

430 Day 2007

MSP430 Ultra-Low-Power MCUs



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EETIMES

Embedded
Systems Design

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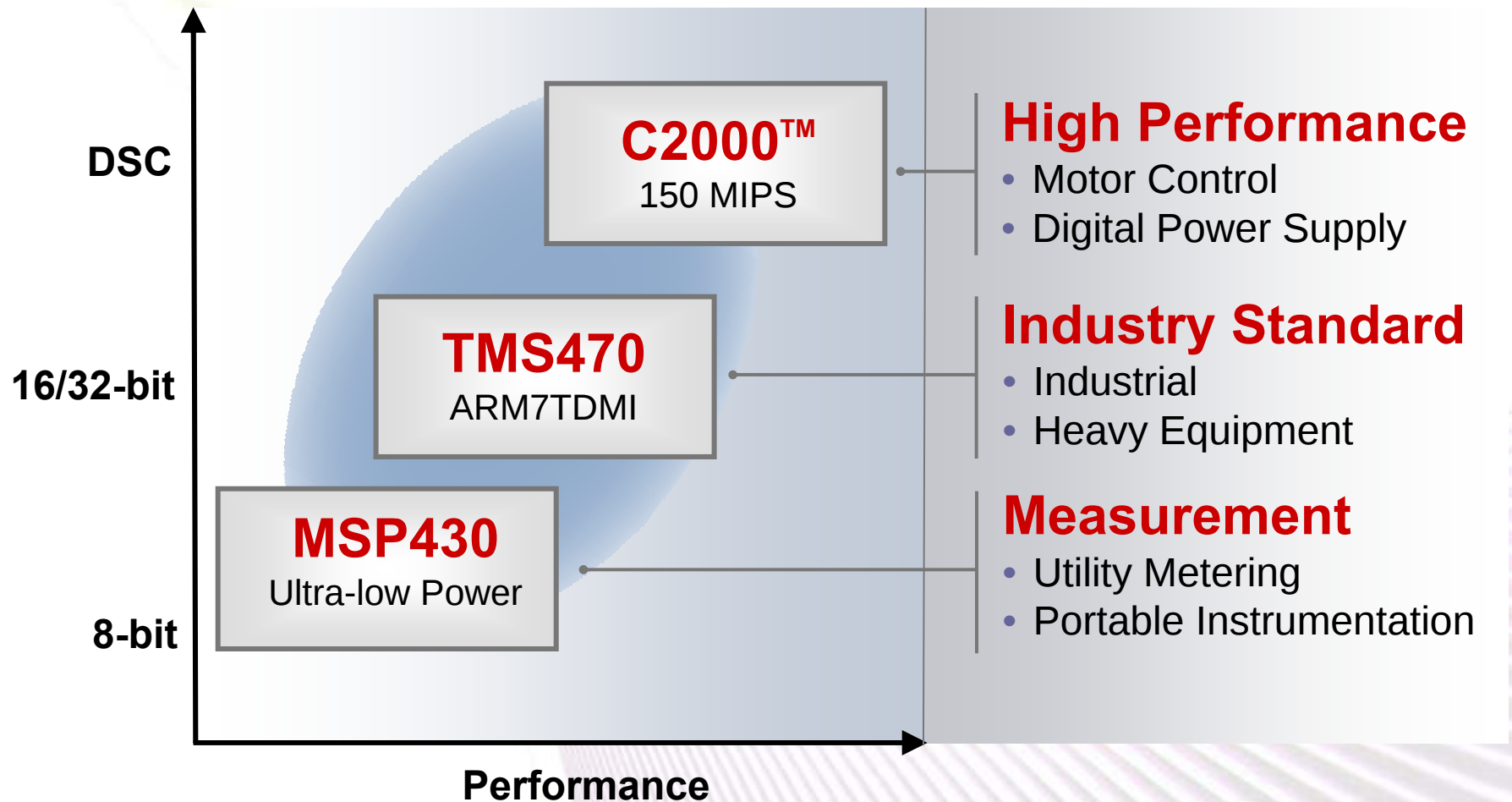
TEXAS INSTRUMENTS

Agenda MSP430 Day 2007

- MSP430 Overview
- MSP430x1xx / 4xx
- MSP430F2xx
- eZ430 + Capacitive Touch
- Wireless
- Resources

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TI Microcontroller Portfolio

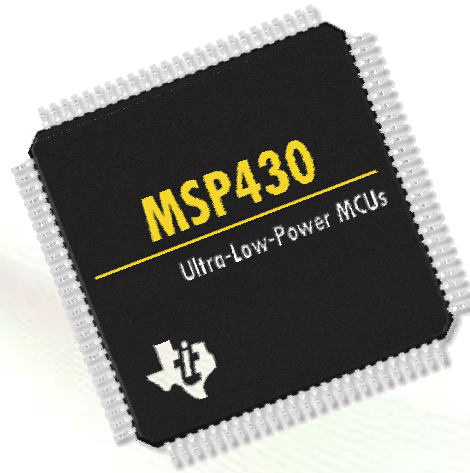


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 **TEXAS INSTRUMENTS**

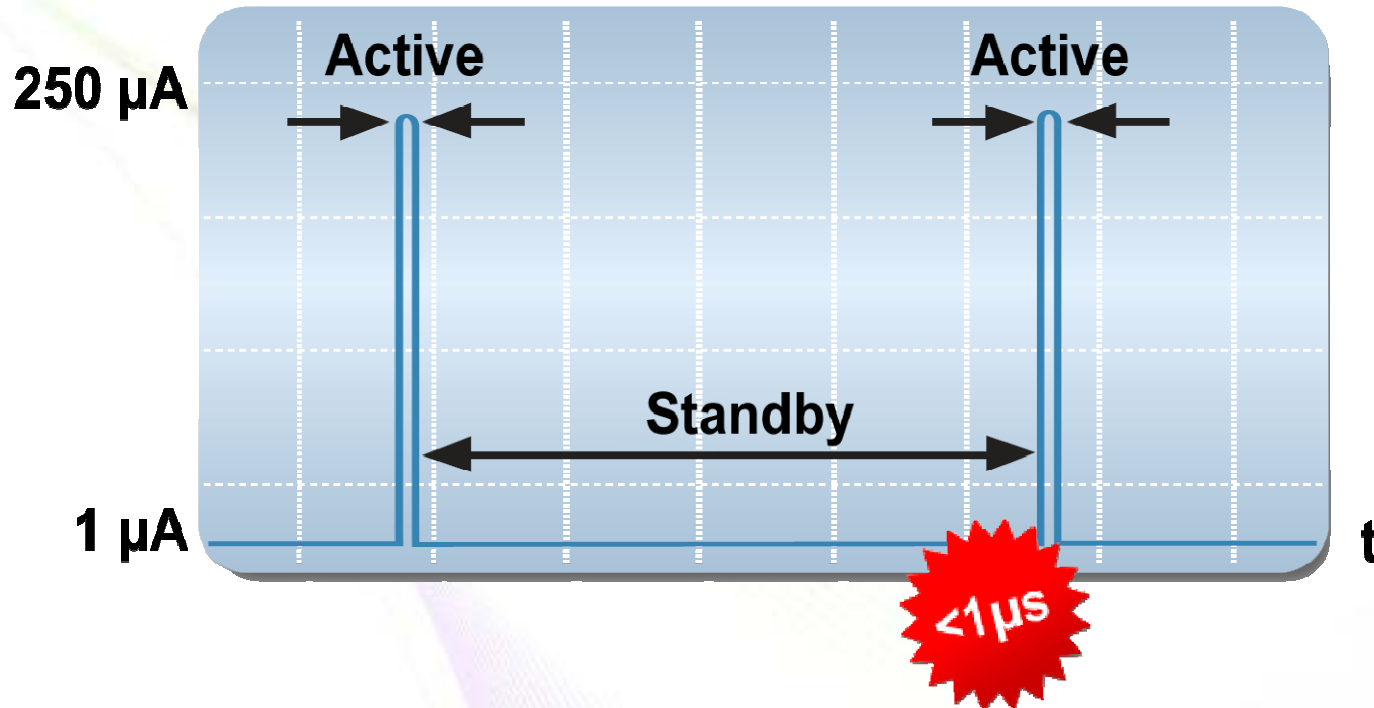
Ultra-low Power + High-Performance



- 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

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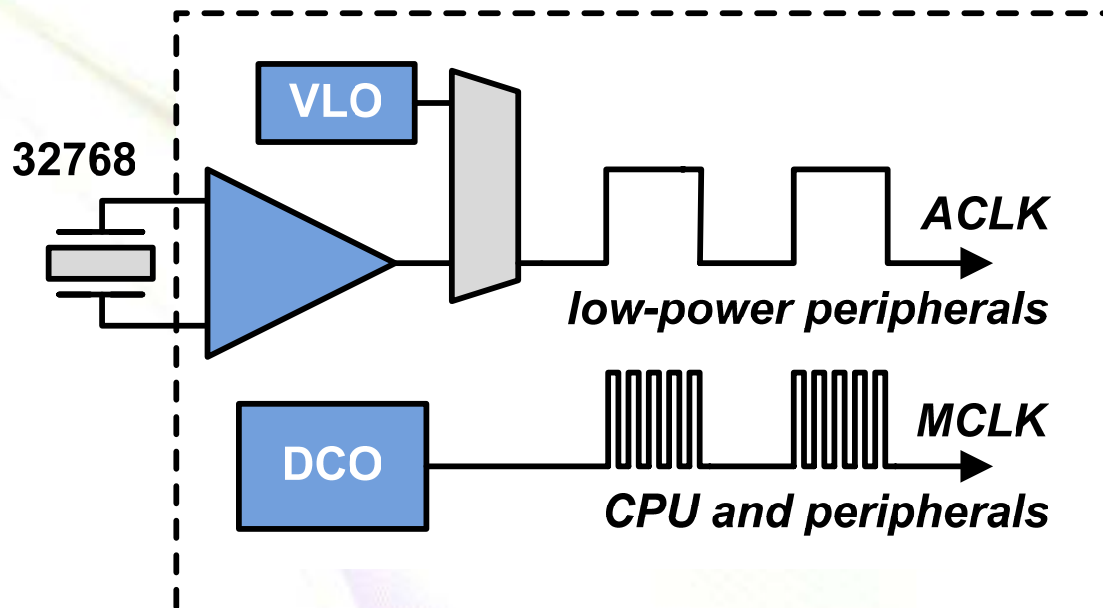
Ultra-low Power Activity Profile



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

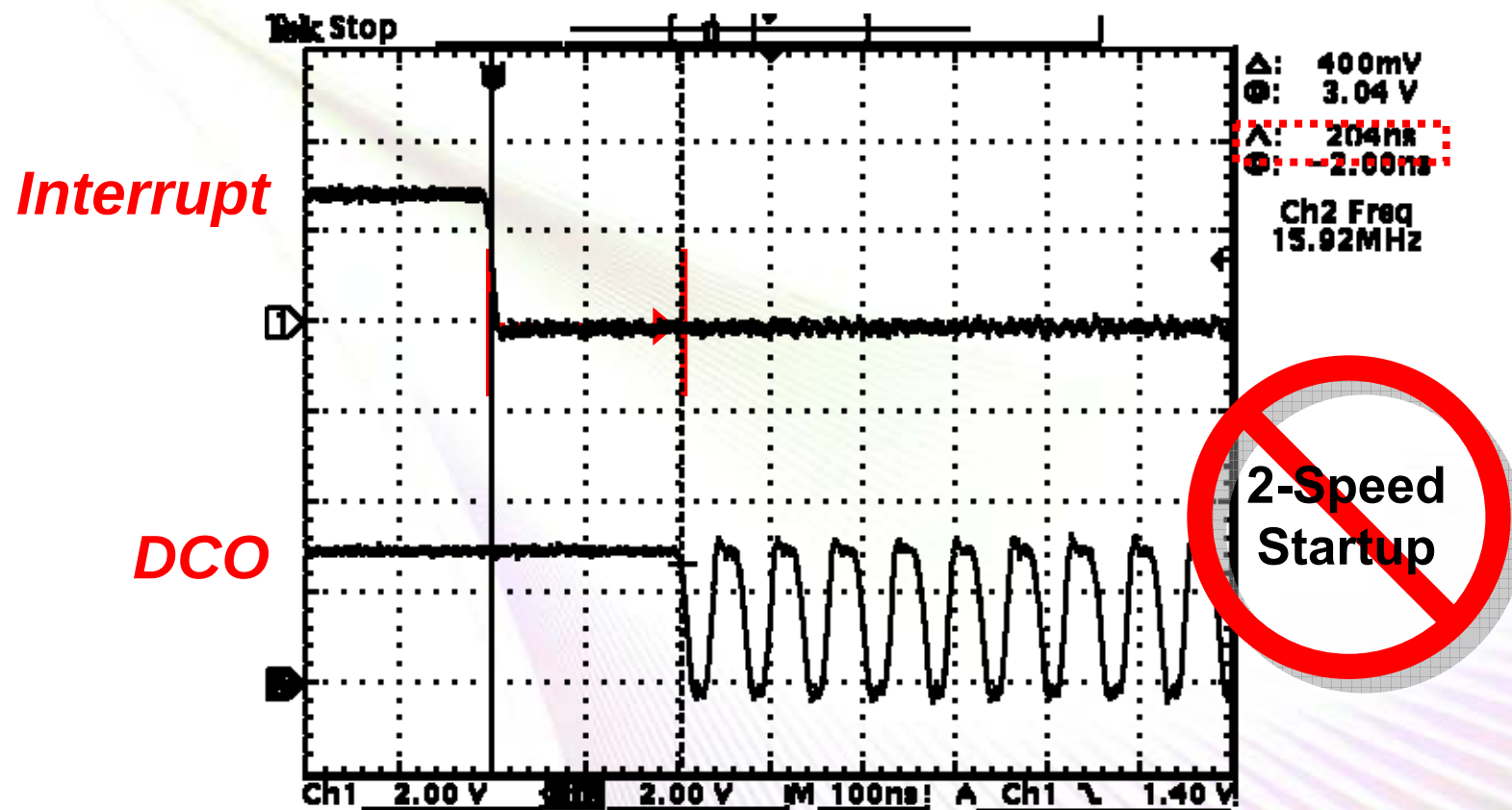
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Ultra-low Power Clock System



