
# TI MSP430 超低功耗单片机

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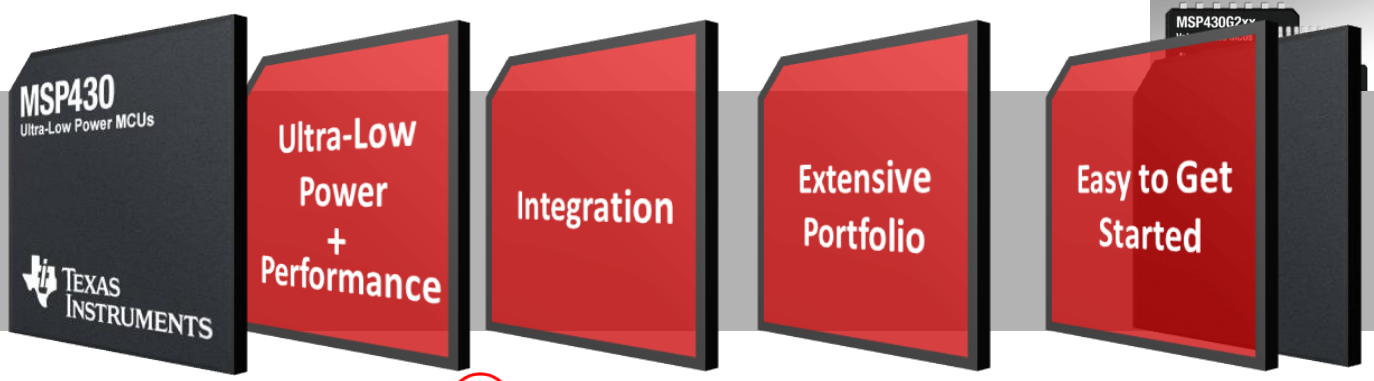
- **MSP430 product line Overview**
- **Getting started with LaunchPad**

# Meet MSP430

**Ultra-Low Power | High Integration | Easy-to-Use**


TEXAS INSTRUMENTS

# MSP430 MCUs
# An Introduction




## Ultra low power

**World's lowest power MCU**

- Ultra-Low Power Active Mode
- 7 Low Power Modes
- Instant Wakeup
- All MSP430 devices are Ultra-Low Power

## Integration

**Intelligent Analog & Digital Peripherals**

- Peripherals operate in low power modes
- Minimize physical footprint and Bill of Materials
- Featuring FRAM, USB, RF, Capacitive Touch I/O, Metrology Engines, LCD, ADC,

## Extensive Portfolio, Low Cost Options

**Find the right MCU for you**

- 400+ devices
- Up 256kB Flash, 18kB RAM, 25+ package options
- Devices starting at $0.25 with Value Line
- Various levels of performance & integration

## Easy to Get Started

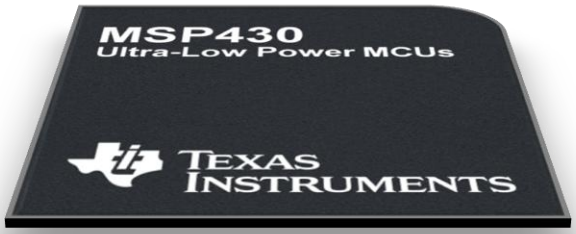
**Low cost and simple point of entry**

- Complete kits starting @ $4.30
- GUI-based coding & debugging tools available
- MSP430Ware Software and Resource Package

# MSP430-Enabled Applications


## Utility Metering

Electricity Meters
Gas Meters
Flow Meters
Smart Meters




**Thousands of applications are enabled by MSP430 MCUs**

**Differentiation is possible with MSP430 MCU's Ultra-Low Power performance, high analog & digital peripheral integration, and easy-to-use tool chain.**

## Portable Medical

Blood Glucose Meters
Thermometers
Heart-Rate Monitors
Implantable Devices

## Wireless Applications

Remote Sensors
Communication Controllers
RFID

## Sensors & Security

Smoke Detector
Motion Detector
Vibration Detector
Smart Sensors

## Consumer Electronics

Portable Electronics
Remote Controls
Personal Care
PC peripherals

## Energy Harvesting

Renewable Energy
Battery-less devices
Solar, thermal, vibration, etc

## Personal Health & Fitness

Sports Watches
Pedometers
Calorimeters
Dive watches

# 超低Active功耗


## Active模式下超低功耗

**F2xx (Gen purpose, max 16MHz)**

- **220uA/MHz ****

**F4xx (w/LCD, max 16MHz)**

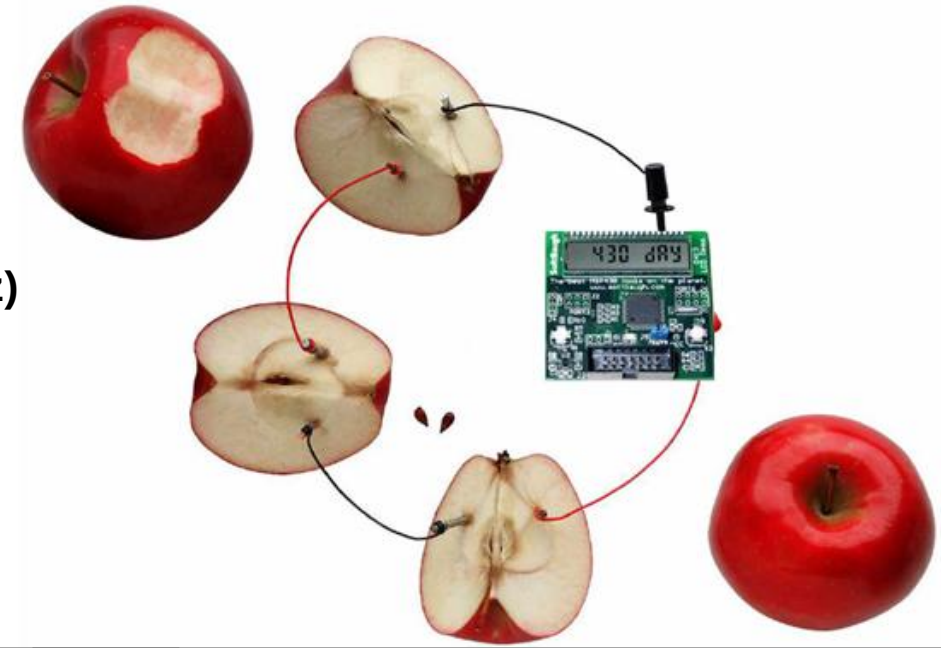
- **200uA/MHz ****

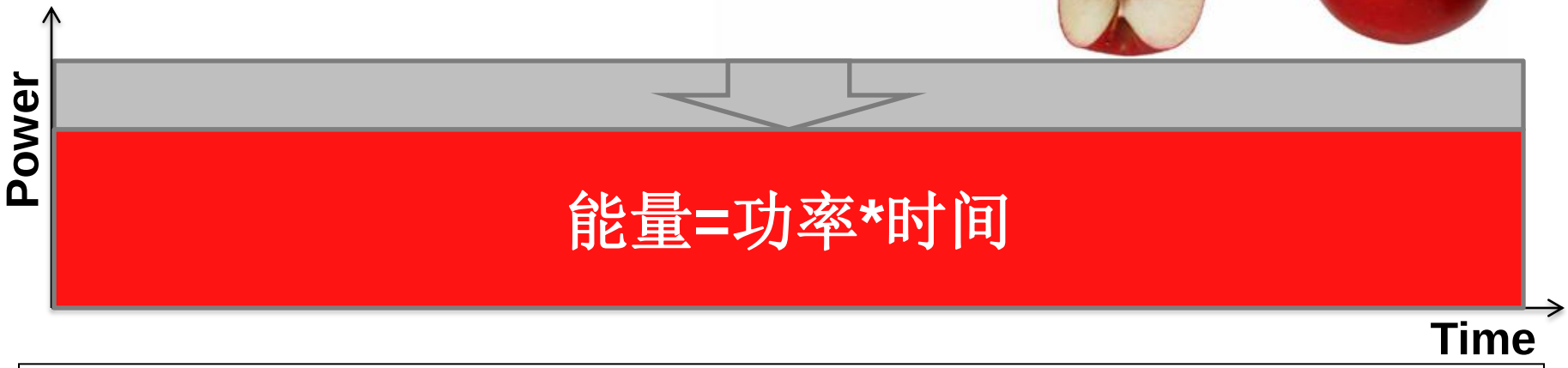
**F5xx (Gen Purpose + USB, max 25MHz)**

- **160uA/MHz ****

**MSP430FR57xx with FRAM**

- **82uA/MHz ****





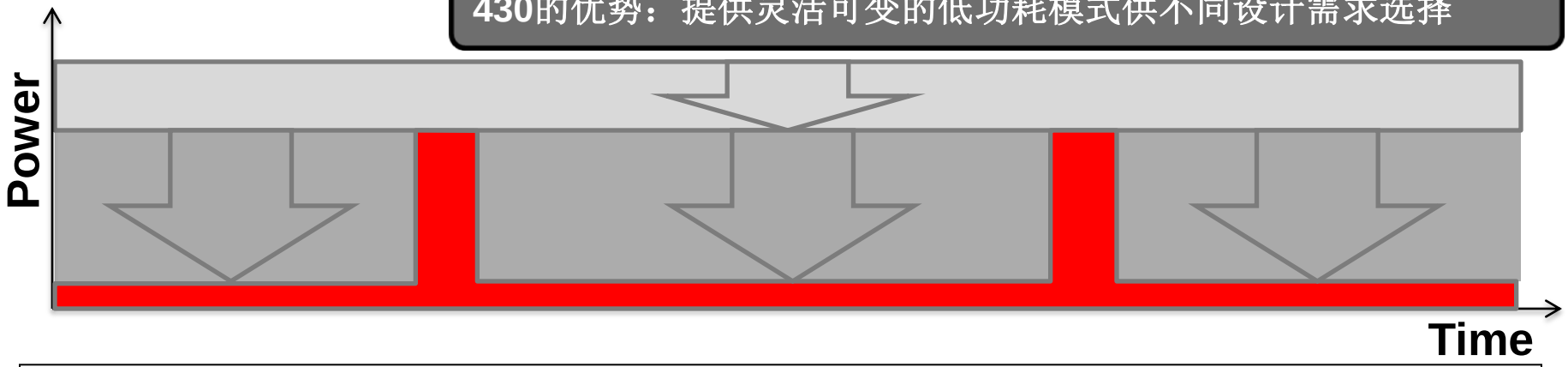

# ☑ 超低Active功耗

# ☑ 7种可配置的低功耗模式LPM

| MSP430 | Active | LPM0 | LPM1 | LPM2 | LPM3 | LPM3.5 | LPM4 | LPM4.5 |
|---|---|---|---|---|---|---|---|---|
| CPU | ✔ | - | - | - | - | - | - | - |
| SMCLK (Hi-Freq peripheral clk) | ✔ | ✔ | ✔ | - | - | - | - | - |
| ACLK (Low Freq peripheral clk) | ✔ | ✔ | ✔ | ✔ | ✔ | - | - | - |
| Autonomous peripherals | ✔ | ✔ | ✔ | ✔ | ✔ | - | - | - |
| RAM Retention | ✔ | ✔ | ✔ | ✔ | ✔ | - | ✔ | - |
| Brown Out Reset | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |

大多数设计中处理器处于低功耗模式的时间长达99-99.9%

430的优势：提供灵活可变的低功耗模式供不同设计需求选择



# 短暂可靠的唤醒时间

## 可以快速从低功耗模式中返回到Active模式（以 LPM3为例）

**F2xx (Gen purpose, max 16MHz)**

- **<1us**

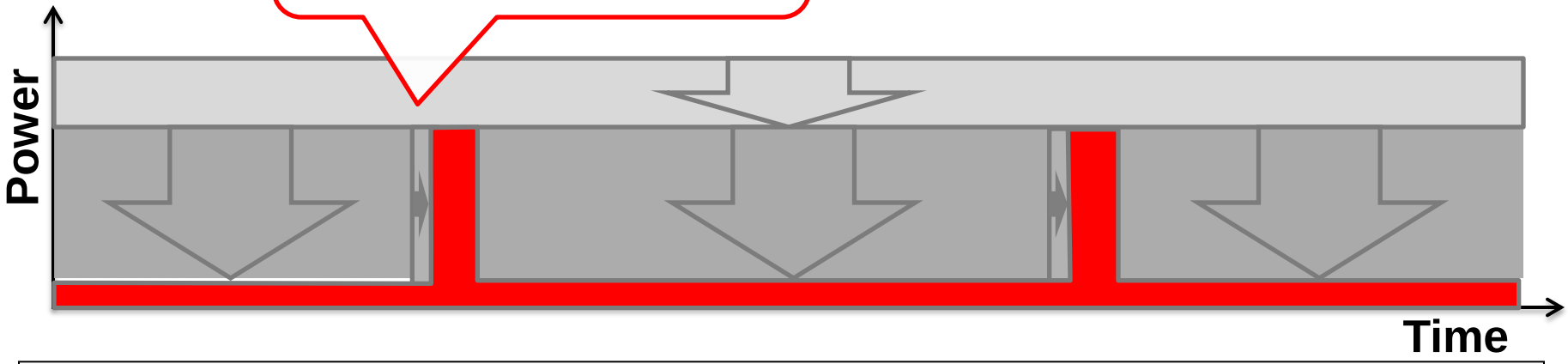
**F4xx (w/LCD, max 16MHz)**

- **<5us**

**F5xx (Gen Purpose + USB, max 25MHz)**

- **<6us**


即时唤醒使得处理器可以更长时间地处在低功耗模式，从而进一步降低系统的功耗。



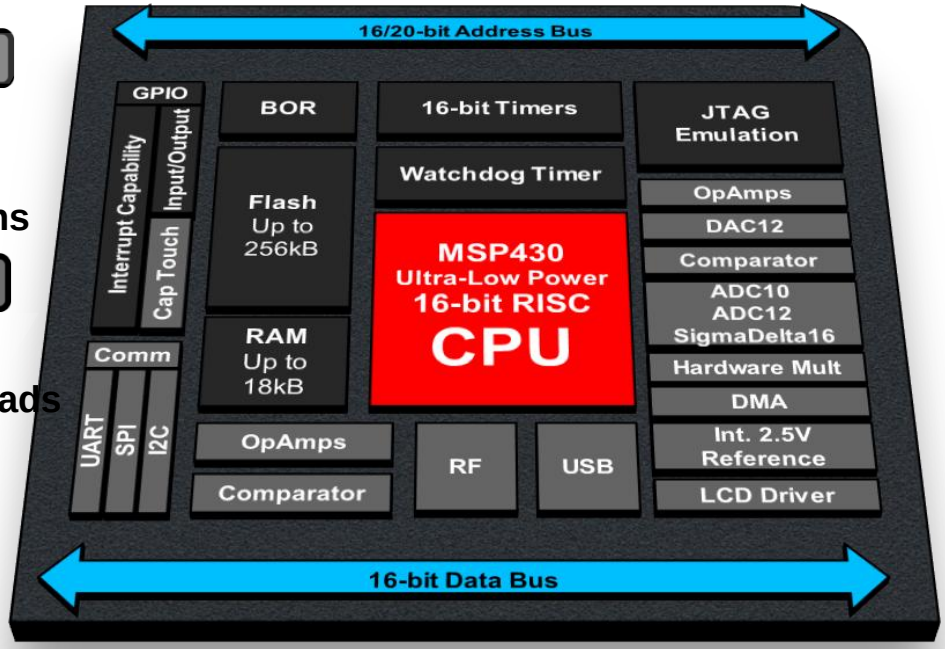
# 高度的模拟与数字集成


## 300+ Device Configurations

- Flash: Up to 256kB Flash, 512kB on the way
- RAM: Up to 18kB RAM
- Package/Pin Count: 24 packages, up to 113 pins

## Innovative Integration

- FRAM – the future of Embedded Memory
- Capacitive touch I/O – directly interface with pads
- Hi-Resolution Timer – 4ns resolution
- A-POOL – Configurable analog blocks
- USB – Full Speed 2.0
- RF – Sub-1GHz (433, 868, 915MHz)
- ESP430 – 2nd core for eMetering algorithms
- 24 Bit – Sigma Delta ADC




## Full peripheral set

- Devices integrated with:
  - 10, 12-bit ADC
  - 16-bit Sigma Delta
  - 12-bit DAC
  - 16-bit Timers
  - I2C, SPI, UART
  - LCD Driver
- USB
- Integrated RF
- Comparator
- OpAmps
- Direct Memory Access Module
- Hardware Multipliers
- AES128 Encrypt/Decrypt module
- Watchdog Timer
- Brown-Out Reset
- Capacitive Touch I/O ports
- Real-Time Clock
- Power Management Module
- **MORE**

# MSP430 系列


**400+ Ultra-Low Power Devices Starting @ $0.25USD**

**Featuring: Up to 256kB Flash, 18kB RAM, 25+ Package Options, Up to 113 pins, High integration**

**Ultra-Low Power Performance — Analog Integration — Easy-to-Use**

**MSP430™ 16-bit RISC CPU**
All devices feature:
- 16-bit timers
- Watchdog timer
- Internal Digitally Controlled Oscillator
- External crystal support
- <50 nA pin leakage
- <6 µs wakeup

**FRAM**
Speed 24 MHz
FRAM 4-16kB
GPIO 14-28
Non-volatile memory
PMM: SVS, SVM, LDO
AES
ADC12 (A)
USCI
DMA

**L092**
0.9V-1.65V
Speed: 4 MHz
ROM: Up to 2Kb
RAM: Up to 2Kb
GPIO: 11
BOR, DAC8, Comp, SVS, BOR, WDT, A-POOL

**F1xx**
Speed: 8 MHz
Flash: 1-60Kb
RAM: Up to 10Kb
GPIO: 14-48
BOR, ADC10, 12, Comp_A, DAC12, DMA, MPY, SVS, USART

**G2xxx**
Speed: 16 MHz
Flash: 0.5-16Kb
RAM: Up to 512b
GPIO: 10-24
BOR, ADC10, Comp_A+, Temp, USCI, UART, Cap sense I/Os

**F2xx**
Speed: 16 MHz
Flash: 1-120Kb
RAM: Up to 8Kb
GPIO: 10-64
BOR, ADC10,12, SD24_A, Comp_A+, DAC12, DMA, MPY, OpAmp, SVS, USCI, USI

**F4xx**
Speed: 8/16 MHz
Flash: 4-120Kb
RAM: Up to 8Kb
GPIO: 14-80
BOR, LCD, ADC10,12, SD16(_A), Comp_A, DAC12, DMA, MPY, OpAmp, SVS, USART, USCI, ESP430, SCAN_IF, Basic Timer, WDT+, RTC_C

**F5xx/6xx**
Speed: 25 MHz
Flash: 8-256Kb
RAM: Up to 18Kb
GPIO: 32-83
PMM: BOR, SVS, SVM, LDO
MPY, USCI, DMA, USB, ADC10, 12 (A), Comp_B, RTC_A/B, WDT, LCD

**CC430**
Speed: 20 MHz
Flash: 8-16Kb
RAM: Up to 4Kb
GPIO: 40
PMM: BOR, SVS, SVM, LDO
MPY, USCI, DMA, Sub 1 GHz RF, AES, Comp_B, RTC_A, ADC12 (A), LCD

Some Devices | All Devices

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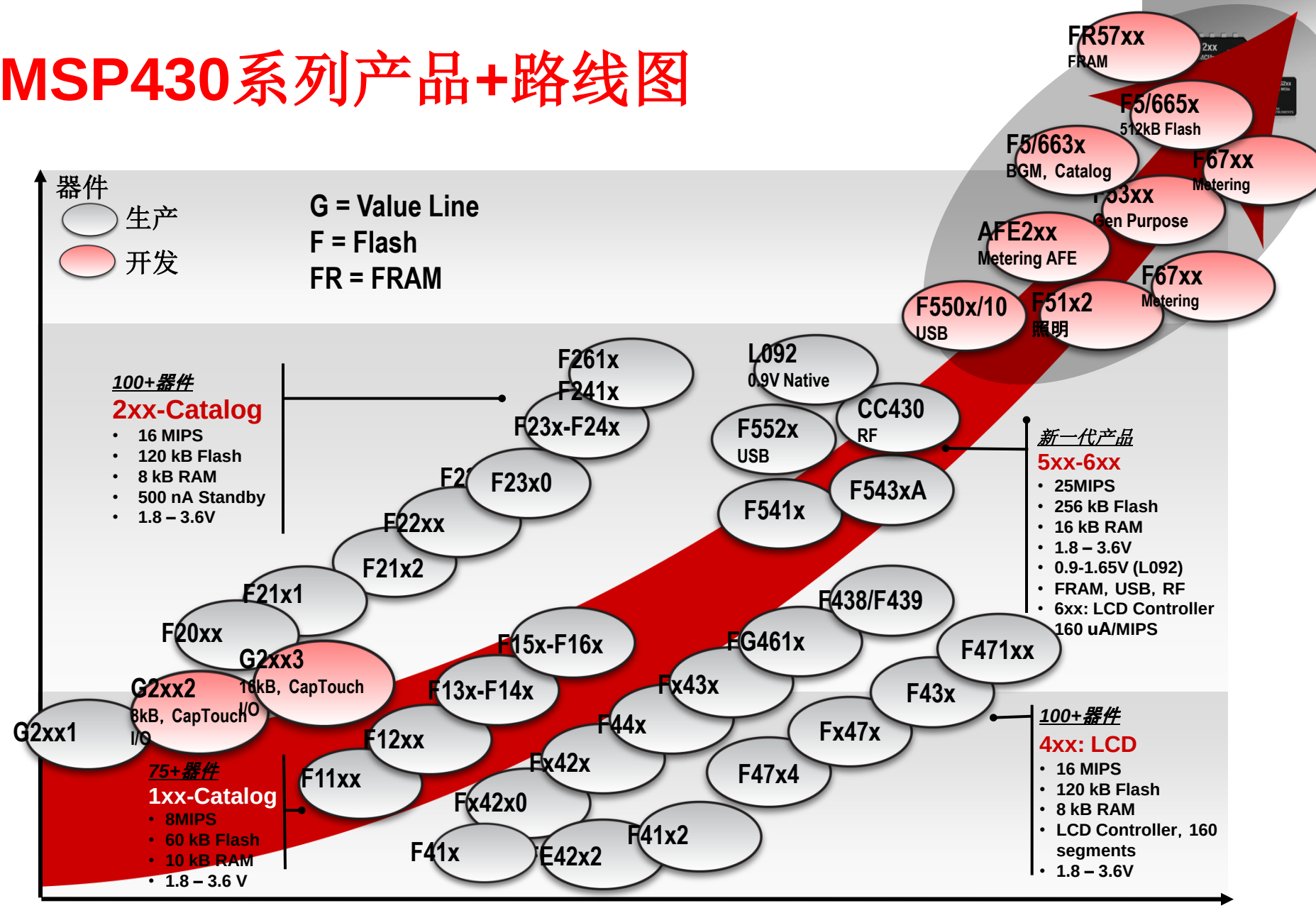
# MSP430系列产品+路线图



# MSP430各代产品


| 1xx | 2xx | 4xx | 5xx |
|---|---|---|---|
| 基本时钟系统 | 基本时钟系统+ | FLL，FLL + | 统一时钟系统UCS |
| 核心电压与供电电压相同 | 核心电压与供电电压相同 | 核心电压与供电电压相同 | 核心电压可以用集成式PMM进行编程 |
| 16位CPU | 16位CPU，CPUX | 16位CPU，CPUX | 16位CPUXV2 |
| GPIO | GPIO，带有上拉及下拉 | GPIO | GPIO，带有上拉及下拉，驱动强度(drive strength) |
| N/A | N/A | N/A | CRC16 |
| 软件RTC | 软件RTC | 软件RTC，带有基本计时器，基本计时器+ RTC | 真正32位RTC带闹钟 |
| USART | USCI，USI | USART，USCI | USCI，USB，RF |
| DMA up to 3-ch | DMA up to 3-ch | DMA up to 3-ch | DMA up to 8-ch |
| MPY16 | MPY16 | MPY16，MPY32 | MPY32 |
| ADC10,12 | ADC10,12 | ADC12 | ADC12_A |
| 4-wire JTAG | 4-wire JTAG，有些器件带有Spy-Bi-Wire | 4-wire JTAG | 4-wire JTAG及Spy-Bi-Wire |

