracy for precise measurements with a 2400:1 dynamic range.
- Multiple SD16s can be used for anti-tampering needs in applications such as utility metering.
- More robust performance and software development with simultaneous sampling.
MSP430 MCU Day

DAC12

Features

• 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

Benefits

• Configurable balance between performance and power
• Allows synchronous update operations when multiple modules are available
Analog Comparators

**Features**
- ~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

**Benefits**
- Ultra-Low Power
- Enables monitoring of external analog signals
- Supports precision slope Analog to Digital Conversions
Direct Memory Access (DMA)

Features
- Edge/level triggers
- Single Block
- Burst-block
- Byte/word or mixed transfer
- Requires just two MCLK cycles

Benefits
- Allows data to be transferred throughout ENTIRE address range.
- Transfer data from ADC conversions to RAM without CPU
- Maximize CPU offloading for lower power and max MIPS throughput
ESP: Single-Chip E-Meter

**Features**
- Dedicated function
- An embedded SoC
- User programmable
- Measures 2 or 3 wire, single phase energy and automatically calculates energy, power factor, etc.

**Benefits**
- Minimize system size with true SoC functionality
- Reduce total system chip count by 80%
- Maximize CPU offload with true encapsulated single phase e-meter module
LCD Controllers

**Features**
- 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

**Benefits**
- Ultra-Low Power functionality
- Easy integration
- Flexible LCD support
Power Management Module

Features

- 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

Benefits

- Ultra-Low Power Functionality
- Ensure proper operation in power on and off sequences
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**
Integrated 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 pins (5 volt tolerant)

Analog and peripheral integration reduces system cost

- Multiple analog options with 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

Added features within MSPF663x / F563x devices

- Integrated 160 segmented LCD driver
- Higher flash memory options up to 256KB
- Battery back-up switch and Enhanced Data Integrity (EDI) feature for added reliability

44 New MSP430 USB devices within next 7 months

- Wide range of memory configurations and package options
- Diverse peripheral mix
- Competitive pricing as low a $0.96 (F550x) in volume
Benefits of MSP430 USB

USB is integrated into our on-chip bootstrap loader (BSL)
• Enables end user to update firmware in the field
• Customizable Windows GUI project you can provide to end users
• Just distribute GUI to end users; nothing else required
• Also can be used in factory programming

High flexibility
• Fully-configurable 2K data buffers that can be used as system RAM when USB module is disabled
• Unused USB interface pins can function as high-current I/O pins

USB power supply system
• Integrated LDO for use with 5V USB bus power
• Can power entire system, saving the battery
• Provides 3.3V/1.8V supporting USB PHY, PLL, and logic
• Separate from 5xx Power Management Module (PMM)

Uses low-cost crystal for USB clock, with flexible, integrated PLL
• Same crystal can source non-USB system clocks
Speedy USB Development

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
CC430 | RF + Ultra-Low Power MCU

**MSP430™ Microcontroller**
- Industry’s lowest power MCU
- 16-bit RISC architecture
- 20 MHz processor
- High-performance analog
- Sensor interface

**CC1101 RF Transceiver SoC**
- High sensitivity
- Low current consumption
- Excellent blocking performance
- Flexible data rate & modulation format

**Intelligent Peripherals**
- 100 nA comparator
- 8ch 12-bit ADC offering 200-ksp/s
- 96 segment LCD controller
- 128-bit AES security encryption/decryption coprocessor

**48QFN Pin Package**
- 7.15 mm x 7.15 mm area
Broad range of applications benefit from 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
CC430: Innovative Peripherals

**LCD_B**
- Blinking of individual segments, Programmable frame frequency, Software-driven contrast control
- Regulated charge pump
- Integrated drivers

**AEC 128**
- Encryption and decryption according to AES FIPS PUB 197 with 128-bit keys
- Key expansion for en- and decryption
- Off-line key generation for decryption

**Comparator_B**
- Flexible - Selectable ref. voltage & voltage hysteresis generator
- High-speed, normal, and ultra-low power 100nA modes
- Internal output to Timer A capture
- Selectable RC filter for comparator output
Strong, Vibrant Ecosystem & Solutions