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

Performance On-Demand



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 **TEXAS INSTRUMENTS**

Why ***Ultra-low Power*** Is Important

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



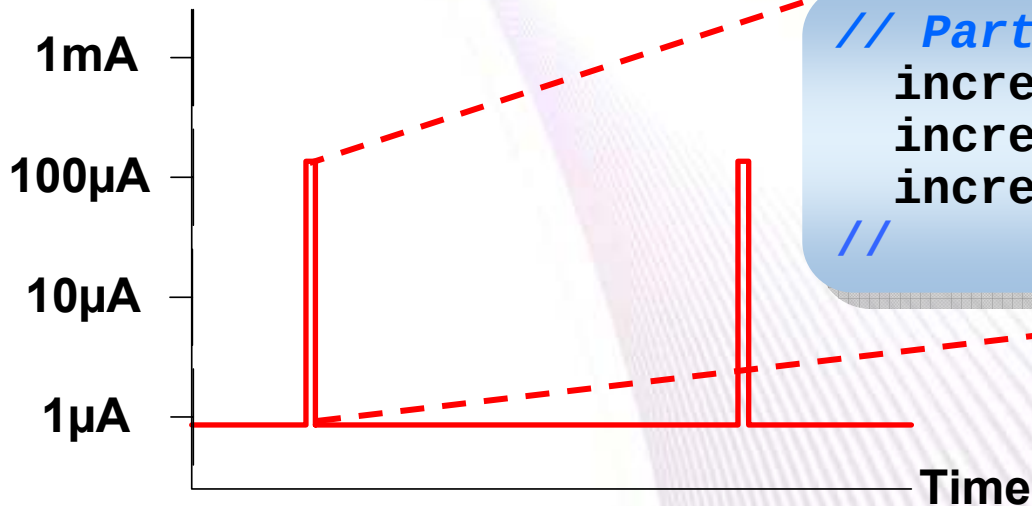
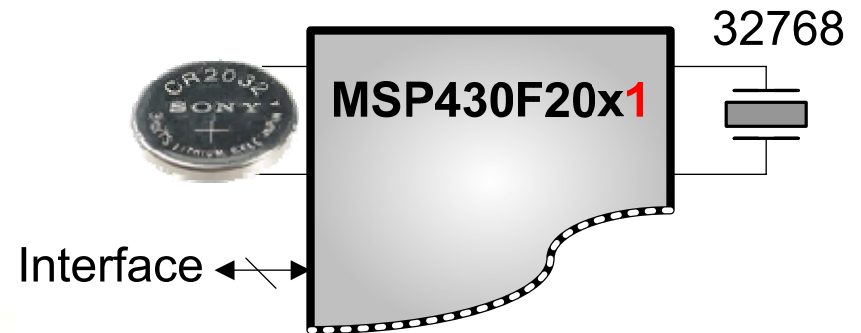
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10-year Embedded Real-Time Clock

= LPM3 + **RTC_Function**

$$0.80\mu\text{A} + 250\mu\text{A} * \frac{100\mu\text{s}}{1000000\mu\text{s}}$$

$$0.80\mu\text{A} + 0.030\mu\text{A} = 0.83\mu\text{A}$$

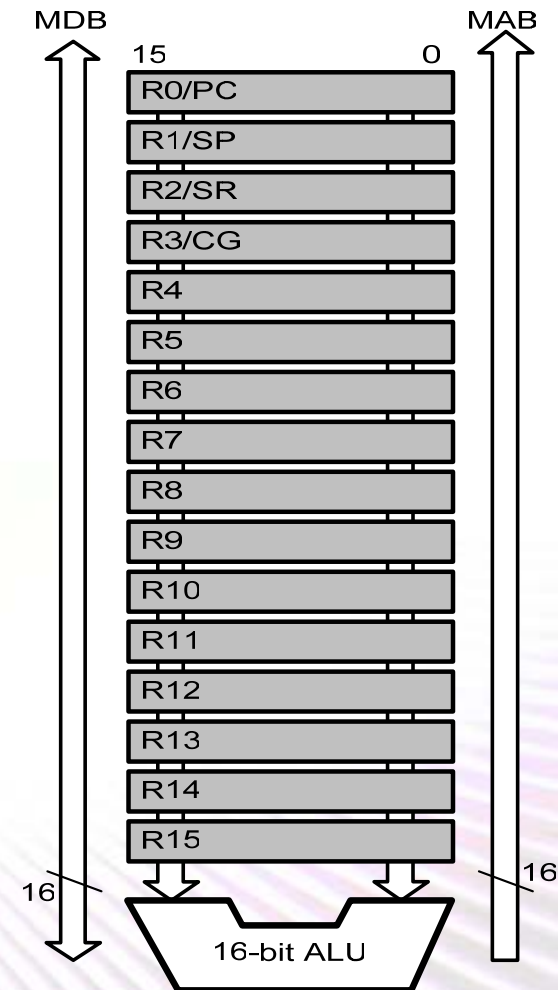


```
// Partial RTC_Function
increment_seconds();
increment_minutes();
increment_hours();
//
```

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Modern 16-bit Orthogonal RISC CPU

- **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**
- **C-compiler friendly**

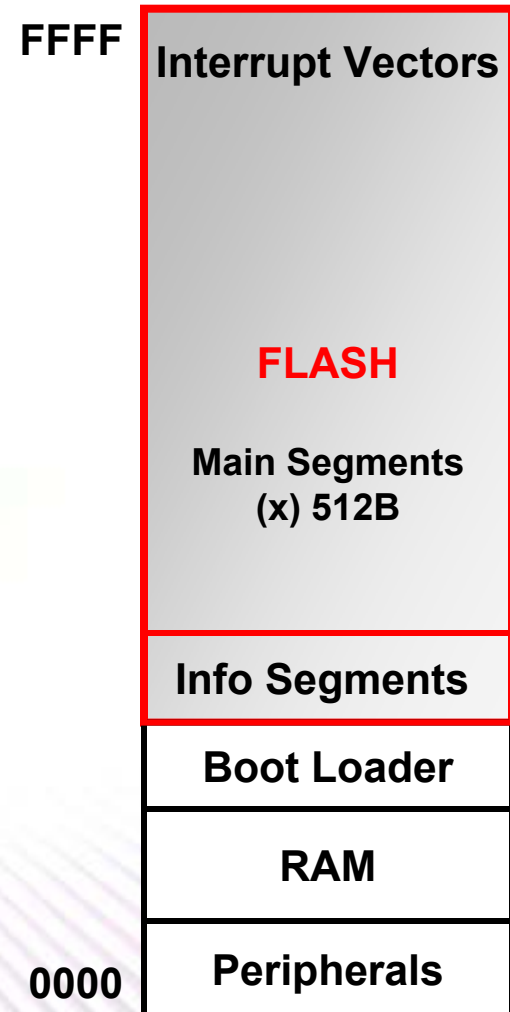


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No Paging Unified Memory Map

- Absolutely no paging
- Supports code agility
- **Flash in-system programming**
 - Self programming
 - JTAG
 - Bootloader
 - Data storage

```
// Flash In System Programming
FCTL3 = FWKEY;           // Unlock
FCTL1 = FWKEY | WRT;     // Enable
*(unsigned int *)0xFC00 = 0x1234;
```



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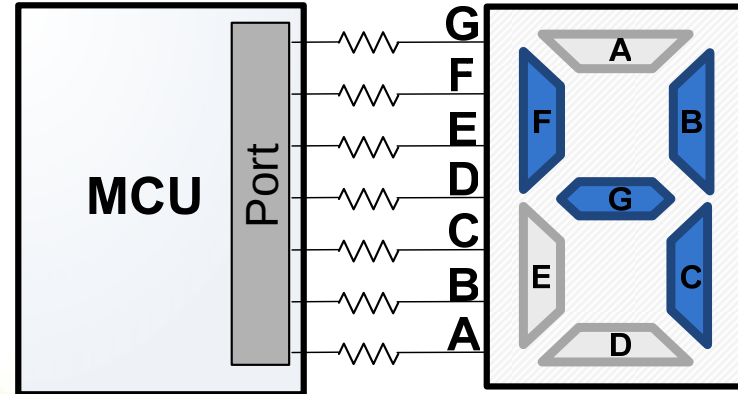
Write Less Code

; Other MCU

```

movlw    HIGH Tab
movwf    PCLATH
movwf    DispVal, W
call     Tab
movwf    PORTB
goto     Continue
Tab addwf    PCL, F
retlw    B'00111111'
retlw    B'00000110'
retlw    B'01011011'
retlw    B'01001111'
retlw    B'01100110'
retlw    B'01101101'
retlw    B'01111101'
retlw    B'00000111'
retlw    B'01111111'
retlw    B'01101111'
Continue
    
```

238 Bits / 48 Cycles



; MSP430

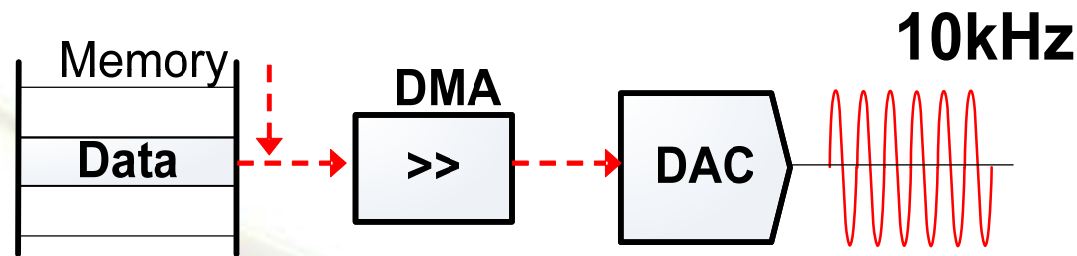
```

mov.b    Tab(DispVal), &P1OUT
Tab DW    0063Fh
      DW    04F5Bh
      DW    06E66h
      DW    0077Ch
      DW    0677Fh
    
```

128 Bits / 6 Cycles

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Intelligent Peripheral Performance



```
// Interrupt
#pragma vector = TA_VECTOR
__interrupt void Timer_A(void){
    P3OUT |= 0x1;
    P3OUT &= ~0x1;
    TXBUF0 = tab[pointer] >> 8;
    TXBUF0 = tab[pointer++];
    pointer &= 0x1F; }
```

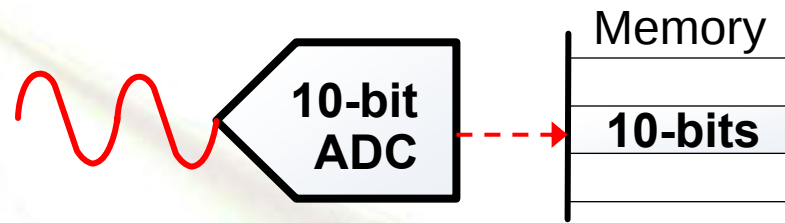
16MIPS

```
// DMA
_BIS_SR(CPUOFF);
```

Fully Automatic

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Do You Use A 10-bit ADC?