# MSP430各代产品


| Category | 2xx | 4xx | 5xx |
|---|---|---|---|
| CPU Clock (max) | 16MHz | 8MHz | 25MHz |
| Active Current (@ 3.0V，typical) | 515uA @ 1MHz<br>4.2mA @ 8MHz<br>9.1mA @ 16MHz | 600uA @ 1MHz<br>4.8mA @ 8MHz<br>N/A | 290uA @ 1MHz<br>1.84mA @ 8MHz → 230 uA/MHz<br>8.90mA @ 25MHz |
| | 120KB / 8KB (Flash / RAM) | 120KB / 8KB (Flash / RAM) | 256KB / 16KB (Flash / RAM) |
| Wake-up Time From LPM3 | 1us | 6us | 5us |
| Standby LPM3 Current | 0.9 – 1.1uA | 1.1 – 2.5uA | 1.9uA (RTC，WDT，SVS enabled) |
| LPM4 Current | 0.1uA | 0.1uA | 1.2uA (LPM4) / 0.1uA (LPM4.5) |
| Flash ISP Minimum $DV_{CC}$ | 2.2V | 2.7V | 1.8V |
| Port I/O Interrupt Capability | P1/P2 | P1/P2 | P1/P2<br>Some devices also P3/P4 |
| Prog. Port Pin Drive Strength | N/A | N/A | All port pins |
| Prog. Pull-ups / Pull-downs | All port pins | N/A | All port pins |
| 12-bit A/D Internal Reference Current | 500 uA | 500 uA | 100 uA* |
| 12-bit A/D Active Conversion Current | 800 uA | 800 uA | 150 uA* |
| Available MCLK Sources | DCO<br>LFXT1<br>XT2 (if available)<br>VLO | FLL<br>LFXT1<br>XT2 (if available) | UCS { FLL<br>LFXT1 / XT1<br>XT2 (if available)<br>VLO<br>REFO |
| Available FLL Reference Clocks | N/A | LFXT1 | LFXT1，REFO，<br>& XT2 (if present) |

* 2xx，4xx – ADC12；5xx - REF & ADC12_A

# MSP430G2xx Value Line MCUs

**Deliver 16-bit performance & ultra-low power at 8-bit price**


## Versus the competition

| | PIC10F202 | MSP430G2001 | |
|---|---|---|---|
| Price | $0.25 | $0.25 | |
| Flash | 512B<br>Ext 12V | 512B<br>In System | Flexible |
| RAM | 25B | 128B | Agile |
| Timers | 8-bit<br>counter | 16-bit<br>multifunction | More Functionality |
| Emulation | 0 | 2-pin<br>In System | Faster Development |
| GPIO/<br>Interrupts | 6<br>0 | 10<br>22 | No Compromise |
| MIPS | 1x 8-bit | 16x 16-bit | Hi-Performance |
| Power Modes | 2 | 5 | MSP430 is lower power in all modes of operation |
| Affordable Development | >$100 | $4.30 | LaunchPad development kit |

**MSP430G2xx1**
27 devices, 2kB Flash, 10 GPIO, 128B RAM

**MSP430G2xx2**
60+ devices, 8kB Flash, 16 GPIO,512B RAM,CapTouch I/O

**MSP430G2xx3**
60+ devices, 16kB Flash, 24 GPIO, 1kB RAM, Cap Touch I/O, UART

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# Value Line: 16-bit performance, 8-bit price


UART
Cap Touch I/O
ADC10
Comparator
SPI/I²C

Flash Size

16KB
8KB
4KB
2KB
1KB
.5 KB

MSP430G25X3 — SC, ADC, UART
MSP430G24X3 — SC, ADC, UART
MSP430G24X2 — SC, ADC
MSP430G23X3 — SC, ADC, UART
MSP430G23X2 — SC, ADC
MSP430G22X2 — SC, ADC
MSP430G22X1* — SC, ADC
MSP430G22X3 — SC, ADC, UART
MSP430G21X2 — SC, ADC
MSP430G21X1* — SC, ADC
MSP430G21X3 — SC, ADC, UART
MSP430G2001*

| 14-pin | 16-pin | 20-pin | 28-pin | 32-pin |
|---|---|---|---|---|
| TSSOP/PDIP | QFN | TSSOP/PDIP | TSSOP | QFN |
| 10 GPIO | 10 GPIO | 16 GPIO | 24 GPIO | 24 GPIO |

** 8-pin SOIC in development*

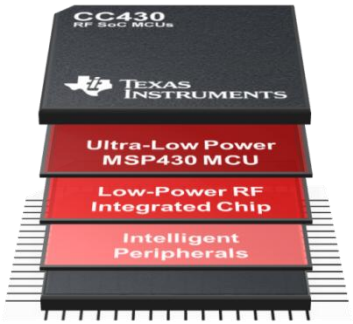
# Integrated Full-Speed USB

- 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)



# CC430

## ——MCU with integrated RF (SoC)





**SmartRF Studio 7**

- Intuitive tool for evaluating TI's Low Power RF ICs and SoCs
- Generates device register values
- Tests RF performance and tune customer-specific hardware solutions.

**Packet Sniffer**

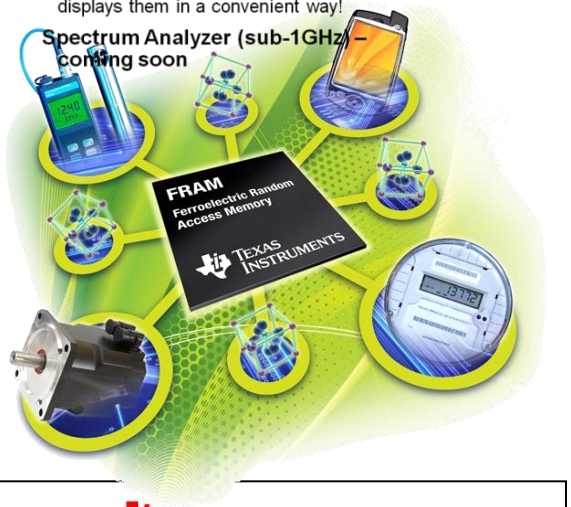
- Analyze RF packets in real-time to greatly simplify RF debugging
- Display and store RF packets captured with a listening RF device
- Filters and decodes packets and displays them in a convenient way!

**Spectrum Analyzer (sub-1GHz) – coming soon**

# FRAM

## ——The Future of Embedded Memory

- *Universal Memory*
- *$10^{15}$ write cycles*
- *1000x faster write*
- *250x lower power*

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# Easy and affordable tool chain


## Get started at just $4.30

**MSP430 offers the world's most affordable development kits!**
**Start developing today with MSP430's $4.30 LaunchPad development kit! Or start using our eZ430 evaluation modules ($49 and under)!**

**These development kits include all of the hardware and software you need to get started today!**

### $4.30 LaunchPad

**MSP-EXP430G2**

Easy development kit for MSP430G2xx MCUs. Includes all the HW/SW needed to start today!

- FEATURES:
  - Integrated emulator for programming and debugging via USB
  - 20-pin DIP target socket
  - 2 switches / 2 LEDs
  - Includes 2 MSP430G2xx devices, USB cable, PCB headers, quick start guide
- PRICE: **$4.30**

### eZ430 Evaluation Kits

**eZ430-F2013**
Based on MSP430F2013.
Integrated emulator, 1 target
Price: $20

**eZ430-RF2500**
Based on MSP430F2274
Includes CC2500 2.5GHz RF
Integrated emulator, 2 target
Price: $49

**eZ430-Chronos**
Based on CC430F6137
Sub-1GHz SoC
Integrated sensors, emulator
Price: $49

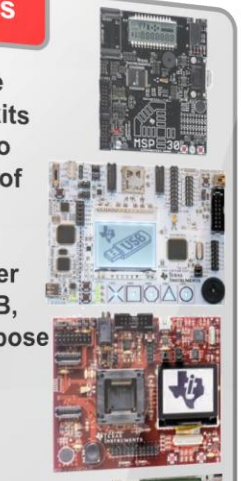
### Experimenter Boards

Experimenter boards are complete development kits that enable developers to explore the full features of an MSP430 device.

MSP430 has experimenter boards for Metering, USB, RF, FRAM and Gen. Purpose applications.

MSP-EXP430FG4618
MSP-EXP430F5529
MSP-EXP430F5438A
MSP-EXP430FR5739
MSP-EXPCC430

Price: $29 - 149 each



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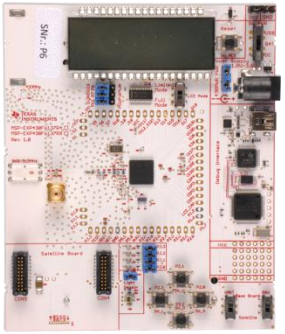
# MSP430 Experimenter's Boards


## MSP-EXP430FG4618

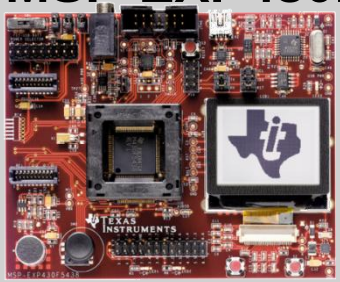
- Featured device: MSP430FG4618
- Featured app: eMetering
- On-board LCD, RF headers, audio jack, microphone, capacitive touch pads, RS232, pushbuttons, LEDs
- Price: $99

## MSP-EXPCC430



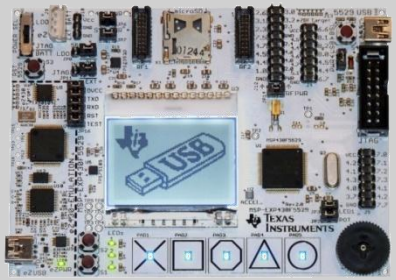
- Featured device: CC430F6137, CC430F5137
- Featured app: Sub1GHz RF
- Includes a main board (F6137) and daughter board (F5137), embedded emulation, push buttons, LEDs.
- Price: $149

## MSP-EXP430F5438



- Featured device: MSP430F5438
- Featured app: General purpose
- On-board dot matrix LCD, joystick, microphone, RF headers, accelerometer, push buttons, LEDs.
- Price: $149

## MSP-EXP430F5529




- Featured device: MSP430F5529
- Featured app: USB
- On-board dot matrix LCD, integrated USB, microSD slot, RF headers, capacitive touch pads, potentiometer, accelerometer, embedded emulation, push buttons, LEDs.
- Price: $149

## MSP-EXP430FR5739

- Featured device: MSP430FR5739
- Featured app: FRAM
- On-board accelerometer, embedded emulation, RF headers, push buttons, LEDs
- Price: $29

## MSP-EXP430G2

- Featured device: MSP430G2xx Value Line MCUs
- Featured app: Low cost, general purpose
- On-board 20-pin DIP socket, push buttons, LEDs, embedded emulation. Also supports plug-in boards called BoosterPacks (starting with capacitive touch)
- Price: $4.30

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# Various IDE options


## Free Integrated Development Environments (IDE) available


**Code Composer Studio**

- Eclipse-based IDE (Compiler, debugger, linker, etc) for all TI embedded processors
- Unrestricted version available for $495
- Free versions are available!
  - Free 16kB code-limited version available for download
  - Free, full-featured, 120-day trial version available

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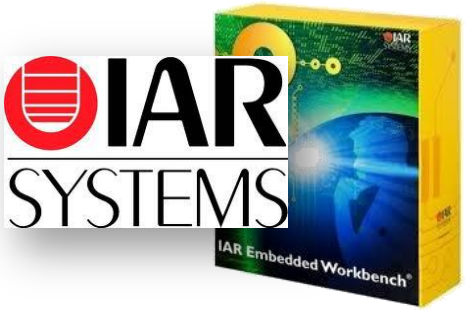


**IAR Embedded Workbench**

- Strong third-party IDE offering with project management tools and editor. Includes config files for all MSP430 devices.
- Free versions are available!
  - Free 4/8/16kB code-limited Kickstart version available for download
  - Free, full-featured, 30-day trial version available

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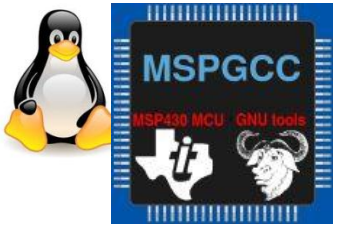


**MSPGCC**

- Free, Open source, GCC tool chain for MSP430
- includes the GNU C compiler (GCC), the assembler and linker (binutils), the debugger (GDB)
- Tools can be used on Windows, Linux, BSD and most other flavors of Unix.
- Learn more @ http://mspgcc.sourceforge.net/

**Other MSP430 IDE options are available! Learn more @ www.ti.com/msp430tools**

# Other Software Tools


## MSP430 Software Tools make USB and RF development EASY

### RF Software Tools

www.ti.com/rfstudio


**SmartRF Studio 7**

- Intuitive tool for evaluating TI's Low Power RF ICs and SoCs
- Generates device register values
- Tests RF performance and tune customer-specific hardware solutions.

**Packet Sniffer**

- Analyze RF packets in real-time to greatly simplify RF debugging
- Display and store RF packets captured with a listening RF device
- Filters and decodes packets and displays them in a convenient way!

**Spectrum Analyzer (sub-1GHz) – coming soon**

### USB Tools

www.ti.com/msp430usbdevpack

**USB Developer's Package (SW Tools, Documentation & Examples)**

- MSP430 API Code Stacks All necessary APIs & examples to start USB development
- USB Field Firmware Updater Project template for building a GUI-based tool that upgrades MSP430 firmware in the field using MSP430's on-chip USB BSL.
- Windows HID API API enabling USB communication between PC and MSP430 MCU
- USB Descriptor Tool Code generation tool for configuring the USB API stack for various interfaces.


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# 在线支持——www.ti.com/msp430
# www.ti.com.cn

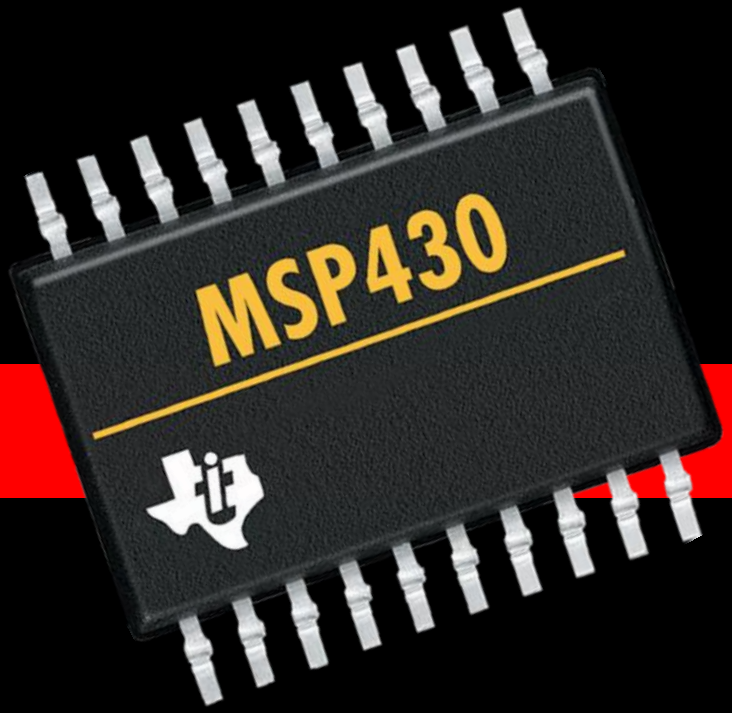
- User's Guides
- Datasheets
- 1000+ Code Examples
- 100+ Application Reports
- Product Brochure
- MCU Selection Tool
- Latest Tool Software
- 3rd Party Listing
- Silicon Errata

试试430Ware!

德仪在线支持社区

http://www.devisupport.com/

# Getting started with MSP430 LaunchPad --G2 Value Line Products



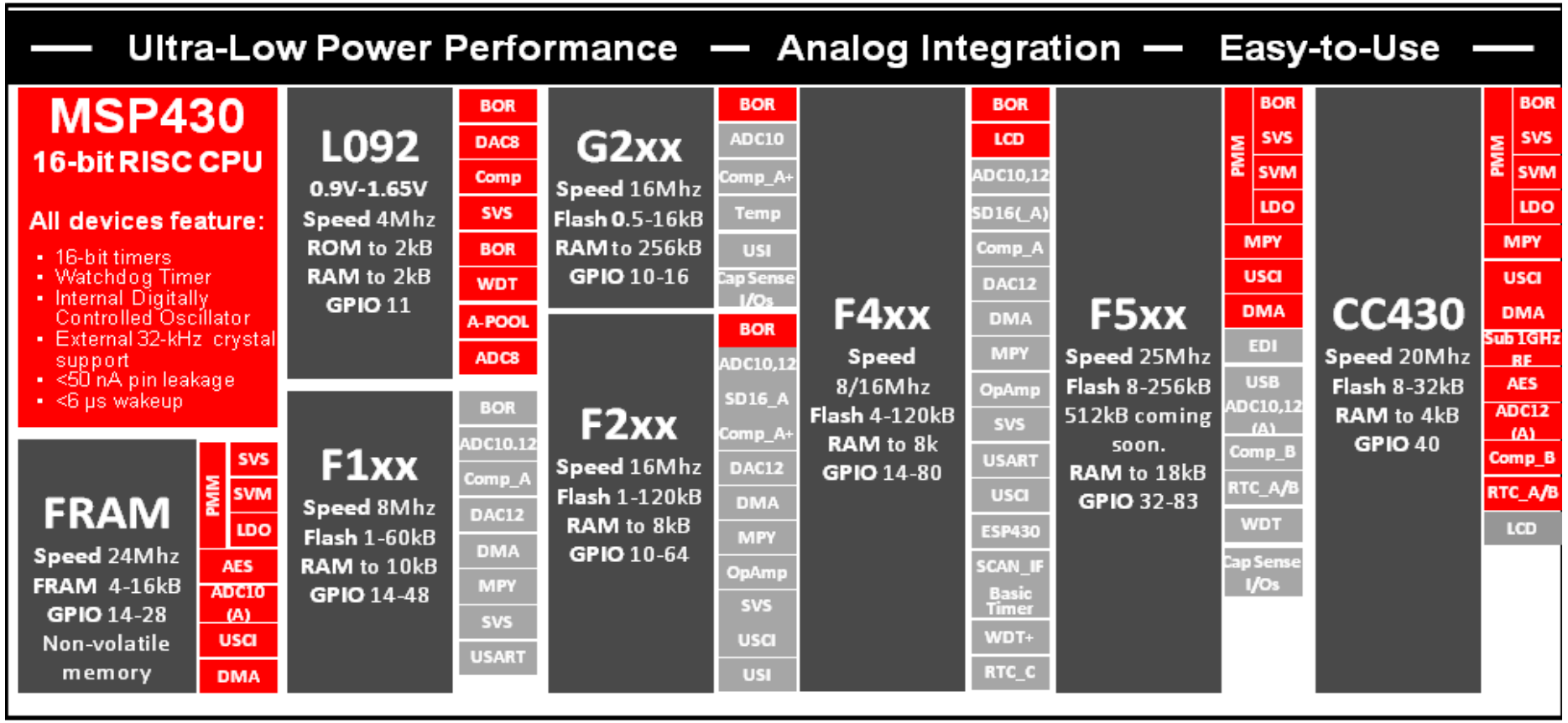

Texas Instruments

# Agenda

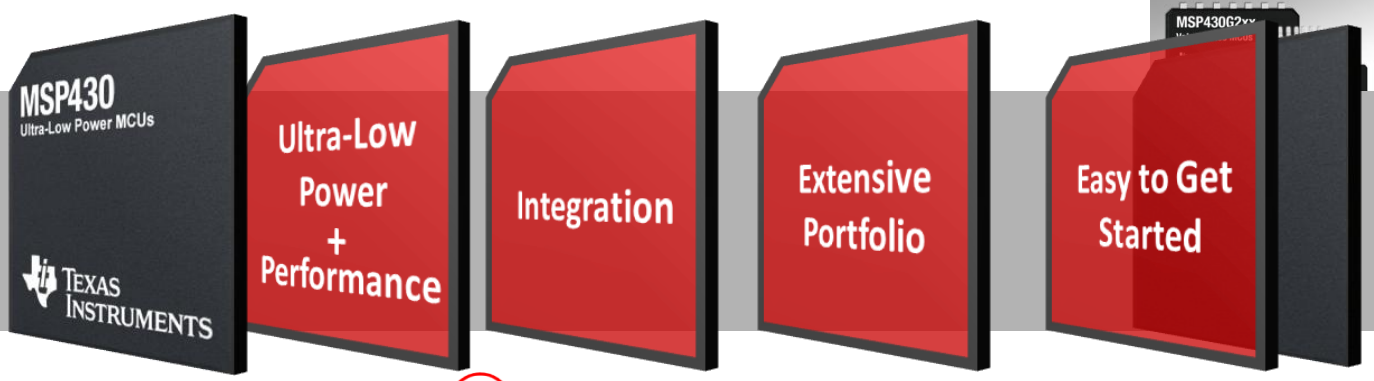

- **Value Line 简介**
- **Code Composer Studio**
- **CPU及基本时钟系统**
- **中断及通用IO**
- **定时器及增强型WDT**
- **低功耗优化设计**
- **ADC10 及 Comparator_A+**
- **串行通信**
- **Grace**
- **Capacitive Touch Solution**

# MSP430 Released Devices

**300+ Ultra-Low Power Devices** Starting @ $0.25USD
**Featuring:** Up to 256kB Flash, 18kB RAM, 25+ Package Options, Up to 113 pins, High integration



# MSP430 MCUs
# An Introduction




## Ultra-Low Power

**World's Lowest Power MCU**

- Ultra-Low Power Active Mode
- 7 Low Power Modes
- Instant Wakeup
- All MSP430 devices are Ultra-Low Power

## Integration

**Intelligent Analog & Digital Peripherals**

- Peripherals operate in low power modes
- Minimize physical footprint and Bill of Materials
- Featuring FRAM, USB, RF, Capacitive Touch I/O, Metrology Engines, LCD, ADC, DAC & MORE

## Extensive Portfolio, Low Cost Options

**Find the right MCU for you**

- 400+ devices
- Up 256kB Flash, 18kB RAM, 25+ package options
- Devices starting at $0.25 with Value Line
- Various levels of performance & integration

## Easy to Get Started

**Low cost and simple point of entry**

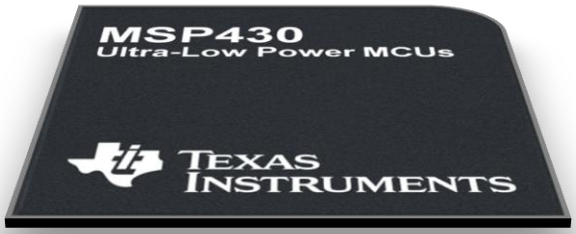
- Complete kits starting @ $4.30
- GUI-based coding & debugging tools available
- MSP430Ware Software and Resource Package
  -Incl. code examples, datasheets, user guides & more!

Texas Instruments

# MSP430-Enabled Applications


## Utility Metering

Electricity Meters
Gas Meters
Flow Meters
Smart Meters




## Portable Medical

Blood Glucose Meters
Thermometers
Heart-Rate Monitors
Implantable Devices

## Wireless Applications

Remote Sensors
Communication
Controllers
RFID

**Thousands of applications are enabled by MSP430 MCUs**

Differentiation is possible with MSP430 MCU's Ultra-Low Power performance, high analog & digital peripheral integration, and easy-to-use tool chain.