- IPv6 over low-power wireless area networks
- Highly efficient use of code and memory
- Direct end-to-end Internet integration
  - Multiple topology options
- Highly efficient use of code and memory
- Direct end-to-end Internet integration
- Multiple topology options

- 6LoWPAN
- Home automation & Lighting Control

- Wireless M-BUS
- Meter-to-meter communication
- Enables a simple star network topology that fits very well to the applications’ requirements.
- Sub 1 GHz band (868 MHz)
  - Quality and low power consumption of the transmission critical

- DASH7
- Asset Tracking & Tire Pressure Monitor
- Ultra-Low Power, Low Bandwidth space
  - Range is scalable, 10 - 2000 m (1.2 mi)
    - 433 MHz, 28 kbps
- Mandated by U.S. Department of Defense, allied militaries
- Asset Tracking, Tire pressure monitoring → sensors, security
Cap Touch – RO Method

- No external switches/analog required
- Contact is determined by the frequency during the measurement window
Cap Touch – RC Method

- No external switches or analog required
- Port pin used to charge sensor capacitance
- RC discharge time measured
- App Note: SLAA363

Diagram:

- Timer Counter
  - Charging
  - Discharging
  - Delta TAR
  - GPIOSENSOR = Vcc
  - GPIOR = Gnd
  - GPIOSENSOR = GND
  - GPIOR = Vcc

- GPIOSENSOR = Vcc
  - GPIOR = GND
- GPIOSENSOR = GND
  - GPIOR = Vcc

- Active LPM0
- Active LPM3
- Active LPM0
- Active LPM3

Coming soon
FRAM: The next generation Non-Volatile memory

• Why?
  – Address 21st century macro trends – Wireless, Low Power, Security
  – Drive new applications in our highly networked world
  – Improve time to market & lower total cost of ownership - enable unprecedented flexibility and efficiency in embedded product development & management

• What? To meet Emerging and Existing needs for embedded non-volatile memory, support
  – Lower power consumption
  – Faster Access speeds
  – Higher Write Endurance
  – Higher inherent security
  – Lower total solution cost
FRAM – Meets the needs of today & tomorrow

Today’s embedded controller applications are limited partly by the embedded memory tech of today.

- **Meet FRAM** (Ferro-electric Random Access Memory)
- **Proven & Mature technology** Used for years in many applications including battery-backed SRAM alternatives in automotive industry.
- **Non-Volatile** Retains data without power
- **Fast Write / Update** RAM like performance. Up to ~ 50ns/byte access times today (>1000x faster than Flash/EEPROM)
- **Low Power** FRAM needs 1.5V to write compared to >10-14V for Flash/EEPROM → no charge pump
- **Superior Data Reliability** - ‘Write Guarantee’ in case of power loss
- **Very High write endurance** >100 Trillion read/write cycles
What is FRAM Technology?

FRAM - Non-volatile embedded memory technology

- Similar DRAM (1T-1C) except data stored in crystal state, not charge
  - Capable of read/write access and cycle times similar to DRAM, but is lower power

- Is a Random Access Memory - Each bit read/written individually

- Single step write process – no separate erase then write cycle (unlike Flash)

- FRAM has been in products for over 15 years, primarily automotive space

- TI has been involved with FRAM for 9 years, ensuring it’s manufacturable, reliable, and cost effective. Focus: FRAM an embedded memory solution

- FRAM implementations are not ideal for high speed single cycle memory access speeds of 25MHz, Flash is currently better.

- Also, we are using a 2T-2C architecture to improve initial reliability for this new embedded implementation of FRAM. Flash is currently better on a die size/memory density standpoint. FRAM holds the advantage for up to 128kB
FRAM Operation

Programming Data to FRAM

WRITE: Apply voltage to plate line (write ‘0’) or bit line (write ‘1’)

• FRAM is intrinsically simpler & faster than current EEPROM technologies, which utilizes a complex charge storage mechanism

• This simplicity means faster operation for reads & writes
  – This also directly leads to lower power consumption
FRAM: Proven, Reliable, Better

**Endurance**
- Proven data retention to 10 years @ 85°C
- 100 Hrs @150°C
- 1K Hrs @125°C
- 10 Yrs @85°C

**Secure**
- Fast access times
- No perceptible difference in read/write processes

**Radiation Resistance**
- Terrestrial Soft Error Rate is below detection limits

**Immune to Magnetic Fields**
- FRAM does not contain iron

www.ti.com/fram
For more info on TI’s FRAM technology
Next Gen Technology Comparison

