

430 Day 2008

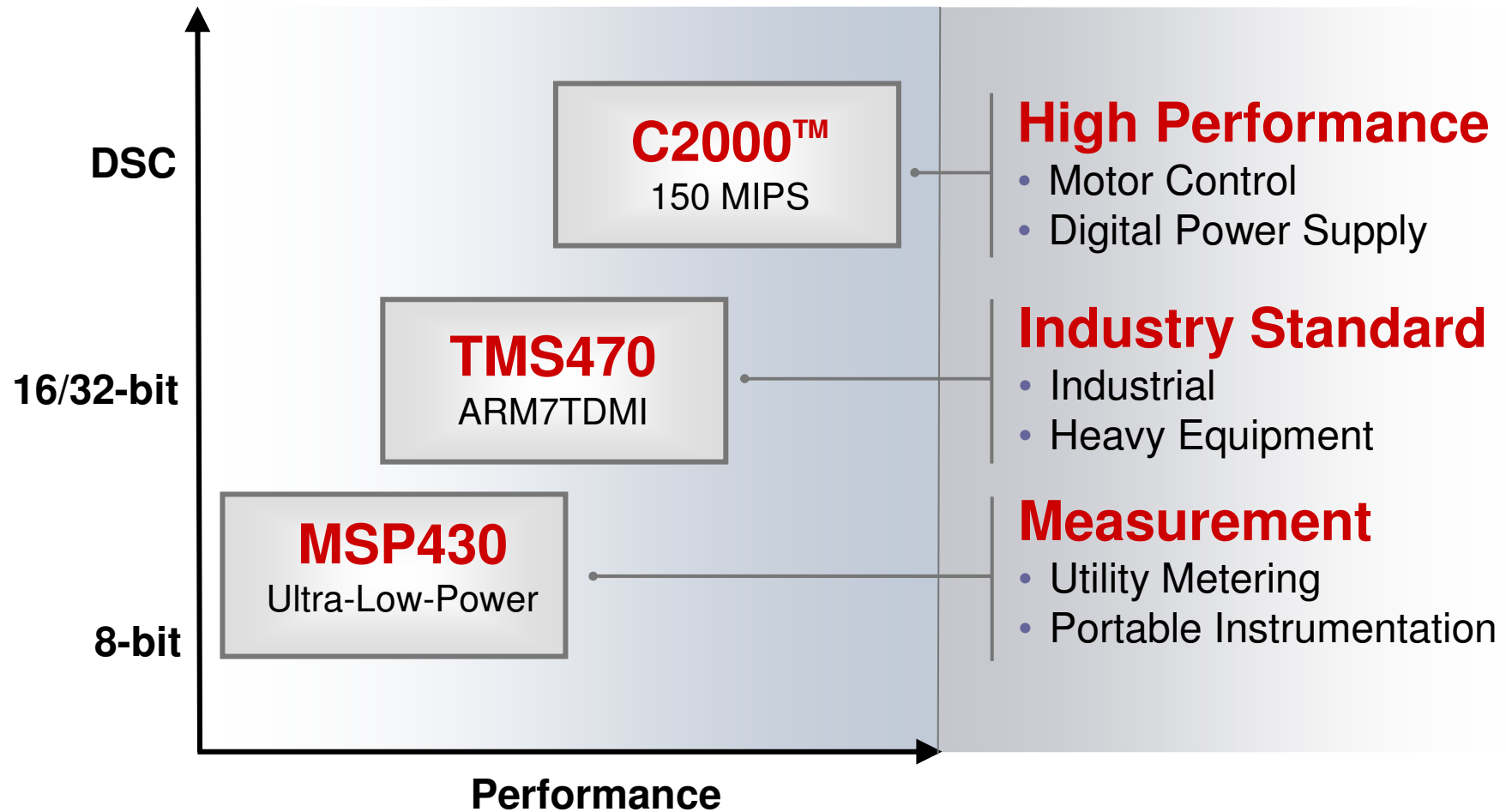
MSP430

Ultra-Low-Power MCUs

MSP430 Day 2008

- MSP430 Overview
- Peripherals
- MSP430x2xx/4xx
- MSP430x5xx
- Tools and Software
- Wireless
- Resources

TI Microcontroller Portfolio



MSP430 Application Spaces

Medical and Industrial Metering

- Glucose and cholesterol meters, thermometer, EKG, heart rate monitor, pulse oxymeter
- Voltage, current, temperature, pressure, pH...meters

Sensing

- Alarm system, smoke/ fire detector
- Home control and automation
- Wireless asset tracking
- Wireless sensors

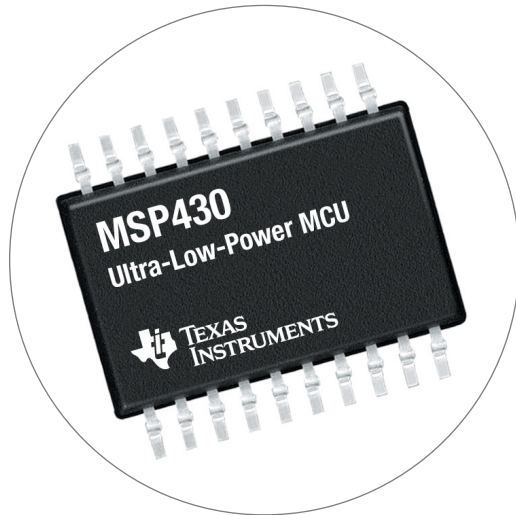
Utility Metering

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

Portable Consumer

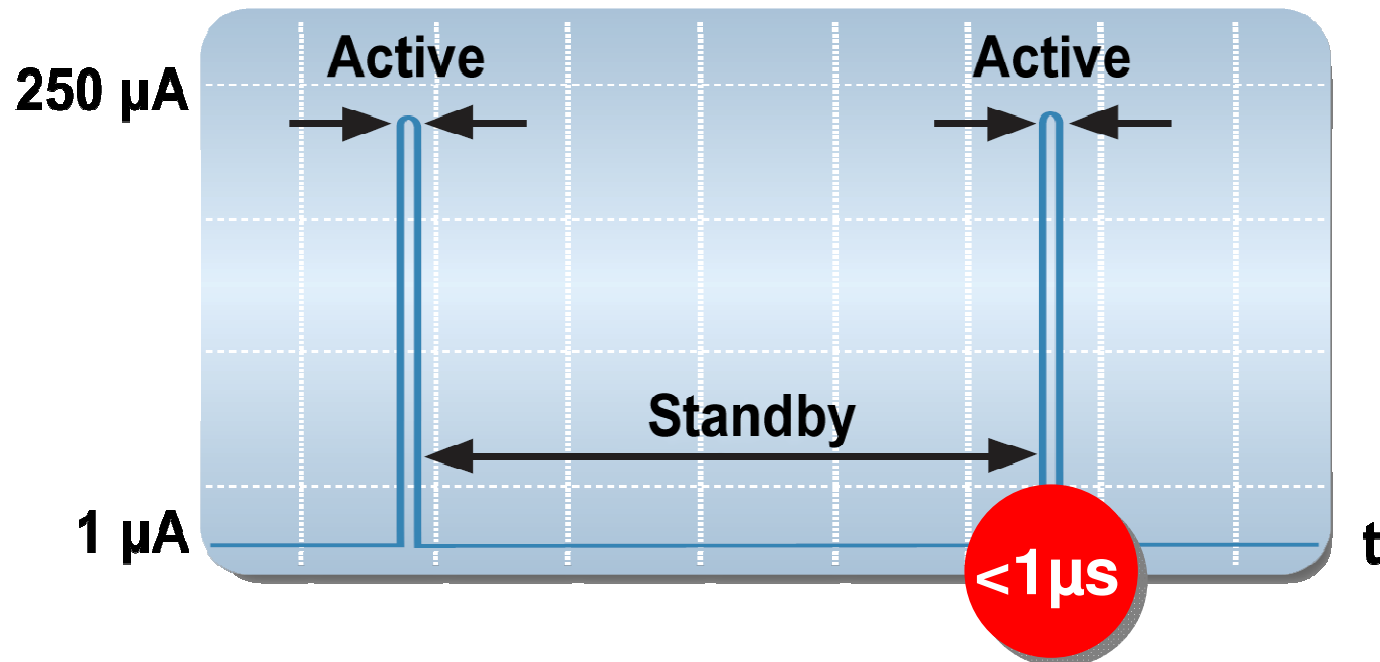
- Cell phone, digital camera, MP3
- Sportwatch and sensors
- Toothbrush, shaver
- Remote control
- Wireless keyboard and mouse

Ultra-Low-Power + High Performance



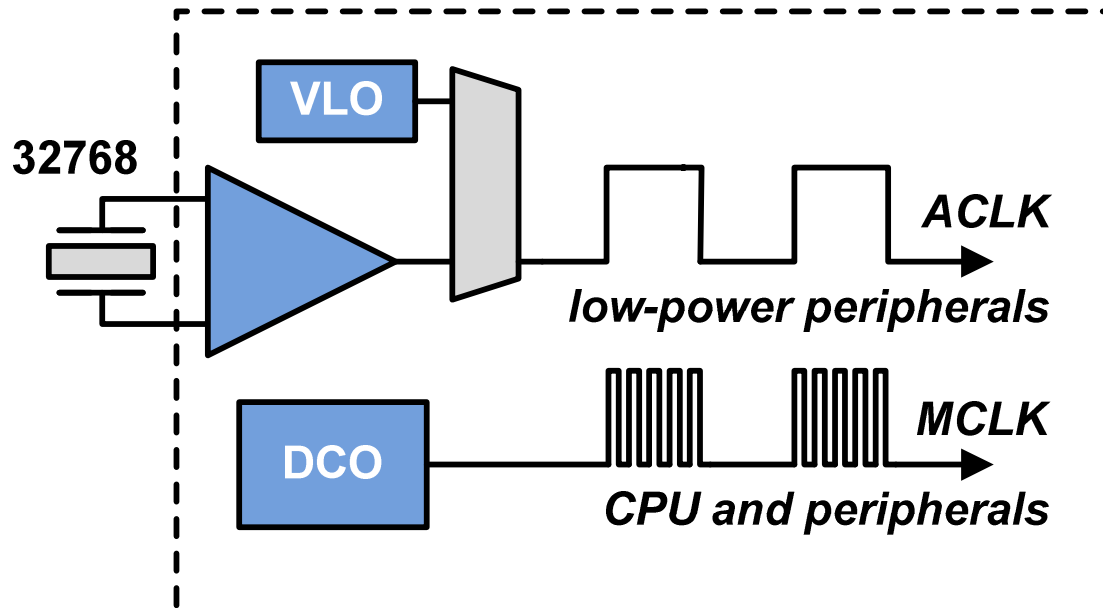
- 0.1 μ A power down
- 0.8 μ A standby mode
- 250 μ A / 1MIPS
- <1 μ s clock start-up
- Zero-power BOR
- <50nA pin leakage
- Modern 16-bit RISC CPU
- 1K to 128KB+ ISP Flash
- 14- to 100-pin options
- Intelligent peripherals boost performance
- Embedded emulation

Ultra-Low-Power Activity Profile



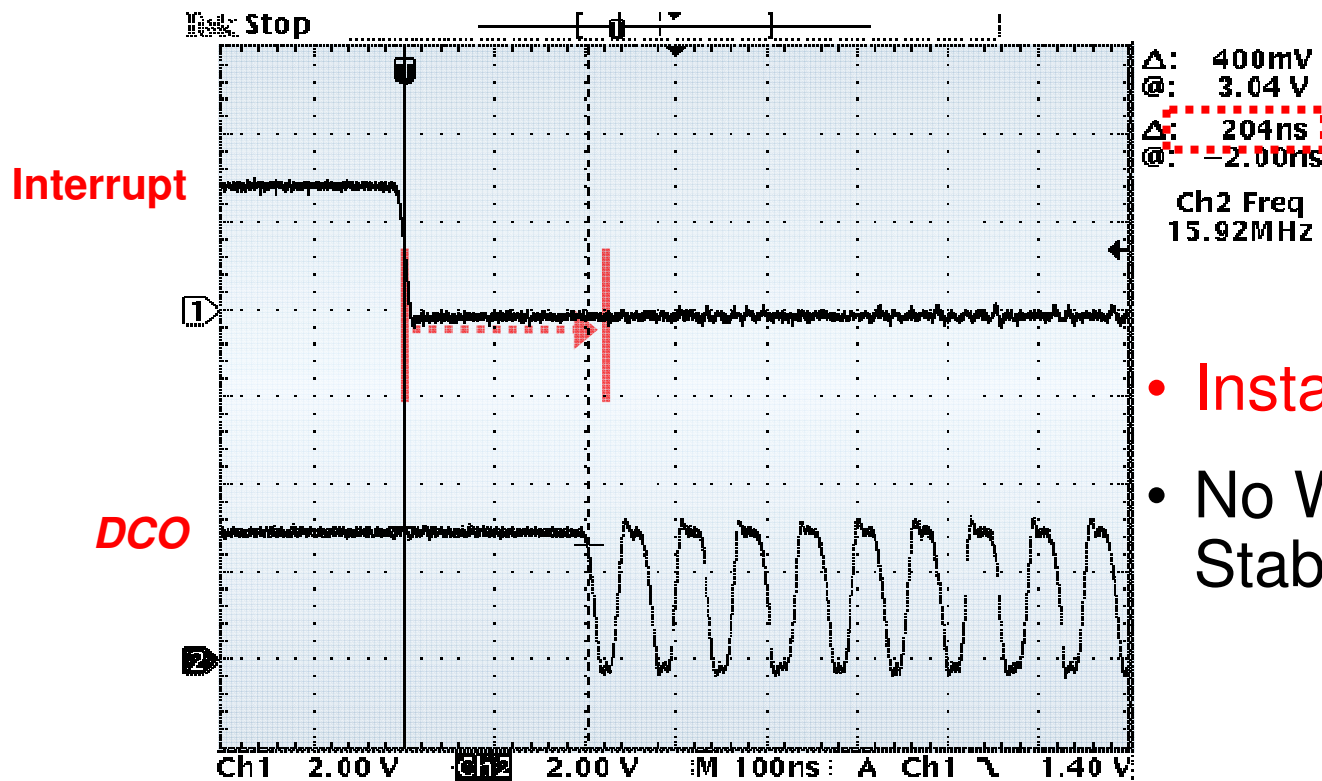
- Extended *Ultra-Low-Power* standby mode
- Minimum active duty cycle
- Interrupt driven performance on-demand