## Sensors & Security

Smoke Detector
Motion Detector
Vibration Detector
Smart Sensors

## Consumer Electronics

Portable Electronics
Remote Controls
Personal Care
PC peripherals

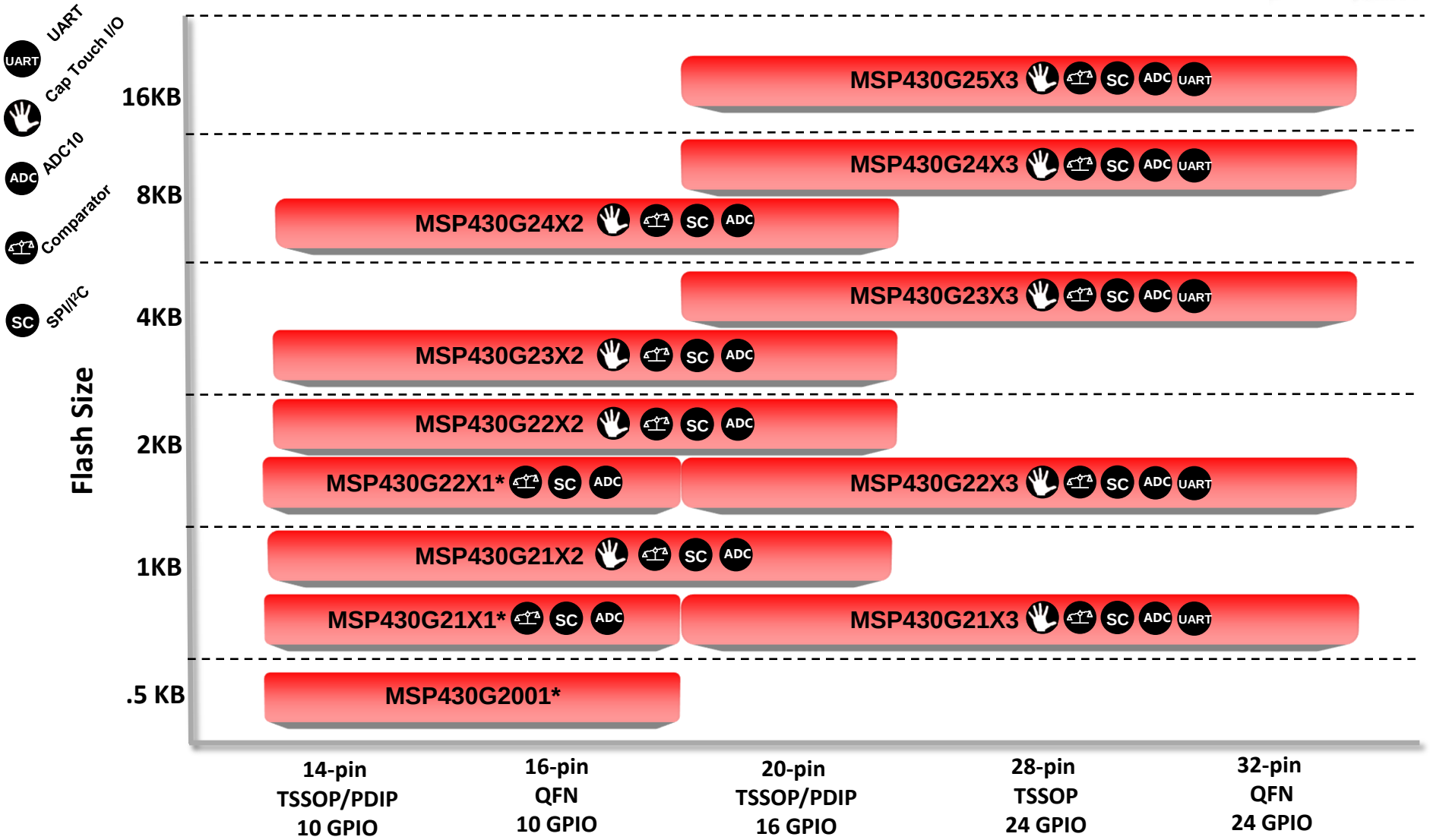
## Energy Harvesting

Renewable Energy
Battery-less devices
Solar, thermal, vibration, etc

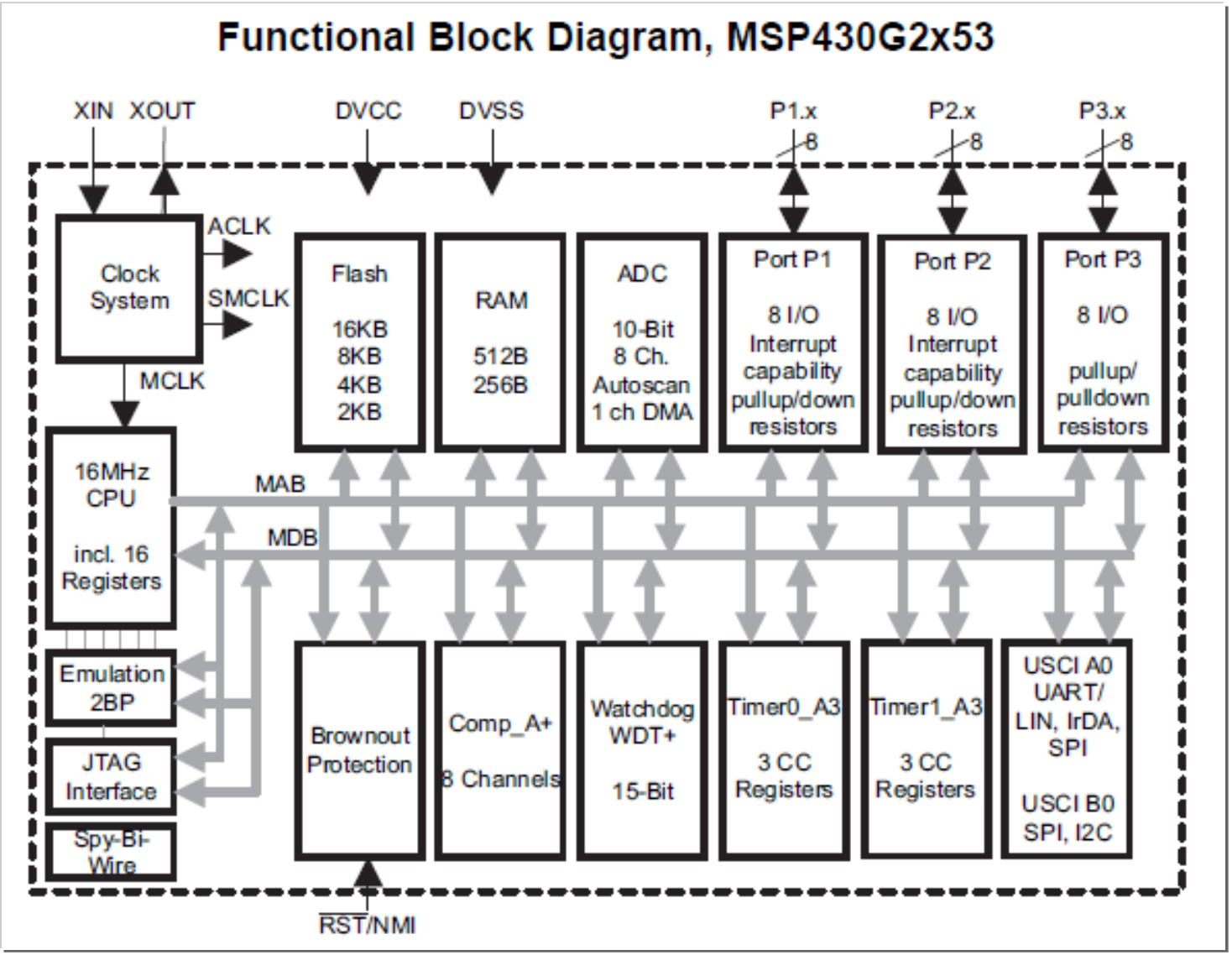
## Personal Health & Fitness

Sports Watches
Pedometers
Calorimeters
Dive watches

# Value Line: 16-bit performance, 8-bit price

# Value Line 外设




注：Port3仅在28pin和32pin的产品中可用

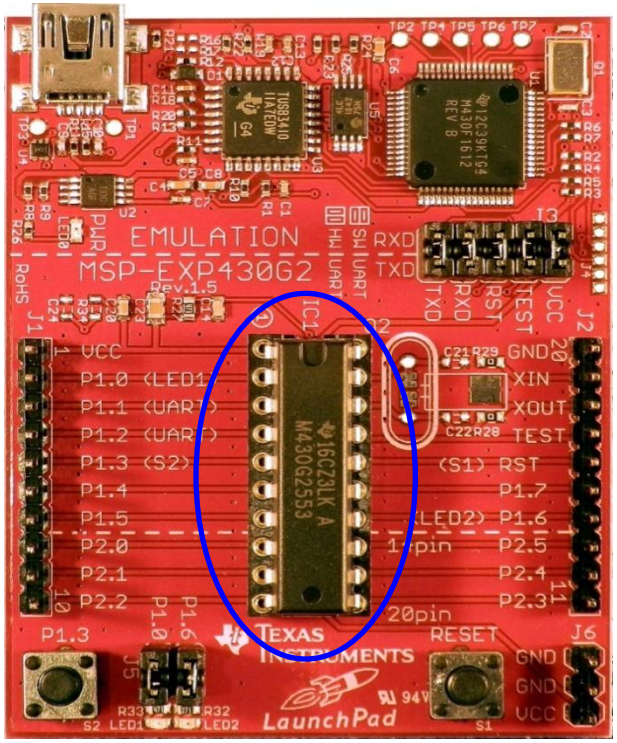
# Value Line 外设


- **通用I/O**
  - 独立可编程
  - 可以对输出，输入以及中断（触发边沿选择）进行控制
  - 所有寻址指令均可对端口控制寄存器进行读/写访问
  - 每个I/O都有一个可独立编程的上拉/下拉电阻
  - 触摸按键模块(PinOsc, CapTouch)
- **16-位 Timer_A3**
  - 3 捕获/比较寄存器
  - 丰富的中断功能
- **WDT+ 看门狗定时器**
  - 同时也可用作普通定时器
- **欠压复位（Brownout Reset）**
  - 在上电和断电时提供准确的复位信号
  - 功耗包括在基本功耗（最低功耗LPM4）的电流计算中

# Value Line 外设

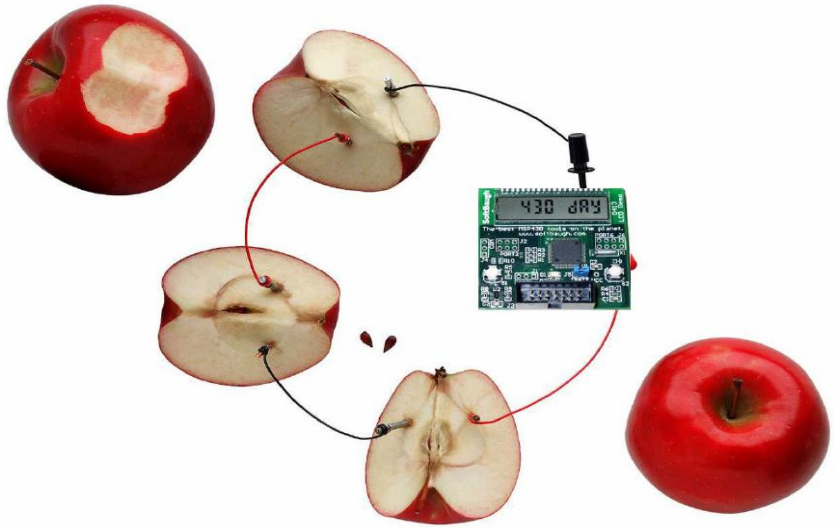

- **串行通讯**
  - USCI支持I2C，SPI及UART（G2553，自动波特率检测）
  - USI支持I2C，SPI
- **比较器_A+**
  - 反相或同相输入
  - 可选的RC输出滤波器
  - 可直接输出至Timer_A2捕获输入
  - 中断支持
- **8通道/10位 200ksps SAR ADC**
  - 8个外部通道
  - 内置电压和温度传感器通道
  - 参考电压可编程控制
  - DTC模块
  - 中断支持

# MSP-EXP430G2 LaunchPad




**MSP430G2553**

- Value Line
  - 16-bit performance@ 8-bit price
- Mixed Signal Processor
  - Ultra low power

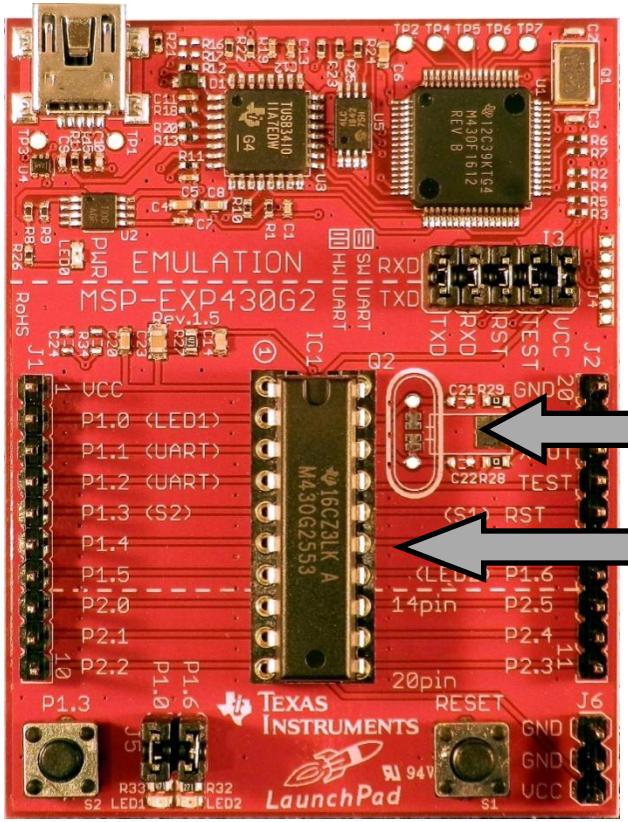


TEXAS INSTRUMENTS

# LaunchPad Development Board


**USB仿真连接**

**提供板上电源**




**片上仿真器模块**

**6-pin eZ430 Connector**

**Crystal Pads**

**Part and Socket**

**Chip Pinouts**

不同型号的G2系列
PinPin兼容

**P1.3 Button**

**Power Connector**

可进行板上电流测量

**LEDs and Jumpers**

**P1.0 & P1.6**

**Reset Button**

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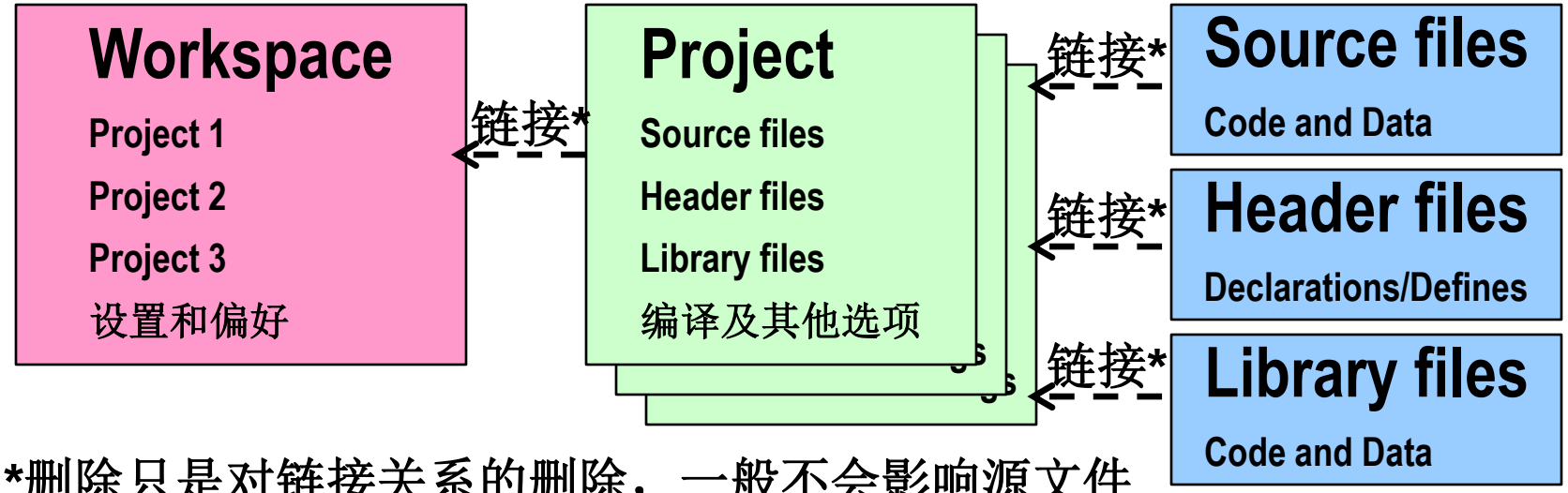
- 串行通信
- Grace
- Capacitive Touch Solution

# What is Code Composer Studio?


- 用于TI嵌入式处理器的集成型开发环境（IDE）
  - 包括 debugger, compiler, editor, simulator, OS…
  - 该环境基于Eclipse 开源软件框架
  - TI对其扩展，支持全系列的TI嵌入式控制器（430，DSP，ARM，OMAP…）
- 目前软件版本——CCS v5
- 集成更多的工具
  - 操作系统应用程序开发(Linux, Android…)
  - 代码分析，源控制…
- 即将支持Linux

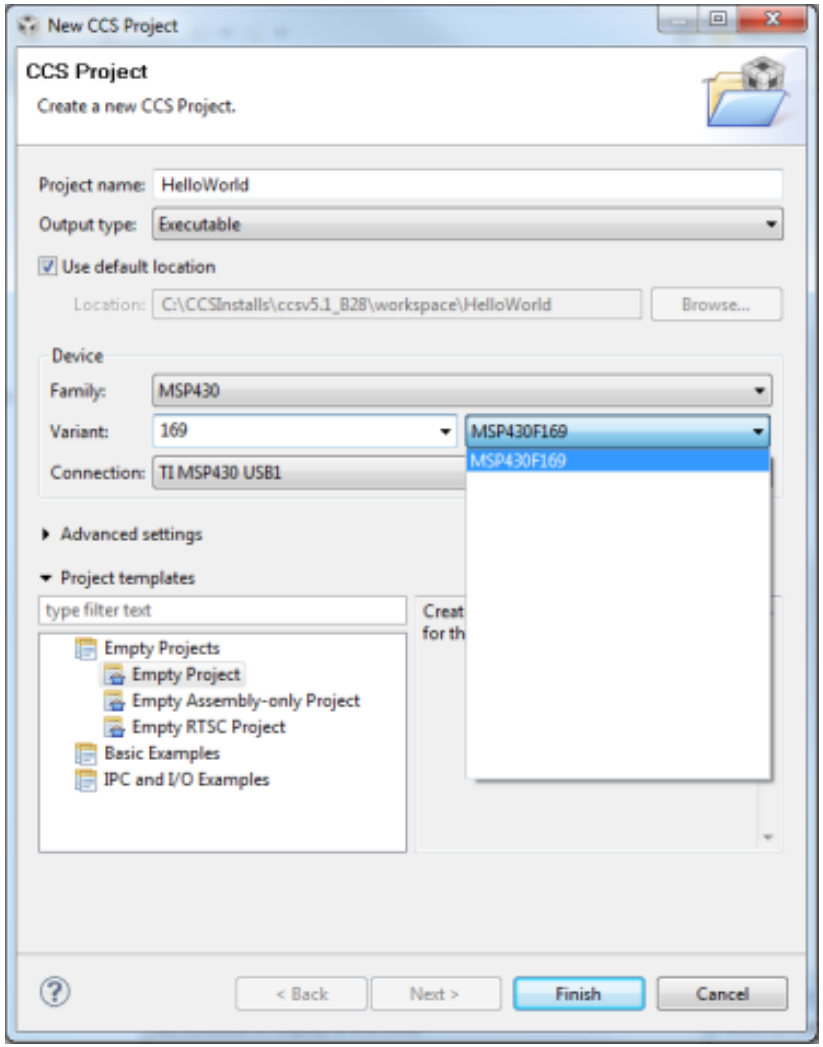
# 常用任务


- 创建新Projects
  - 提供创建新 project的模板，简单易用
- –Build选项
  - 通过Build选项菜单对工程的编译环境进行配置
- –Debug调试
  - 提供断点，单步等调试工具




*删除只是对链接关系的删除，一般不会影响源文件

# Project 创建向导



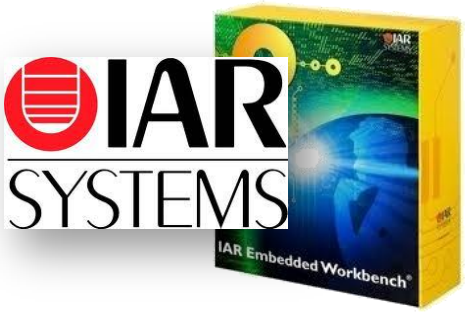

- 一步完成工程的创建，满足大多数情况的需求
  - 当NEXT按钮可用时，提醒需要进一步的选择
- 包括Debugger的设置
  - 在选择了芯片后，可以选择所用的连接方式，环境会自动生成一个 ccxml 文件，在后续可以在该文件中对配置进行修改
- 使用默认配置
  - 大多数情况下，使用默认配置可以满足要求。其余，如Compiler version, endianness… 在 advanced 中可进行配置

# Various IDE options


## Free Integrated Development Environments (IDE) available

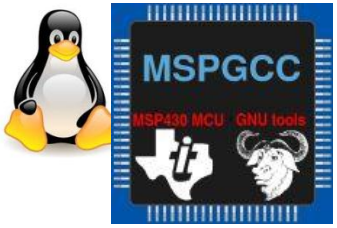

### Code Composer Studio

- Eclipse-based IDE (Compiler, debugger, linker, etc) for all TI embedded processors
- Unrestricted version available for $495
- Free versions are available!
  - Free 16kB code-limited version available for download
  - Free, full-featured, 120-day trial version available




### IAR Embedded Workbench

- Strong third-party IDE offering with project management tools and editor. Includes config files for all MSP430 devices.
- Free versions are available!
  - Free 4/8/16kB code-limited Kickstart version available for download
  - Free, full-featured, 30-day trial version available

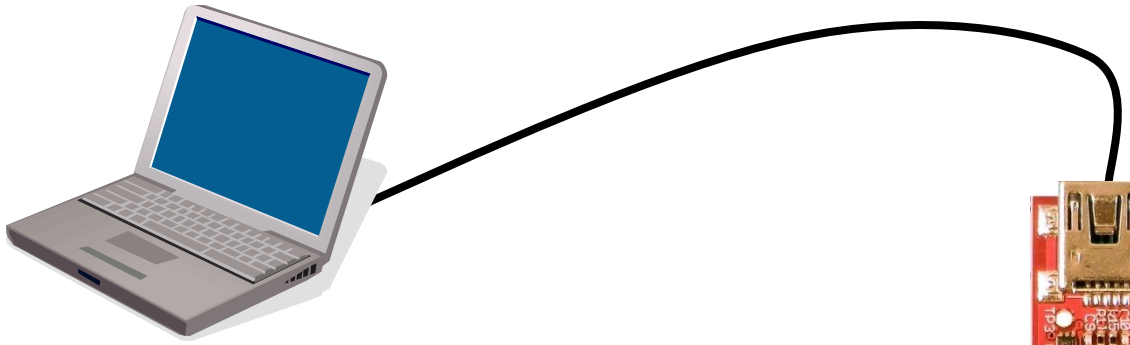


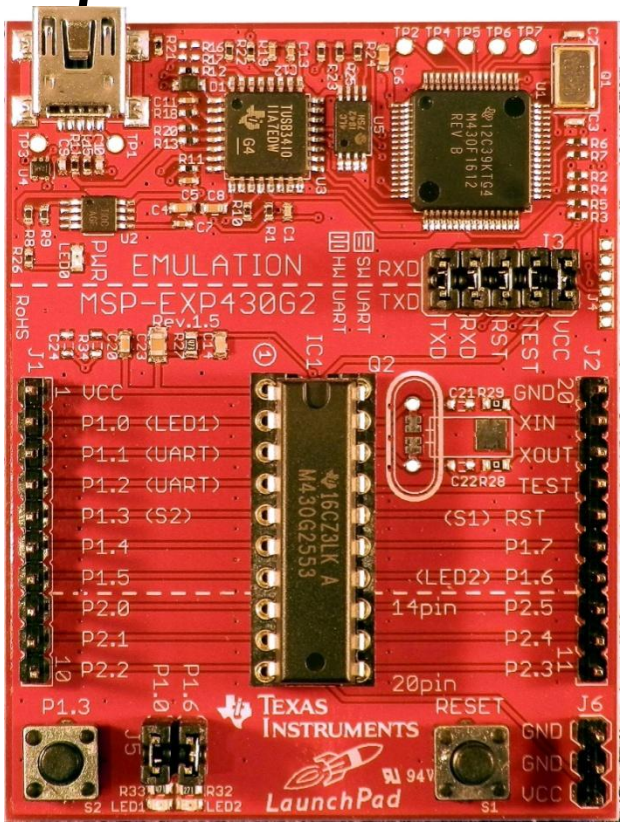

### MSPGCC

- Free, Open source, GCC tool chain for MSP430
- includes the GNU C compiler (GCC), the assembler and linker (binutils), the debugger (GDB)
- Tools can be used on Windows, Linux, BSD and most other flavors of Unix.
- Learn more @ http://mspgcc.sourceforge.net/