**Floating Gate**

- Floating gate memories need high voltages to write (>10 V)
- Exhibit slow writes/erase cycles
- Subject to added cost, increased power consumption

**MRAM**

- Access speeds comparable to DRAM
- Low Power supported in some implementations
- Bit cell size comparable to FRAM
- Read/Write currents higher than FRAM (~mA)

Photo: [www.eetimes.com](http://www.eetimes.com)
## FRAM Current Gen Technology Performance Comparison

<table>
<thead>
<tr>
<th></th>
<th>FRAM</th>
<th>EEPROM</th>
<th>Flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to write 64 bytes to memory</td>
<td>1.6 μs</td>
<td>2,200 μs</td>
<td>6,400 μs</td>
</tr>
<tr>
<td>Time to read 64 bytes from memory</td>
<td>1.6 μs</td>
<td>4.5 μs</td>
<td>4.5 μs</td>
</tr>
<tr>
<td>Number of write cycles</td>
<td>100 trillion</td>
<td>500,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Voltage needed to write</td>
<td>1.5 V</td>
<td>10 to 14 V</td>
<td>10 to 14 V</td>
</tr>
<tr>
<td>Manufacturing cycle time</td>
<td>–</td>
<td>&gt;3×</td>
<td>3×</td>
</tr>
<tr>
<td>Resistance to gamma radiation</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
MSP430: it’s what’s on the inside that counts.

...most of the time
Need more _______ ?

- Functionality, Precision, Power Management, Interface….
  - Sometimes you just need more, and the TI analog portfolio offers it.
- We make it easy for you to find more “____”:
  - [www.ti.com/mcu4analog](http://www.ti.com/mcu4analog)
    - Summary of complementary analog and mcu components, sorted by End Equipments and Specific Analog Function.
  - [www.ti.com/processorpower](http://www.ti.com/processorpower)
    - Reference designs for your power needs.
  - [www.ti.com/plus1](http://www.ti.com/plus1)
    - Season your design with “salt and pepper” logic.
MSP430 is Affordable and Scalable
MSP430 Value Line

- 16-bit performance, 8-bit price
- Starting at $0.25 USD
- 100+ New Devices in 15 months
MSP430 Value Line

Deliver increased features and functionality with optimized 16-bit MSP430 architecture

- 10X more MIPS throughput
- Reduced cycles/task
- 50% greater code density

Design products with up to 20 years of battery life through leading ultra-low power consumption

- 10X lower power
- Smart ADC
- Sub 1μs wakeup

Accelerate time to market with easy-to-use tools, free software & extensive third party support

- 100 new MCUs as low as $0.25
- Full compatibility across entire MSP430 platform

Starting @ $0.25 USD!

MSP430 MCU Day
## What do I get for 25 cents?

<table>
<thead>
<tr>
<th>Feature</th>
<th>PIC10F200</th>
<th>MSP430G2001</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flash</strong></td>
<td>512B Ext 12V</td>
<td>512B In System</td>
</tr>
<tr>
<td><strong>RAM</strong></td>
<td>25B</td>
<td>128B</td>
</tr>
<tr>
<td><strong>Timers</strong></td>
<td>8-bit counter</td>
<td>16-bit multifunction</td>
</tr>
<tr>
<td><strong>Emulation</strong></td>
<td>0</td>
<td>2-pin In System</td>
</tr>
<tr>
<td><strong>GPIO/Interrupts</strong></td>
<td>6 0</td>
<td>10 22</td>
</tr>
<tr>
<td><strong>MIPS</strong></td>
<td>1x 8-bit</td>
<td>16x 16-bit</td>
</tr>
<tr>
<td><strong>Power Modes</strong></td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>$0.25</td>
<td>$0.25</td>
</tr>
</tbody>
</table>

- **Flexible**: More Functionality
- **Agile**: Faster Development
- **More Functionality**: No Compromise
- **Faster Development**: Hi-Performance
- **No Compromise**: MSP430 is lower power in all modes of operation

**MSP430 MCU Day**
MSP430 Value Line Competitive Snapshot

Typical battery powered applications spend 99 – 99.9% of their time in standby mode.