Ultra-Low-Power Clock System



- Always-on low-frequency ACLK
- On-demand high-speed DCO
- DCO on and *stable* in $<1\mu\text{s}$

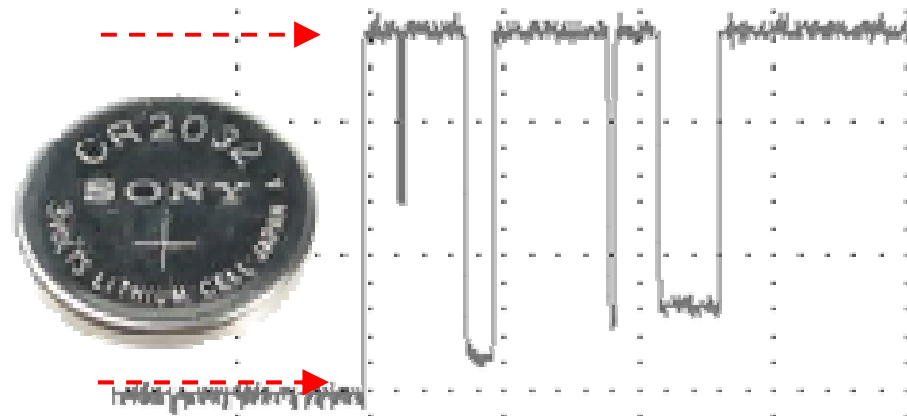
Performance On-Demand



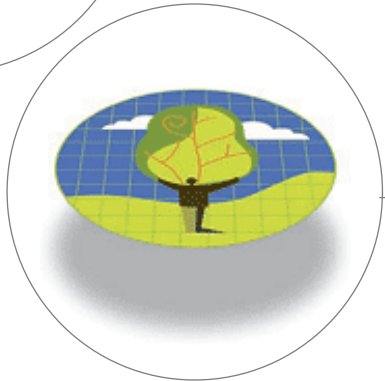
- Instant on CPU Clock
- No Wait for MCLK Stabilization

Supply Supervision & Monitoring

- BOR/POR
 - Always-on
 - Zero-power
- SVS
 - 10uA
 - S/W enable/disable
 - Internal or External Ref
 - Fixed: 1.8V
 - Programmable: 14 thresholds
- ADCs
 - Support internal Vcc measurement



Why *Ultra-Low-Power* Is Important

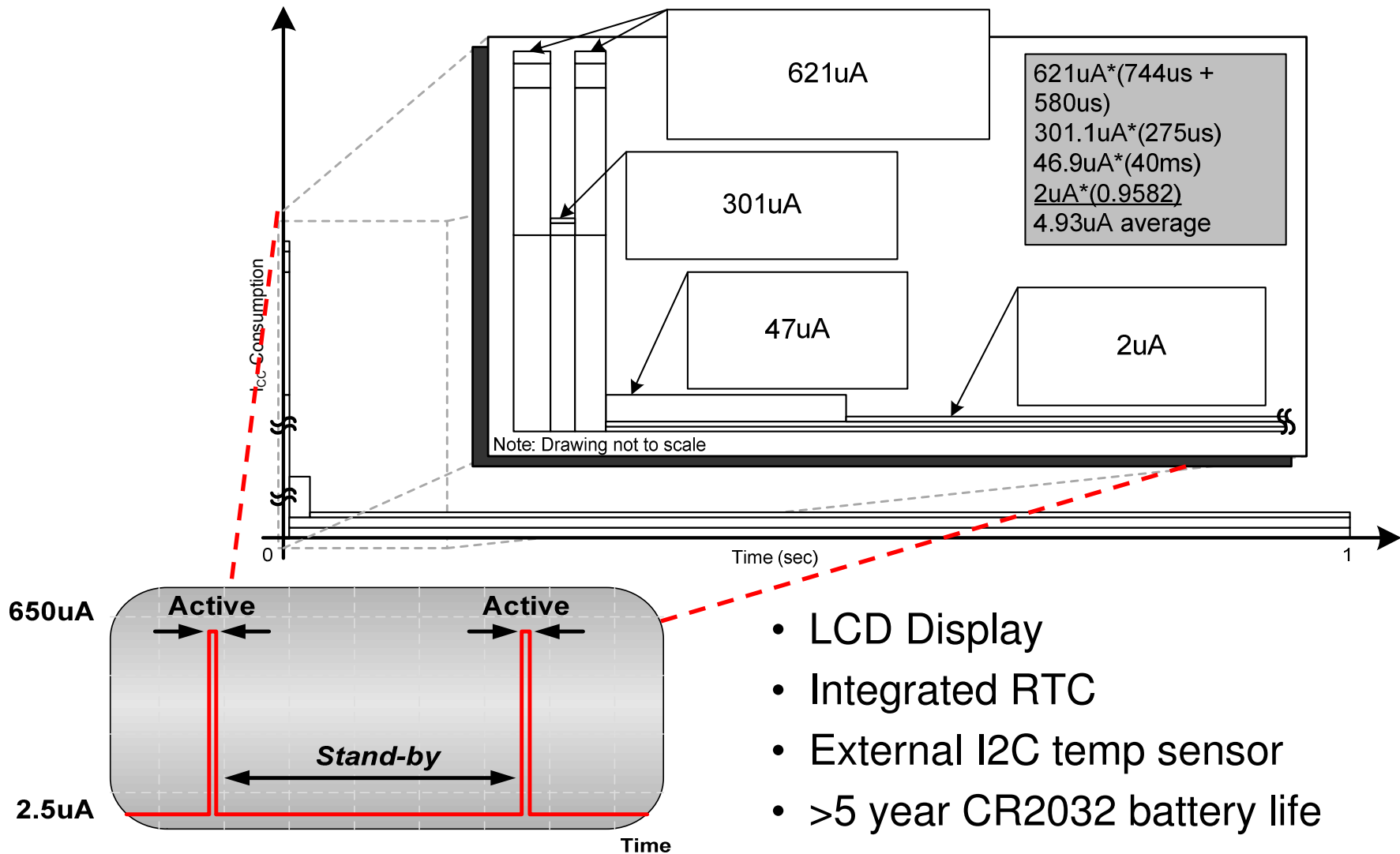


- Longer battery life
- Smaller products
- Simpler power supplies
- Less EMI simplifies PCB
- *Permanent* battery
- Environmental Stewardship
- Reduced Liability

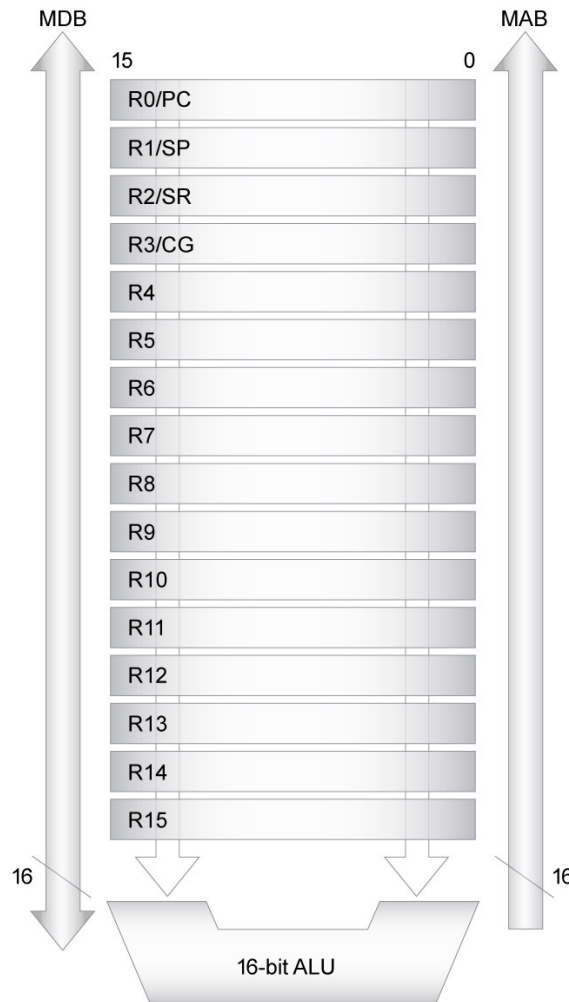
Ultra-Low-Power MCU Checklist

- ✓ Multiple operating modes
 - 0.1µA power down
 - 0.8µA standby
 - 250µA / 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
- ✓ Performance over required operating conditions

Burst Processing: Time & Temp Example

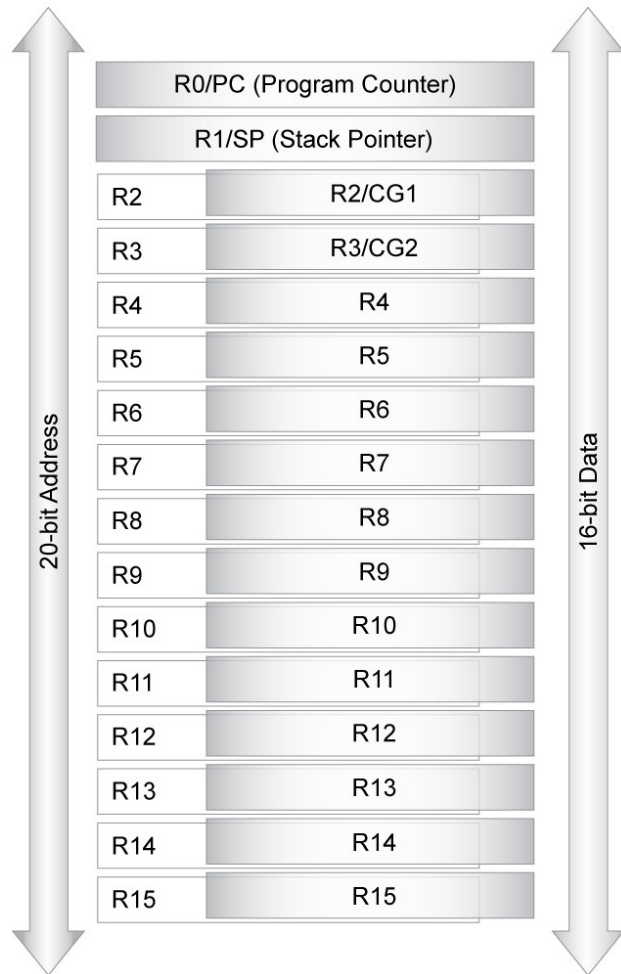


16-bit Orthogonal RISC CPU



- C-compiler friendly
- No accumulator bottleneck
- 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