**Other MSP430 IDE options are available! Learn more @ www.ti.com/msp430tools**

# Lab1: Code Composer Studio



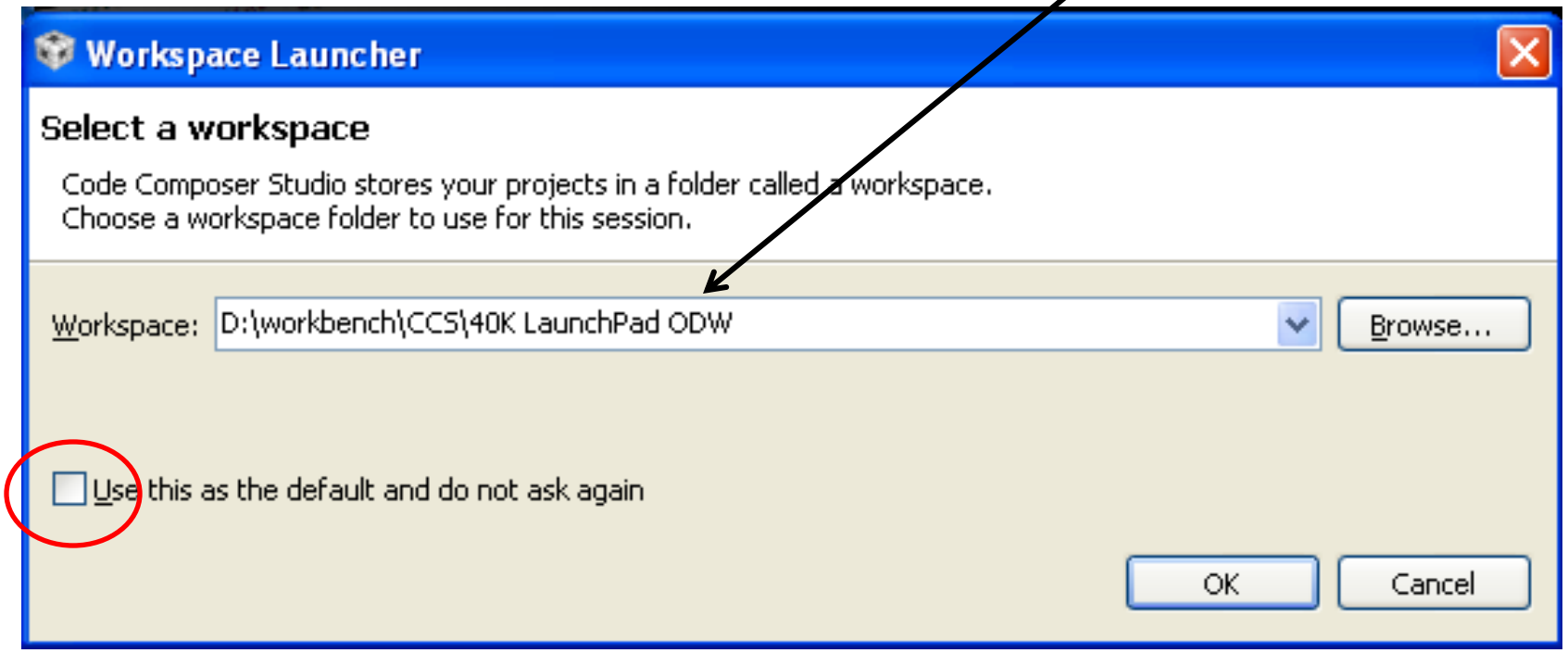



- **Lab1:**
  - **建立一个新的workspace**
  - **创建 Lab1 Project**
  - **在Project中添加.C文件**
  - **对Project进行编译与运行**

# Step 1: 新建 CCS workspace

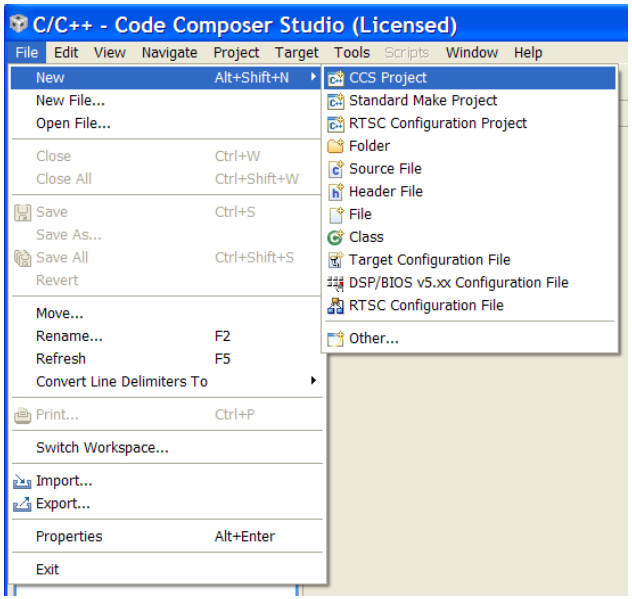
- 双击图标，启动 CCS v5 
- 若未选择默认路径，设置 “Workspace” 路径

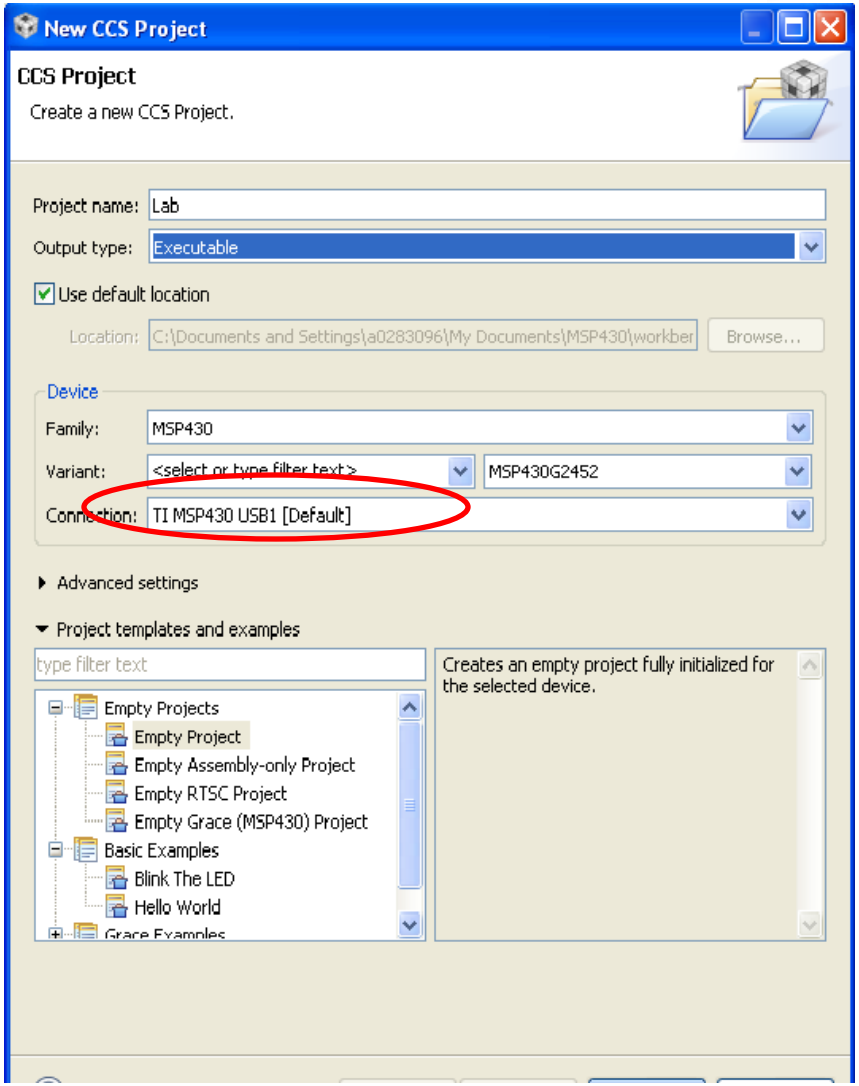
*尽量避免中文字符（桌面？）



# Step 2: 创建 a CCS Project

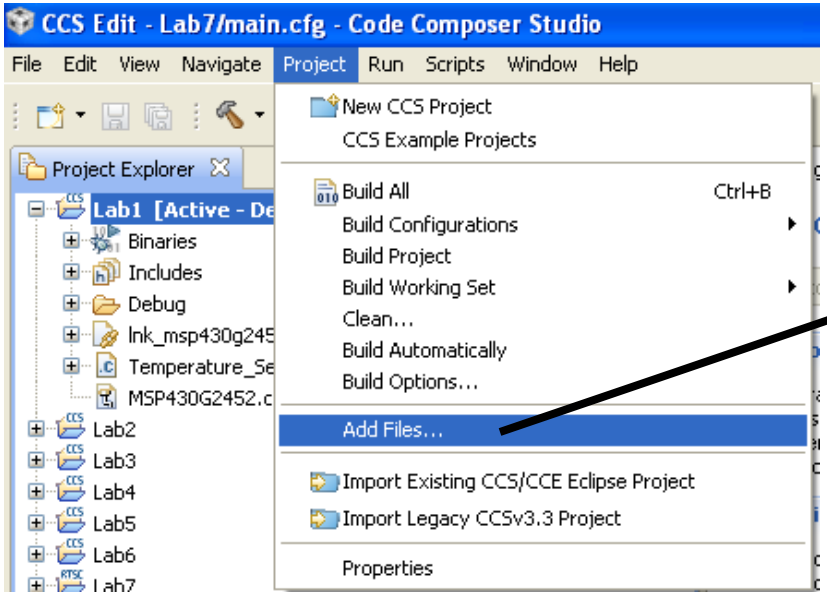
- File > New > CCS Project
- Project 名称: Lab1
- Device>Family: MSP430
- Variant: MSP430G2553
- Project templates and examples
  : Empty Project

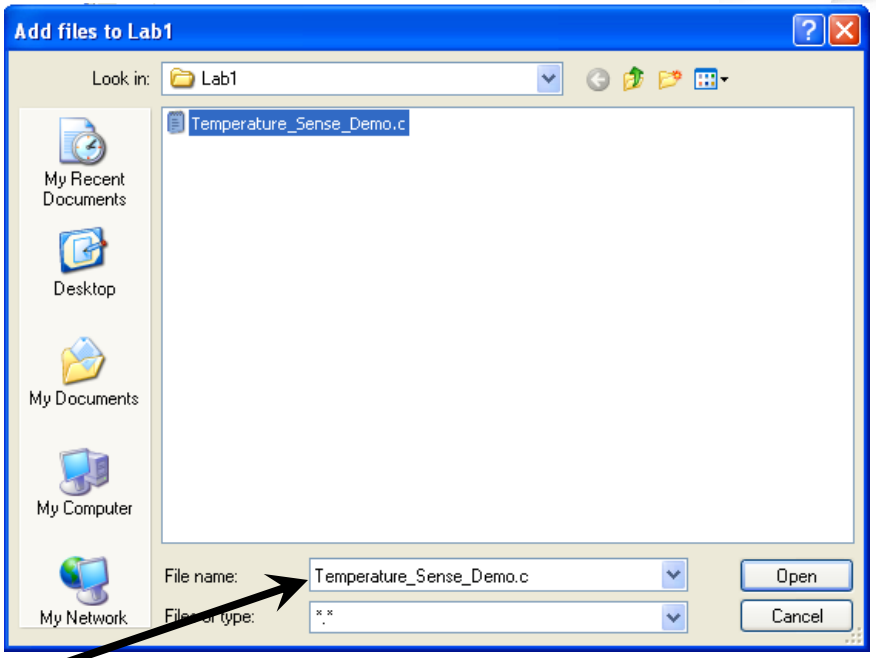


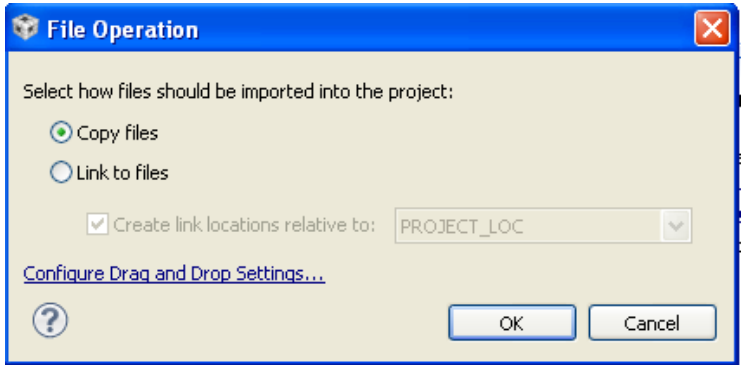



# Step 3: 在CCS Project中添加文件

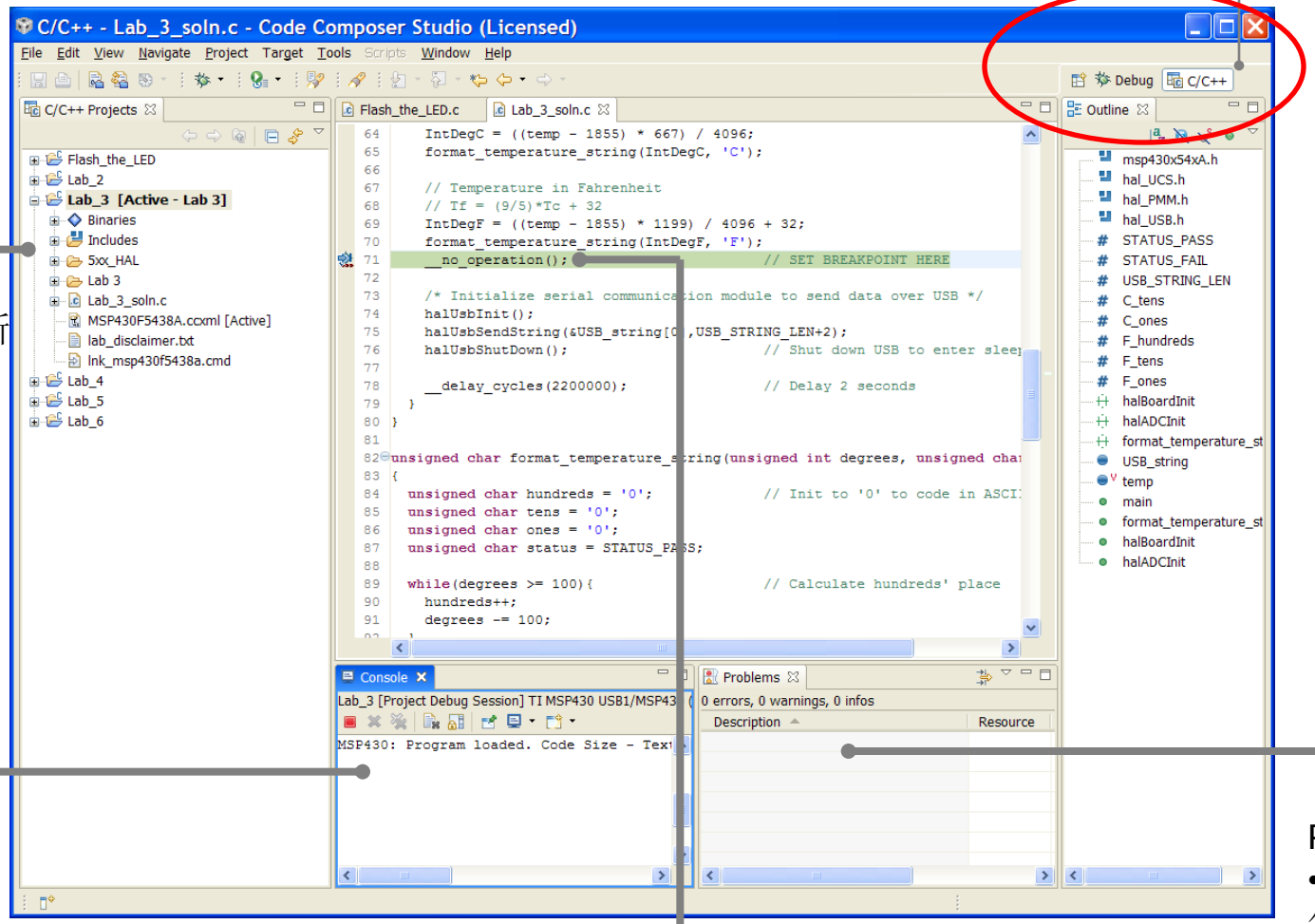
- Project > Add Files
- Navigate to Lab source folder
- And select : Temperature_Sense_Demo.c



# CCS 界面 – C/C++ Perspective Overview




显示当前所有Projects

Console
- 显示Build信息

Code Window

Problems View
- 显示Build结果，包括error，warning等

# CCS 界面 – Debug Perspective Overview


Debug界面

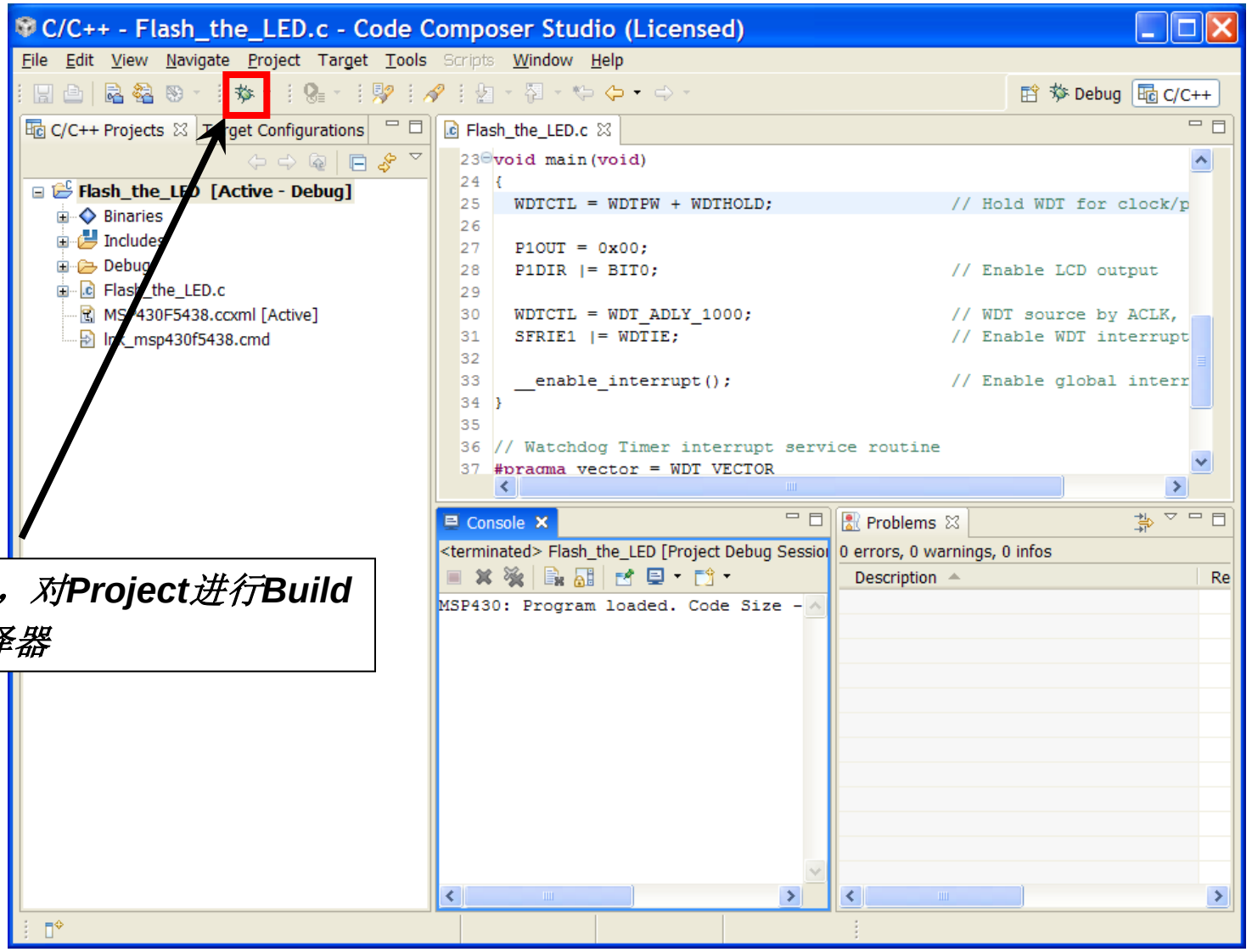
Target 控制
- Start
- Stop
- Halt
- Stepping
- Stack Trace