MSP430 power consumption is lower than competing 8-bit MCUs; as low as (values @ 2.2V):
- 0.1 μA RAM retention
- 0.4 μA Standby mode (VLO)
- 0.7 μA real-time clock mode
- Ultra-Fast Wake-Up From Standby Mode in <1 μs

10X lower power
ADC + Data Transfer Controller

The competition requires the CPU to be active for each ADC conversion and loaded data transfer.

**PIC12F508: ADC**

**MSP430G2xx: ADC + DTC**

CPU is free for advanced features

**Competitor A**

```
movlw 0x28
movwf E5
movlw 0x0C
movWF CH
movwf ADCON0
defc Channel
btfss STATUS Z
mov 0x03
btfss ADCON0, GO
btfss ADCON0, GO
goto Wait
movf ADDRES, W
movwf INDF
incf FSR, F
bcf STATUS, 0x20
movwf INDF
incf FSR, F
btfss STATUS, Z
goto Main
```

**MSP430 + DTC**

```
bis.w #CPUOFF,SR
```

Limited to 10,638 samples/s @ 100% CPU load

Up to 200,000 samples/s @ 0.6% CPU load

MSP430’s ADC10 with Data Transfer Controller (DTC) can manage ADC samples throughout entire memory range – All without CPU overhead!

- Less time in Active Mode saves power
- CPU available for other more advanced tasks
- Intelligent autonomous sampling
- Deterministic behavior
100 devices over the next 15 months

Flash Size:
- 512 B
- 1KB
- 2KB
- 4KB
- 8KB
- 16KB
- 32KB

- 8-pin SOIC
- 14-pin TSSOP/PDIP
- 16-pin QFN
- 4/10 GPIO
- 14/20-pin TSSOP
- 20-pin PDIP
- 16 pin QFN
- 10/16 GPIO
- 20/28-pin TSSOP
- 20-pin PDIP
- 32-pin QFN
- 16/24 GPIO

Intelligent Peripherals:
- ADC
- Comparator
- Serial Communications (SPI/I2C)
- UART
- Cap Touch I/O

Device Count:
- > 100 devices
- 68 devices in 4 packages
  - From 1 KB to 16 KB Flash
- 64 devices in 4 packages
  - From 512 B to 8 KB Flash
- 27 devices in 3 Packages
  - From 512 B to 2 KB Flash

Order now
In Development

In Development
Order now
Meet the new MSP430 LaunchPad

Everything you need to Launch your applications!

+ Embedded emulation
  Includes mini USB Cable

+ 14 and 20-pin DIP Socket
  Supports all MSP430 Value Line devices

+ Includes 2x MSP430 Devices
  MSP430G2231 & MSP430G2211

+ 2 Pushbuttons

+ 2 LEDs

+ FREE software Compiler/Debugger
  Code Composer Studio Ver 4
  IAR Embedded Workbench

$4.30 & for a limited time only
FREE SHIPPING!
Accelerate time to market with LaunchPad

- Shopping cart
- $4.30
- LaunchPad
- Breadboard
- Production
- HW/SW Debug
Other Value Line Tools

**eZ430-F2013: $20 Development System**
- Real-time, in-system emulation
- Removable target with full pin access

**Free, code-limited software IDEs**
- Code Composer Studio™ v4
- IAR Embedded Workbench

**Flash Emulation Tools**
- Compatible with all MSP430 devices
- Socketed target boards available

Complete Development – starting @ $4.30
MSP430 Value Line is completely code-compatible with the rest of the MSP430 Portfolio!

Easy Migration Path for Scalable Solutions!
# MSP430 Scalable Portfolio | 200+ Devices

## MSP430
16-bit RISC CPU

**All devices feature:**
- 16-bit timers
- Watchdog Timer
- Internal Digitally Controlled Oscillator
- Ext 32-kHz crystal support
- <50 nA pin leakage
- <6 µs wakeup