; Other MCU

```
movf    ADCRESH, W
movwf   RAMH
bsf     STATUS, 0x20
movf    ADCRESL, W
bcf     STATUS, 0x20
movwf   RAML
```

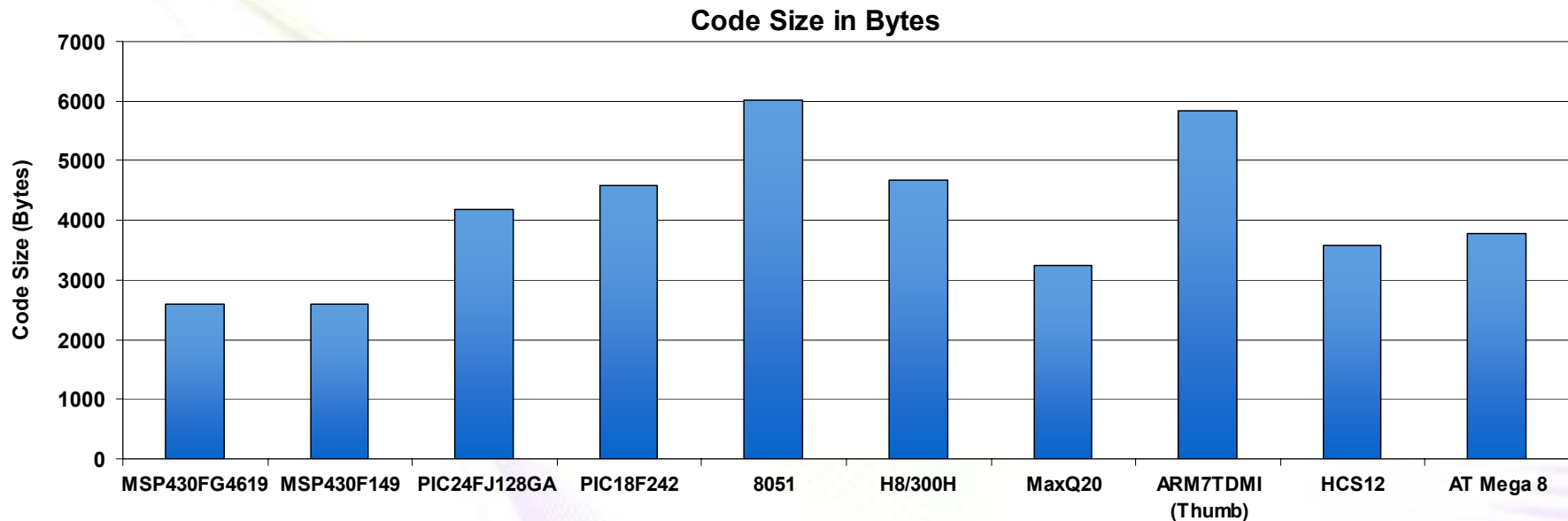
84 Bits / 24 Cycles

; MSP430

```
mov .w   &ADCRES, &RAM
```

48 Bits / 6 Cycles

Compiler Friendly

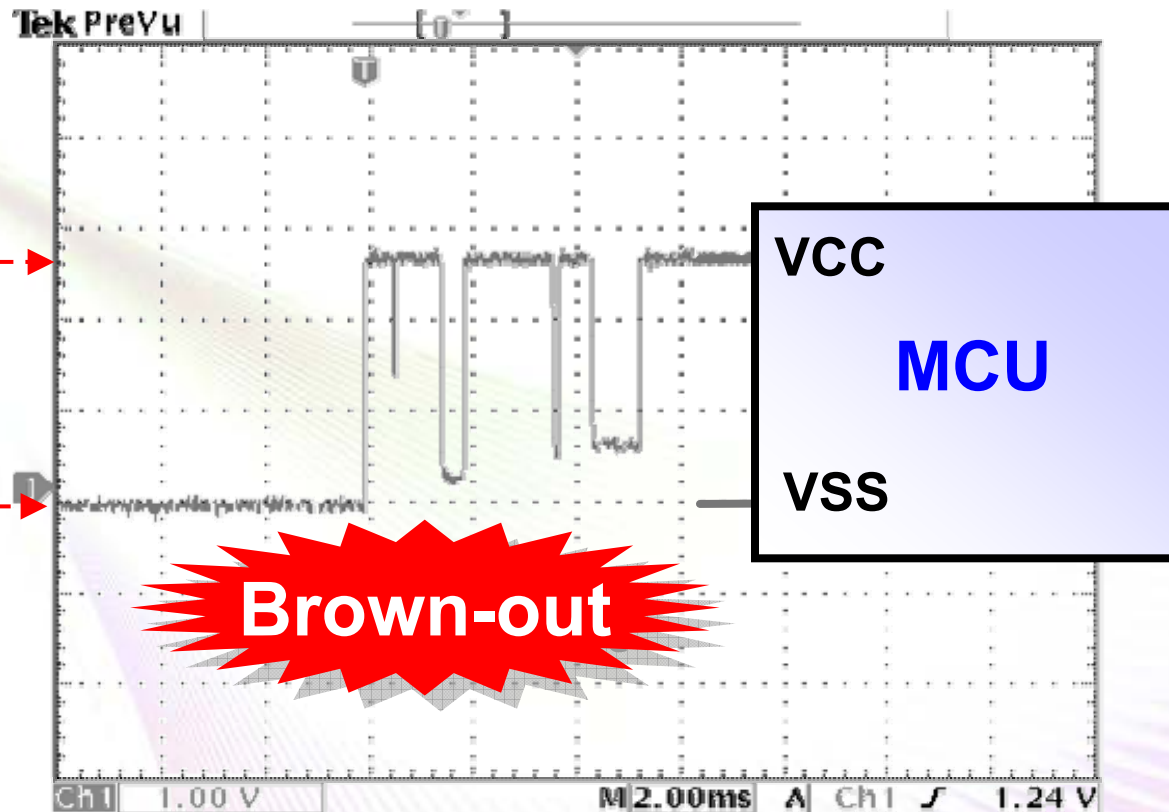


- Instruction set and register orthogonality
- Direct stack addressing for passing parameters
- **Application report SLAA205**

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Always-on Zero-Power BOR

*Battery
Insertion*



MSP430 BOR is always-on and *zero-power*

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Embedded Emulation

- **Real-time in-system debug**

- No application resources used
- Full speed execution
- H/W breakpoints
- Single stepping
- Complex triggering
- Trace capability

- **Easy to use tools**

- **Spy Bi-Wire**

- 2-wire debug interface
- No pin function impact



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Complete Flash Emulation Tool

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



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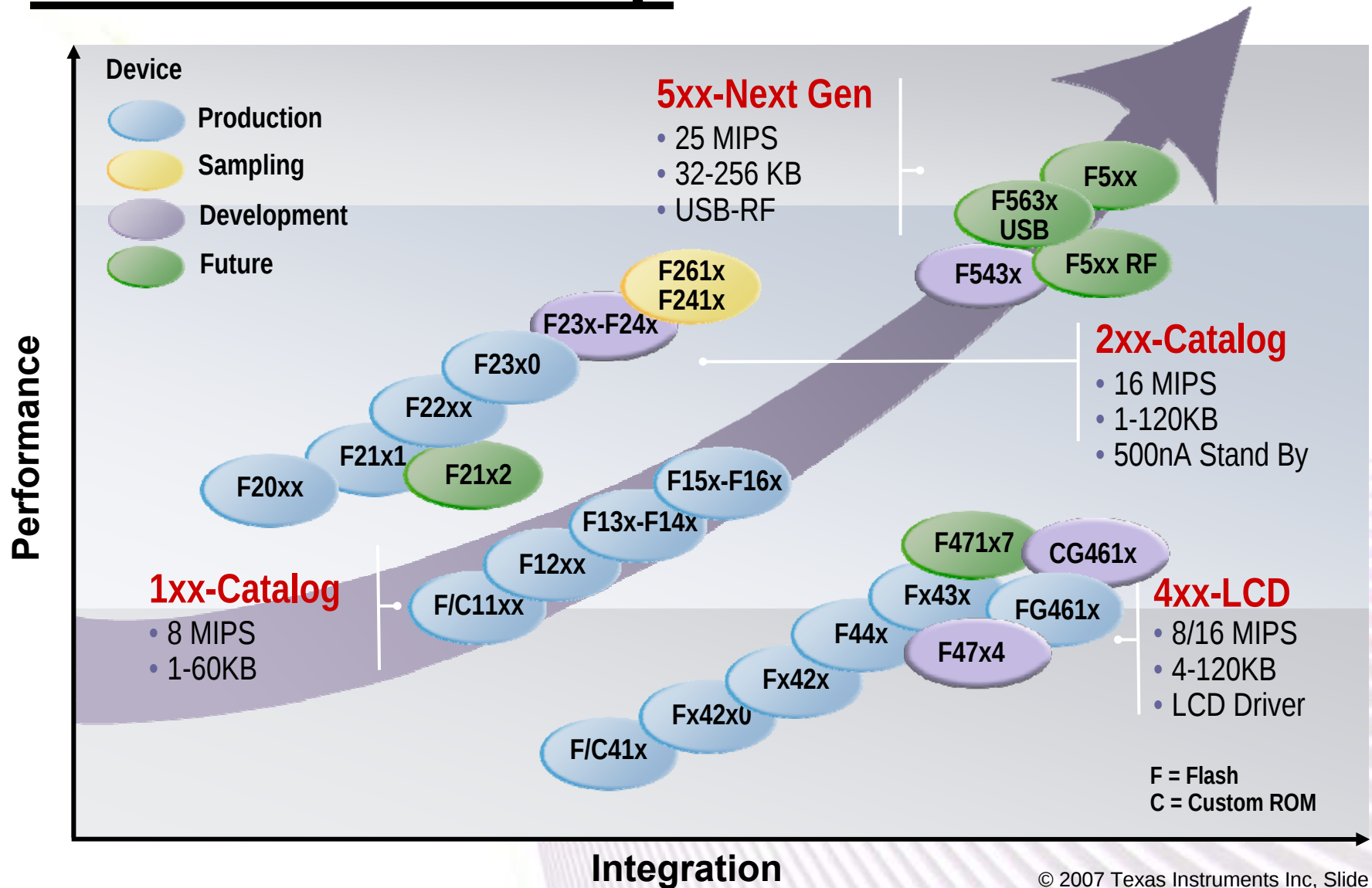
Ultra-Low Power MCU Checklist

- ✓ **Multiple operating modes**
 - 0.1 μ A power down
 - 0.8 μ A standby
 - 250 μ A / 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**

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MSP430 Roadmap



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 **TEXAS INSTRUMENTS**

MSP430F1xx Multi-Purpose Devices

Device	Pins	Flash/RAM	Timers	Communication	BOR	Features
F11x1	20	4k/256	A3			Comp_A
F11x2	20	8k/256	A3		✓	ADC10
F12x	28	8k/256	A3	USART		Comp_A
F12x2	28	8k/256	A3	USART	✓	ADC10
F13x	64	16k/512	A3,B3	USART		ADC12
F14x	64	60k/2k	A3,B7	(2)USART		ADC12, MPY
F15x	64	32k/1k	A3,B3	USART, I2C	✓	ADC12, (2)DAC12, (3)DMA
F16x	64	60k/10k	A3,B7	(2)USART, I2C	✓	ADC12, (2)DAC12, (3)DMA
All devices include watchdog timer (WDT) and basic clock system (BCS)						

- **World's most popular low-power MCU family**
- **Upgrade path to 2xx available**

F4xx Application Specific Devices

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
New FG42x0	48	32KB / 256B	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						
* In development ** ROM version coming soon						

Peripheral Cheat Sheet...

USART:
• UART & SPI

USCI_A:
• UART/LIN, IrDA & SPI

USCI_B:
• I2C & SPI

- Ideal for portable instrumentation and metering

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MSP430xG461x

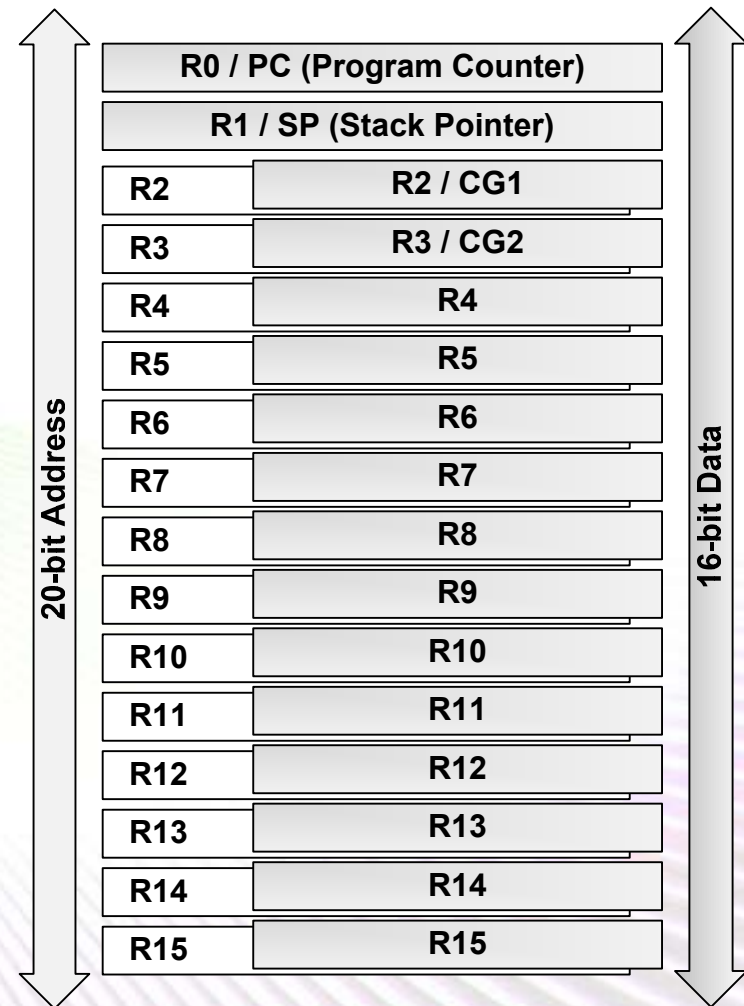
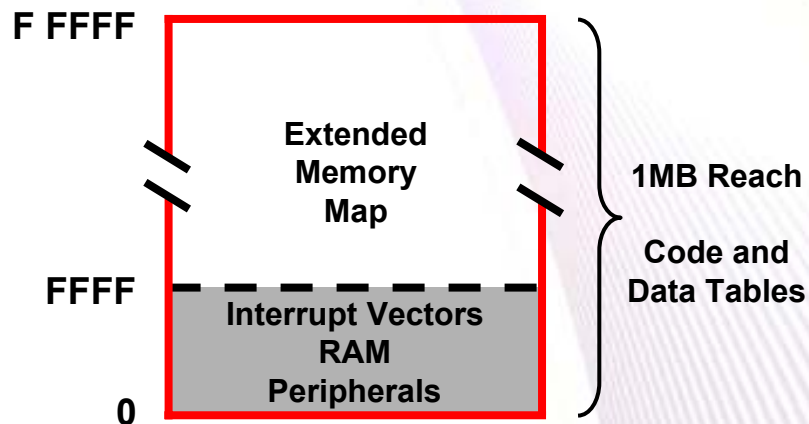
- Complete System on-Chip
- **120KB ROM/Flash**, 8KB RAM
- <3 μ A Real Time Clock
- LCD_A 160 segments with boost
- **USCI**: UART, SPI, I²C, IrDA
- On-board signal chain:
OPA→ADC→DMA→DAC→OPA
- New MSP430**X** CPU
- **BGA** package for space constrained applications