实时，430信息显示
- 寄存器值
- Flash, RAM, Info segment
- 汇编代码显示

程序大小信息CodeSize

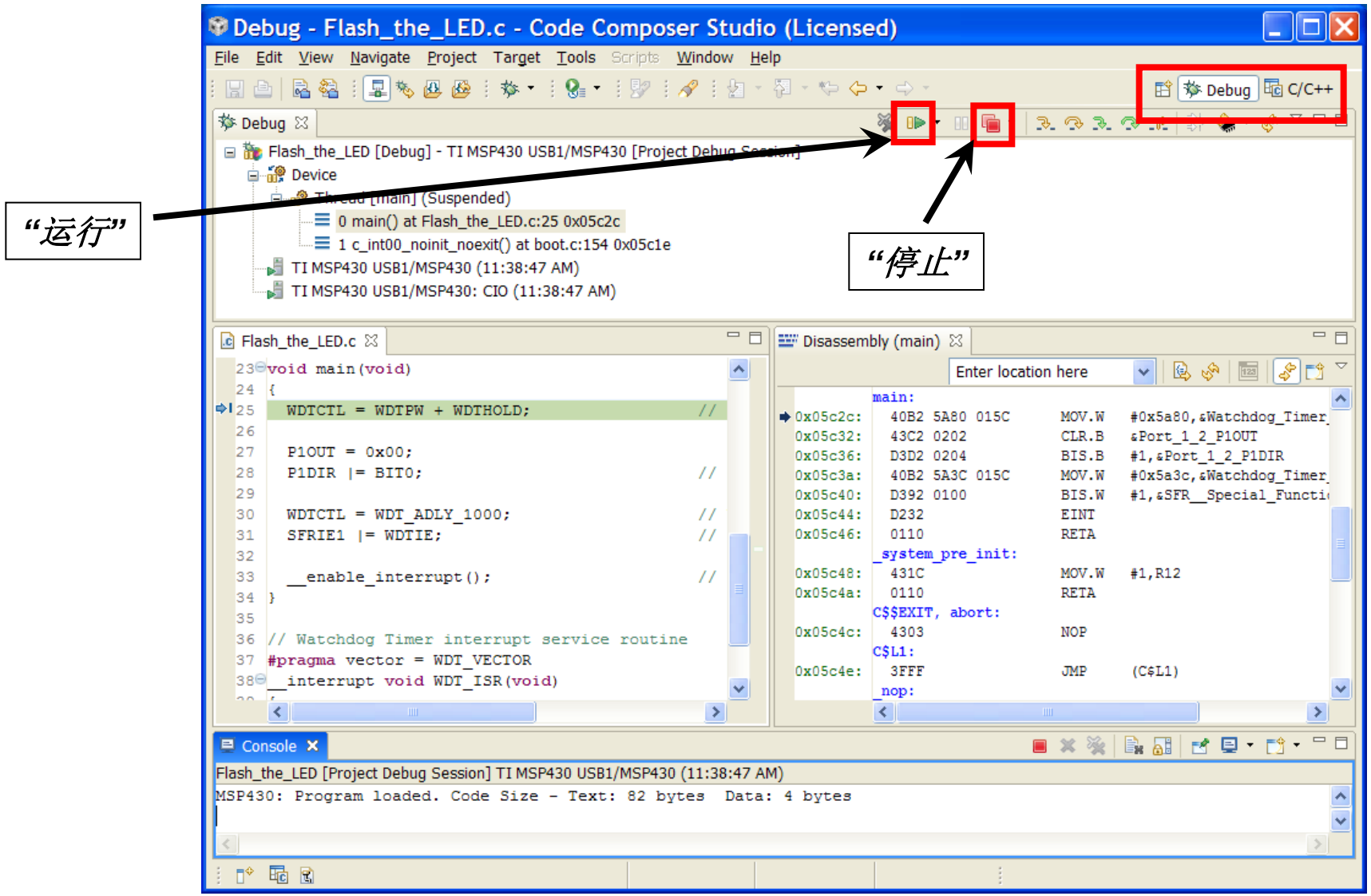
Code Window
- 实时断点，运行状况显示

# Step 4: Build & Debug a CCS Project

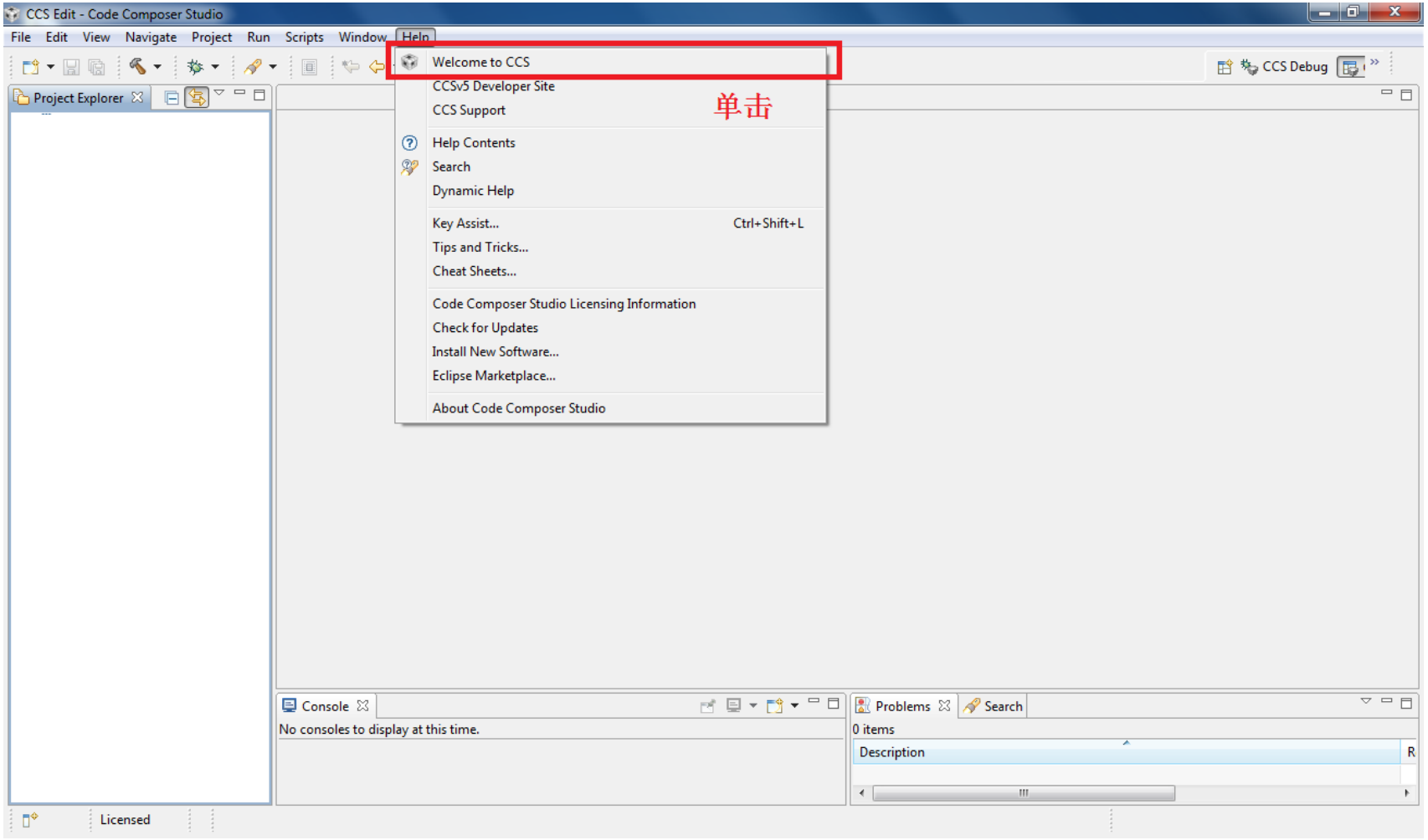



*单击“BUG”，对Project进行Build并连接到编译器*

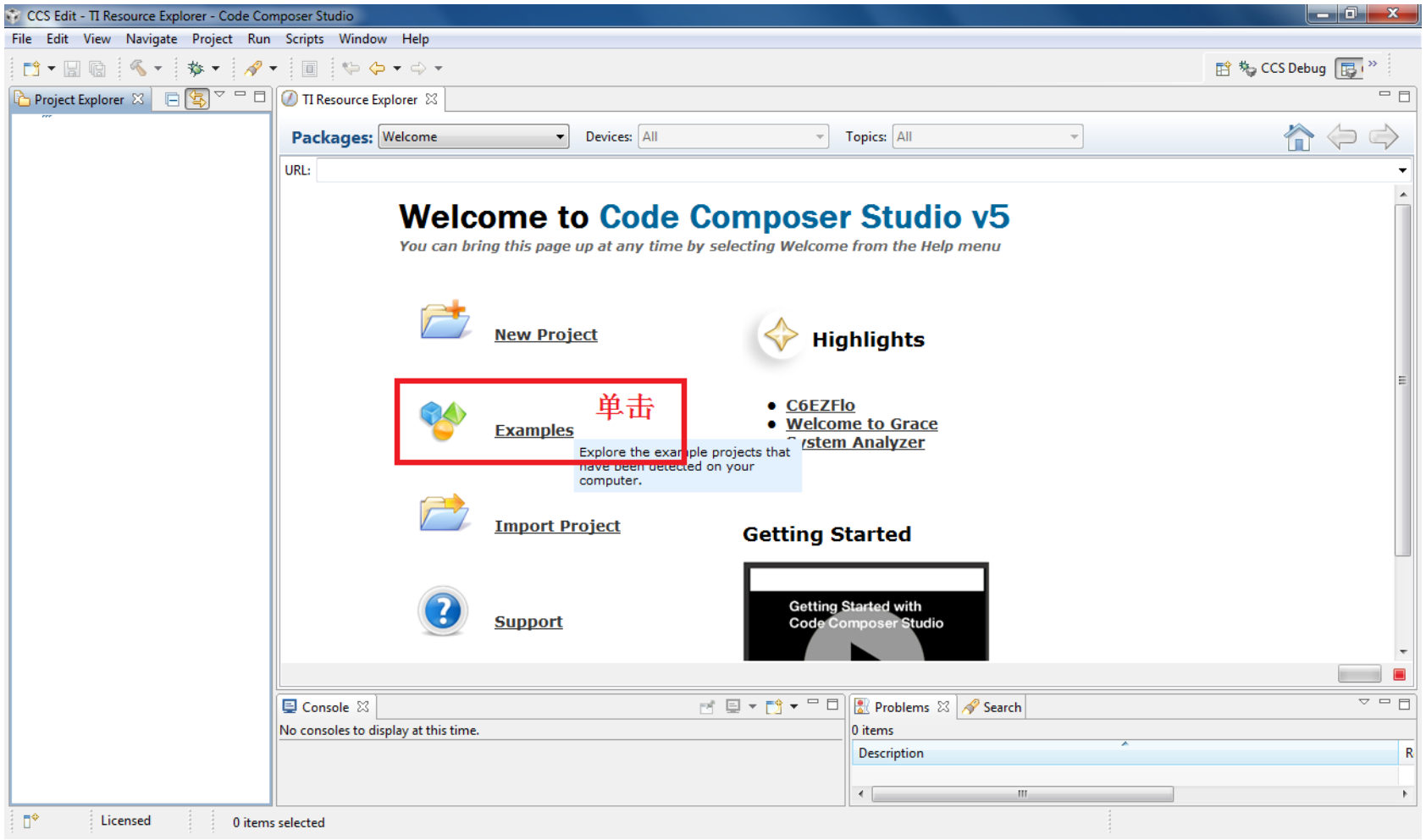
# Step 5: 运行，终止 CCS Project



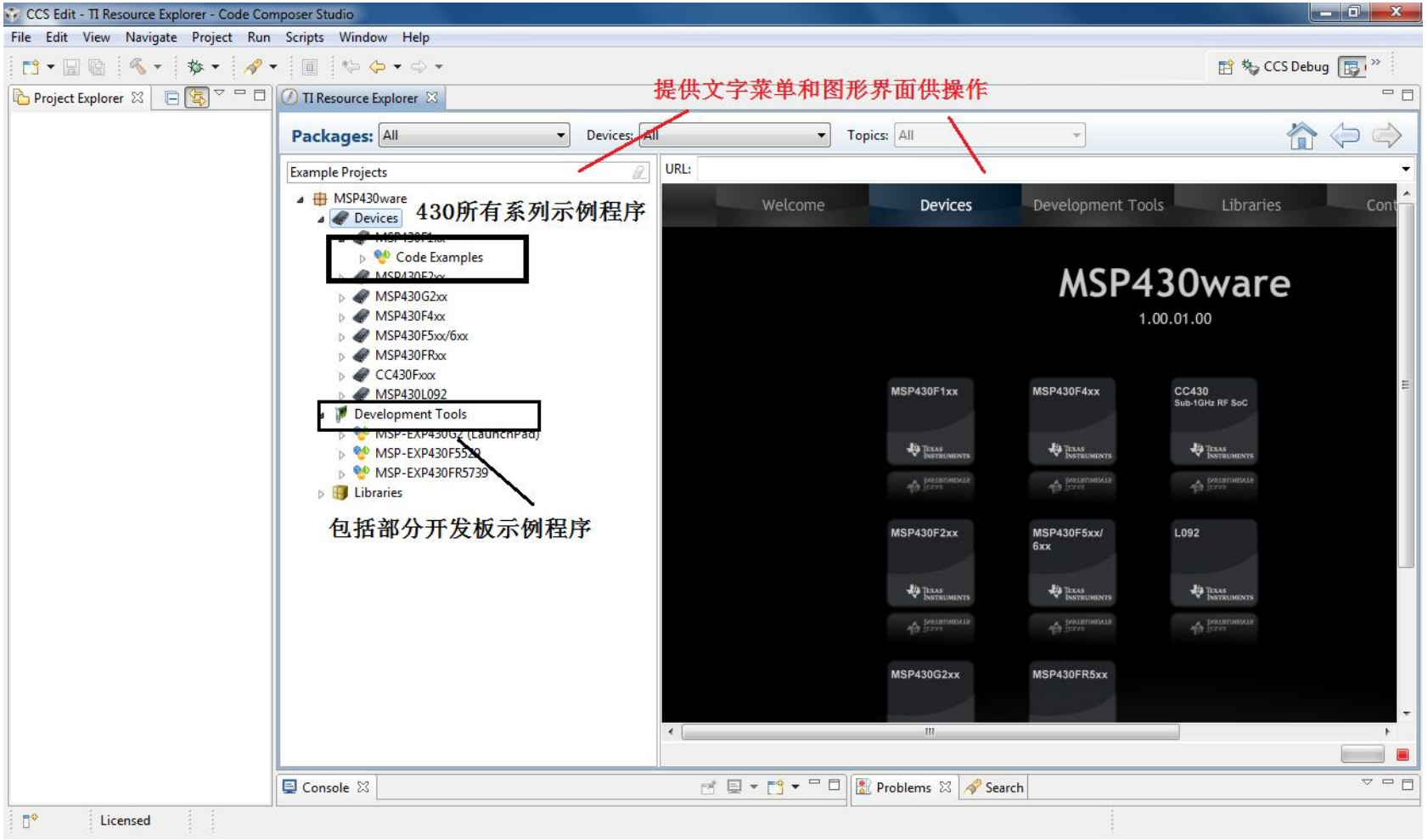
# 430Ware—快速程序开发工具



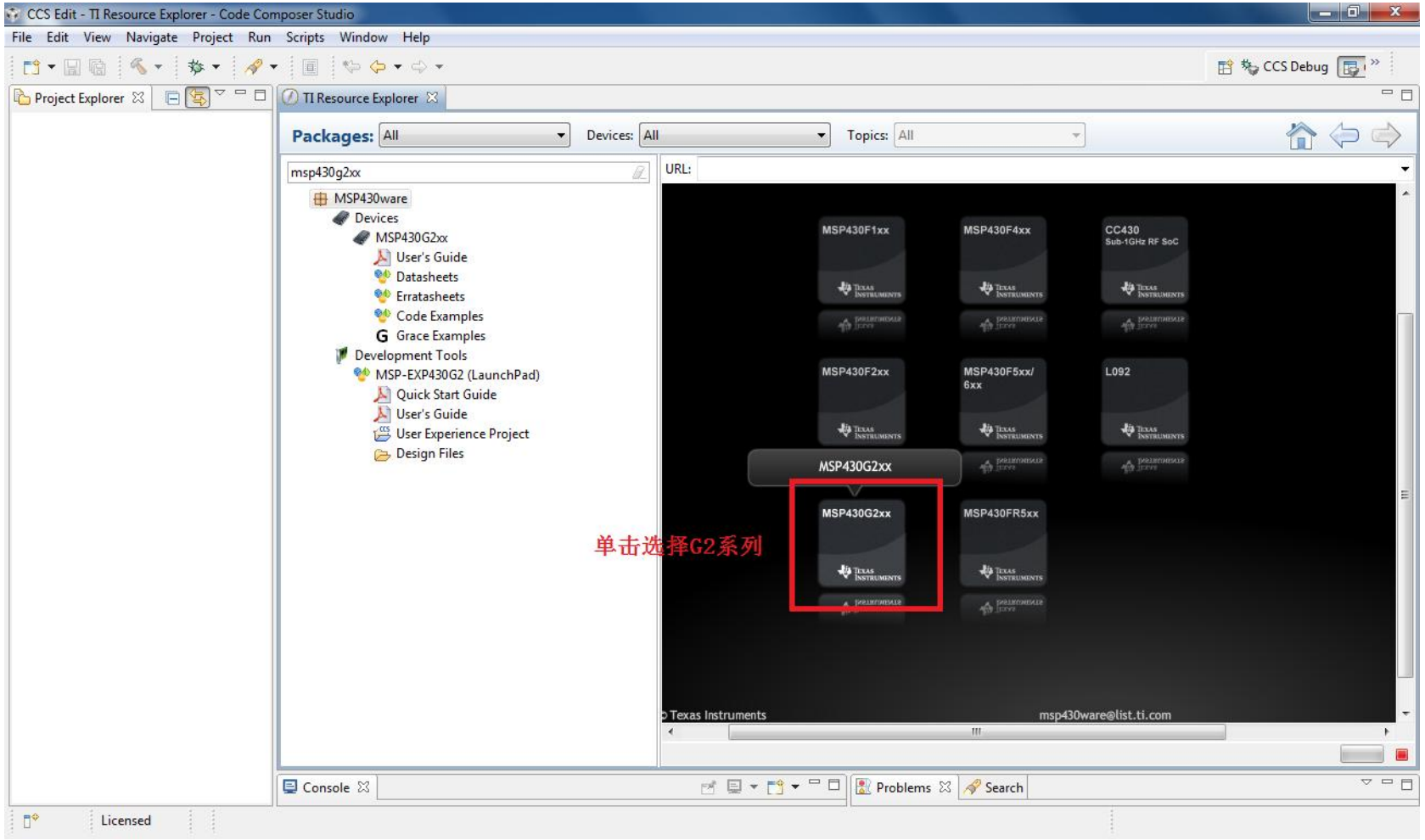
# 430Ware—快速程序开发工具



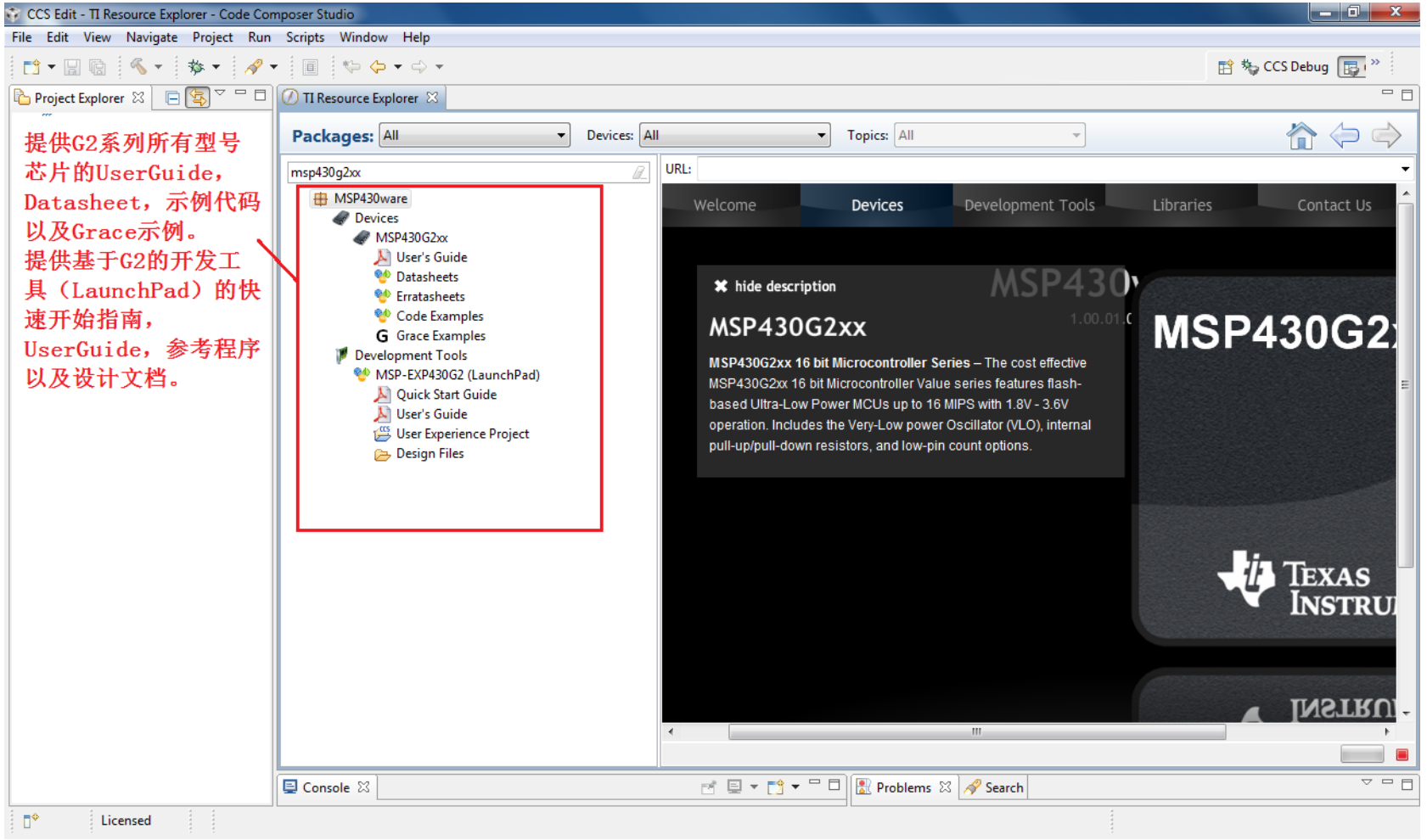
# 430Ware—快速程序开发工具



# 430Ware—快速程序开发工具



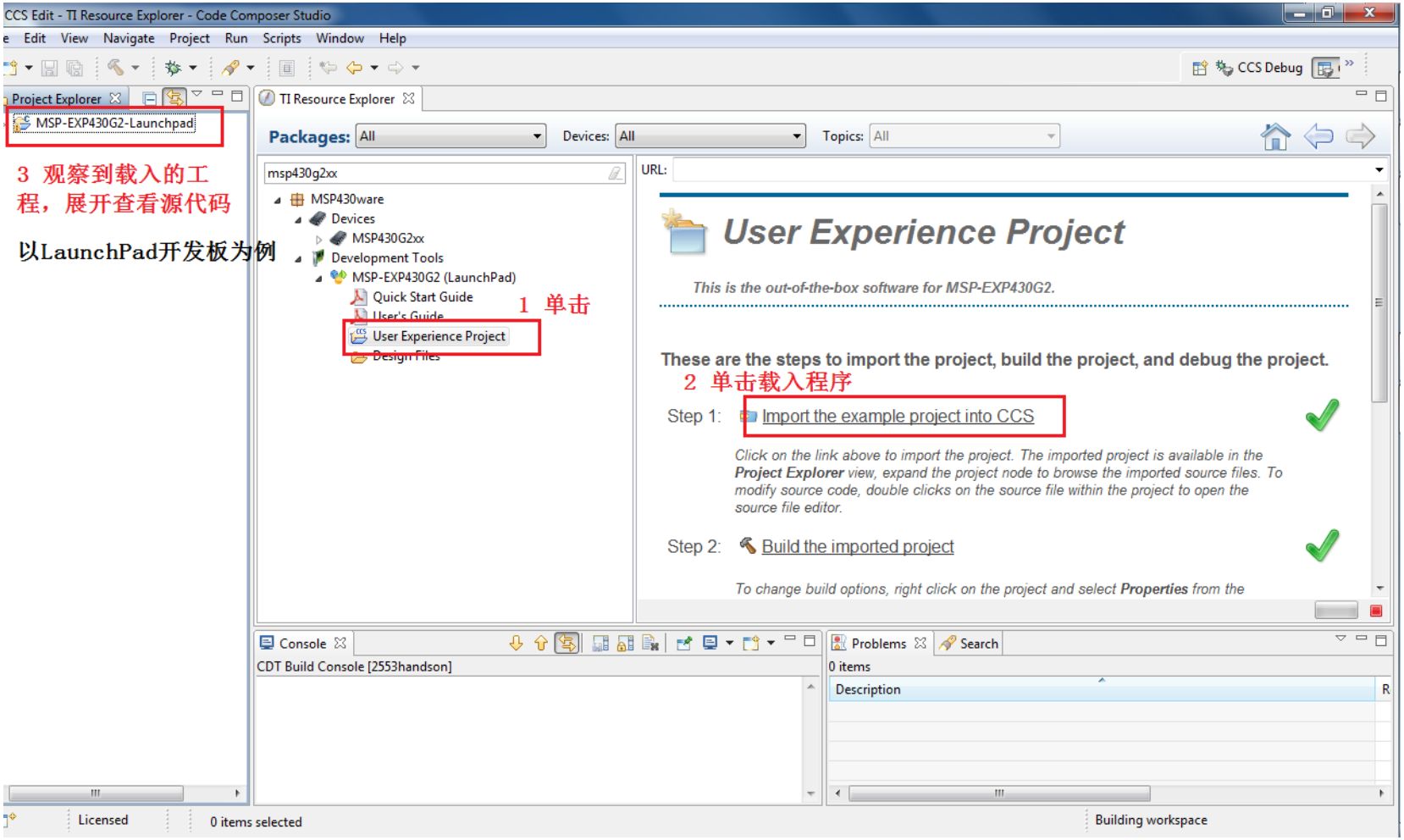
# 430Ware—快速程序开发工具




提供G2系列所有型号芯片的UserGuide，Datasheet，示例代码以及Grace示例。

提供基于G2的开发工具（LaunchPad）的快速开始指南，UserGuide，参考程序以及设计文档。

# 430Ware—快速程序开发工具



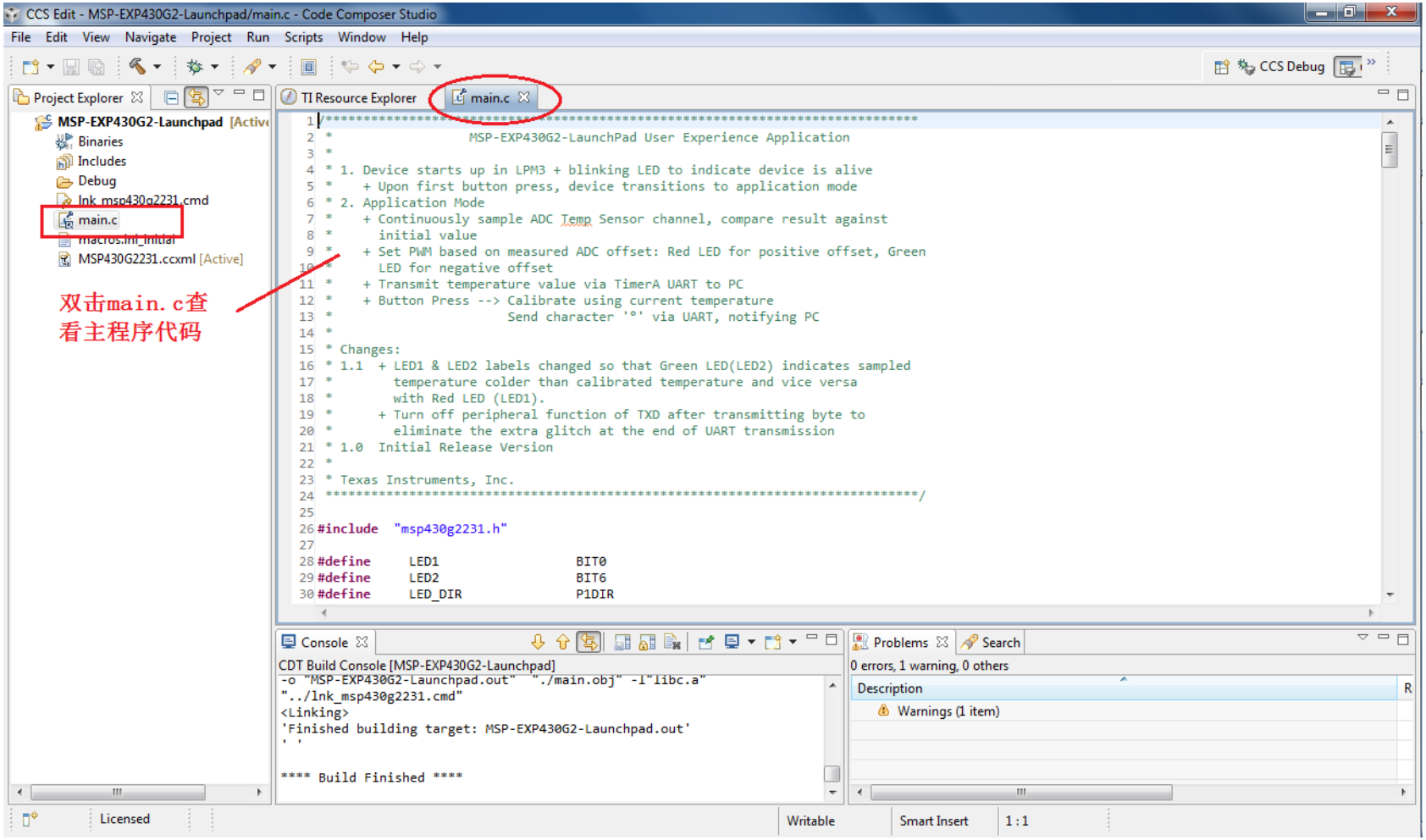

3 观察到载入的工程，展开查看源代码

以LaunchPad开发板为例

1 单击

2 单击载入程序

# 430Ware—快速程序开发工具



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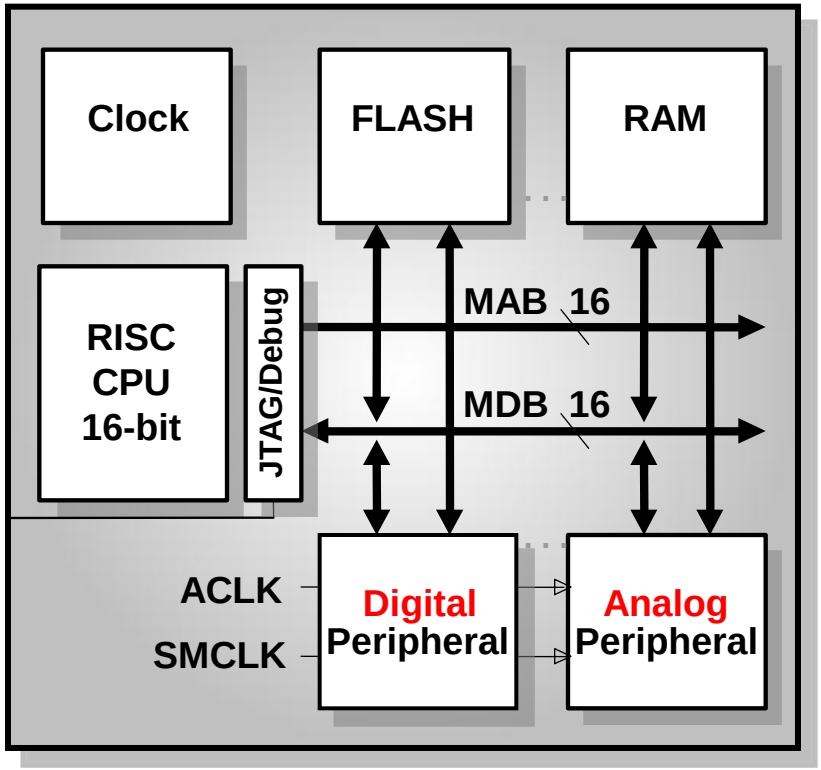
# MSP430G2xx 结构


## 超低功耗

- 0.1uA 断电模式
- 0.8uA 待机模式
- 220uA / 1MIPS
- <1us 时钟唤醒
- <50nA 端口漏电流
- 零功耗欠压复位(BOR)

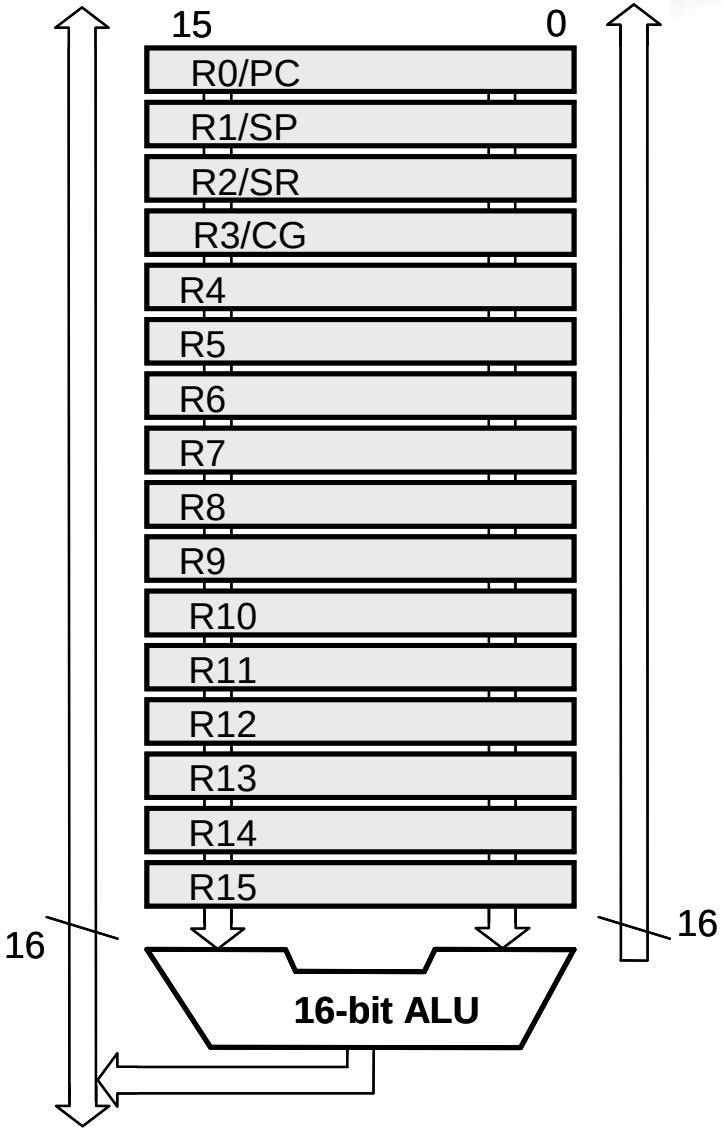
## 超灵活

- 0.5k-16kB 系统内可编程 (ISP) Flash
- 16-bit Timer
- SPI, I2C，UART
- 10bit ADC
- 嵌入式仿真



# 16-位 RISC CPU

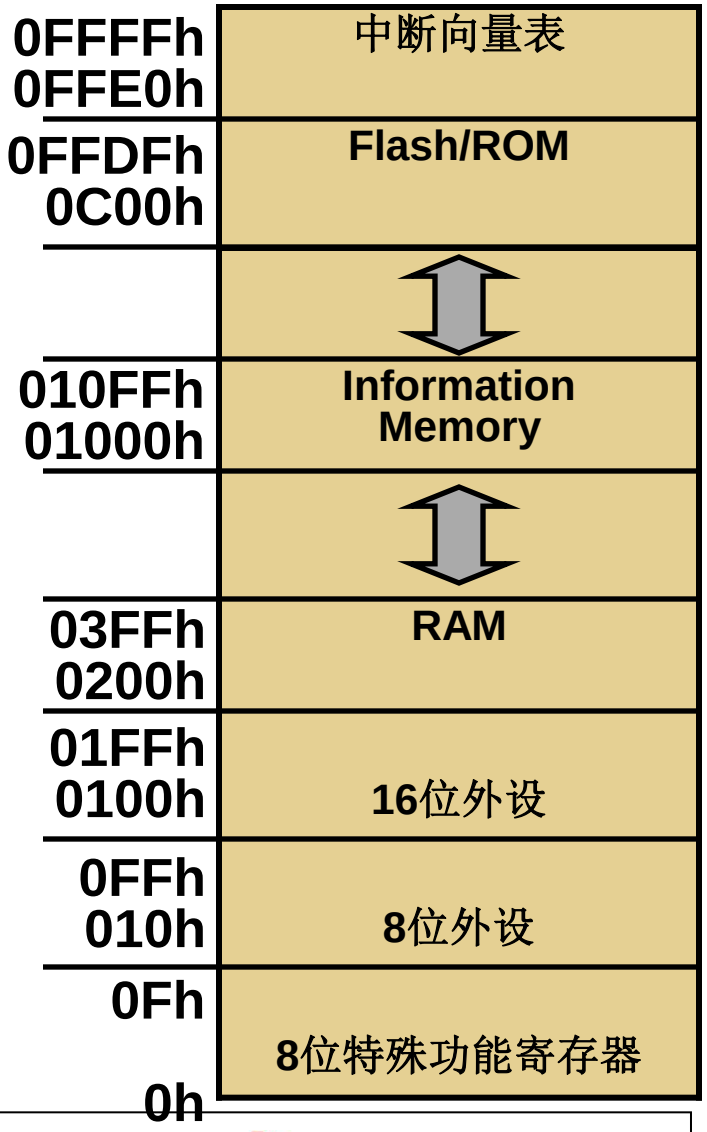
- **单周期寻址寄存器文件**
  - 4 专用寄存器
  - 12 通用寄存器
  - 无累加器瓶颈
- **RISC 架构**
  - 27 核心指令
  - 24 仿真指令
  - 7 寻址模式
- **Atomic 内存至内存寻址**
- **Bit, byte及word 处理**
- **常数发生器（CG，不占用程序空间）**



# 内存映射

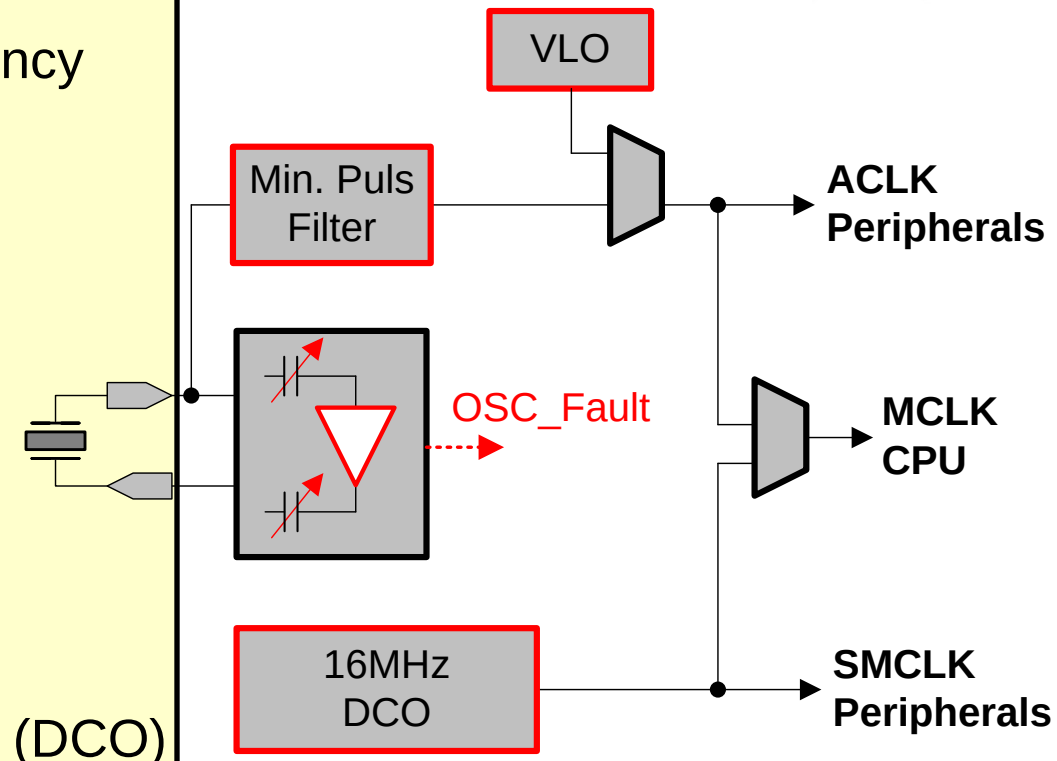

- 可通过JTAG或系统内（ISP）方式对闪存进行编程
- 编程电压低至 2.2V。单字节byte或单字Word编程
- **Main memory: 512 byte/segment (0-n).** 可分段擦除或全部擦除
- **Information memory: 64 byte/ segment(A-D)**