## Ultra-Low Power Performance

### G2xx
- Speed 16Mhz
- Flash 0.5-2kB
- RAM 120kB
- GPIO 10

### F2xx
- Speed 16Mhz
- Flash 1-120kB
- RAM to 8kB
- GPIO 10-64

### F4xx
- Speed 8/16Mhz
- Flash 4-120kB
- RAM to 8kB
- GPIO 14-80

### F5xx
- Speed 25Mhz
- Flash 8-256kB
- RAM to 16kB
- GPIO 32-83

## Analog Integration

- ADC
- DAC
- OpAmp
- SVS
- SVM
- USCI
- LDO
- PMM
- BOR
- LCD

## Easy-to-Use

- EDI
- USB
- Sub 1GHz
- RF
- AES
- ADC12
- Comp_B
- RTC_A/B
- LCD

---

**ARROW ELECTRONICS AND TEXAS INSTRUMENTS**

- MSP430 MCU Day
- Embedded Series
### MSP430 Package Options

**Flexible options to fit your need**
- Many package types
- Wide range from 14 to 113 pin devices

**Miniaturization to enable small-sized design**
- MSP430F2370 available in Die-Sized BGA
- 49-pin; 3.232mm x 3.232mm

<table>
<thead>
<tr>
<th>Package Type</th>
<th>Pin Count</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-pin PW (TSSOP)</td>
<td>14</td>
<td>(5.10) x (5.60)</td>
</tr>
<tr>
<td>14-pin N (PDIP)</td>
<td>14</td>
<td>(19.69) x (10.92)</td>
</tr>
<tr>
<td>16-pin RSA (QFN)</td>
<td>16</td>
<td>(4.00) x (4.00)</td>
</tr>
<tr>
<td>20-pin DGV (TVSOP)</td>
<td>20</td>
<td>(5.10) x (5.60)</td>
</tr>
<tr>
<td>20-pin PW (TSSOP)</td>
<td>20</td>
<td>(5.10) x (5.60)</td>
</tr>
<tr>
<td>20-pin DW (SOIC)</td>
<td>20</td>
<td>(13.00) x (10.63)</td>
</tr>
<tr>
<td>24-pin RGE (QFN)</td>
<td>24</td>
<td>(4.00) x (4.00)</td>
</tr>
<tr>
<td>28-pin DW (SOIC)</td>
<td>28</td>
<td>(18.10) x (10.63)</td>
</tr>
<tr>
<td>28-pin PW (TSSOP)</td>
<td>28</td>
<td>(9.80) x (4.00)</td>
</tr>
<tr>
<td>28-pin RHD (QFN)</td>
<td>28</td>
<td>(6.63) x (6.60)</td>
</tr>
<tr>
<td>32-pin RHB (QFN)</td>
<td>32</td>
<td>(5.15) x (5.15)</td>
</tr>
<tr>
<td>38-pin DA (TSSOP)</td>
<td>38</td>
<td>(12.60) x (5.00)</td>
</tr>
<tr>
<td>40-pin RHA (QFN)</td>
<td>40</td>
<td>(8.40) x (7.00)</td>
</tr>
<tr>
<td>48-pin RGZ (QFN)</td>
<td>48</td>
<td>(12.20) x (7.10)</td>
</tr>
<tr>
<td>48-pin DL (SSOP)</td>
<td>48</td>
<td>(16.00) x (10.67)</td>
</tr>
<tr>
<td>49-pin YFF (DSBGA)</td>
<td>49</td>
<td>(3.23) x (2.23)</td>
</tr>
<tr>
<td>64-pin RGC, RTD (QFN)</td>
<td>64</td>
<td>(5.11) x (9.1)</td>
</tr>
<tr>
<td>64-pin PM, PAG (LQFP/TQFP)</td>
<td>64</td>
<td>(12.20) x (5.10)</td>
</tr>
<tr>
<td>80-pin ZOE (BGA)</td>
<td>80</td>
<td>(14.20) x (14.20)</td>
</tr>
<tr>
<td>80-pin PN (LQFP)</td>
<td>80</td>
<td>(16.20) x (7.10)</td>
</tr>
<tr>
<td>100-pin P2 (LQFP)</td>
<td>100</td>
<td>(16.20) x (7.10)</td>
</tr>
<tr>
<td>113-pin ZOW (BGA)</td>
<td>113</td>
<td>(7.10) x (7.10)</td>
</tr>
</tbody>
</table>