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MSP430X

- Architecture upgrade
- **100% code compatible**
- **1MB** unified memory map
- **Extended addressing modes**
 - Page-free 20-bit reach
 - Improved code density
 - Faster execution



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New MSP430FG42x0

- Midrange System On-Chip
- **32KB Flash**, 256B RAM
- Zero Power BOR
- <2 μ A RTC - 10-year battery life
- 56 Segment LCD_A with boost
- Timer A3, Basic Timer
- 2x Op Amps
- **DAC12**
- **SD16_A**
- 32 GPIO



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New F47x4 High Performance

- 60KB Flash / 2.5KB RAM
- 16MHz CPU
- 32x32 MPY
- (4) SD16
- (2) USCI_A & B
- 2.2v Flash ISP
- Integrated pull up/down resistors
- Timer_A3, B3, BT
- 160 segment LCD_A
- Metering made easy



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New **F2xx** Multi-Purpose Devices

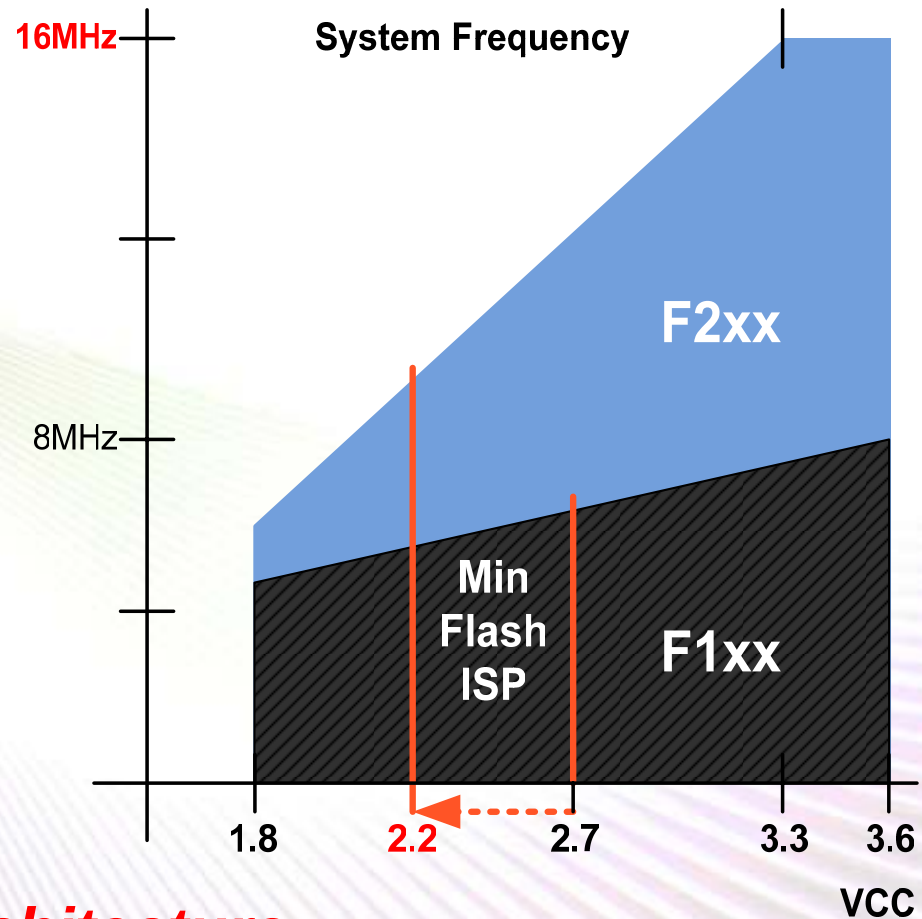
Device	Pins	Flash/RAM	Timers	Communication	Features	Peripheral Cheat Sheet...
F20x1	14	2KB / 128B	A2		Comp_A+	
F20x2	14	2KB / 128B	A2	USI	ADC10	USI: • I2C & SPI
F20x3	14	2KB / 128B	A2	USI	SD16	
F21x1	20	8KB / 256B	A3		Comp_A+	USCI_A: • UART/LIN, IrDA & SPI
New F22x2	38/40	32KB / 1KB	A3,B3	USCI	ADC10	
F22x4	38/40	32KB / 1KB	A3,B3	USCI	ADC10, (2)OPA	USCI_B: • I2C & SPI
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						

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

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F2xx Enhancements

- **<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***



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F2xx Enhanced Clock System

- **New VLO**

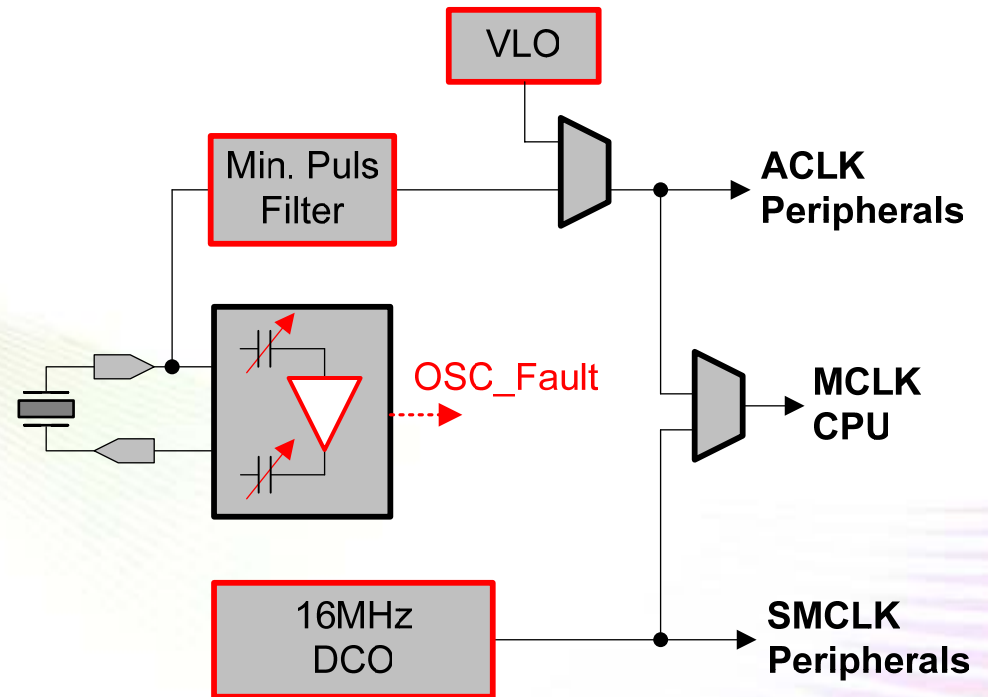
- Very Low-power Oscillator
- Embedded 12kHz
- 500nA standby

- **Crystal oscillator**

- Programmable capacitors
- Failsafe OSC_Fault
- Minimum pulse filter

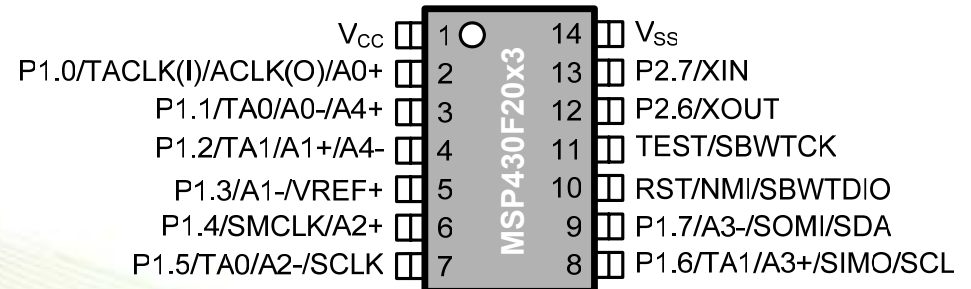
- **Improved DCO**

- <1μs 0-to-16MHz
- ± 3% tolerance
- Factory calibration in Flash



F20xx Tiny Yet Powerful

- **16 MIPS, <<1μA LPM3**
- **500nA Standby**
- **USI**
- **10 GPIO**
- **Timer_A2 / WDT+**
- **14-pin** (QFN, TSSOP, DIP)
for cost sensitive applications



Device	Flash	RAM	Analog	USI	1ku
F20x1	1/2KB	128B	Comparator		\$0.55
F20x2	1/2KB	128B	10-bit ADC	✓	\$0.99
F20x3	1/2KB	128B	16-bit ADC	✓	\$1.65

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USI Fast Synchronous Data Transfer

- **SPI Mode**

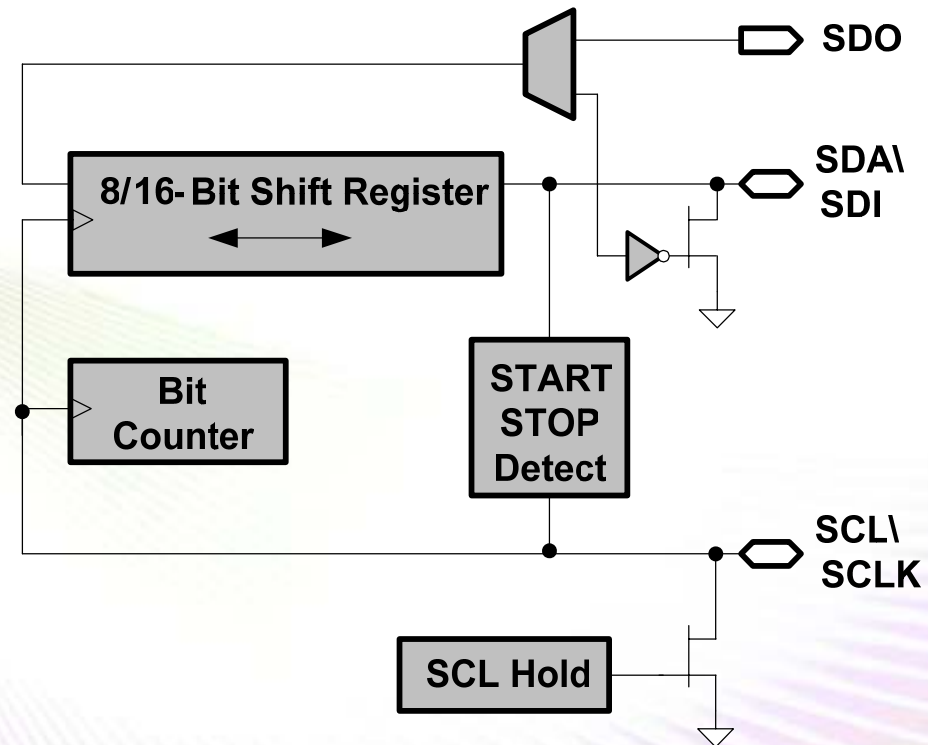
- 8/16-bit shift register
- MSB/LSB first

- **I2C Mode Support**

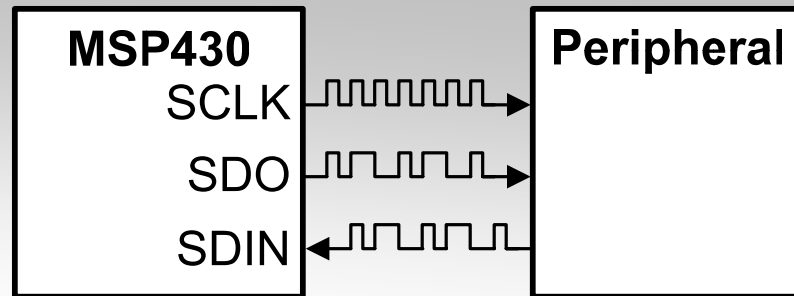
- START/STOP detection
- Arbitration lost detection