  - **Section A contains device-specific calibration data and is lockable**
- **Programmable Flash Memory Timing Generator**

G2553 shown



# 时钟系统

- Very Low Power/Low Frequency Oscillator (VLO)
  - 4 – 20kHz (典型值12kHz)
  - 500nA 待机流耗
  - 0.5%/° C and 4%/V 漂移
- 外接晶体振荡器(LFXT1)
  - 片内可编程电容
  - 故障保护 OSC_Fault
  - 脉冲滤波器
- Digitally Controlled Oscillator (DCO)
  - 0-to-16MHz
  - ± 3% 容差
  - 出厂校准（Flash I.M.）




上电后：

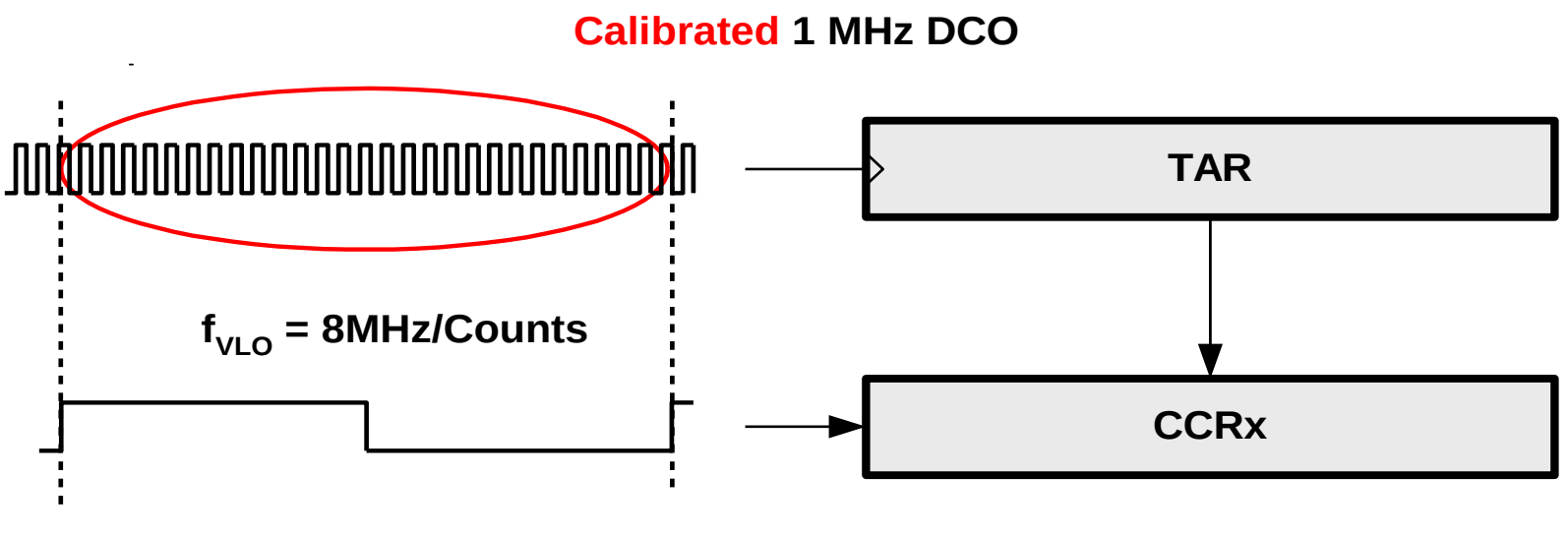
- MCLK 和 SMCLK 由 DCOCLK 提供（~1.1 MHz）
- ACLK 由 LFXT1CLK 提供（LF 模式，6pF内部负载电容）

# DCO校准


| DCO Calibration Data (provided from factory in flash info memory segment A) | | | |
|---|---|---|---|
| DCO Frequency | Calibration Register | Size | Address |
| 1 MHz | CALBC1_1MHz | byte | 010FFh |
| | CALDCO_1MHz | byte | 010FEh |
| 8 MHz | CALBC1_8MHz | byte | 010FDh |
| | CALDCO_8MHz | byte | 010FCh |
| 12 MHz | CALBC1_12MHz | byte | 010FBh |
| | CALDCO_12MHz | byte | 010FAh |
| 16 MHz | CALBC1_16MHz | byte | 010F9h |
| | CALDCO_16MHz | byte | 010F8h |

```
 // Setting the DCO to 1MHz
 if (CALBC1_1MHZ ==0xFF || CALDCO_1MHZ == 0xFF)
   while(1);                // Erased calibration data? Trap!
BCSCTL1 = CALBC1_1MHZ;      // Set range
DCOCTL  = CALDCO_1MHZ;      // Set DCO step + modulation
```

# VLO校准

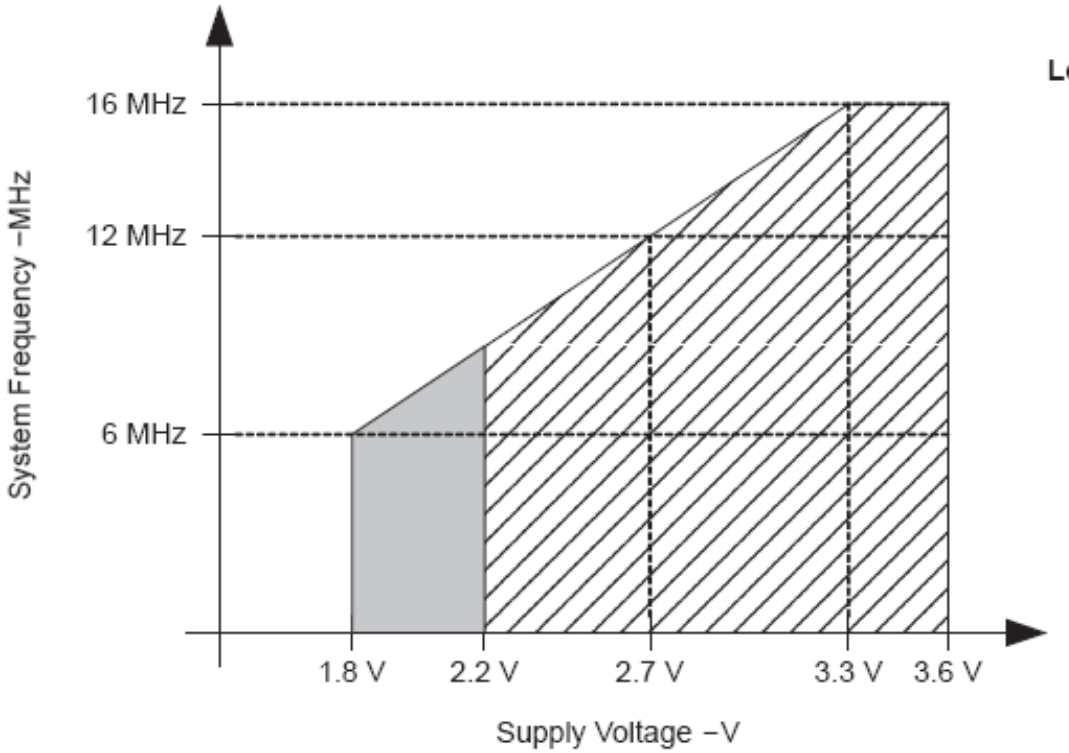



- 在运行期间对VLO进行校准

- 定时器 Timer_A 时钟源采用校准的1MHz DCO
- 采用由VLO提供的ACLK/8进行上升沿捕获
- $f_{VLO}$ = 8MHz/Counts

- *参考例程 (SLAA340)*

# 系统 MCLK & Vcc




**Legend:**

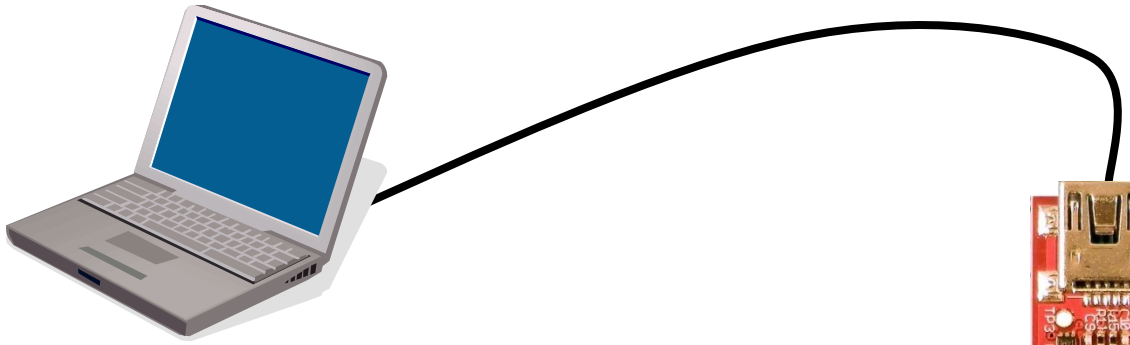
Supply voltage range, during flash memory programming

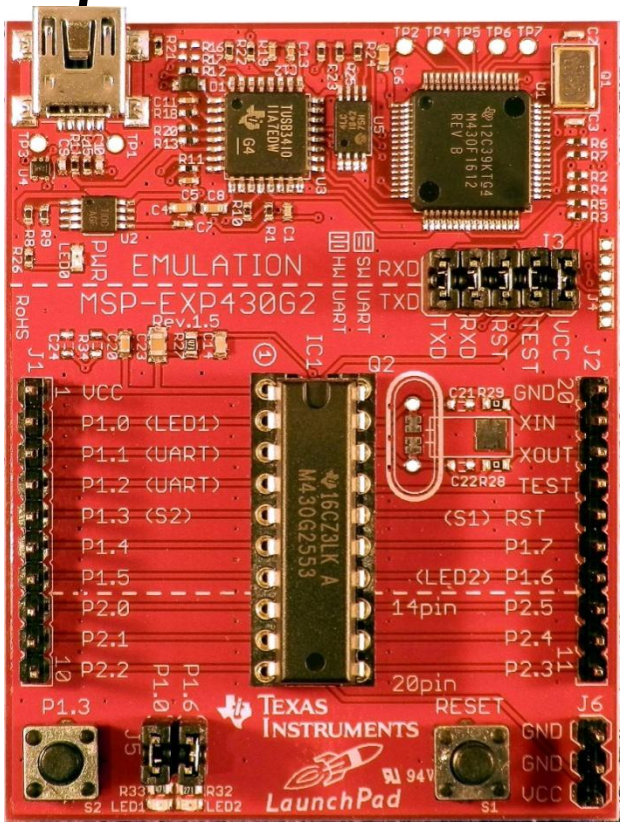
Supply voltage range, during program execution