**Red:** New  
**Blue:** Preview
MCU Selection Tool

- Find the right MCU for your application
- Browse the 200+ MSP430 devices and explore the rest of TI’s MCU offerings
MSP430 is Easy to Get Started
Easy To Use, Innovative Tools

Flash Emulation Tools
- Compatible with all devices
- $99 ($149 w/ target board)
- Target boards available w/o FET

Free Software IDEs Available
- CCSv4 MCU Edition
- IAR Embedded Workbench

MSP430 Experimenter Boards
- Fully features prototyping system
- Available for FG4618 & F5438
- Starting at $99 ($4.30 for LaunchPad)

eZ430 Tools
- Complete development system in USB stick
- Available for wireless and energy harvesting
- Starting at $20
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
Chronos | Advanced Features at Your Disposal

- CC430F6137 MCU
- 3-Axis Accelerometer
- Pressure & Altitude Sensor
- Temperature Sensor
- Voltage & Battery Sensor
- CR2032 Battery
- <1GHz RF
  - 433, 868 & 915 MHz
- 2-Wire JTAG Access
- 96 segment LCD
- Buzzer
- eZ430 Programmer
- RF Access Point
- Chronos Disassembly Tool
Endless possibilities: Chronos serves as a central hub for nearby wireless sensors

- Raise & lower blinds
- Control ceiling fan
- Adjust thermostat
- Adjust entertainment system settings
- Pair with heart rate monitor
- Display GPS data
- Map Chronos buttons for PC Automation, motion-based control and more
- Pair with pedometer
Enabling Customer Innovation
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:
  - Speed
  - Code size improvements
  - Auto-updating
  - License manager
  - Support for all TI MCUs
- Only $495 for MCU Edition
  - $249 for MCU Day attendees
- FREE 16KB-limited edition

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 MSP430 microcontrollers

TI Stellaris microcontrollers

RF/IF and ZigBee Solutions
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)

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

**MSPGCC Tool Chain**
- Free
- Open Source
- GNU C Compiler, Assembler/Linker, GDB Debugger
- Windows, Linux, Unix

[http://mspgcc.sourceforge.net](http://mspgcc.sourceforge.net)

**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

---

**Elprotronic***

**MSPGCC**

**Amber Wireless**

**USB Stacks**
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
Extensive Community Support

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

**Processor Wiki**
- Growing collection of technical wiki articles
- Tips & tricks, common pitfalls, and design ideas
- http://wiki.msp430.com
Roadmap
MSP430 Portfolio + Roadmap

100+ devices

2xx-Catalog
- 16 MIPS
- 120 kB Flash
- 8 kB RAM
- 500 nA Standby
- 1.8 – 3.6V
- Value Line (G2xx)

100+ devices

The New Generation
5xx-6xx
- 25MIPS
- 512 kB Flash
- 64 kB RAM
- 1.8 – 3.6V
- USB, RF connectivity
- 6xx: LCD Controller
- New Low Power Modes

75+ devices

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

4xx: LCD
- 8 and 16 MIPS available
- 120 kB Flash
- 8 kB RAM
- LCD Controller, 160 segments
- 1.8 – 3.6V
MSP430 Value Line Roadmap

- **Flash Size**
  - 512 B
  - 1KB
  - 2KB
  - 4KB
  - 8KB
  - 16KB
  - 32KB

- **Order now**
  - 1KB
  - 2KB

- **In Development**
  - > 100 devices

- **64 devices in 4 packages**
  - From 512 B to 8 KB Flash

- **68 devices in 4 packages**
  - From 1 KB to 16 KB Flash

- **27 devices in 3 Packages**
  - From 512 B to 2 KB Flash

- **Intelligent Peripherals**
  - ADC
  - Comparator
  - Serial Communications (SPI/I2C)
  - UART
  - Cap Touch I/O

- **Packages**
  - 8-pin SOIC
  - 14-pin TSSOP/PDIP
  - 16-pin QFN
  - 4/10 GPIO
  - 14/20-pin TSSOP
  - 20-pin PDIP
  - 16 pin QFN
  - 10/16 GPIO
  - 20/28-pin TSSOP
  - 20-pin PDIP
  - 32-pin QFN
  - 16/24 GPIO