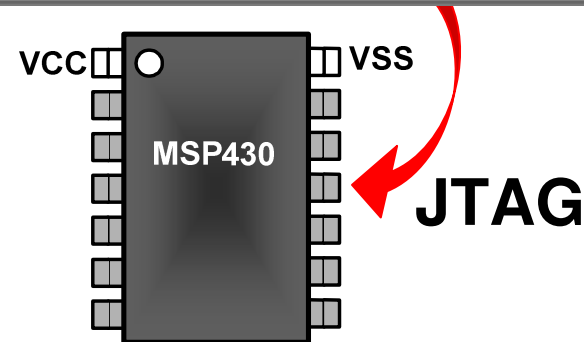
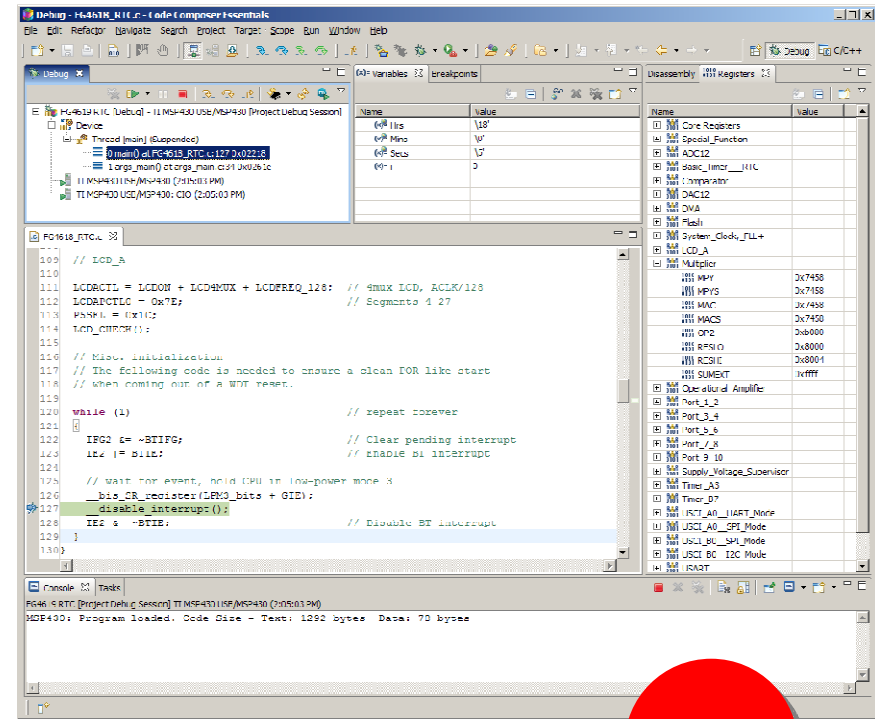
MSP430X Implementation



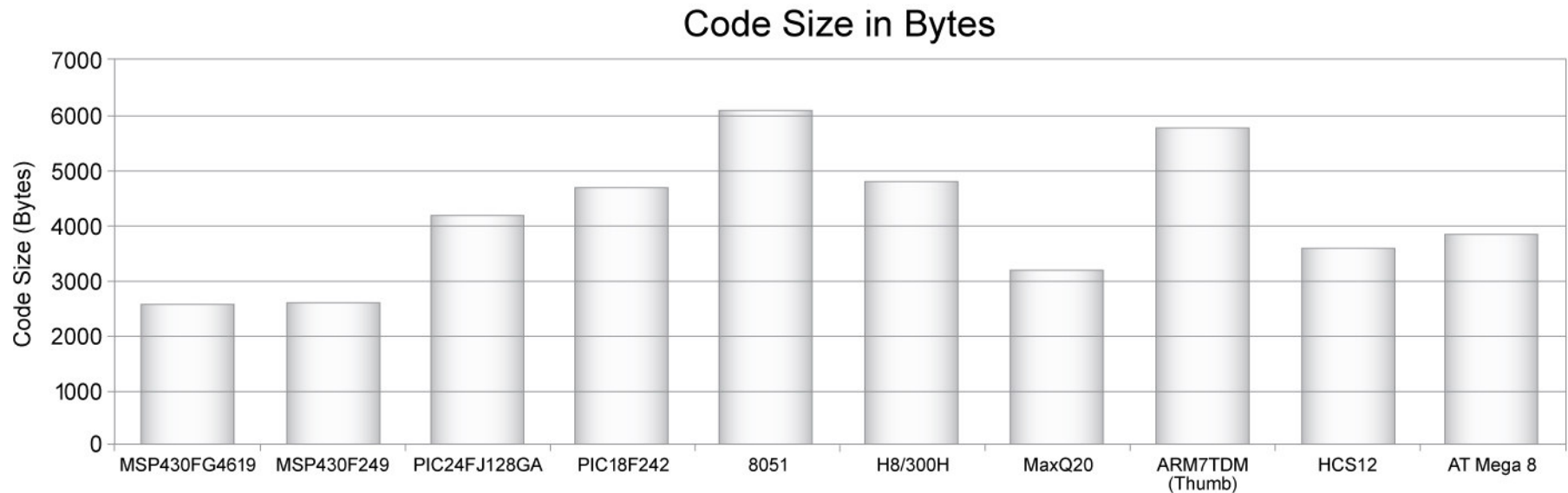
- C-compiler friendly
- Memory address increased to 1MB
- CPU registers increased to 20-bits
- Address word instructions
 - Direct 20-bit CPU register access
- Code compatible with MSP430
- Cycle count optimization
- Extension word allows all instructions
 - Direct access to 1MB address space
 - Bit, byte, word and address-word data
 - Repeat instruction function

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

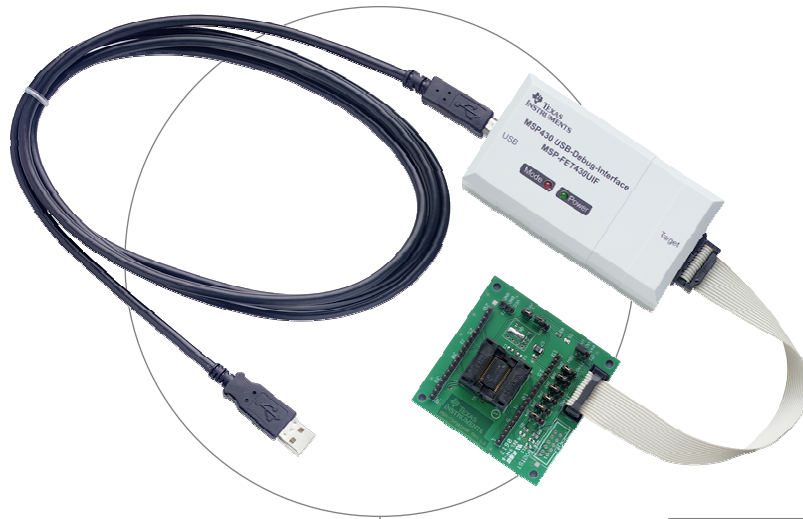


Compiler Friendly



- Instruction set and register orthogonality
- Direct stack addressing for passing parameters
- Application report SLAA205

Flash Emulation Tools



- Compatible with **ALL** devices
- Universal USB JTAG interface
- Package specific target boards
- Starting at **\$99** USD
- Free IDEs included

MSP430 Day 2008

- MSP430 Overview
- Peripherals
- MSP430x2xx/4xx
- MSP430x5xx
- Tools and Software
- Wireless
- Resources

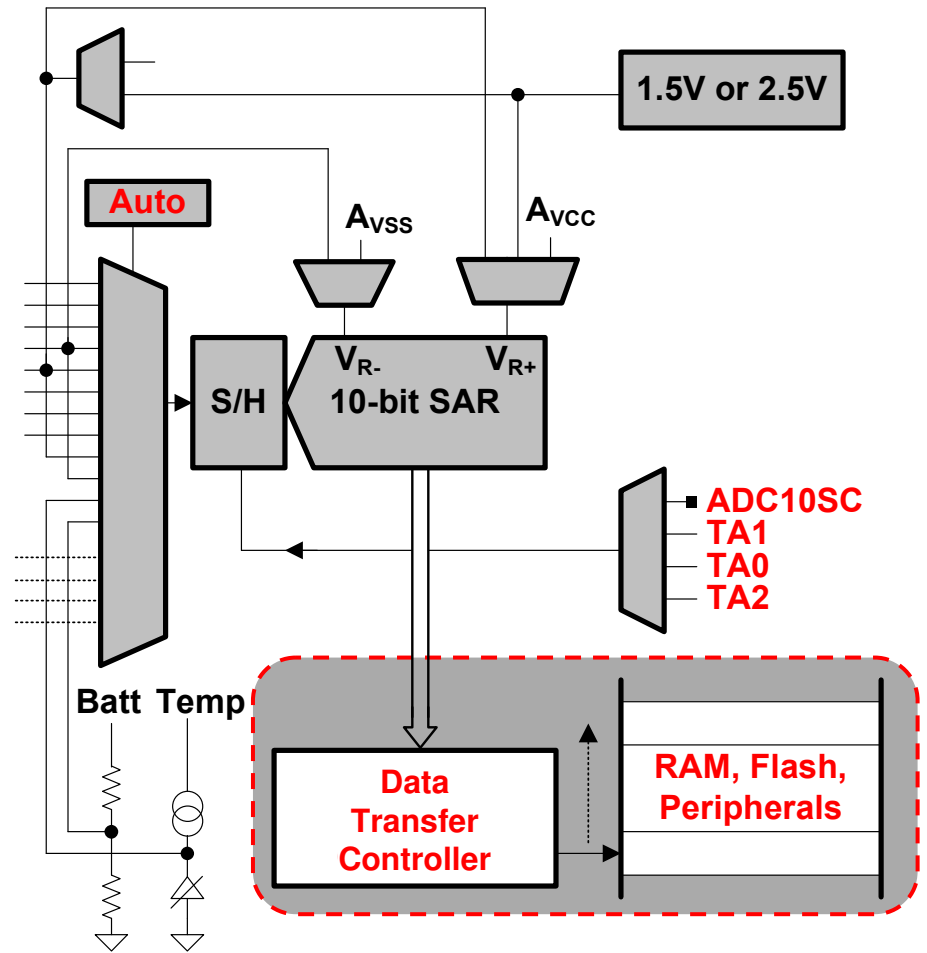
Peripheral Overview

- ADC10/ADC12
- SD16/SD16_A
- Comparator_A+
- Op-Amp
- DAC12
- SVS
- ESP430
- Scan IF

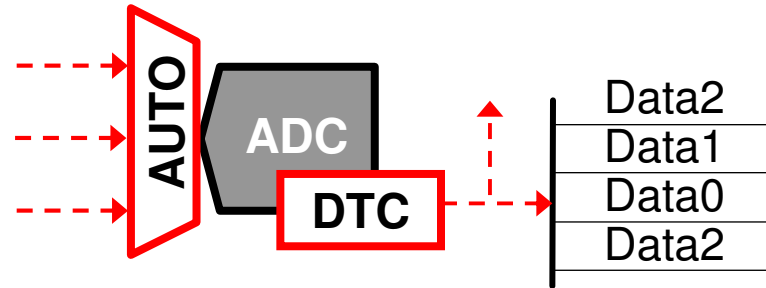
- LCD/LCD_A
- DMA
- Hardware Multiplier
- Timer A/Timer B
- USART
- USCI
- USI

Fast Flexible ADC10

- 10-bit ADC
- 200ksps+
- Autoscan
- Single Sequence Repeat-single Repeat-sequence
- Int/ext ref
- TA SOC triggers
- Data Transfer Controller (DTC)



Autoscan + DTC Performance Boost



```
// Software
Res[pRes++] = ADC10MEM;
ADC10CTL0 &= ~ENC;
if (pRes < NR_CONV)
{
    CurrINCH++;
    if (CurrINCH == 3)
        CurrINCH = 0;
    ADC10CTL1 &= ~INCH_3;
    ADC10CTL1 |= CurrINCH;
    ADC10CTL0 |= ENC+ADC10SC;
}
```