- **Interrupt Driven**

- **Reduces CPU load**



USI... No More Bit Banging!



```
//Shift16_inout_Software
SR = DATA;
for (CNT=0x10;CNT>0;CNT--)
{
    P2OUT &= ~SD0;
    if (SR & 0x8000)
        P2OUT |= SD0;
    SR = SR << 1;
    if (P2IN & SDIN)
        SR |= 0x01;
    P2OUT |= SCLK;
    P2OUT &= ~SCLK;
}
```

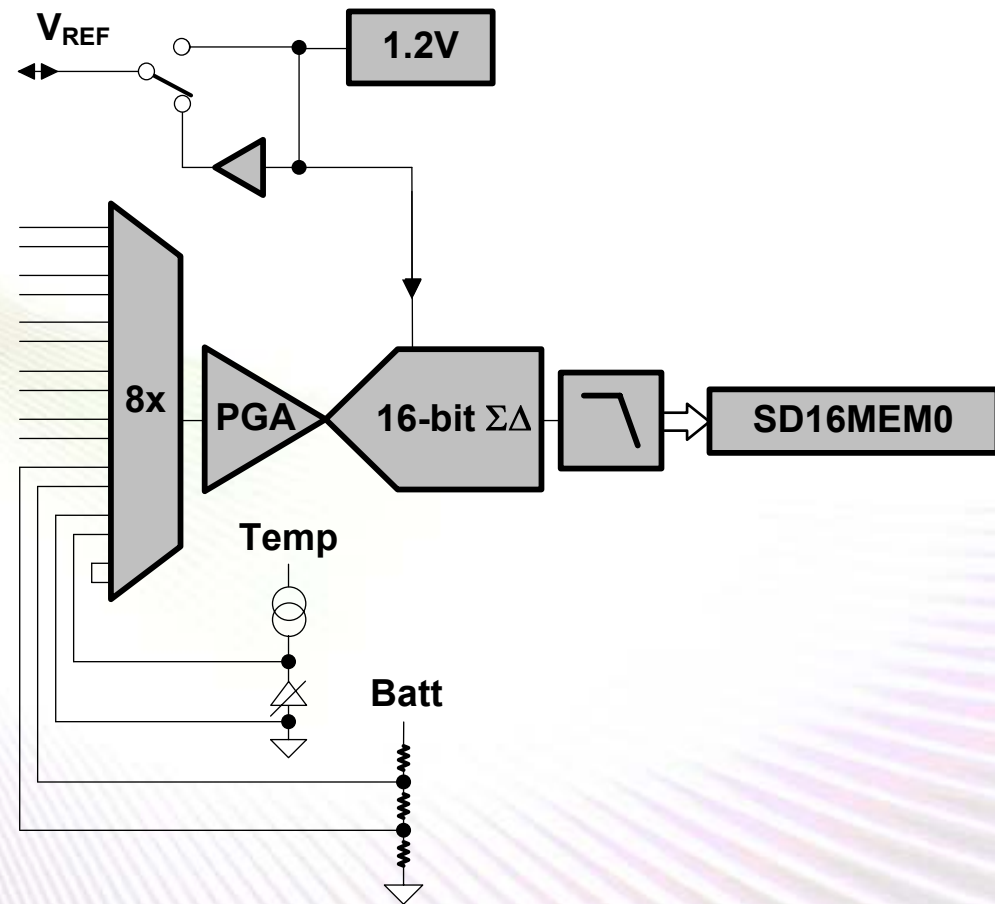
425 Cycles

```
// Shift16_inout_USI
USISR = DATA;
USICNT = 0x10;
```

10 Cycles

F20x3 High-Precision SD16 A

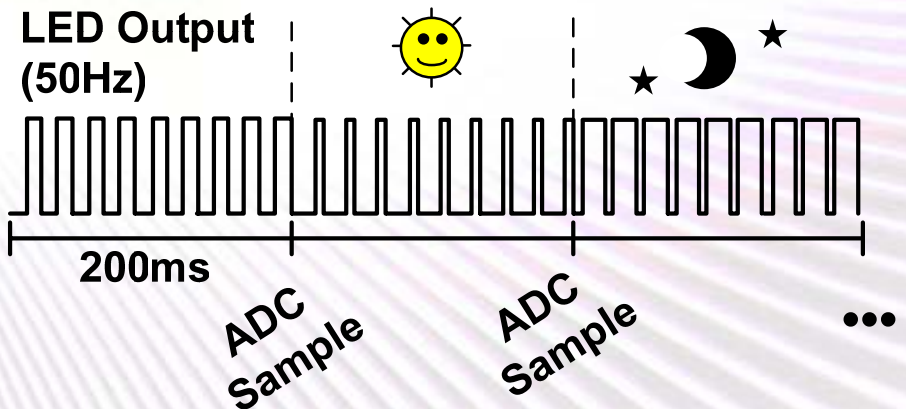
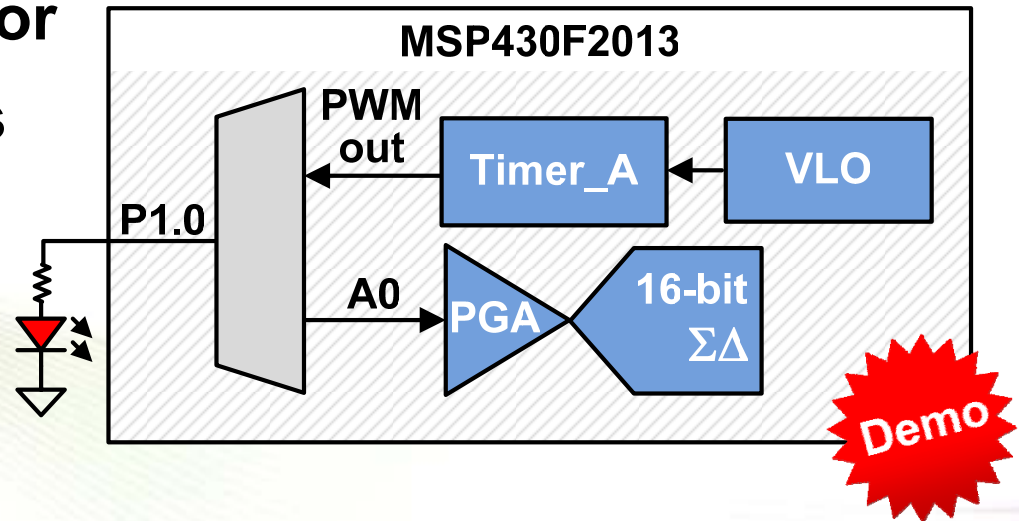
- **16-bit $\Sigma\Delta$ ADC**
- Differential inputs
- 4.096ksps
- 85dB SINAD
- **32x PGA**
- 18ppm 1.2V ref
- Temp sensor
- Battery input



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Intelligent LED Illumination

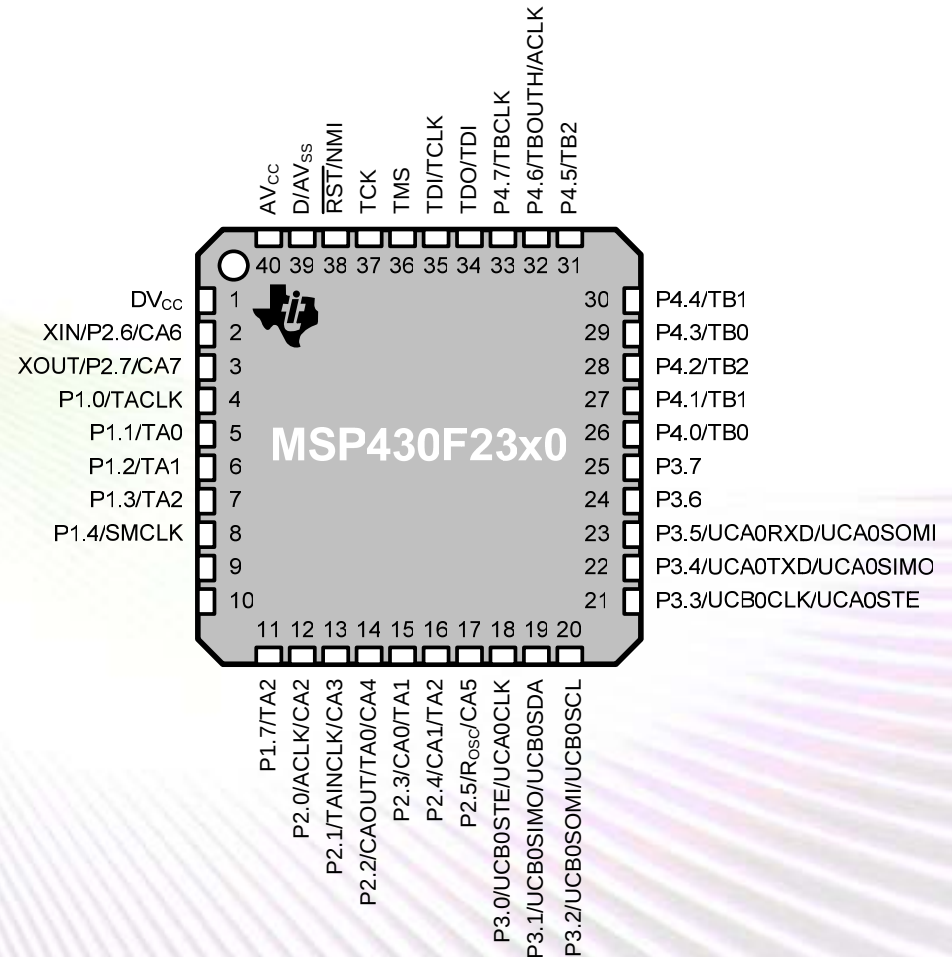
- LED used as light sensor
- Ambient light produces small voltage on LED
- Adaptive brightness from variable PWM based on environment
- Possible with **SD16**
- Internal VLO provides system timing
- Ultra Low Power: 10 μ A



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New F23x0 40-pin

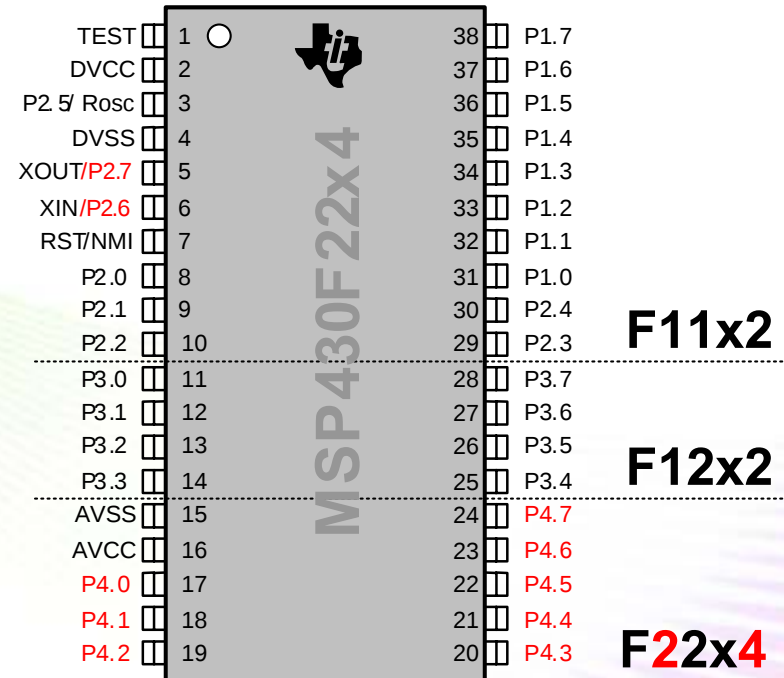
- **32KB** Flash / **2KB** RAM
- 16 MIPS, **<<1μA** LPM3
- **MPY**, Comp_A+
- Timer_A3 / B3, WDT+
- **USCI_A & B**
- 32 GPIO
- New **40-pin** mid-range
- Ideal for cost sensitive applications



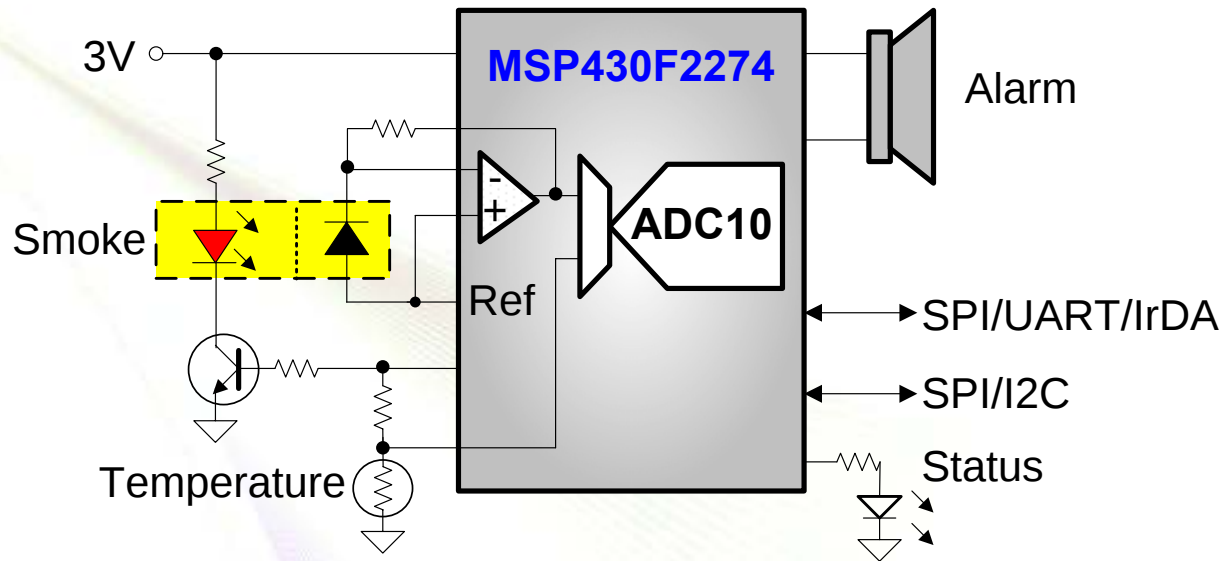
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New F22x4 For Sensor Applications