**ARROW ELECTRONICS AND TEXAS INSTRUMENTS**
### MSP430 Summary

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>200+ Ultra-Low Power Devices</strong></td>
<td><strong>25¢ Starting Price</strong></td>
</tr>
<tr>
<td><strong>Ultra-Low Power + Performance</strong></td>
<td><strong>$4.30 LaunchPad Tool</strong></td>
</tr>
<tr>
<td>- Six Low-Power Modes</td>
<td>- 25MHz speed</td>
</tr>
<tr>
<td>- &lt;1 µs wakeup time</td>
<td>- Leading Code Density</td>
</tr>
<tr>
<td>- Zero-Power BOR</td>
<td>- Do more without CPU</td>
</tr>
<tr>
<td><strong>High Integration</strong></td>
<td></td>
</tr>
<tr>
<td>- Intelligent Analog &amp; Digital Peripherals</td>
<td></td>
</tr>
<tr>
<td>- 16-bit ADC, 12-bit DAC, LCD Controllers, DMA</td>
<td></td>
</tr>
<tr>
<td>- Communication Interfaces include RF &amp; USB</td>
<td></td>
</tr>
<tr>
<td><strong>Extensive Portfolio with Low Cost Options</strong></td>
<td></td>
</tr>
<tr>
<td>- MSP430 Value Line starting @ $0.25</td>
<td></td>
</tr>
<tr>
<td>- 200+ Devices, various levels of integration/performance</td>
<td></td>
</tr>
<tr>
<td>- Roadmap with new technology</td>
<td></td>
</tr>
<tr>
<td><strong>Easy to Get Started</strong></td>
<td></td>
</tr>
<tr>
<td>- One programming tool for all devices</td>
<td></td>
</tr>
<tr>
<td>- Free Software IDEs</td>
<td></td>
</tr>
<tr>
<td>- Upcoming MSP430 LaunchPad!</td>
<td></td>
</tr>
<tr>
<td>- Code compatibility throughout MSP430 platform</td>
<td></td>
</tr>
</tbody>
</table>
TI has a complete portfolio of Analog and Embedded Processing Solutions…
## Embedded processing portfolio

### TI Embedded Processors

<table>
<thead>
<tr>
<th>Microcontrollers (MCUs)</th>
<th>ARM®-Based Processors</th>
<th>Digital Signal Processors (DSPs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-bit ultra-low power MCUs</td>
<td>32-bit ARM Cortex™-M3 MCUs</td>
<td>DSP</td>
</tr>
<tr>
<td>32-bit real-time MCUs</td>
<td>ARM Cortex-A8 MPUs</td>
<td>DSP+ARM</td>
</tr>
<tr>
<td>MSP430™</td>
<td>Sitara™ ARM® Cortex™-A8 &amp; ARM9</td>
<td>Multi-core DSP</td>
</tr>
<tr>
<td>C2000™ Delfino™ Piccolo™</td>
<td>C6000™ DaVinci™ video processors OMAP™</td>
<td>Ultra Low power DSP</td>
</tr>
<tr>
<td>Up to 25 MHz</td>
<td>300MHz to &gt;1GHz</td>
<td>Up to 300 MHz +Accelerator</td>
</tr>
<tr>
<td>Flash 1 KB to 256 KB</td>
<td>Cache, RAM, ROM</td>
<td>Cache RAM, ROM</td>
</tr>
<tr>
<td>Analog I/O, ADC LCD, USB, RF</td>
<td>Cache, RAM, ROM</td>
<td>USB, ENET, PCIe, SATA, SPI</td>
</tr>
<tr>
<td>Measurement, Sensing, General Purpose</td>
<td>Industry computing, POS &amp; portable data terminals</td>
<td>Floating/Fixed Point</td>
</tr>
<tr>
<td>$0.25 to $9.00</td>
<td>$1.00 to $8.00</td>
<td>Telecom test &amp; meas., media gateways, base stations</td>
</tr>
</tbody>
</table>

### Software & Dev. Tools

- **MSP430 MCU Day**
- **Embedded Series**
- **ARROW ELECTRONICS AND TEXAS INSTRUMENTS**
- **Software & Dev. Tools**
- **Texas Instruments eXpressDSP™**

**MPUs – Microprocessors**
Helpful Links

• MSP430 homepage – www.ti.com/msp430
• Complete list of MSP430 tools – www.ti.com/msp430tools
• Complete list of MSP430 code examples – www.ti.com/msp430codeexamples
• Chronos wiki - www.ti.com/chronoswiki
• LaunchPad wiki – www.ti.com/launchpadwiki
Exclusive MSP430 Day Discounts
50% off Select MSP430 Tools!