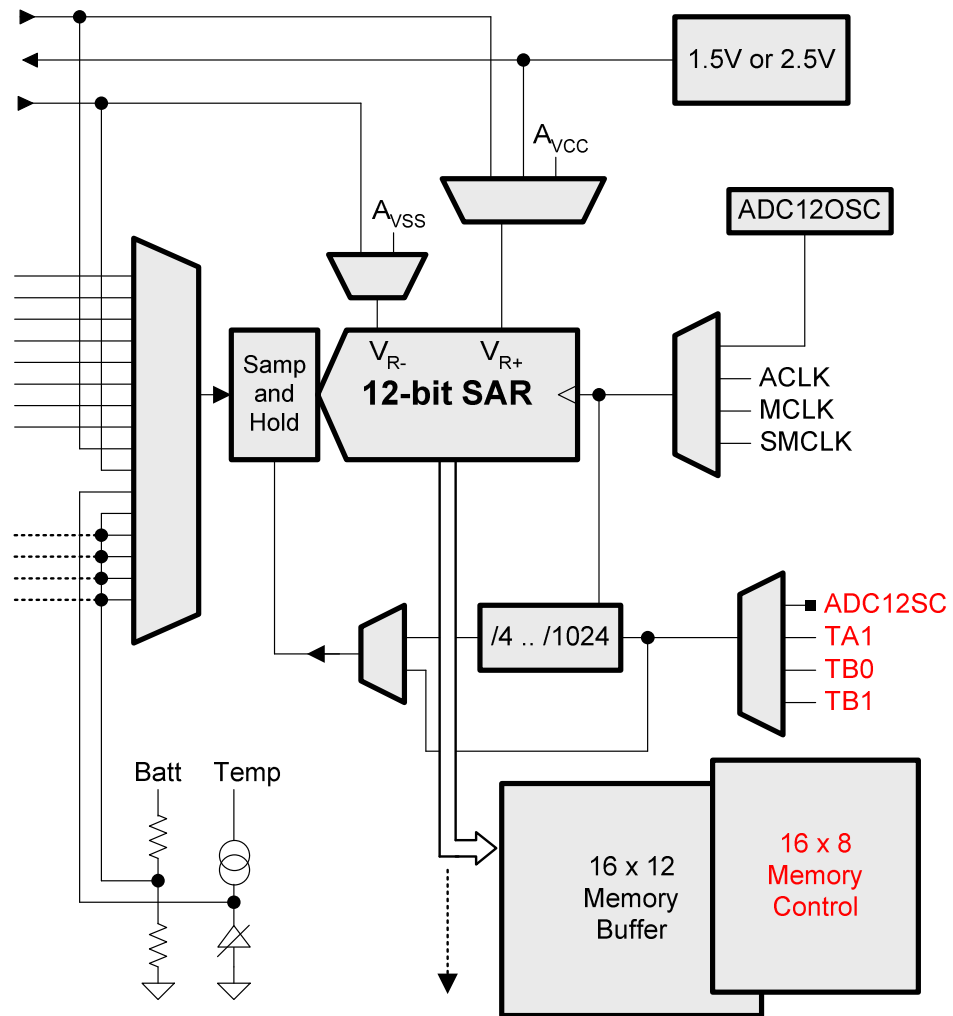
```
// Autoscan + DTC
_BIS_SR(CPUOFF);
```

Fully Automatic

70 Cycles / Sample

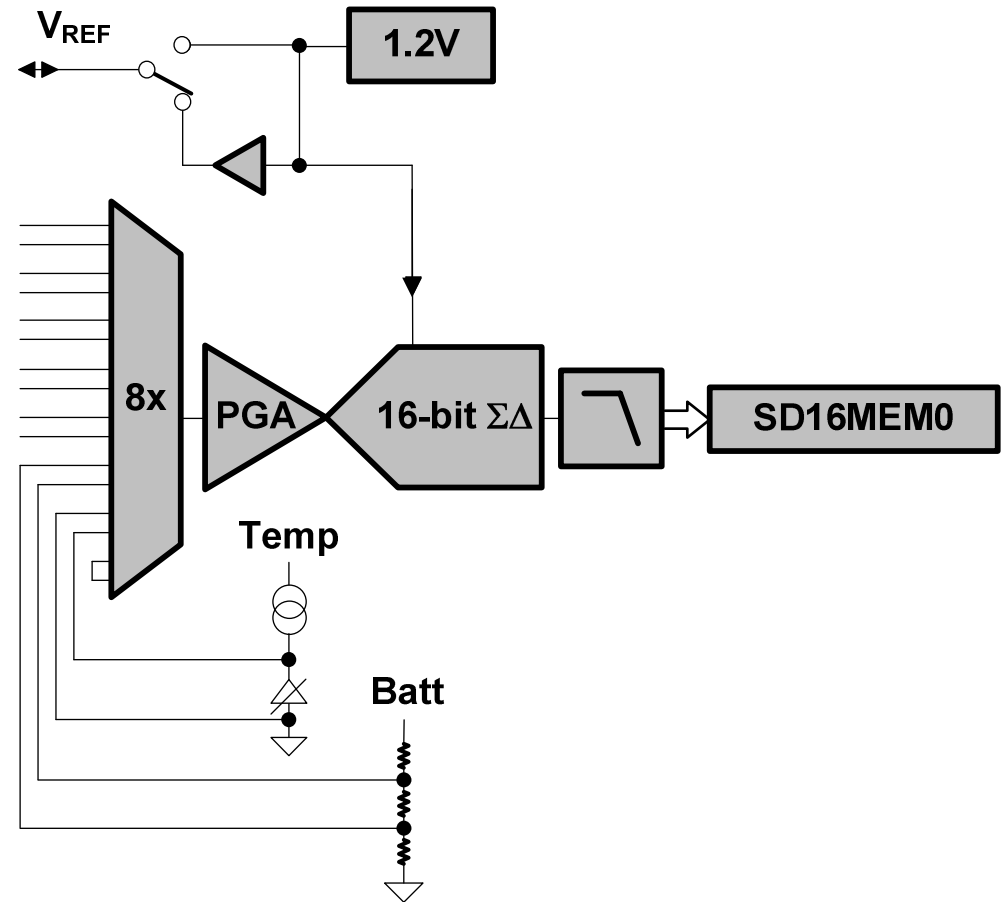
ADC12

- 200ksps+
- Single Sequence Repeat-single Repeat-sequence
- Int/ext reference
- TA/TB SOC triggers
- Configuration memory/buffer
- DMA enabled



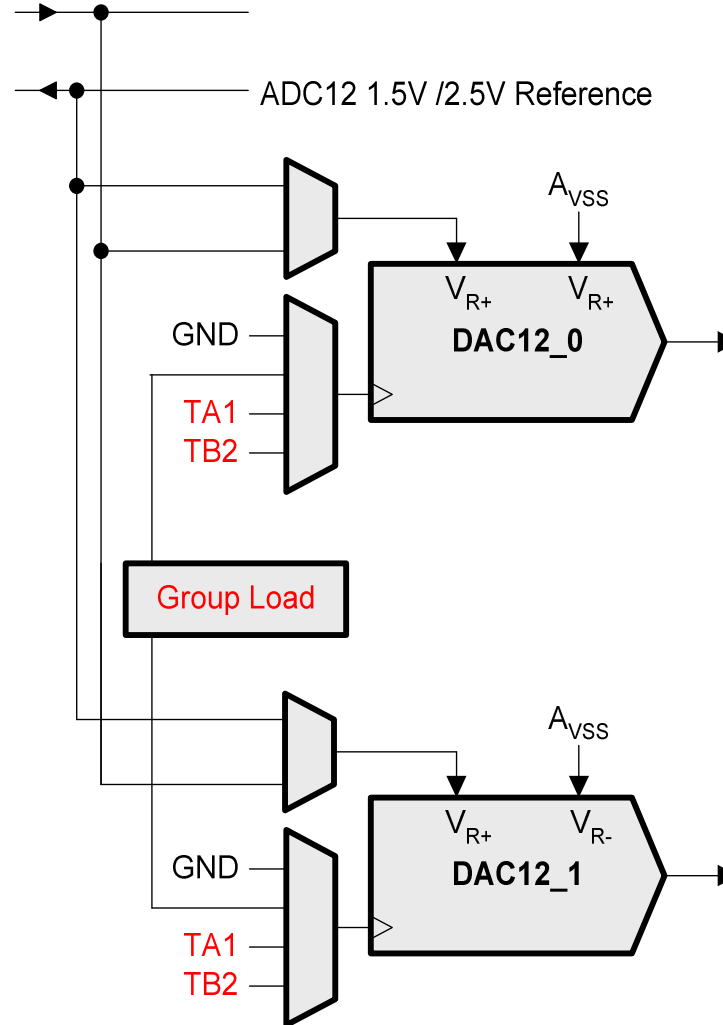
High-Precision SD16

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

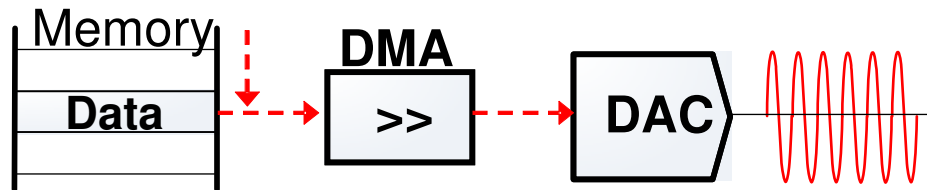


DAC12

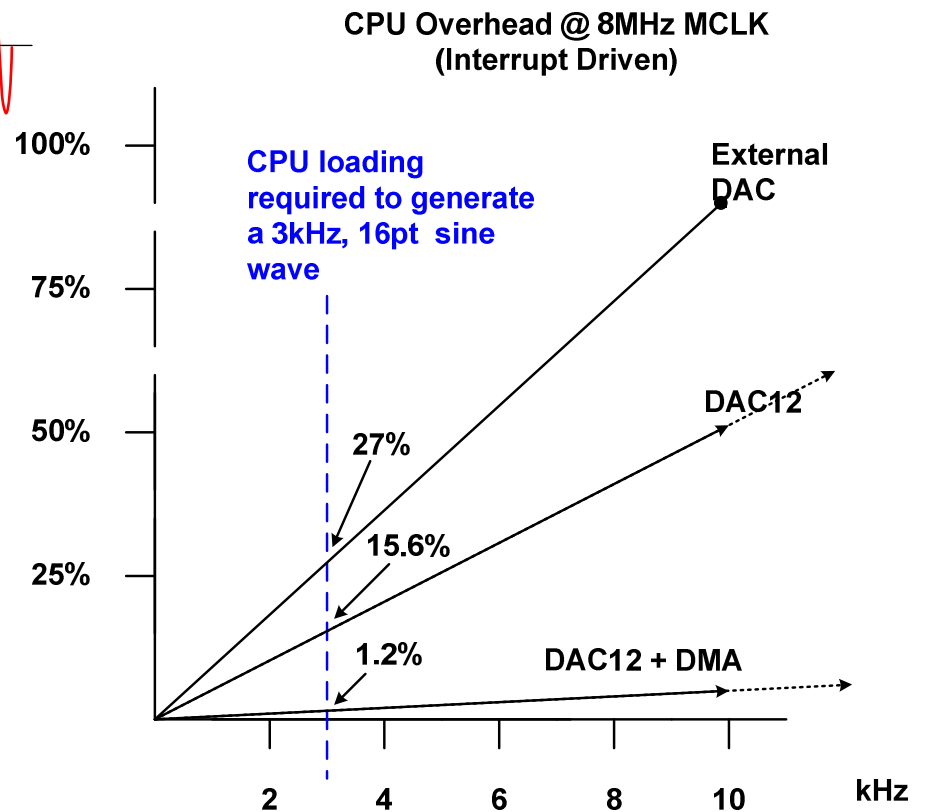
- 12-bit monotonic
- 8/12-bit voltage output
- Programmable settling time versus power
- Int/ext reference
- Binary or 2's compliment
- Self-calibration
- Group sync load
- DMA enabled



Intelligent Peripheral Performance

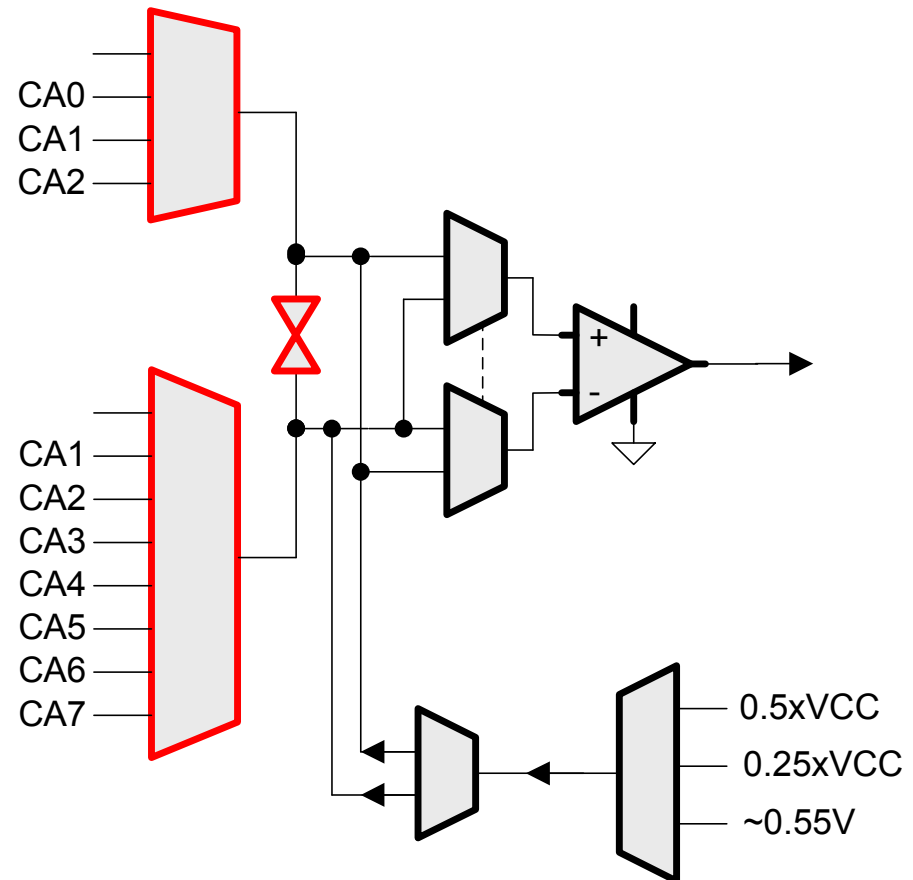


- Increased system flexibility
- No code execution required
- Lower power
- Higher efficiency