- **32KB Flash / 1KB RAM**
- **16 MIPS, <1μA LPM3**
- **10-bit 200ksps ADC**
- **2 Op Amps**
- **USCI_A & B**
- **Timer_A3 / B3, WDT+**
- **32 GPIO**
- **38-pin F1xx2 upgrade ideal for sensor apps**
- **MSP430F22x2 available without Op Amps**



MSP430F2274 Smoke Detector

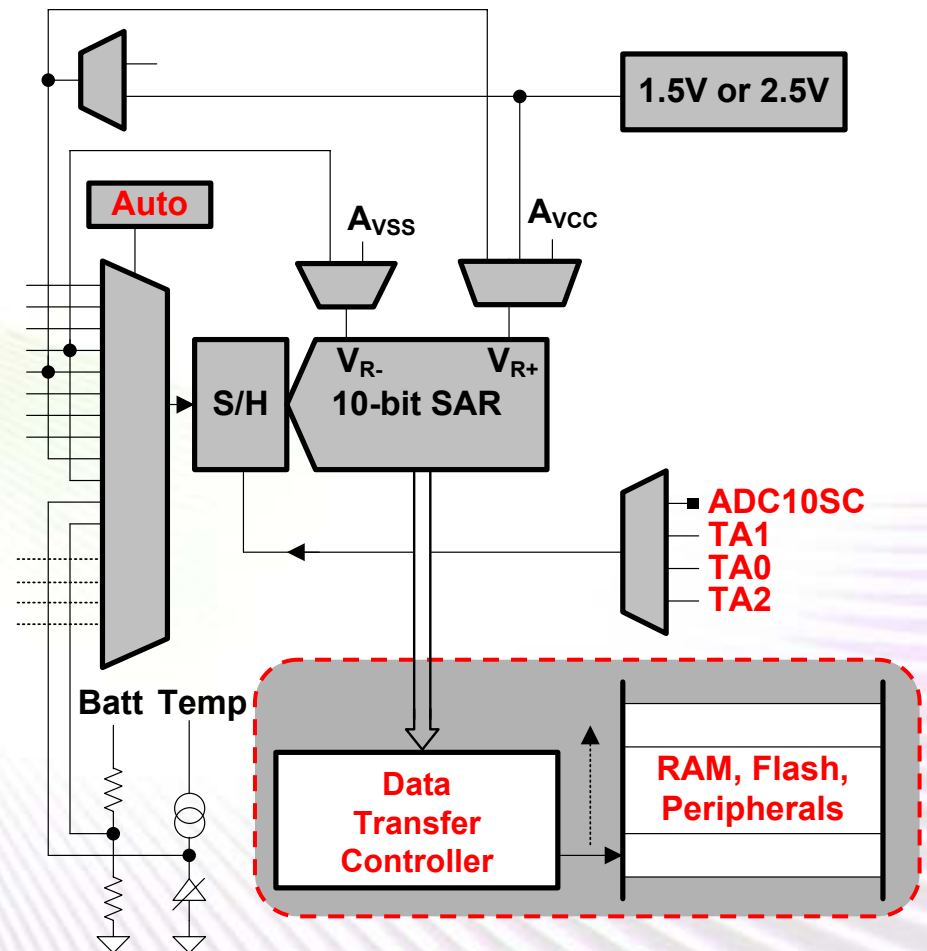


- Ultra-low Power
- Fully programmable SoC
- Very low cost
- No crystal needed - VLO
- Enhanced watchdog
- App Note: **SLAA335**

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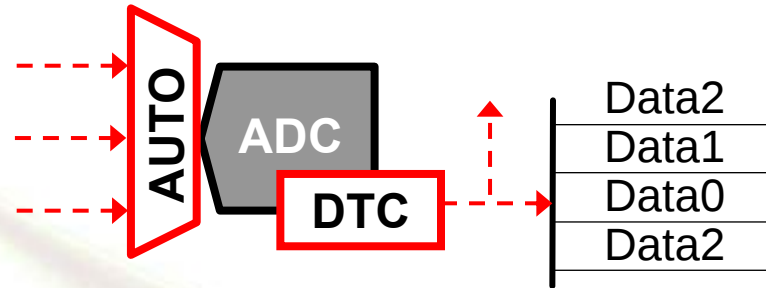
Fast Flexible ADC10

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



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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);

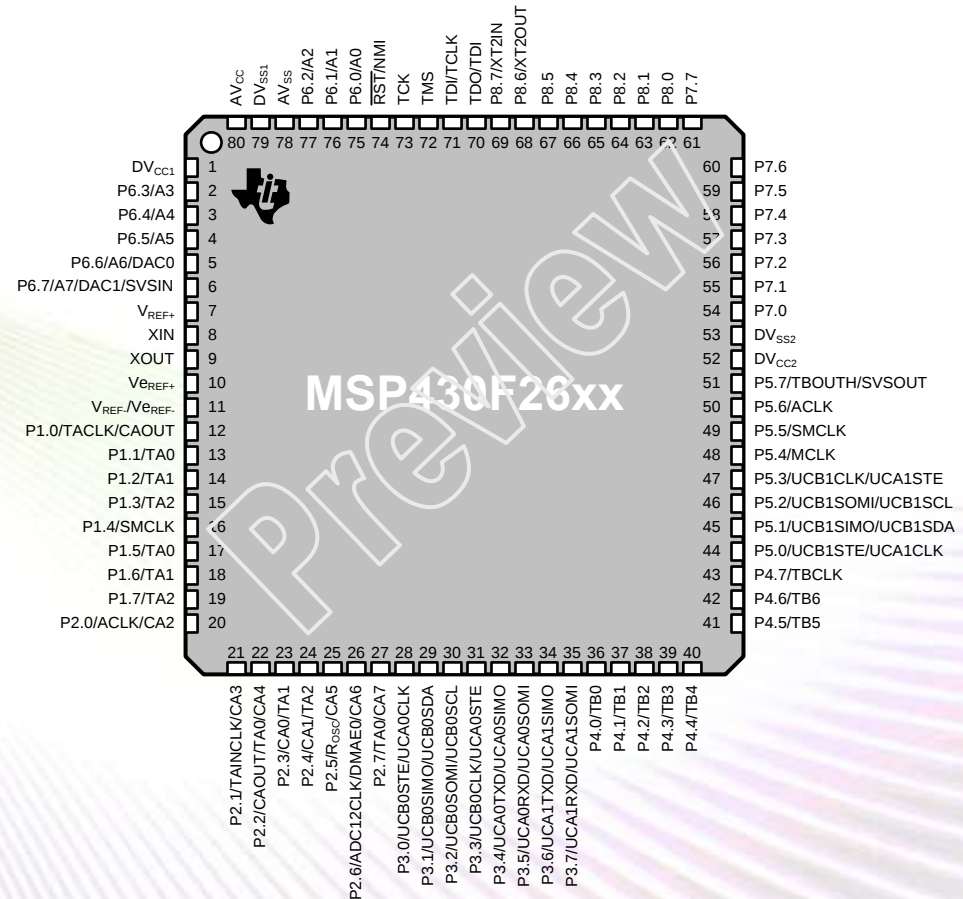
Fully Automatic

70 Cycles / Sample

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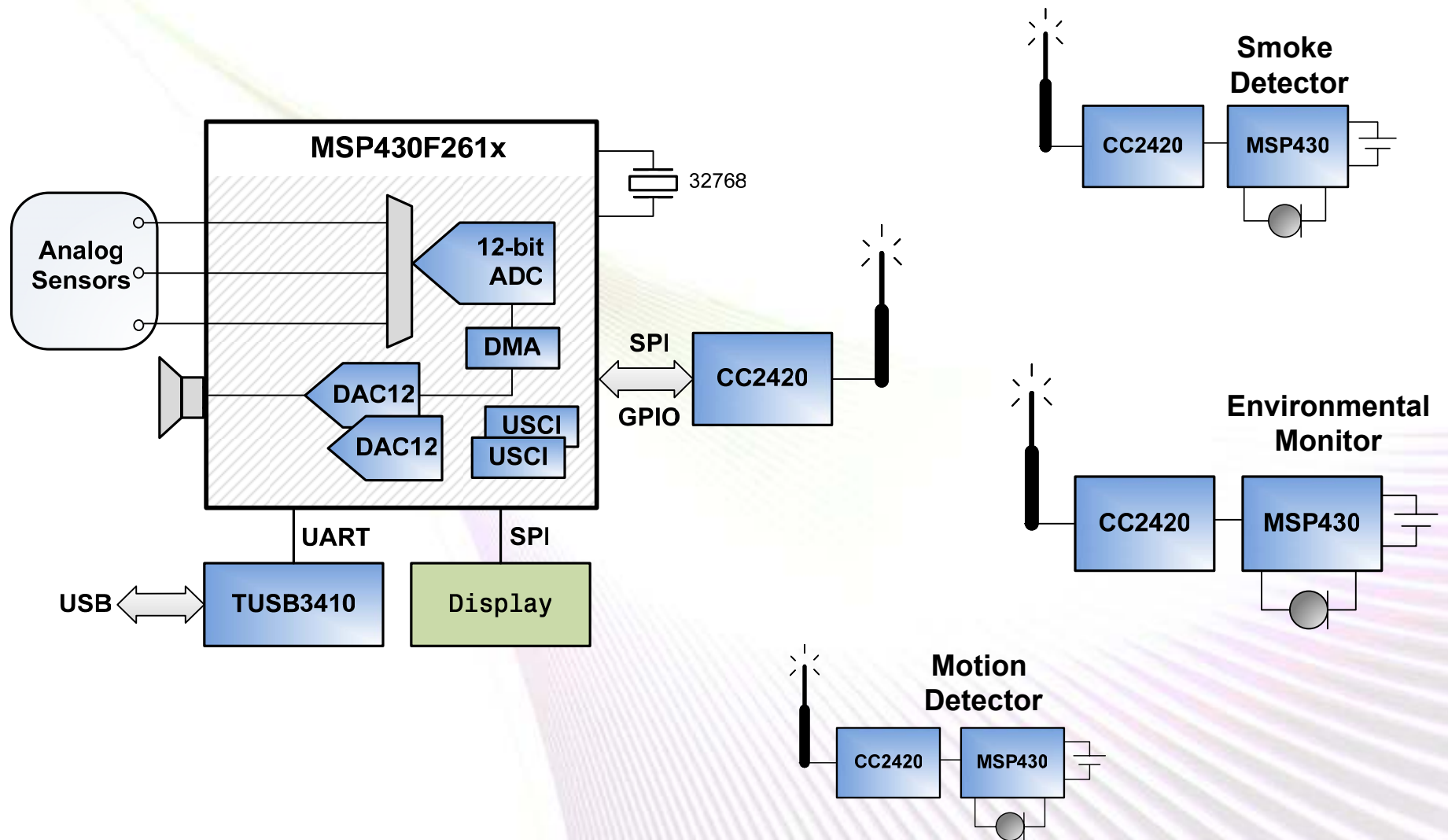
MSP430F261x/241x – Coming Soon

- **120KB Flash / 8KB RAM**
- **16 MIPS, 1 μ A LPM3**
- **12-bit 200ksps ADC**
- **(2) 12-bit DAC**
- **(2) USCI, DMA, MPY**
- **Timer_A3 / B7, WDT+**
- **64 GPIO**
- **64 / 80-pin high-end F16x/14x upgrade**