Visit the TI eStore at [http://www.ti-estore.com](http://www.ti-estore.com) and take advantage of these limited time discounts!

- **Experimenter Board for MSP430 New Generation 5xx**
  - Regular price: $149. MSP430 Day Price: $75
  - Part number: MSP-EXP430F5438
  - Code: 430day1

- **eZ430-Chronos Wireless Watch Development Tool (915 MHz)**
  - Regular price: $49. MSP430 Day Price: $25
  - Part number: EZ430-CHRONOS
  - Code: 430day2

- **eZ430-RF2500 2.4GHz Wireless Development Tool**
  - Regular price: $49. MSP430 Day Price: $25
  - Part number: eZ430-RF2500
  - Code: 430day3

- **MSP430 Debugging Interface**
  - Regular price: $99. MSP430 Day Price: $50
  - Part number: MSP-FET430UIF
  - Code: 430day4

- **Code Composer Studio™ MCU Edition**
  - (Full support of MSP430™, Stellaris®, C2000™ and TMS570 MCUs)
  - Regular price: $495. MSP430 Day Price: $250
  - Part number: TMDSCCS-MCUN01
  - Code: 430day5

Discount Terms:
- Each customer can order up to one of each of the 5 tools at a 50% discount.
- You can enter multiple discount codes in one order.
- Codes are valid through October 15, 2010.
- You do need to have a my.TI account to place an order, however, if you do not have one signing up will only require you to enter a user name and password. This will allow you to review, track and reorder at a later date.
- If you do not want to enter a user name and password, you can also call the Product Info Center and order the tools with your discount codes at (972) 644-5580.
- For questions or help please email TI_Store@ti.com
Thank you.

Lunch time!
# Low Power Mode Overview

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Description</th>
<th>CPU (MCLK)</th>
<th>SMCLK</th>
<th>AMCLK</th>
<th>RAM Retention</th>
<th>BOR</th>
<th>Self Wakeup</th>
<th>Interrupt Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>CPU, all clocks and peripherals available.</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Timers, ADC, DMA, USART, WDT, I/O, comparator, USI, Ext. Interrupt, USCI, RTC, other peripherals</td>
</tr>
<tr>
<td>LPM0</td>
<td>CPU is shutdown, peripheral clocks available.</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Timers, ADC, DMA, USART, WDT, I/O, comparator, USI, Ext. Interrupt, USCI, RTC, other peripherals</td>
</tr>
<tr>
<td>LPM1</td>
<td>CPU is shutdown, peripheral clocks available. DCO is disabled and the DC generator can be disabled.</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Timers, ADC, DMA, USART, WDT, I/O, comparator, USI, Ext. Interrupt, USCI, RTC, other peripherals</td>
</tr>
<tr>
<td>LPM2</td>
<td>CPU is shutdown, only one peripheral clock available. DC generator is enabled.</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Timers, ADC, DMA, USART, WDT, I/O, comparator, USI, Ext. Interrupt, USCI, RTC, other peripherals</td>
</tr>
<tr>
<td>LPM3</td>
<td>CPU is shutdown, only one peripheral clock available. DC generator is disabled.</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Timers, ADC, DMA, USART, WDT, I/O, comparator, USI, Ext. Interrupt, USCI, RTC, other peripherals</td>
</tr>
<tr>
<td>LPM3.5</td>
<td>No RAM retention, RTC can be enabled. (MSP430F5xx generation only)</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Ext. Interrupt, RTC</td>
</tr>
<tr>
<td>LPM4</td>
<td>CPU is shutdown and all clocks disabled.</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Ext. Interrupt</td>
</tr>
<tr>
<td>LPM4.5</td>
<td>No RAM retention, RTC disabled. (MSP430F5xx generation only)</td>
<td>● ● ● ● ● ●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● ● ● ● ● ●</td>
<td>Ext. Interrupt</td>
</tr>
</tbody>
</table>

**BACK**

**ARROW ELECTRONICS AND TEXAS INSTRUMENTS**