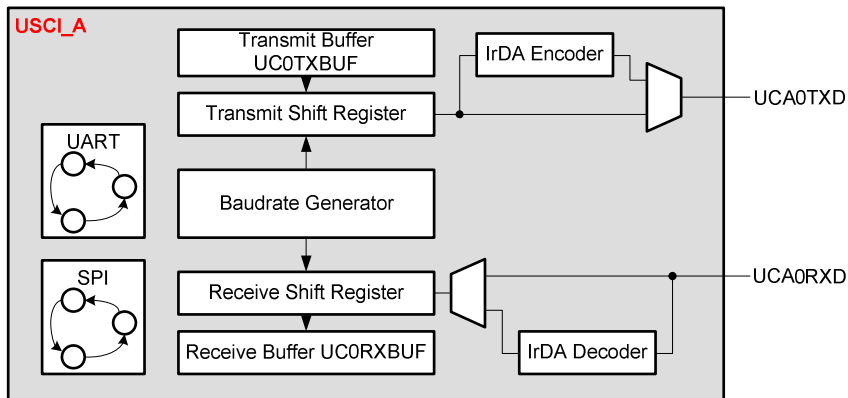
Comparator_A+

- Expanded input multiplexer
- Reference generator
- Low-pass filter
- Battery detect
- Interrupt source
- Timer_A capture
- Multiplexer short for sample-and-hold



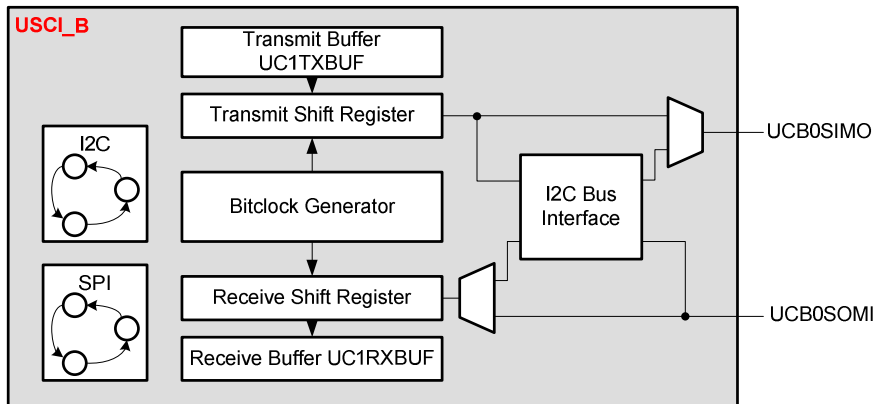
USCI

USCI_A



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

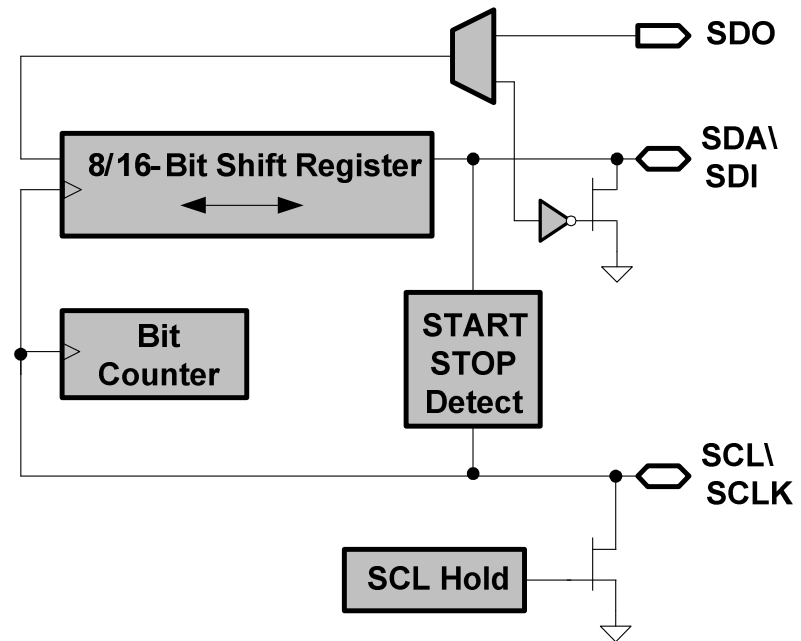
USCI_B



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

USI

- SPI and I2C mode support
- Timing managed in hardware
- Programmable data length
- **Interrupt Driven**
- Reduces CPU load
- Provides efficient combination of cost & function for a software-friendly serial interface



MCU Development Checklist

Ultra-Low-Power MCU Checklist

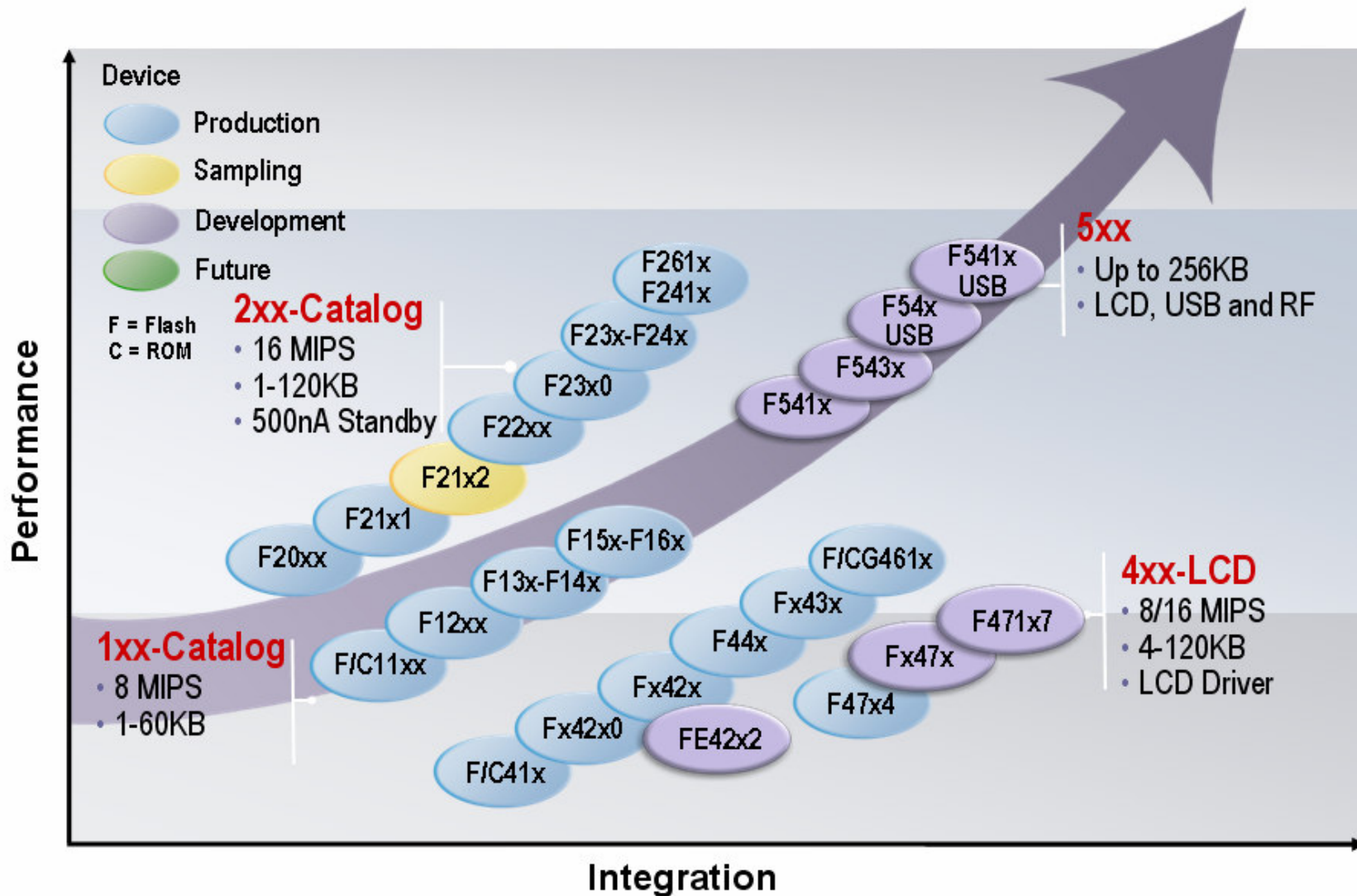
- ✓ Multiple operating modes
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 - 0.8µA standby
 - 250µA / MIPS
- ✓ Instant-on **stable** high-speed clock
- ✓ 1.8 - 3.6V **single-supply** operation
- ✓ **Zero-power** BOR
- ✓ **<50nA** pin leakage
- ✓ CPU that minimizes cycles per task
- ✓ Low-power intelligent peripherals
- ✓ Performance over required operating conditions

- ✓ **Ultra-Low-Power**
- ✓ Orthogonal Architecture
- ✓ Easy to Use
- ✓ High-Performance
- ✓ Integrated, Smart Analog Peripherals
- ✓ Powerful, In-system Debugging
- ✓ Broad Portfolio
- ✓ Environmental Stewardship

MSP430 Day 2008

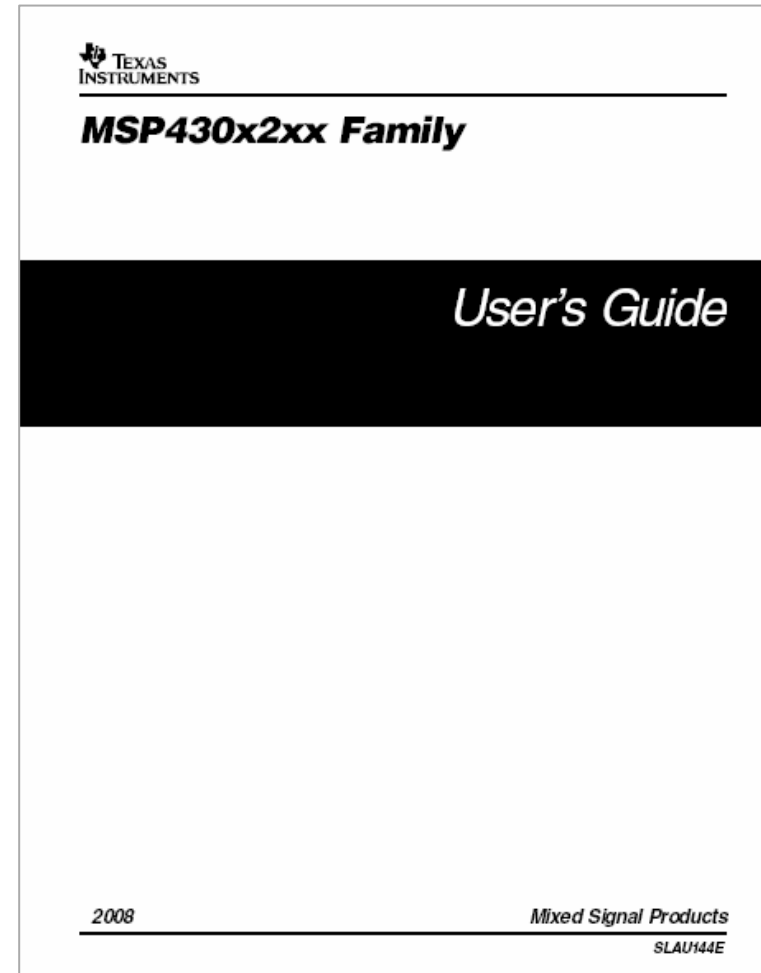
- MSP430 Overview
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MSP430 Roadmap



F2xx Key Features

- <1 μ A standby LPM3
- <1 μ s 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*



New F2xx General-Purpose Devices

Device	Pins	Flash/RAM	Timers	Communication	Features
F20x1	14	2KB / 128B	A2		Comp_A+
F20x2	14	2KB / 128B	A2	USI	ADC10
F20x3	14	2KB / 128B	A2	USI	SD16
F21x1	20	8KB / 256B	A3		Comp_A+
NEW F21x2*	28/32	8KB/512B	A2,A3	USCI	Comp_A+, ADC10
F22x2	38/40	32KB / 1KB	A3,B3	USCI	ADC10
F22x4	38/40	32KB / 1KB	A3,B3	USCI	ADC10, (2)OPA
RTM F23x0	40	32KB / 2KB	A3,B3	USCI	Comp_A+, MPY
F23x	64	16KB / 2KB	A3,B3	USCI	Comp_A+, MPY, ADC12
F24x	64	60 KB / 4 KB	A3, B7	(2)USCI	Comp_A+, MPY, ADC12
F241x	64/80	120KB / 8KB	A3,B7	(2)USCI	Comp_A+, MPY, ADC12
F261x	64/80	120KB / 8KB	A3,B7	(2)USCI	Comp_A+, MPY, ADC12, (2)DAC12, (3)DMA
All devices include enhanced watchdog timer (WDT+) and enhanced basic clock system (BCS+)					
* In development					

Peripheral Cheat Sheet...