**系统时钟是否越快越好？**

- **时钟速度的选取必须与VCC相匹配**
- **外部 LDO稳压器**
- **当VCC低于所选频率的最小工作电压时，系统工作状态不稳定**

# Lab2: 基本时钟配置






- **Lab2**
  - **Import Lab2 project to Workspace**
  - **Setup DCO = 1MHz**
  - **Use DCO/8 as  MCLK, LED Blink**
  - **Use VLO/8 as MCLK,  LED Blink**

# Lab 2:


```
// Configure Basic Clock
BCSCTL1 = _____; // Set range
DCOCTL = _____;// Set DCO step + modulation
BCSCTL3 |= LFXT1S_2;// Set LFXT1
```

```
// Configure MCLK
BCSCTL2 |= _____ + DIVM_3; // Set MCLK
```

# 基本时钟控制寄存器


### 5.3.3 BCSCTL2, Basic Clock System Control Register 2

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| SELMx | | DIVMx | | SELS | DIVSx | | DCOR(1)(2) |
| rw-0 | rw-0 | rw-0 | rw-0 | rw-0 | rw-0 | rw-0 | rw-0 |

**SELMx** Bits 7-6 Select MCLK. These bits select the MCLK source.

- 00 DCOCLK
- 01 DCOCLK
- 10 XT2CLK when XT2 oscillator present on-chip. LFXT1CLK or VLOCLK when XT2 oscillator not present on-chip.
- 11 LFXT1CLK or VLOCLK

**DIVMx** Bits 5-4 Divider for MCLK

- 00 /1
- 01 /2
- 10 /4
- 11 /8

**SELS** Bit 3 Select SMCLK. This bit selects the SMCLK source.

- 0 DCOCLK
- 1 XT2CLK when XT2 oscillator present. LFXT1CLK or VLOCLK when XT2 oscillator not present

**DIVSx** Bits 2-1 Divider for SMCLK

- 00 /1
- 01 /2
- 10 /4
- 11 /8

**DCOR** Bit 0 DCO resistor select. Not available in all devices. See the device-specific data sheet.

- 0 Internal resistor
- 1 External resistor

# Lab 2:


```
// Configure Basic Clock
BCSCTL1 = CALBC1_1MHZ; // Set range
DCOCTL = CALDCO_1MHZ;// Set DCO step + modulation
BCSCTL3 |= LFXT1S_2;// Set LFXT1
```

```
// Configure MCLK
BCSCTL2 |= SELM_1 + DIVM_3; // Set MCLK
```

对MCLK，即指令运行的时钟源进行分频

DIVM_0： MCLK=1M

DIVM_1： MCLK=1M/2

DIVM_2： MCLK=1M/4

DIVM_3： MCLK=1M/8

# 在CCS中可以对头文件定义进行查看


Temperature_Sense_Demo.c | Lab2.c | Lab3.c | Lab4.c | Lab4_1.c | msp430g2452.h

```
262 #define DIVA_2                  (0x20)          /* ACLK Divider 2: /4 */
263 #define DIVA_3                  (0x30)          /* ACLK Divider 3: /8 */
264
265 #define DIVS0                   (0x02)          /* SMCLK Divider 0 */
266 #define DIVS1                   (0x04)          /* SMCLK Divider 1 */
267 #define SELS                    (0x08)          /* SMCLK Source Select 0:DCOCLK / 1:XT2CLK/LFXTCLK */
268 #define DIVM0                   (0x10)          /* MCLK Divider 0 */
269 #define DIVM1                   (0x20)          /* MCLK Divider 1 */
270 #define SELM0                   (0x40)          /* MCLK Source Select 0 */
271 #define SELM1                   (0x80)          /* MCLK Source Select 1 */
272
273 #define DIVS_0                  (0x00)          /* SMCLK Divider 0: /1 */
274 #define DIVS_1                  (0x02)          /* SMCLK Divider 1: /2 */
275 #define DIVS_2                  (0x04)          /* SMCLK Divider 2: /4 */
276 #define DIVS_3                  (0x06)          /* SMCLK Divider 3: /8 */
277
278 #define DIVM_0                  (0x00)          /* MCLK Divider 0: /1 */
279 #define DIVM_1                  (0x10)          /* MCLK Divider 1: /2 */
280 #define DIVM_2                  (0x20)          /* MCLK Divider 2: /4 */
281 #define DIVM_3                  (0x30)          /* MCLK Divider 3: /8 */
282
283 #define SELM_0                  (0x00)          /* MCLK Source Select 0: DCOCLK */
284 #define SELM_1                  (0x40)          /* MCLK Source Select 1: DCOCLK */
285 #define SELM_2                  (0x80)          /* MCLK Source Select 2: XT2CLK/LFXTCLK */
286 #define SELM_3                  (0xC0)          /* MCLK Source Select 3: LFXTCLK */
287
```

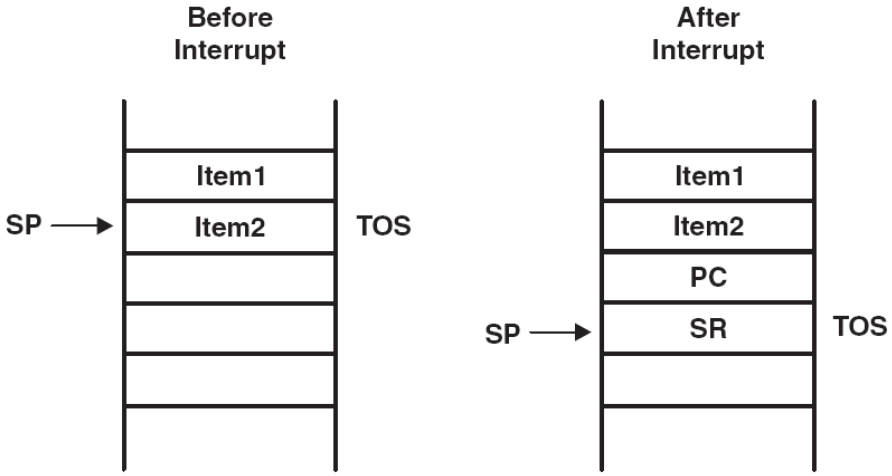
# Agenda


- Value Line 简介
- Code Composer Studio
- CPU及基本时钟系统
- 中断及通用IO
- 定时器及增强型WDT
- 低功耗优化设计
- ADC10 及 Comparator_A+
- 串行通信
- Grace
- Capacitive Touch Solution

# 中断和堆栈


进入堆栈后

- 完成当前正在执行的指令；指向下一条指令的PC压栈
- 状态寄存器 SR 压栈；选择高优先级别的中断
- 中断请求标志复位
  - 若为单中断源，则自动复位
  - 若为多中断源，则保持置位状态，由软件控制
- SR清零：终止任何低功耗模式; 由于GIE清零，禁止执行更多的中断
- PC指向中断服务子程序， 执行相应的子程序



# 中断向量表


| INTERRUPT SOURCE | INTERRUPT FLAG | SYSTEM INTERRUPT | WORD ADDRESS | PRIORITY |
|---|---|---|---|---|
| Power-Up<br>External Reset<br>Watchdog Timer+<br>Flash key violation<br>PC out-of-range(1) | PORIFG<br>RSTIFG<br>WDTIFG<br>KEYV(2) | Reset | 0FFFEh | 31, highest |
| NMI<br>Oscillator fault<br>Flash memory access violation | NMIIFG<br>OFIFG<br>ACCVIFG(2)(3) | (non)-maskable<br>(non)-maskable<br>(non)-maskable | 0FFFCh | 30 |
| Timer1_A3 | TA1CCR0 CCIFG(4) | maskable | 0FFFAh | 29 |
| Timer1_A3 | TA1CCR2 TA1CCR1 CCIFG,<br>TAIFG(2)(4) | maskable | 0FFF8h | 28 |
| Comparator_A+ | CAIFG(4) | maskable | 0FFF6h | 27 |
| Watchdog Timer+ | WDTIFG | maskable | 0FFF4h | 26 |
| Timer0_A3 | TA0CCR0 CCIFG(4) | maskable | 0FFF2h | 25 |
| Timer0_A3 | TA0CCR2 TA0CCR1 CCIFG, TAIFG<br>(5)(4) | maskable | 0FFF0h | 24 |
| USCI_A0/USCI_B0 receive<br>USCI_B0 I2C status | UCA0RXIFG, UCB0RXIFG(2)(5) | maskable | 0FFEEh | 23 |
| USCI_A0/USCI_B0 transmit<br>USCI_B0 I2C receive/transmit | UCA0TXIFG, UCB0TXIFG(2)(6) | maskable | 0FFECh | 22 |
| ADC10<br>(MSP430G2x53 only) | ADC10IFG(4) | maskable | 0FFEAh | 21 |
| | | | 0FFE8h | 20 |
| I/O Port P2 (up to eight flags) | P2IFG.0 to P2IFG.7(2)(4) | maskable | 0FFE6h | 19 |
| I/O Port P1 (up to eight flags) | P1IFG.0 to P1IFG.7(2)(4) | maskable | 0FFE4h | 18 |
| | | | 0FFE2h | 17 |
| | | | 0FFE0h | 16 |
| See (7) | | | 0FFDEh | 15 |
| See (8) | | | 0FFDEh to<br>0FFC0h | 14 to 0, lowest |

# 中断处理函数（ISR）编程

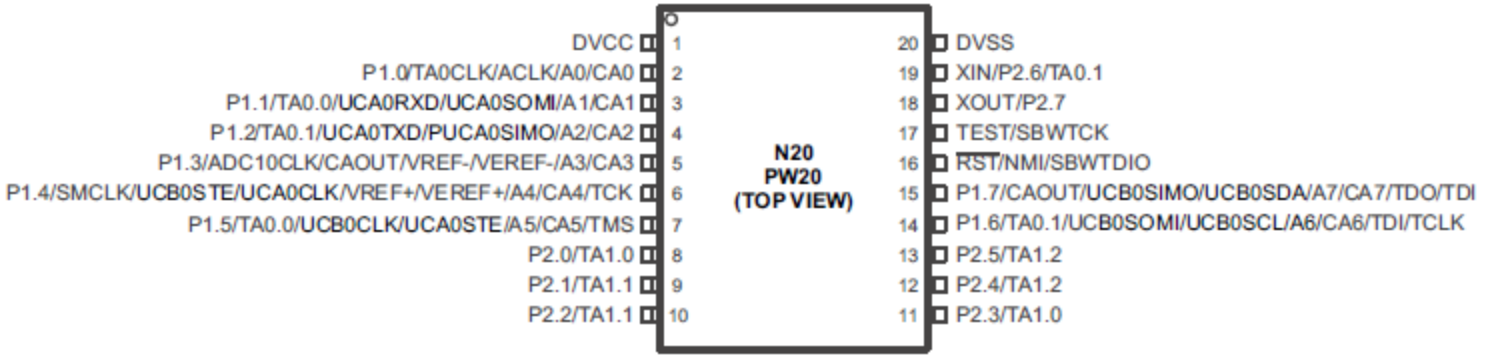

```
#pragma vector=WDT_VECTOR
__interrupt void WDT_ISR(void)
{
    IE1 &= ~WDTIE;                  // disable interrupt
    IFG1 &= ~WDTIFG;                // clear interrupt flag
    WDTCTL = WDTPW + WDTHOLD;       // put WDT back in hold state
    BUTTON_IE |= BUTTON;            // Debouncing complete
}
```

**#pragma vector** - 下面的函数是用于所列适量的ISR

**_interrupt void** – 定义ISR名称

一般而言不需要特定的返回值

# GPIO端口




## GPIO Register

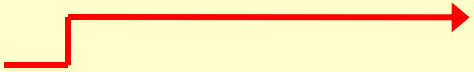
- Input Register PxIN
- Output Register PxOUT
- Direction Register PxDIR
- Function Select PxREN
- Function Select PxSEL
- Function Select PxSEL2
- Interrupt Edge PxIES
- Interrupt Enable PxIE
- Interrupt Flags PxIFG

用于GPIO中断

## GPIO Code Example

```
P1DIR |= BIT4;
P1SEL |= BIT4;
```

```
P1DIR |= BIT0;
P1OUT |= BIT0;
```



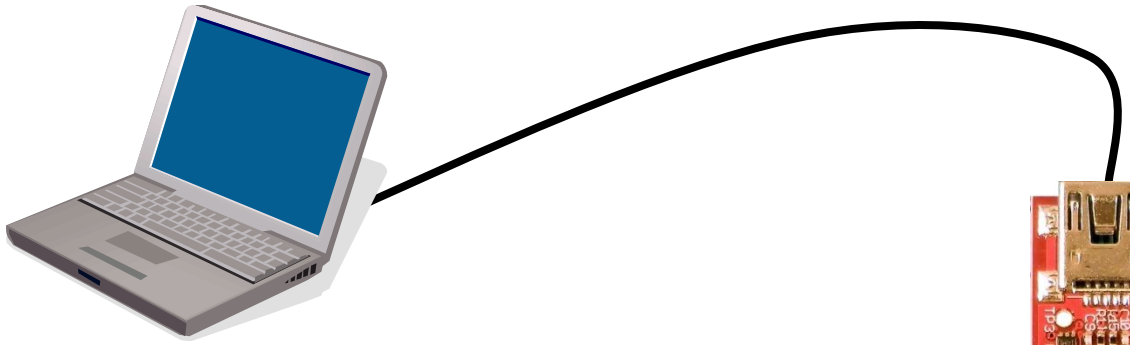
# 引脚复用

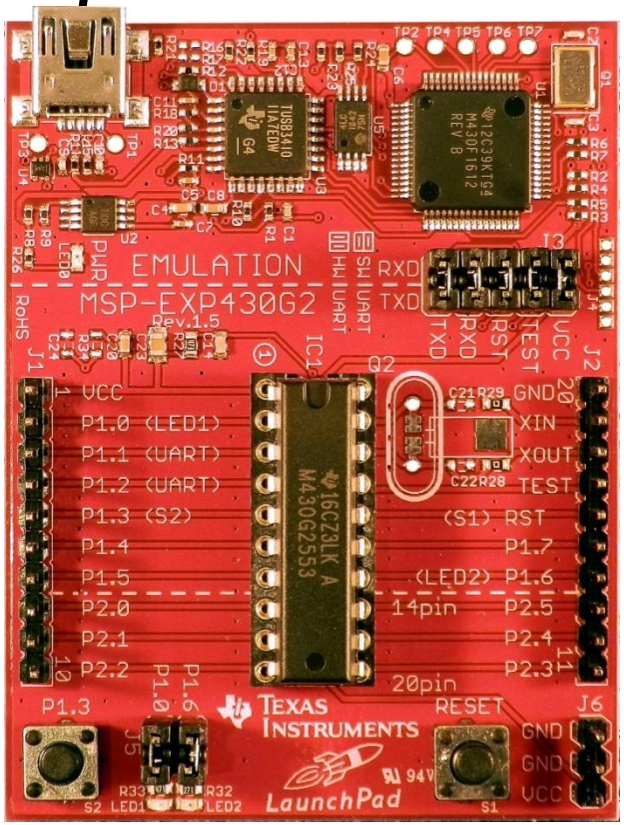

**Table 16. Port P1 (P1.4) Pin Functions**

| PIN NAME (P1.x) | x | FUNCTION | CONTROL BITS / SIGNALS[1] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | P1DIR.x | P1SEL.x | P1SEL2.x | ADC10AE.x (INCH.x=1)[2] | JTAG Mode | CAPD.y |
| P1.4/ | 4 | P1.x (I/O) | I: 0; O: 1 | 0 | 0 | 0 | 0 | 0 |
| SMCLK/ | | SMCLK | 1 | 1 | 0 | 0 | 0 | 0 |
| TA0.2/ | | TA0.2 | 1 | 1 | 1 | 0 | 0 | 0 |
| | | TA0.CCI2A | 0 | 1 | 1 | 0 | 0 | 0 |
| VREF+[2]/ | | VREF+ | X | X | X | 1 | 0 | 0 |
| VEREF+[2]/ | | VEREF+ | X | X | X | 1 | 0 | 0 |
| A4[2]/ | | A4 | X | X | X | 1 (y = 4) | 0 | 0 |
| CA4/ | | CA4 | X | X | X | 0 | 0 | 1 (y = 4) |
| TCK/ | | TCK | X | X | X | 0 | 1 | 0 |
| Pin Osc | | Capacitive sensing | X | 0 | 1 | 0 | 0 | 0 |

- 每个引脚均有多项功能
- 通过sel和sel2组合设置功能引脚
- 参考datasheet

# Lab3: GPIO






**Lab3**

- **Setup P1.3 to Button**
- **Setup P1.0 to LED control**
- **LED toggle with Button**

# Lab 3:


```
P1DIR |= BIT0; // Set P1.0 to output direction
P1IES |= BIT3; // P1.3 Hi/lo edge
_____ &= ~BIT3; // P1.3 IFG cleared
_____ |= BIT3; // P1.3 interrupt
```

```
 // Port1 interrupt service routine
#pragma vector = __________
__interrupt void Port_1(void)
```

```
 // Port1 interrupt service routine
P1OUT ^= BIT0;   // P1.0 = toggle
______ &= ~BIT3; // P1.3 IFG cleared
```

# Lab 3:


```
P1DIR |= BIT0; // Set P1.0 to output direction
P1IES |= BIT3; // P1.3 Hi/lo edge
P1IFG &= ~BIT3; // P1.3 IFG cleared
P1IE  |= BIT3; // P1.3 interrupt
```

```
 // Port1 interrupt service routine
#pragma vector = PORT1_VECTOR
__interrupt void Port_1(void)
```

```
 // Port1 interrupt service routine
P1OUT ^= BIT0;    // P1.0 = toggle
P1IFG &= ~BIT3; // P1.3 IFG cleared
```

# Agenda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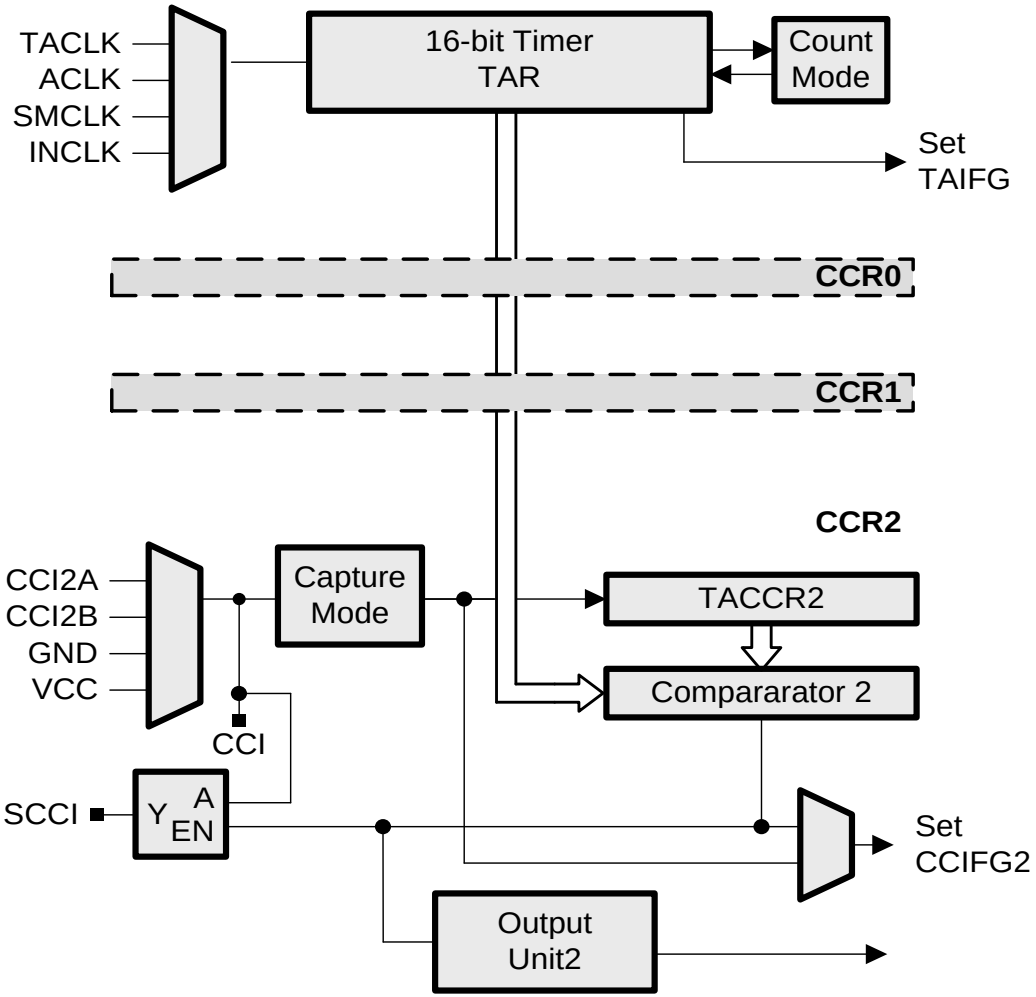
- Grace
- Capacitive Touch Solution

# Timer_A

- 异步16位定时器/计数器
- 4种计数模式
- 3个可配置捕获/比较寄存器
- PWM 输出
- 中断向量寄存器，快速中断响应
- 可触发DMA
- 多个时钟源可选
- 所有430均有Timer_A



# Timer_A 计数模式

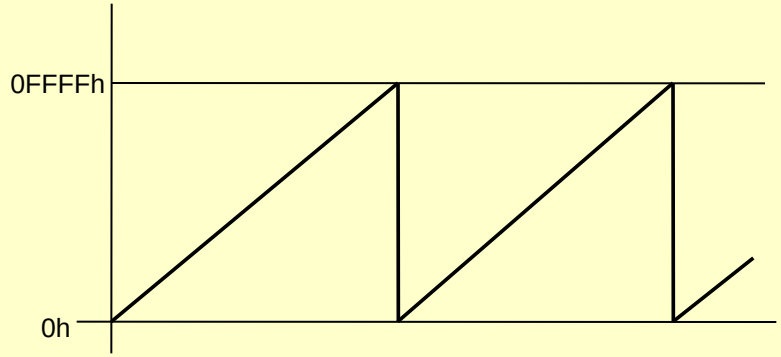

**Stop/Halt**

定时器停止



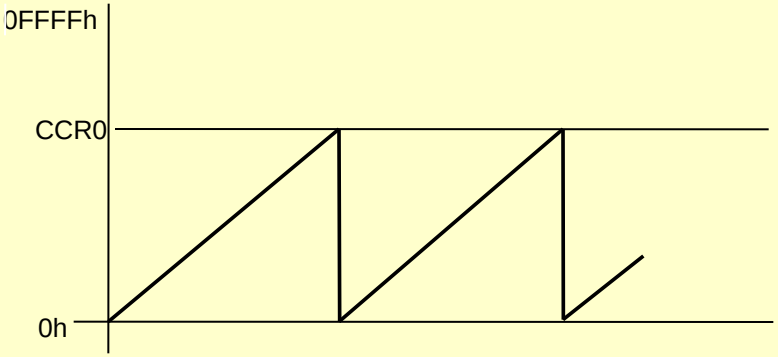
**Continuous**

定时器连续递增计数至FFFF



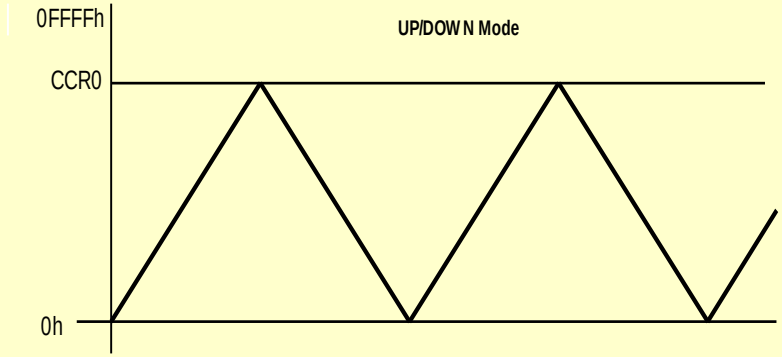

**Up**

定时器连续递增至CCR0




**Up/Down**

定时器递增至CCR0后递减至0




**CCR – Count Compare Register**

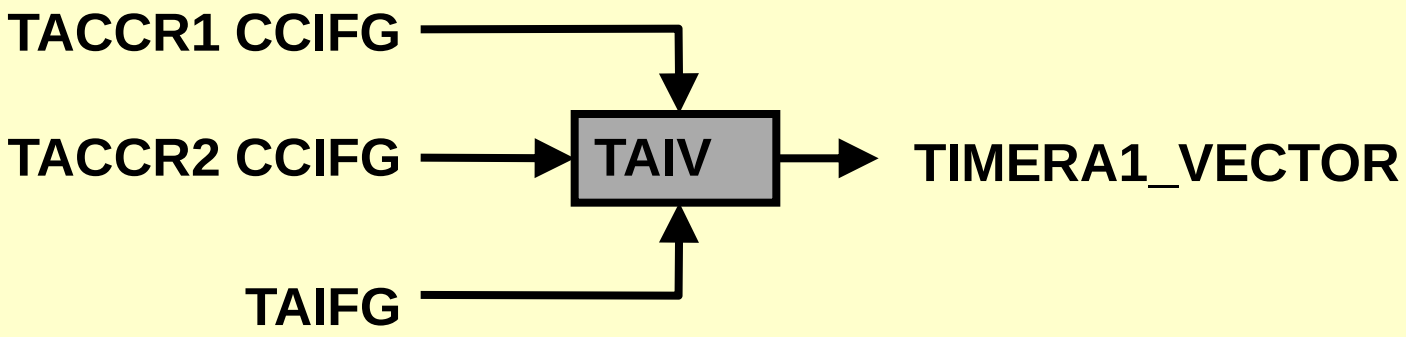
# Timer_A 中断


Timer_A 捕获/比较寄存器TACCR0 能够产生一个单独的中断向量

TACCR0 CCIFG → **TIMERA0_VECTOR**

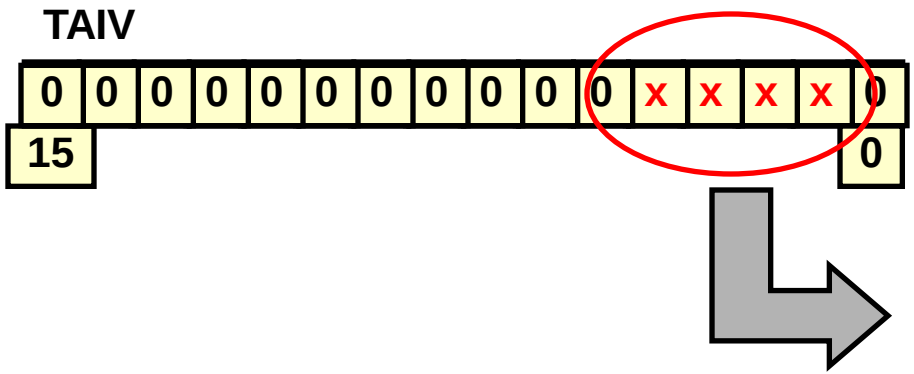
无需额外的处理程序

TACCR1, TACCR2 以及 TA 中断标志进行优先级处理，组成TAIV中断向量。




需要程序判断中断的触发源

# TAIV 处理程序示例




| Source | TAIV Contents |
|---|---|
| No interrupt pending | 0 |
| TACCR1 CCIFG | 02h |
| TACCR2 CCIFG | 04h |
| Reserved | 06h |
| Reserved | 08h |
| TAIFG | 0Ah |
| Reserved | 0Ch |
| Reserved | 0Eh |