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MSP430F261x PAN Coordinator

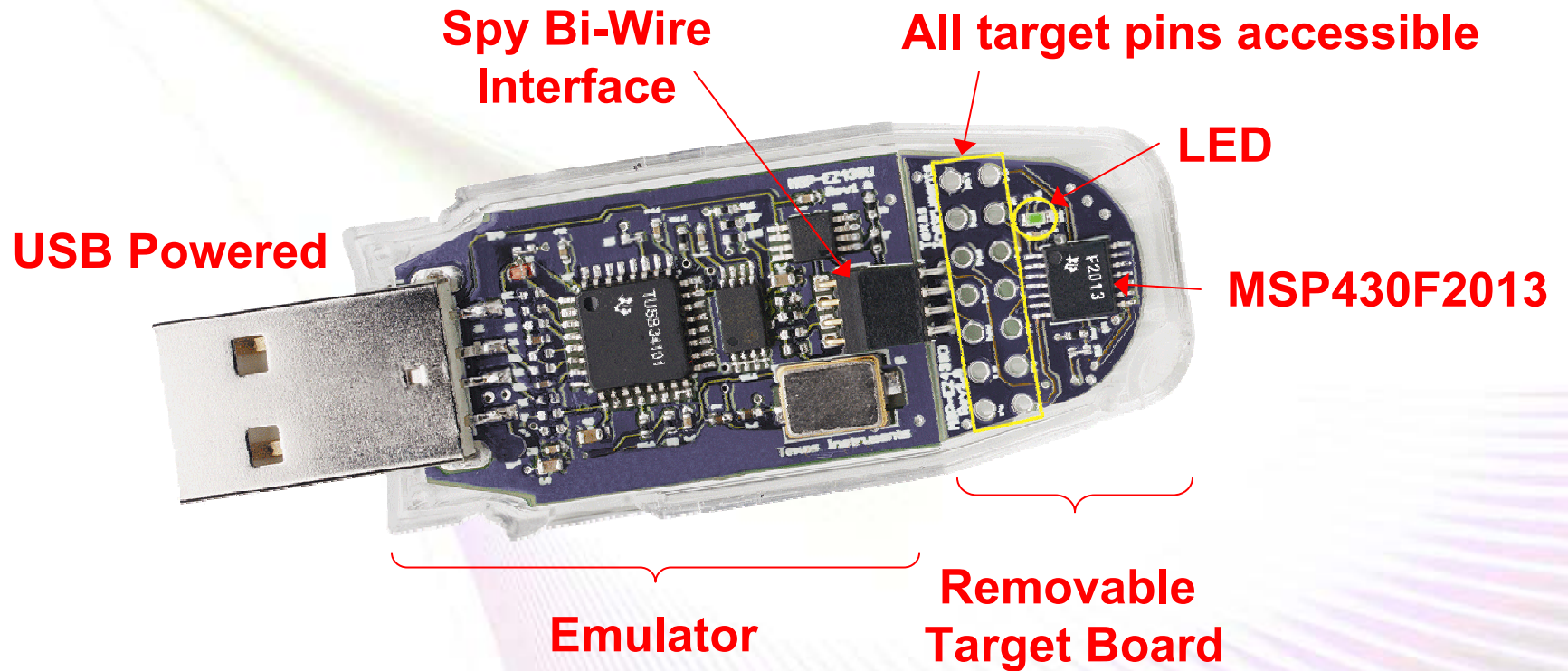


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Agenda MSP430 Day 2007

- MSP430 Overview
- MSP430x1xx / 4xx
- MSP430F2xx
- eZ430 + Capacitive Touch
- Wireless
- Resources

eZ430-F2013 - Under The Hood

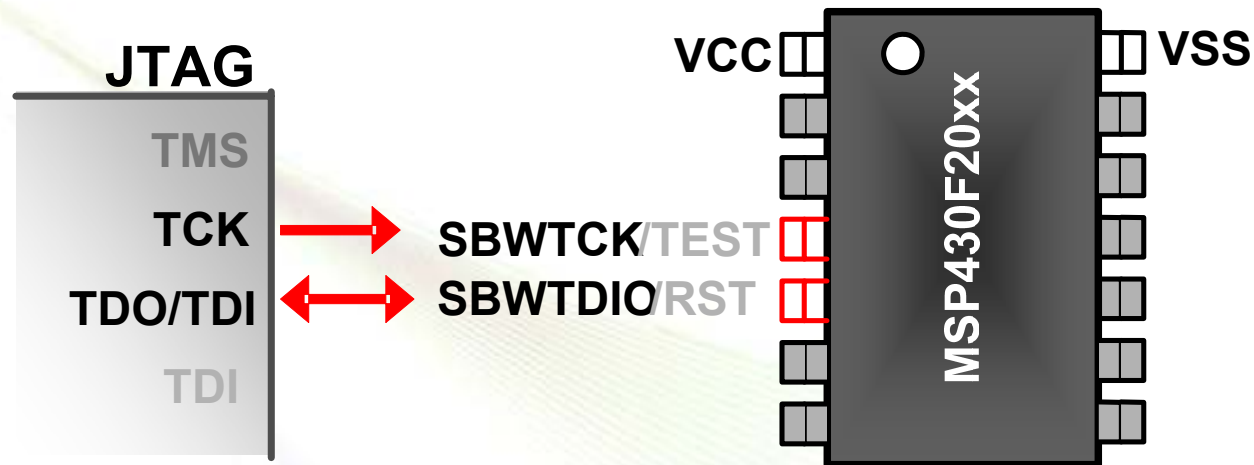


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Easy In-System Development



- **Full-speed in-system development using 2 signals**
 - Single step
 - Clock control
 - Hardware breakpoints
 - No device resources used
- **Compatible with available MSP430 IDEs**

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MSP430 Capacitive Touch Board



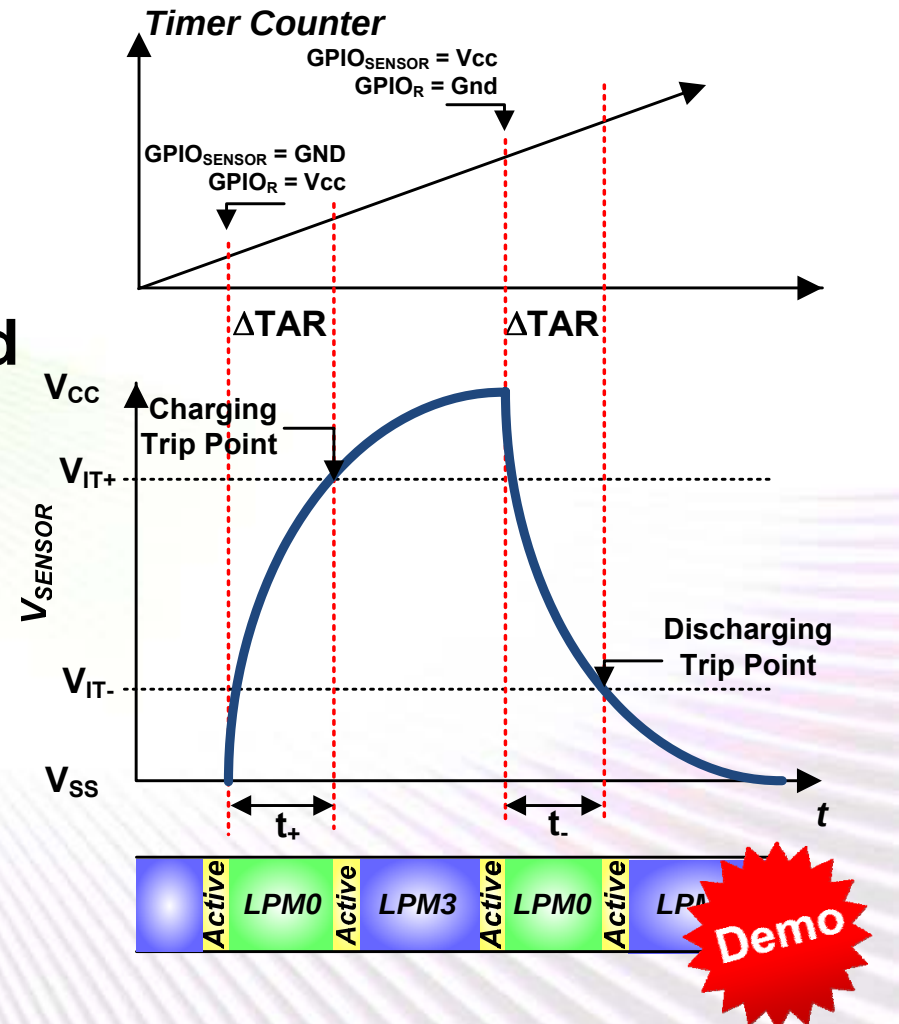
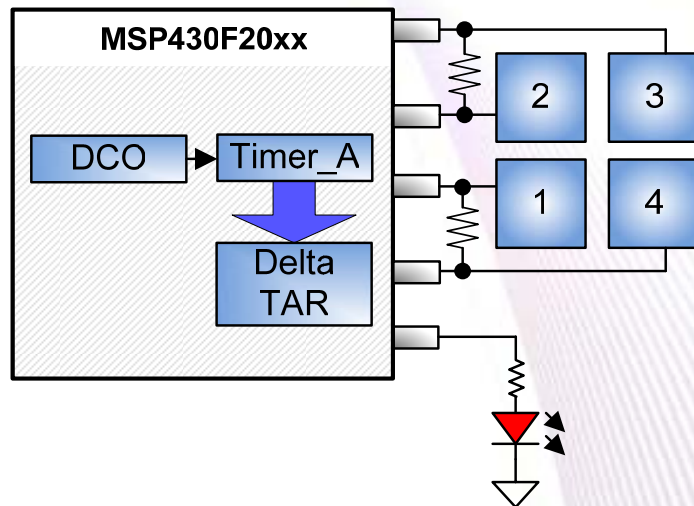
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Capacitive Touch Sensing

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



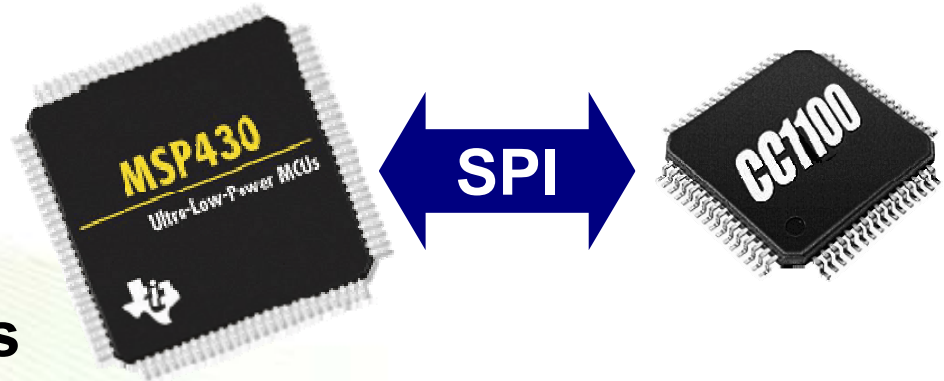
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Agenda MSP430 Day 2007

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MSP430 + Chipcon for Wireless

- **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		F16x F23x/F24x	FG461x F261x
Low Power Wireless	<1GHz	CC1xxx (CC1101)		
	2.4GHz	CC2xxx (CC2420, CC2500)		

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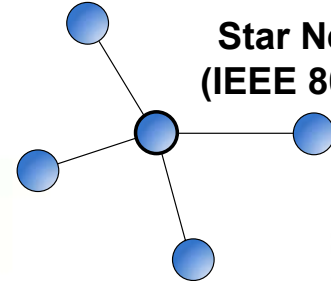
MSP430 Goes Wireless

- 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

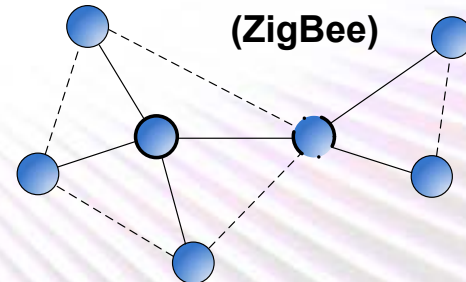
Point-to-Point
(MSP430 + RF HAL)



Star Network
(IEEE 802.15.4)



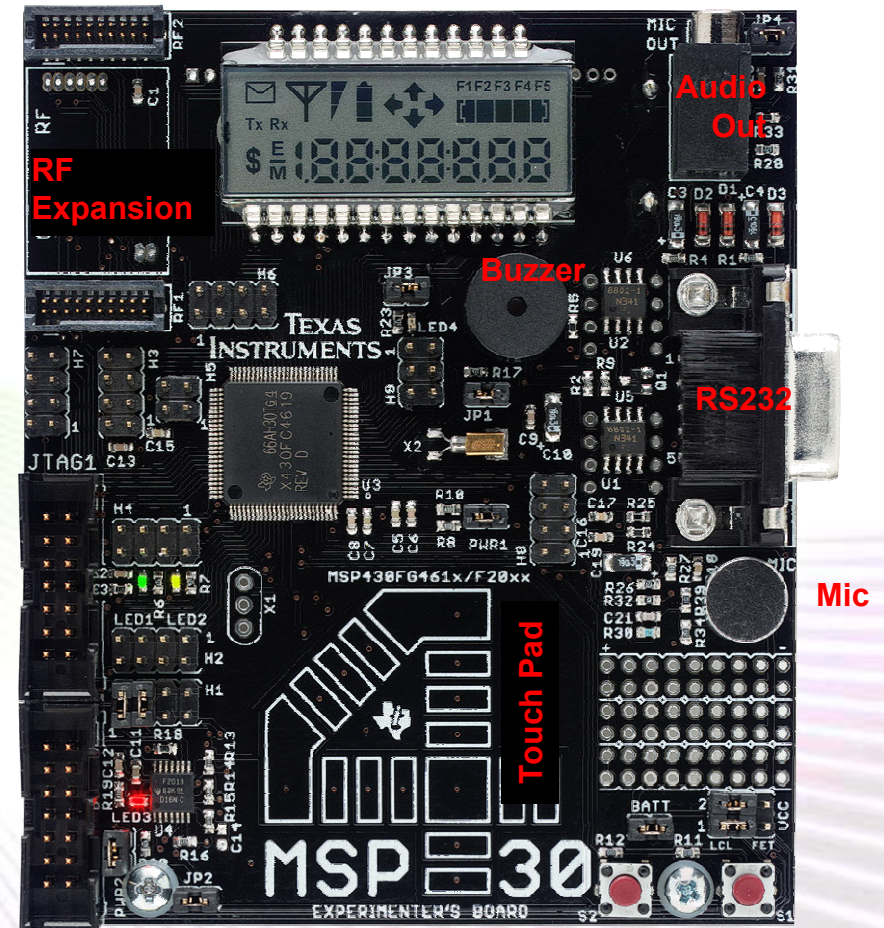
Mesh Network
(ZigBee)