USI

• I2C & SPI

USCI_A

• UART/LIN, IrDA & SPI

USCI_B

• I2C & SPI

- Perfect choice for new projects
- Pin compatible upgrade path for 1xx designs

F2xx Flexible Clock System

- Very-Low-Power Oscillator (VLO)

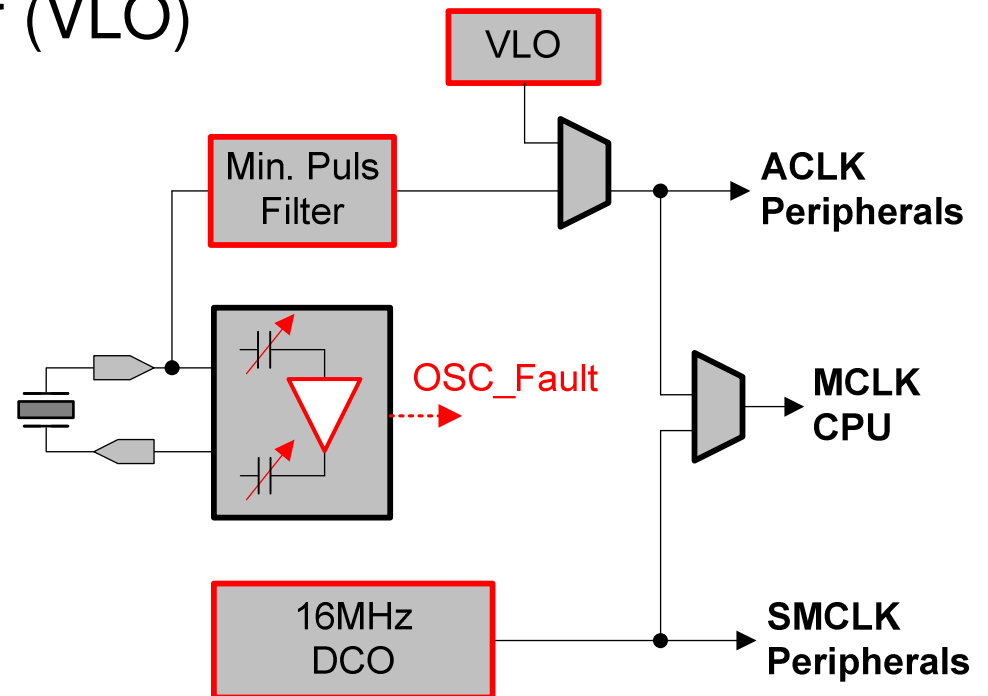
- Embedded 12kHz
- 500nA standby

- Crystal oscillator

- Programmable capacitors
- Failsafe OSC_Fault
- Minimum pulse filter

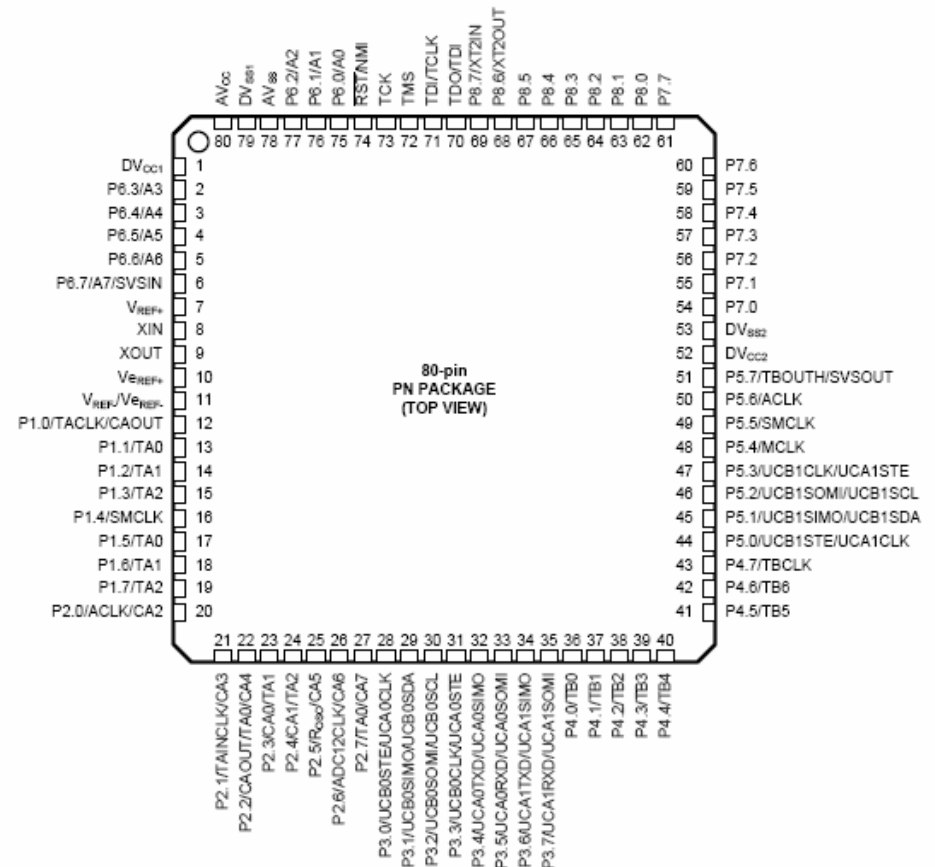
- Improved DCO

- <1 μ s 0-to-16MHz
- $\pm 3\%$ tolerance
- Factory calibration in Flash



MSP430F261x/241x

- **Most Integrated** 2xx family
- Upgrades for F16x & F14x families
- **MSP430X** architecture
- **120KB** Flash / 8KB RAM
- 12-bit 200ksps ADC
- (2) 12-bit DAC
- (2) USCI, DMA, MPY
- **RTM – October 2007**
- **Available today**



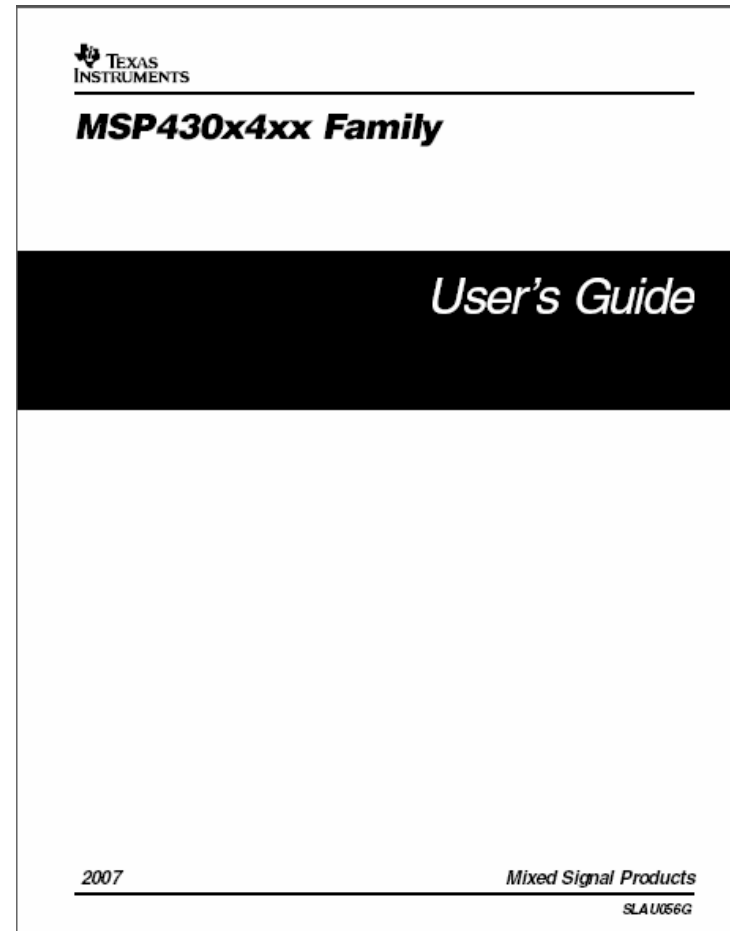
MSP430F21x2

- ADC10
- Comp_A+
- Timer_A3/A2
- USCI_A0/B0
- 8KB Flash/512B RAM
- Target Applications
 - Smoke detectors
 - Battery chargers
 - Wireless security systems
 - Wireless sensors



F4xx Key Features

- $<1\mu\text{A}$ standby LPM3
- $<1\mu\text{s}$ 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*



F4xx Application Specific Devices

Peripheral Cheat Sheet...

USI

- I2C & SPI

USCI_A

- UART/LIN, IrDA & SPI

USCI_B

- I2C & SPI

Device	Pins	Flash/RAM	Timers	Communication	LCD	Features
F41x	64	32KB / 1KB	BT,A3		96	Comp_A
F42x0	48	32KB / 512B	BT,A3		56A	SD16, DAC12
F42x	64	32KB / 1KB	BT,A3	USART	128	SD16, MPY
FE42x	64	32KB / 1KB	BT,A3	USART	128	MPY, ESP430, E-meter
FW42x	64	32KB / 1KB	BT,A3,A5		96	Comp_A, Flow Meter
F43x	80	32KB / 1KB	BT,A3,B3	USART	128	Comp_A, ADC12
F44x	100	60KB / 2KB	BT,A3,B7	USART	160	Comp_A, ADC12, MPY
FG43x	80	60KB / 2KB	BT,A3,B3	USART	128	Comp_A, ADC12, (3)OA, (2)DAC12, DMA
FG42x0	48	32KB / 512B	BT, A3		56	SD16, (2)OA, DAC12
F43x1	80	32KB / 1KB	BT,A3,B3	USART	128	COMP_A
xG461x	100	120KB / 8KB	BT,A3,B7	USCI, USART	160A	ADC12, (3)OA, (2)DAC12, (3)DMA, MPY
F47xx	100	60KB / 2.5KB	BT,A3,B3	(2)USCI	160A	Comp_A, (4)SD16, MPY32, 16MHz
All devices include a watchdog timer (WDT/WDT+) and enhanced frequency locked loop (FLL+) clock system						

RTM

- Ideal for portable instrumentation and metering

MSP430F47xx

- High Performance SoC
- 60KB Flash / 2.5KB RAM
- 16MHz CPU
- 32x32 MPY
- (4) SD16
- (2) USCI_A & B
- 2.2v Flash ISP
- Integrated pull up/down resistors
- 160 Segments Integrated LCD Driver

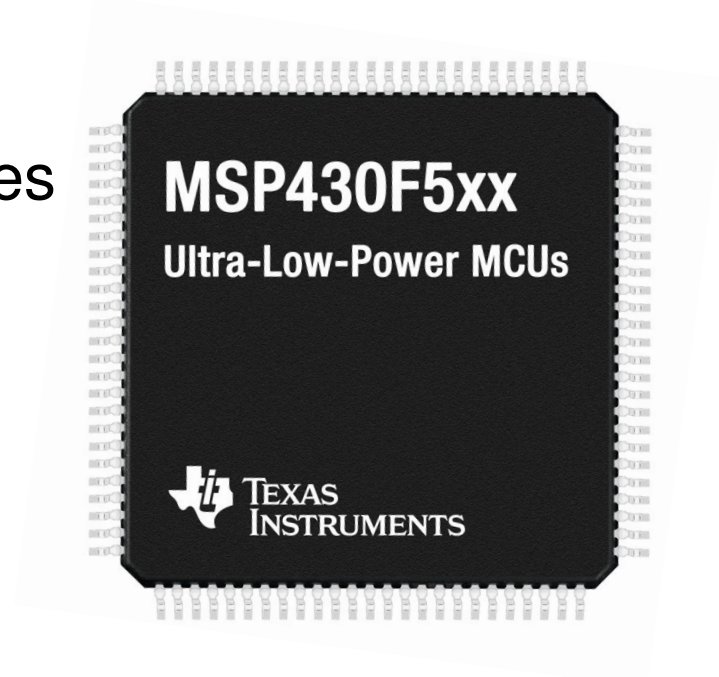


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MSP430F5xx: The Next Generation

- Next generation MSP430 family
- Advanced ultra-low-power features
- Increased performance, functionality and ease-of-use
- Easy migration from other MSP430 families



5xx: Advanced Ultra-Low-Power Performance

- Lowest active current/MHz:
 - $<200\mu\text{A}/\text{MHz}$
- Less than $2\mu\text{A}$ LPM3 mode for large memory device
 - LDO, BOR, WDT+, RTC, Full-State Retention
- Significantly longer battery life
 - 12MHz @ 1.8V
 - 1.8V Flash erase and write



5xx: Increased Performance, Functionality and Ease-of-Use

- Increased performance
 - Up to 25MHz
 - 12MHz @ 1.8V
- Increased functionality
 - More design options (USB, encryption, RF, improved analog peripherals)
 - Large memory devices
 - ISP Flash to 1.8V
 - Read during erase operation
- Increased ease of use
 - Fail-safe & flexible clocking system (UCS)
 - Fail-safe Flash timing
 - User defined Boot Strap Loader (BSL)
 - Integrated voltage reference



5xx: Advanced ULP Features

- Power Management Module (PMM)
 - Advanced capabilities to the user
 - Integrated low power voltage regulator
 - Programmable dual supply voltage management and supervision (SVM/SVS)
 - Dual power domains
 - Adjustable core voltage for power optimization



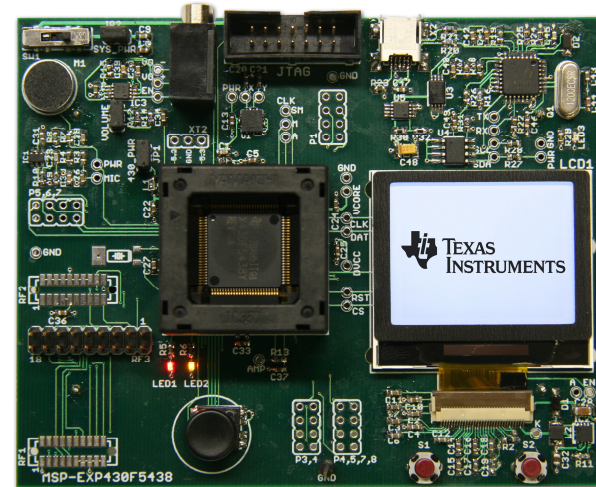
5xx: Ease of Migration

- Same instruction set
- CPUX
- Compatible peripherals with enhancements
 - ADC12 with lower power & improved voltage reference accuracy
 - Enhanced 32x32 Multiplier
- Same tools suite
- Major product announcement
June 9th, 2008



Advanced Technical Conference

- Don't miss out on the premier training event for the MSP430 MCU community!
- **Experience** the newest **5xx** MSP430 Ultra-Low-Power MCUs through hands-on labs
 - **5xx Full Multi-Day Track**
 - **5xx Multi-Day Lab**
- **Collaborate** with MSP430 MCU technology experts and third parties
- **Master** MSP430 MCUs through new and challenging labs and technical lectures
- **Register Today!**
www.ti.com/atc



- **Locations and Dates**

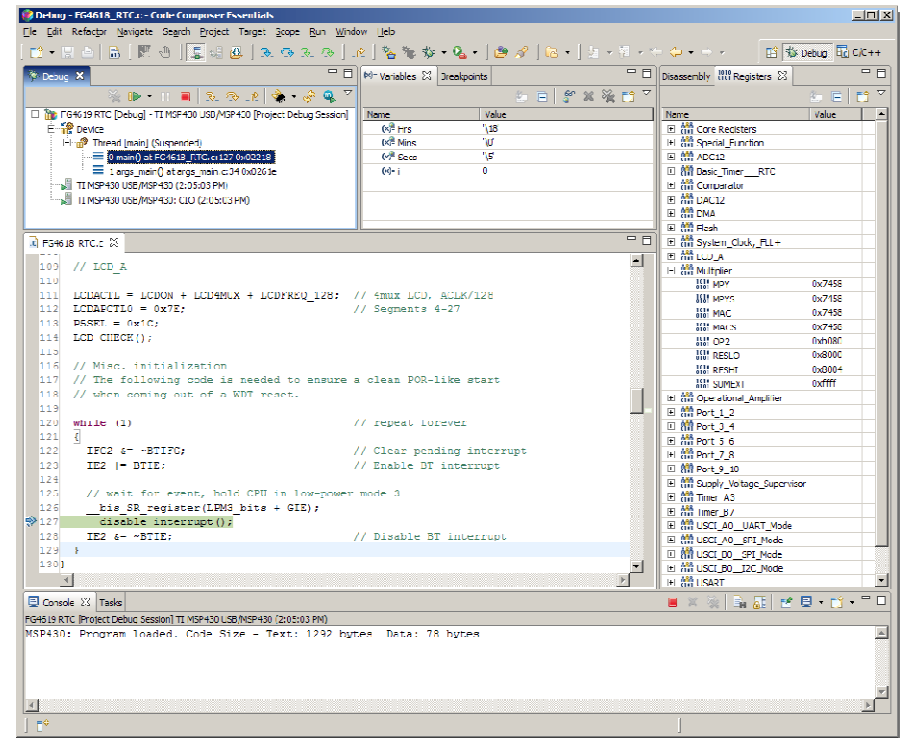
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|----------------------|-----------|
| - Sonthofen, Germany | Jun 9-12 |
| - Dallas, Texas | Jun 23-26 |
| - Taipei, Taiwan | Jul 28-29 |
| - Bangalore, India | Aug 20-22 |
| - Pune, India | Aug 25-27 |
| - Tokyo, Japan | Aug 27-28 |
| - Shanghai, China | Sep 10-11 |

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Code Composer Essentials 3.0

- Real-time IDE supporting all Flash MSP430 devices
- 3.0 Coming April 30, 2008
- **Free** for applications <16KB
- Updated C-code intrinsics
 - Support most existing code examples & libraries
- Built on the Eclipse 3.2 **open-source** framework
- New high-speed TI debugger for faster development
- **\$499 USD**

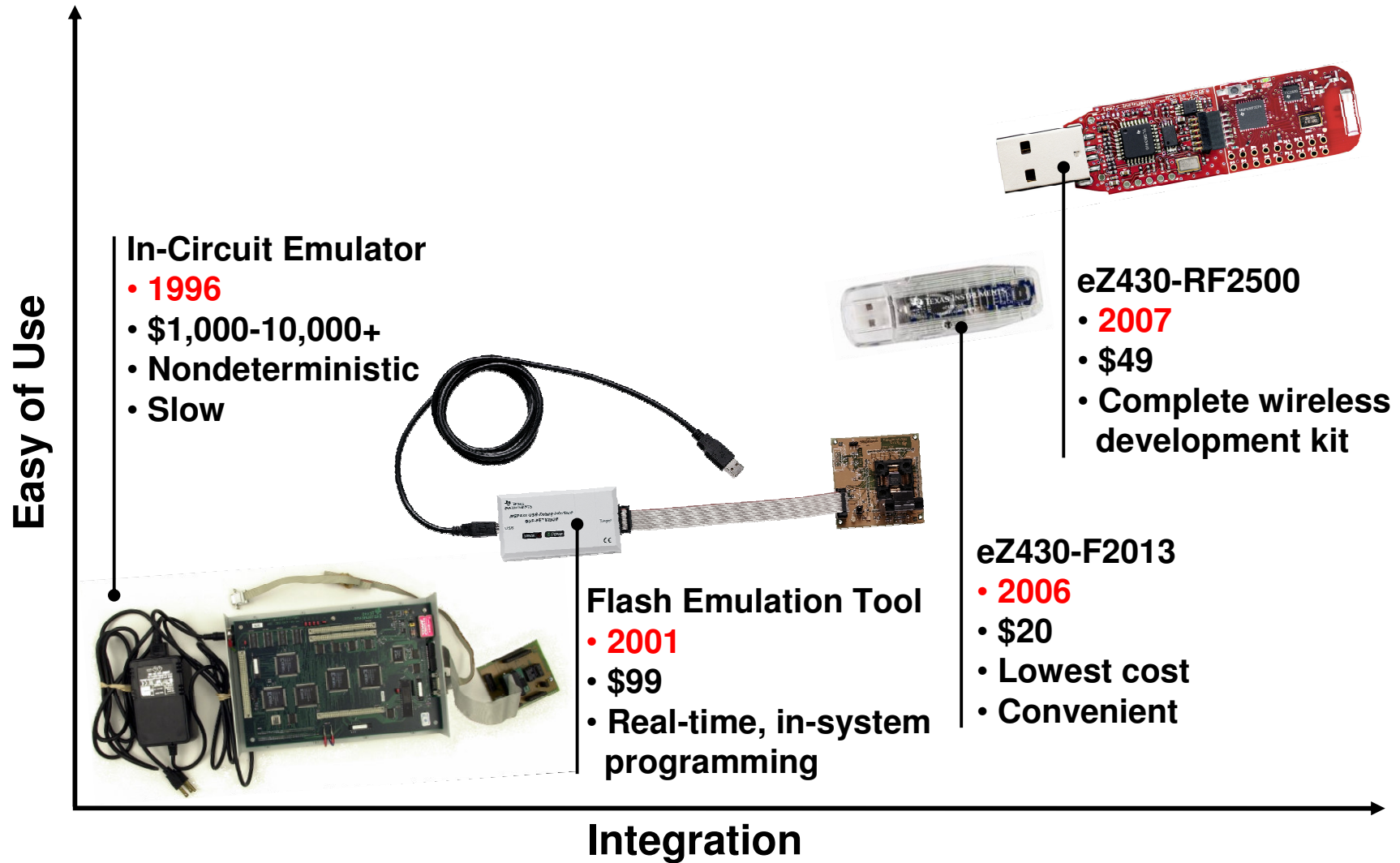


3rd Party Development Tools Overview

- IAR Embedded Workbench
 - www.iar.com
- Rowley CrossWorks
 - Complete solution, High code density, Simulator
 - www.rowley.co.uk
- ImageCraft
 - ANSI C Compiler, Easy to use IDE
 - www.imagecraft.com
- GCC Toolchain – Free
 - GNU C Compiler, Assembler / Linker, GDB Debugger
 - Windows, Linux, Unix
 - <http://mspgcc.sourceforge.net>
- Quadravox
 - <http://www.quadravox.com>