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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**

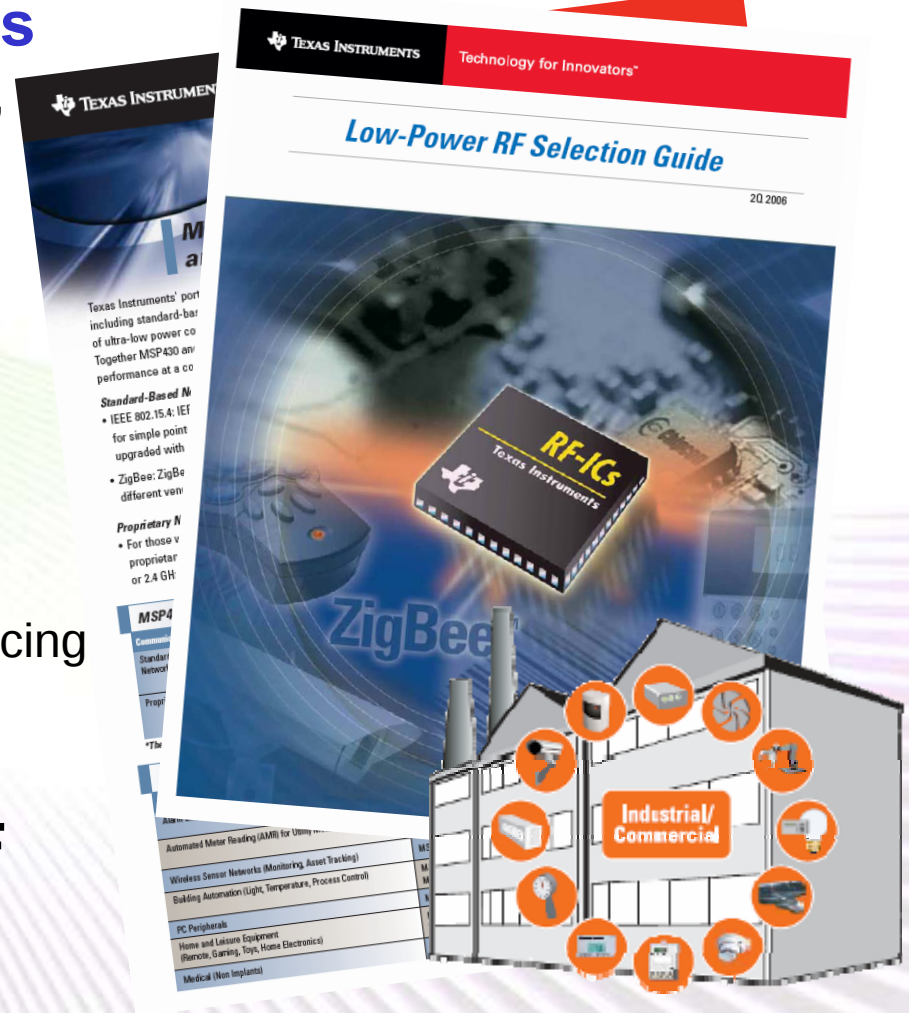


FG4618 / F2013 Experimenter Board (MSP-EXP430FG4618)

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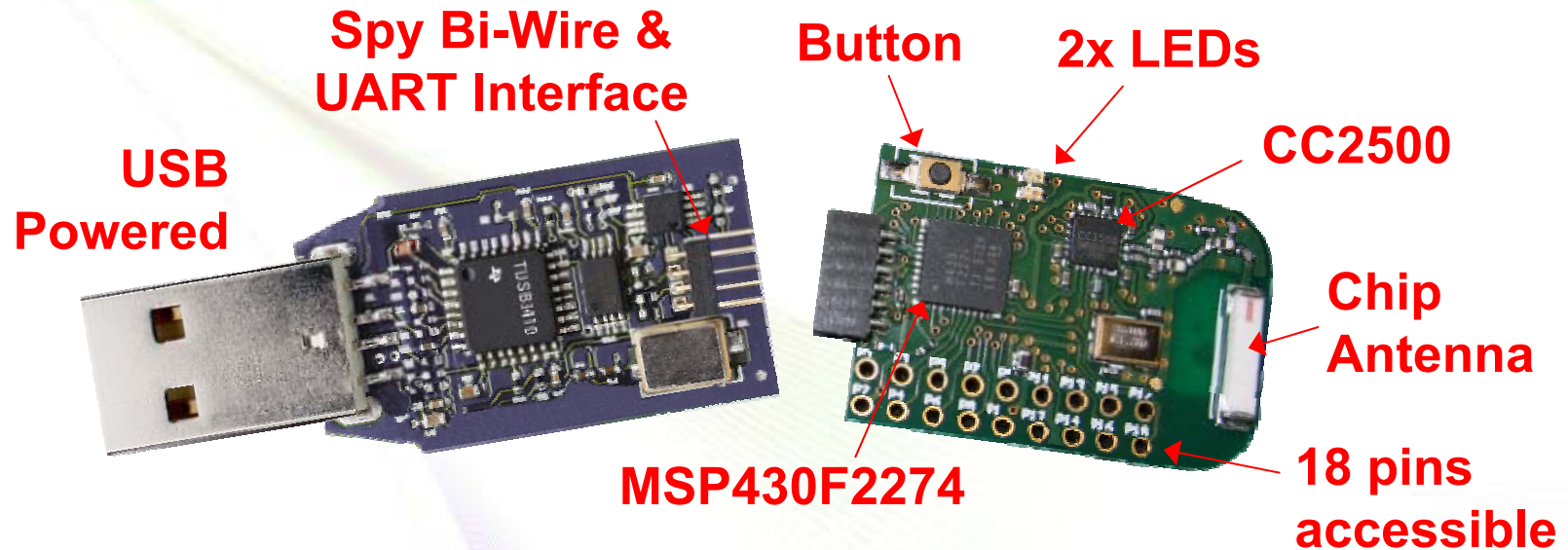
App Specific Resources: Wireless

- www.ti.com/msp430wireless
 - Resources for Low-Power Wireless, RFID and 27MHz applications
 - Links to Free Software Downloads
 - Links to recommended EVMs
 - Recommend Devices
- **Application Collateral: Reference Designs, Code Libraries**
 - MSP430 and Low-Power RF Interfacing
 - Ultra-Low-Power 27-MHz Wireless Mouse Reference Design
- **MSP430 and Low Power RF Selection Guide (SLYT265)**



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eZ430-RF2500. Wireless Made Easy.



- Star network stack included
- Includes 2 RF targets & battery expansion board
- \$49
- **Coming Fall '07**

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Visit
www.ti.com/eZ430-RF
October 1.

The first 100 visitors
will receive a
FREE eZ430-RF2500.

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Agenda MSP430 Day 2007

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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



MSP430x1xx Family

User's Guide

MSP430C11x1, MSP430F11x1A
MIXED SIGNAL MICROCONTROLLER

SLAS244P – SEPTEMBER 1999 – REVISED MARCH 2003

- Low Supply Voltage Range 1.8 V – 3.6 V
- Ultralow-Power Consumption
 - Active Mode: 100 μ A at 1 MHz, 2.2 V
 - Standby Mode: 0.7 μ A
 - Off Mode (RAM Retention): 0.1 μ A
- Family Members Include:
 - MSP430C1101: 1KB ROM, 128B RAM
 - MSP430C1101: 2KB ROM, 128B RAM
 - MSP430C1101: 4KB ROM, 256B RAM
 - MSP430F1101A: 1KB + 128B Flash Memory, 128B RAM



Application Report
C.L. Huettner – October 2001

Andreas Dannenberg

Computer
Increasing
Personal C
notes, too
browser, to



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App Specific Resources: Medical

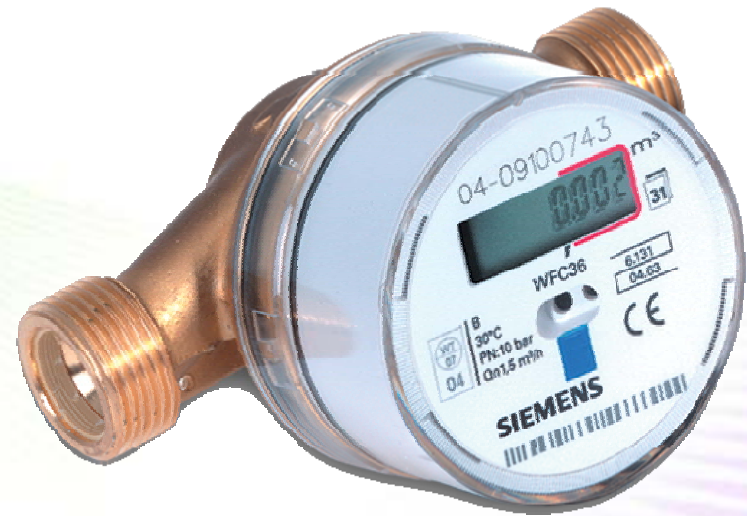
- www.ti.com/430medical
 - Suggested Devices
 - Application Collateral and Tools
- **Block Diagrams**
 - Blood Pressure Monitor
 - General Portable Medical
- **Application Notes and Reference Designs**
 - A Single Chip Pulse Oximeter Design
 - Heart Rate and EKG Monitor using the MSP430FG439



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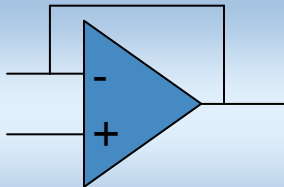
App Specific Resources: Metering

- www.ti.com/430metering
 - Resources for Electricity, Gas, Water and AMR Metering
 - Recommend Devices
- **Application Notes and Reference Designs**
 - Current Transformer Phase Shift Compensation and Calibration
 - Low-Cost Single-Phase Electricity Meter
 - Implementing Electronic Watt-Hour Meter
 - Using GMR Sensors With the MSP430 Scan Interface
 - Rotary/Linear Motion Detection Using the MSP430 Scan IF & Optical Sensors
 - Rotation Detection with MSP430 Scan IF



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Complementary Low Power HPA Devices



Amplifiers

❑ OPA333

❑ OPA334

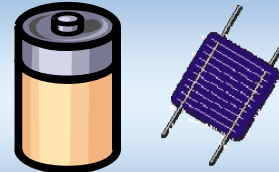


Low Power Wireless

❑ CC1101

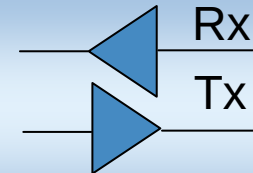
❑ CC2500

❑ CC2500



Power

❑ TPS61200



RS-485 / RS-232

❑ MAX3222E

❑ SN65HVD33



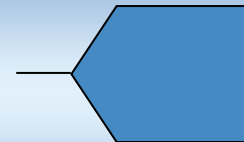
Temp Sensor

❑ TMP275



Reference

❑ REF33XX
(Preview)

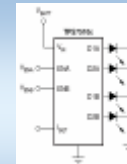


Data Converter

❑ ADS1225

❑ ADS8326

❑ DAC8560



LED Backlight

❑ TPS7510X

www.ti.com/lowpower

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Advanced Technical Training



MSP430
Advanced Technical Training

Ready for more?

- **2xx Advanced Technical Seminar**

- **Free** one-day technical seminar on new expansion of MSP430F2xx portfolio
- In-depth training covering architecture, applications and new integrated peripheral modules
- Learn how to get started and migrate from existing MSP430 devices
- For dates and locations visit www.ti.com/msp430advanced
- Coming **Fall 2007**

- **MSP430 Advanced Technical Conference**

- Multi-day Conference at multiple worldwide locations
- Coming **Summer 2008**

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Thanks for Joining!

- **50% off TI USB MSP430 Flash Emulation Tools**
 - MSP-FET430UIF, U14, U28, U23x0, U38, U48, U64, U80 & U100
 - Valid for limited time only at TI's eStore www.ti.com/estore
 - Coupon Code: **430DAY2007**
- **Follow up Training**
 - One Day Workshop
 - Online Training
 - designmsp430.com
- **How was 430 Day?**
 - Watch your email for online survey



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430 Day 2007



Thanks For Attending!

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