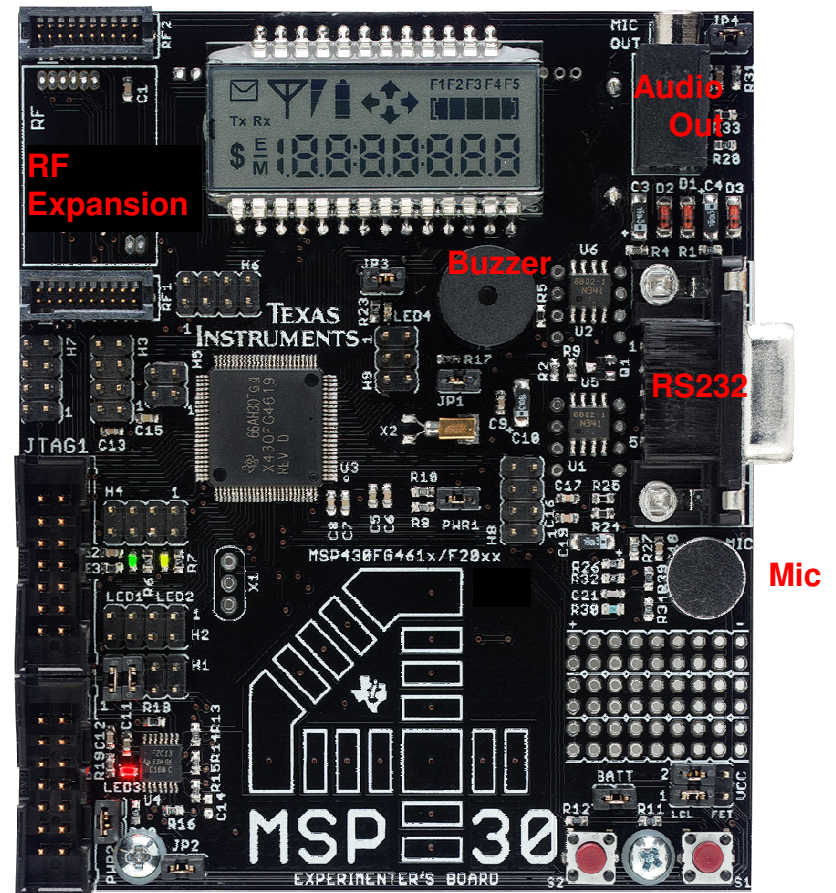


Emulator Evolution



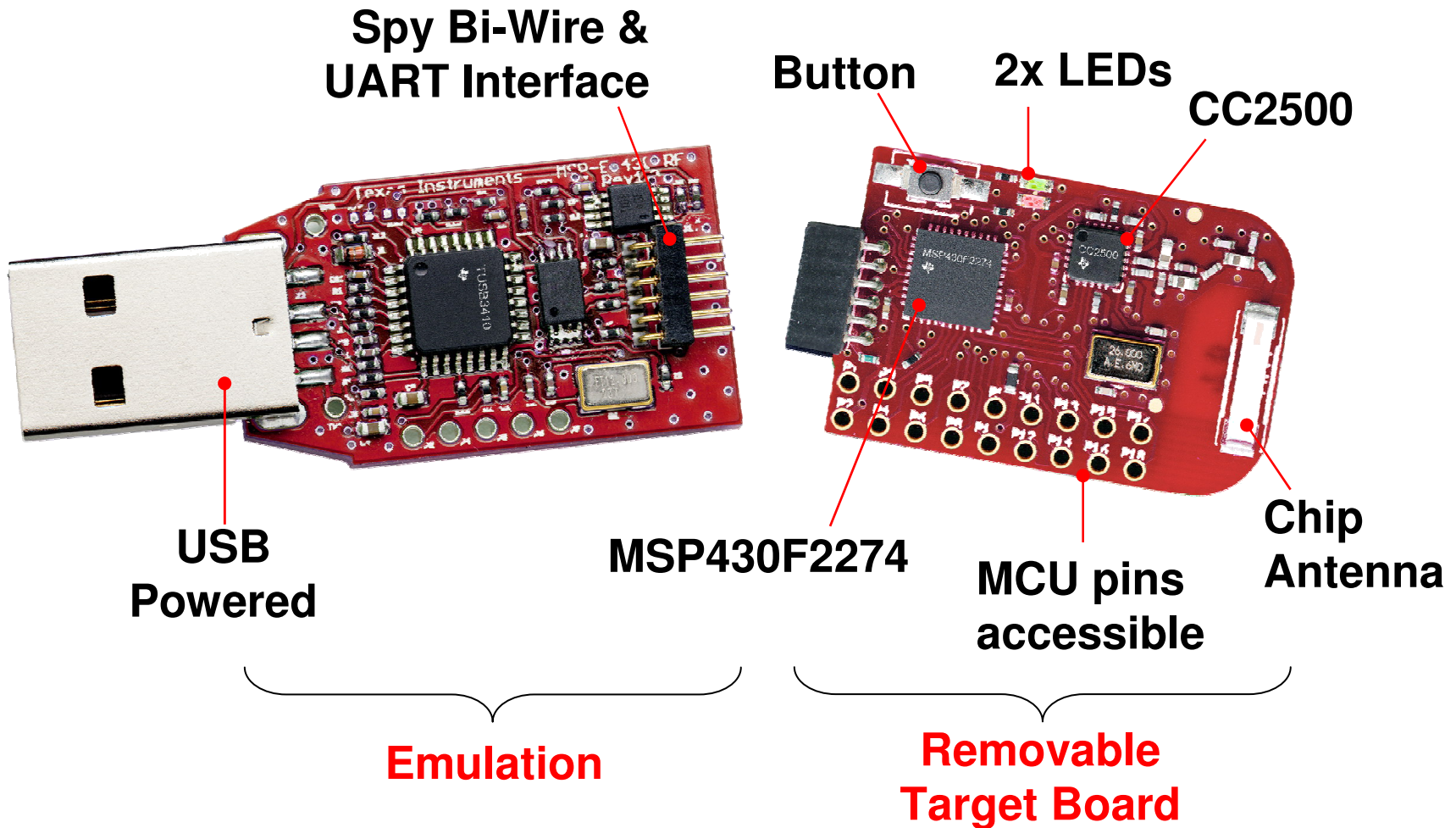
MSP430 Experimenter's Board

- Highly integrated
- MSP430FG4618 + F2013
- Supports Low Power RF Wireless modules
- Perfect for prototyping
- Complete software libraries and RF stacks available
- \$99



FG4618 / F2013 Experimenter Board
(MSP-EXP430FG4618)

eZ430-RF2500 Teardown

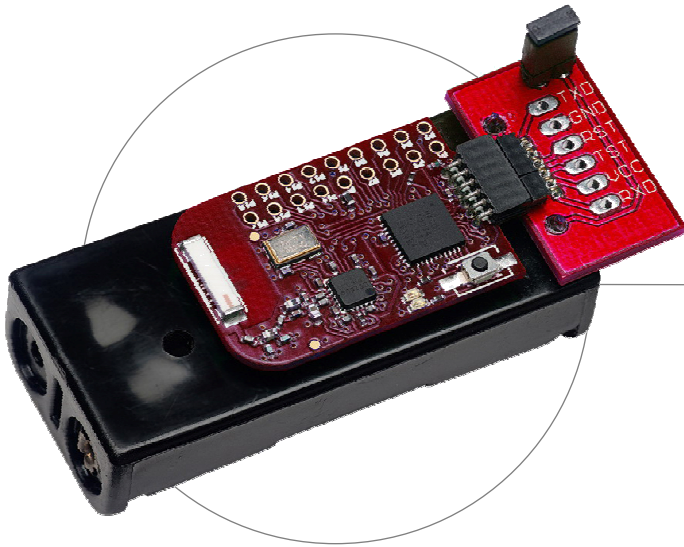


eZ430-RF Emulator



- Supports all MSP430 Spy Bi-Wire devices
 - Compatible with original eZ430-F2013 and -T2012 target boards
- MSP430 Application UART
 - Allows communications from PC Virtual COM port to MSP430 target
 - Available in or out of a debug session

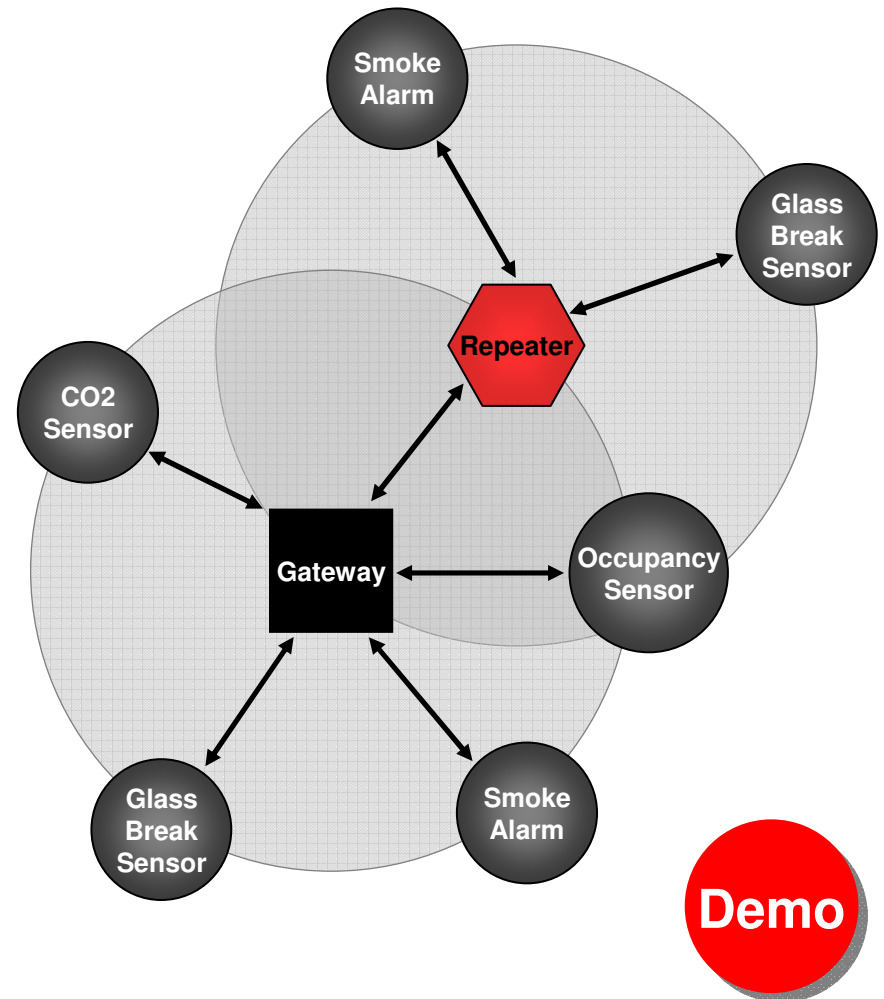
Detachable Target Board



- Separate emulator to debug remotely
- Includes 2xAAA batteries and expansion board for instant deployment
- Easy interface to external sensors and projects
- Separate target boards orderable by 3Q 2008

Wireless Out Of The Box

- **SimpliciTI:**
free, proprietary, low power
RF network stack
- **Low Cost:**
uses <8K FLASH, <1K RAM
- **Flexible:**
simple **star** or **p2p** topology
- **Simple:**
utilizes a **basic** API
- **Low-Power:**
Average current $\sim 1\mu A^*$



MSP430 Day 2008

- MSP430 Overview
- Peripherals
- MSP430x2xx/4xx
- MSP430x5xx
- Tools and Software
- Wireless
- Resources

MSP430 + LPW for Applications

- A perfect fit for low power wireless solutions
 - Designed for low power
 - Simple connection through SPI
- Compatible with **ALL** MSP430 devices
- Standard based protocols (ZigBee / 802.15.4) and proprietary stacks available



Suggested Devices	Cost Efficient	General Purpose	High End
MSP430	F22xx F41x	F241x F23x/F24x	FG461x F261x
Low Power Wireless	<1GHz	CC1xxx (CC, 1100, 1150*, CC1101)	
	2.4GHz	CC2xxx (CC2420, CC2500, 2520, 2550*)	

*transmitter only

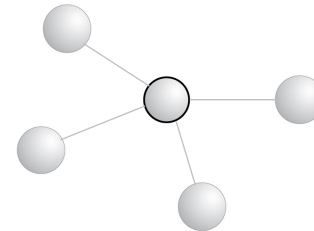
MSP430 Goes Wireless

- Free RF libraries and stacks
- MSP430 + Low-Power RF Hardware Abstraction Layer (HAL) Library
- TIMAC – IEEE 802.15.4 Medium Access Control (MAC)
- Z-Stack – Free ZigBee Stack
 - Out of the box support for EXP430FG4618 + CC2420EMK
 - Compliant with 2006 ZigBee™ spec
 - www.ti.com/zigbee
- SmartRF® Studio
 - Automatically generates register values

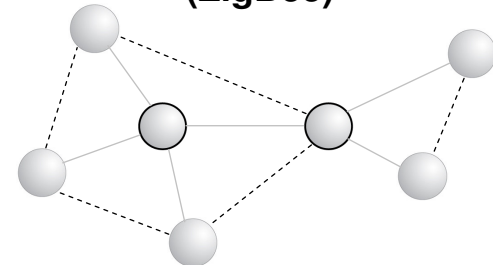
Point-to-Point
(MSP430 + RF HAL)



Star Network
(IEEE 802.15.4)

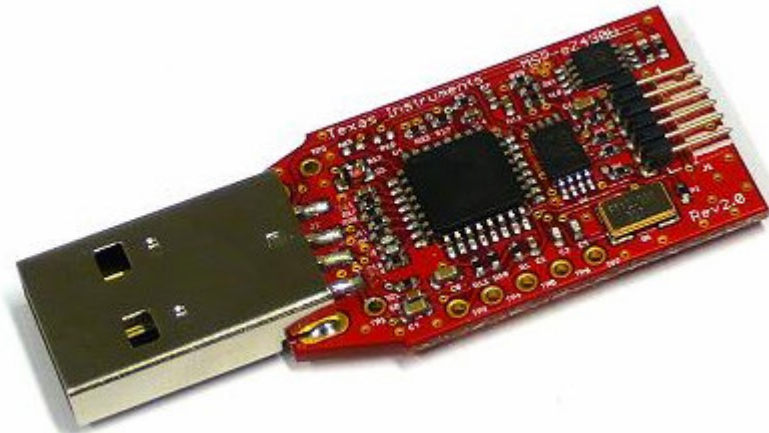


Mesh Network
(ZigBee)



eZ430-RF2480

- ZigBee Certified Network Processor solution
- **MSP4302274** + CCZACC
 - Communicates over SPI or UART
- **Easy to Use:** SimpleAPI
 - 10 API Calls
 - Device configuration
 - Binding of devices
 - Sending and receiving data
- Orderable for all 430 Day Attendees



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www.ti.com/msp430

- User's Guides
- Datasheets
- Code Libraries
- 100+ Application Reports
- 1000+ Code Examples
- Product Brochure
- Latest Tool Software
- 3rd Party Listing
- Silicon Errata



App Specific Resources

- Wireless, Metering, Medical, Industrial
 - Application notes
 - **Block diagrams**
 - Links to **Free** software downloads
 - Links to recommended EVMs
 - Recommended devices
 - **Reference designs**
 - Code libraries
 - **www.ti.com/msp430**



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