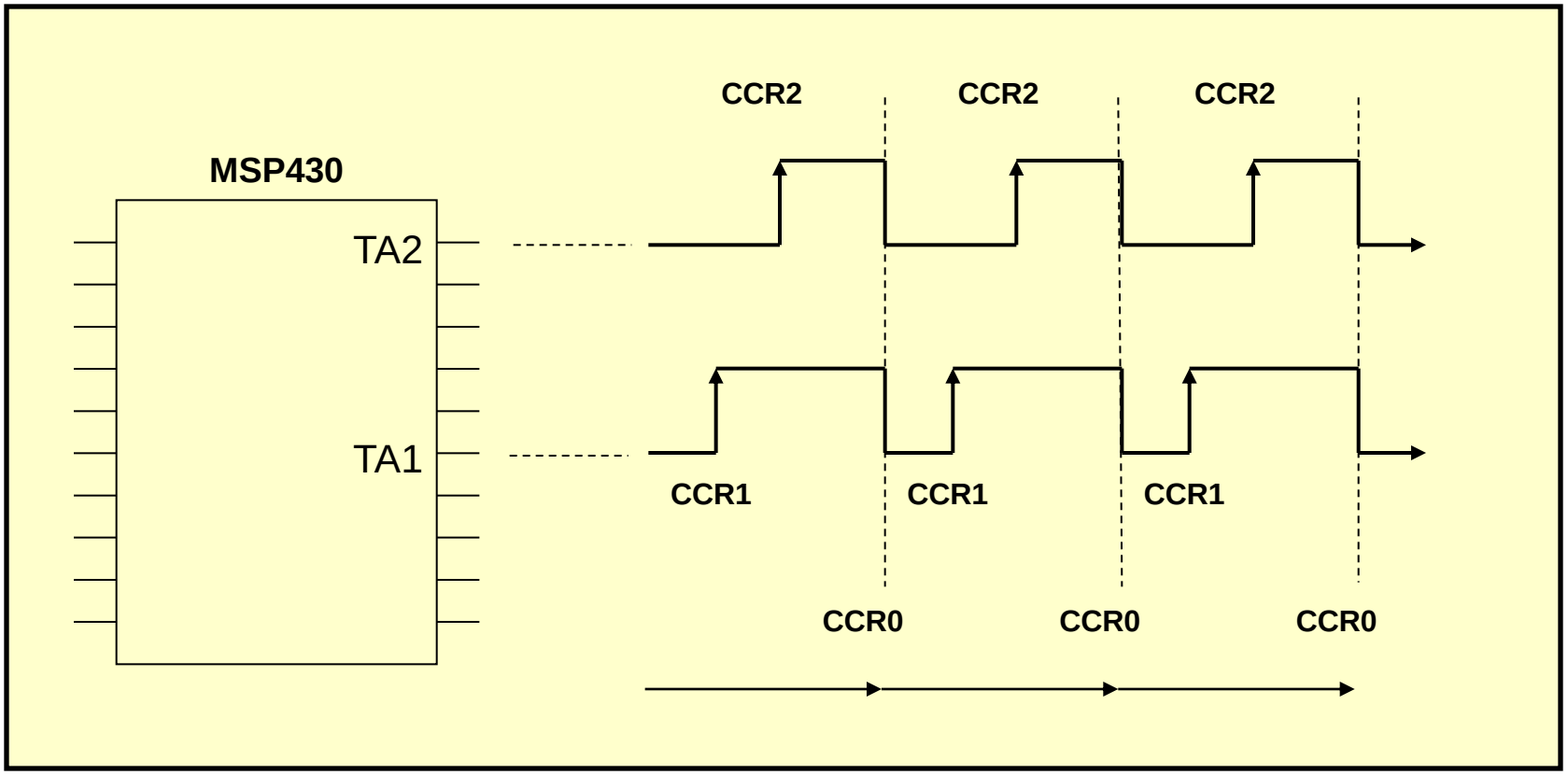
```
#pragma vector = TIMERA1_VECTOR
__interrupt void TIMERA1_ISR(void)
{
  switch(__even_in_range(TAIV,10))
  {
    case  2 :       // TACCR1 CCIFG
      P1OUT ^= 0x04; break;
    case  4 :       // TACCR2 CCIFG
      P1OUT ^= 0x02; break;
    case 10 :       // TAIFG
      P1OUT ^= 0x01; break;
   }
}
```

C code

```
0xF814   add.w   &TAIV,PC
0xF818   reti
0xF81A   jmp     0xF824
0xF81C   jmp     0xF82A
0xF81E   reti
0xF820   reti
0xF822   jmp     0xF830
0xF824   xor.b   #0x4,&P1OUT
0xF828   reti
0xF82A   xor.b   #0x2,&P1OUT
0xF82E   reti
0xF830   xor.b   #0x1,&P1OUT
0xF834   reti
```

汇编

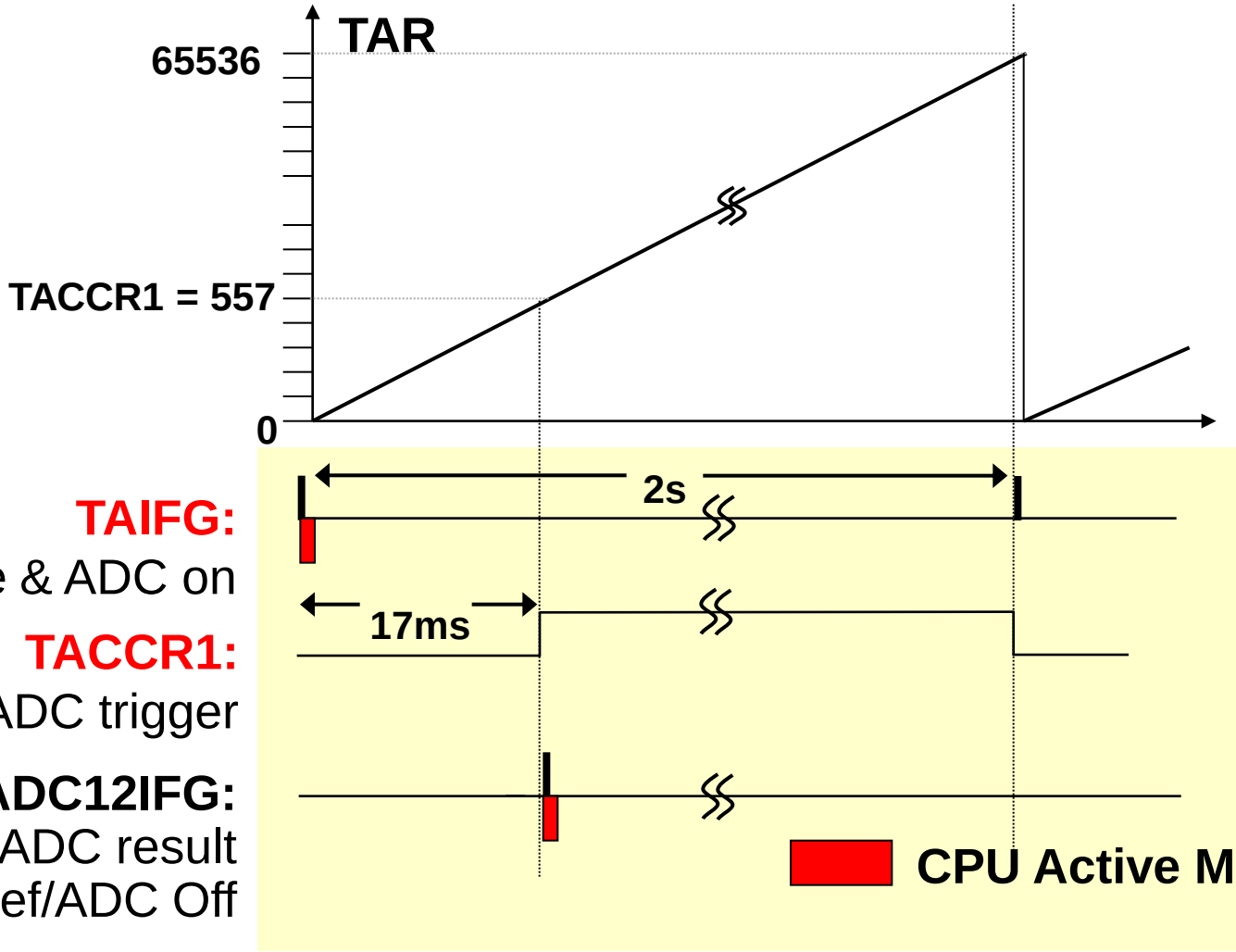
# Timer_A 产生PWM




- PWM完全自动产生
- 通过对每个CCR寄存器参数单独配置，可以产生不同占空比的PWM
- 可以在网上找到参考程序

# 采用Timer_A直接进行硬件控制


**ADC10**



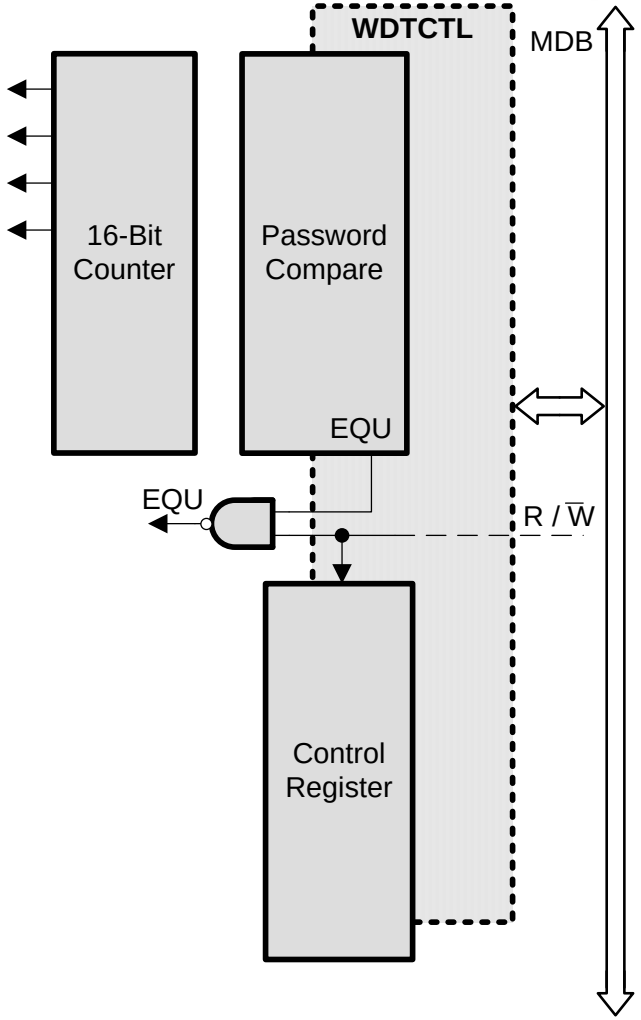

**TAIFG:**
Reference & ADC on

**TACCR1:**
Ref delay / ADC trigger

**ADC12IFG:**
Process ADC result
Ref/ADC Off

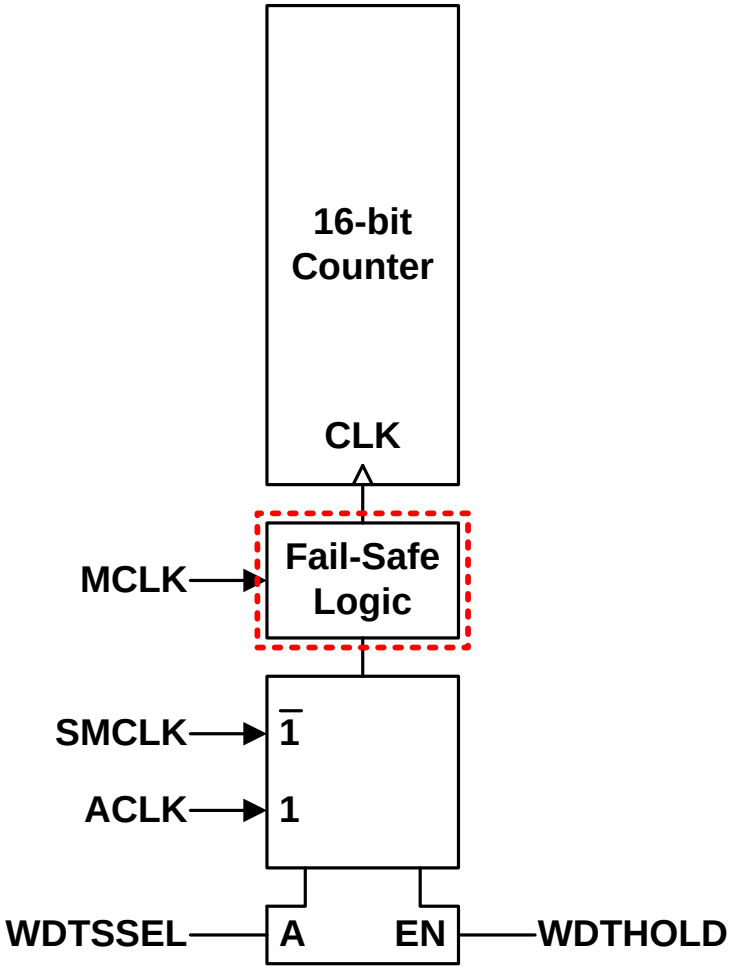
# WDT+ 模块


- 所有430中均有WDT
- 两种模式
  - –看门狗定时器
  - –间隔定时器
- 访问密码保护
- 单独的中断向量
- ACLK 或 SMCLK提供时钟源
- 控制 RST/NMI 引脚模式
- WDT+ 增加了故障保护时钟



# 看门狗定时器故障保护操作


- 当ACLK / SMCLK 发生故障时，时钟会切换到MCLK
  *(WDT+ fail safe feature)*
- 如果MCLK由晶振提供，当晶振发生故障时，MCLK切换到DCO
  *(XTAL fail safe feature)*



# WDT：关闭看门狗

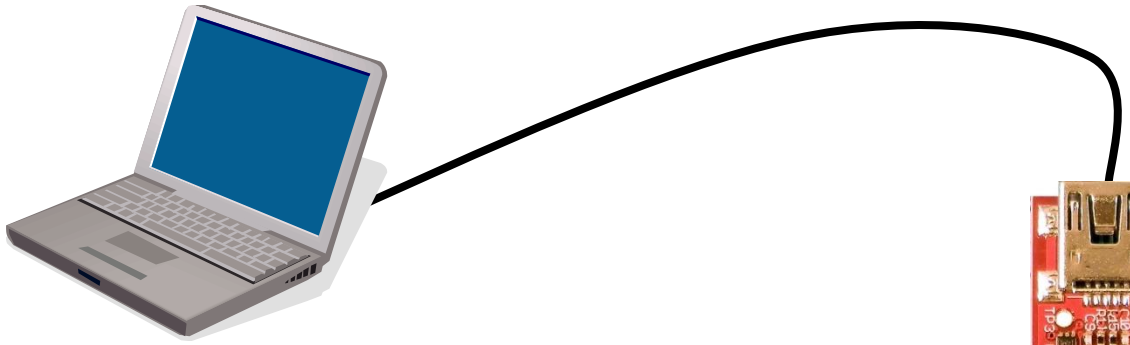

- 程序一直自动复位
- 在调试时，可以关闭看门狗：

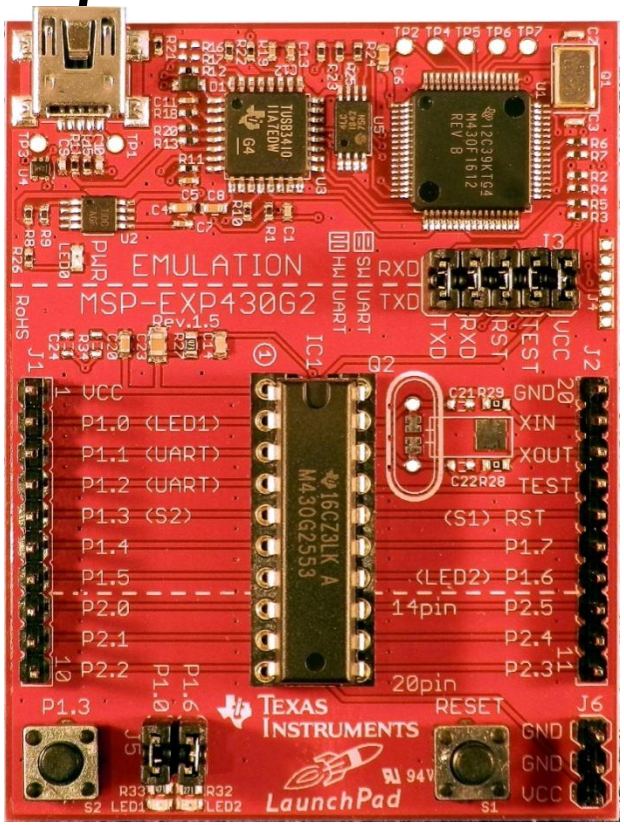
```
void main(void)
{
   WDTCTL = WDTPW+WDTHOLD; // Stop the dog
   .
   .
}
```

# WDT：间隔定时器功能


- 在间隔到达时，不会产生PUC事件
- 如果对其中断使能（WDTIE和GIE置位），当间隔到达后，会产生一个WDT间隔中断，非复位中断
- 定时间隔可以进行配置

# Lab4: 定时器和中断






**Lab4**

- **Use TimerA to implement Lab2**
- **通过TimerA产生中断控制LED闪烁**

# Lab 4:


```
// Configure TimerA
TACTL = _____; // Source: ACLK, UP mode
CCR0 = 5100;                    //Timer count 5100
CCR1 = 100;                     //Timer count 100
CCTL0 = CCIE;                   //CCR0 interrupt enabled
CCTL1 = CCIE;                   //CCR1 interrupt enabled
```

```
 // Timer A0 interrupt service routine
#pragma vector = _____
__interrupt void Timer_A0(void)
```

```
 // Timer A1 interrupt service routine
#pragma vector = _____
__interrupt void Timer_A1(void)
```

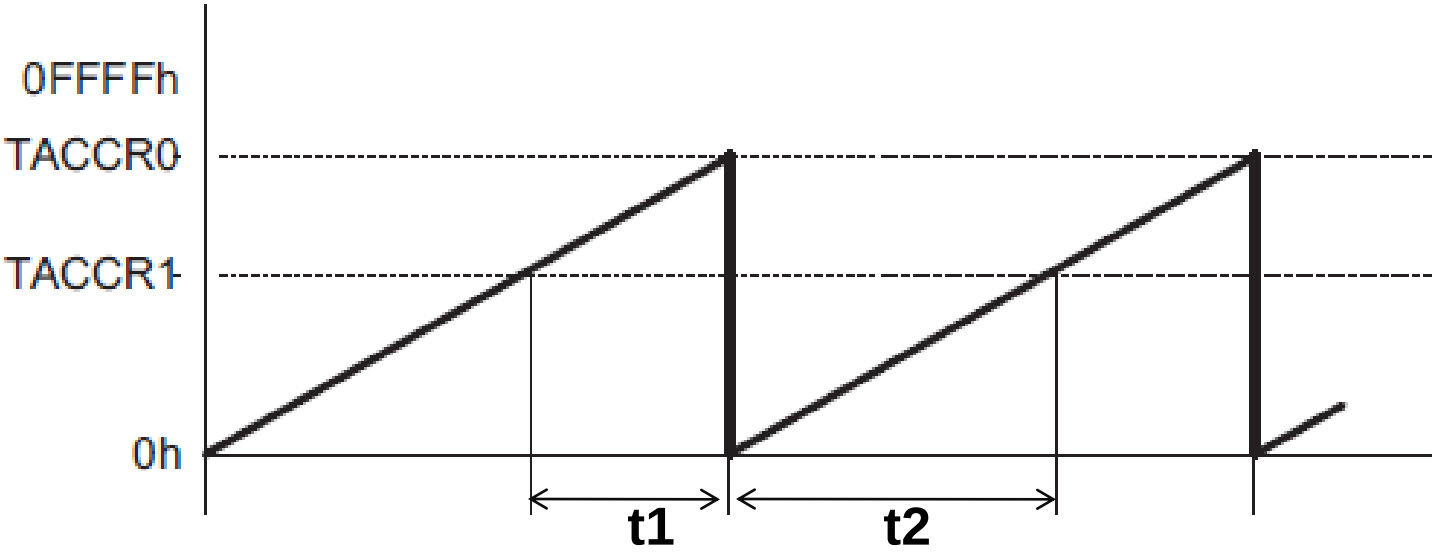
# Lab 4:


```
// Configure TimerA
TACTL = TASSEL_1 + MC_1 + TAIE ; // Source: ACLK, UP mode
CCR0 = 5100;                    //Timer count 5100
CCR1 = 100;                     //Timer count 100
CCTL0 = CCIE;                   //CCR0 interrupt enabled
CCTL1 = CCIE;                   //CCR1 interrupt enabled
```

```
 // Timer A0 interrupt service routine
#pragma vector = TIMER_A0_VECTOR
__interrupt void Timer_A0(void)
```

```
 // Timer A1 interrupt service routine
#pragma vector = TIMER_A1_VECTOR
__interrupt void Timer_A1(void)
```

# Timer_A up mode 工作示意图




**t1——LED 熄灭（CCR0-CCR1）**

**t2——LED点亮（CCRR1）**

# Agenda


- Value Line 简介
- Code Composer Studio
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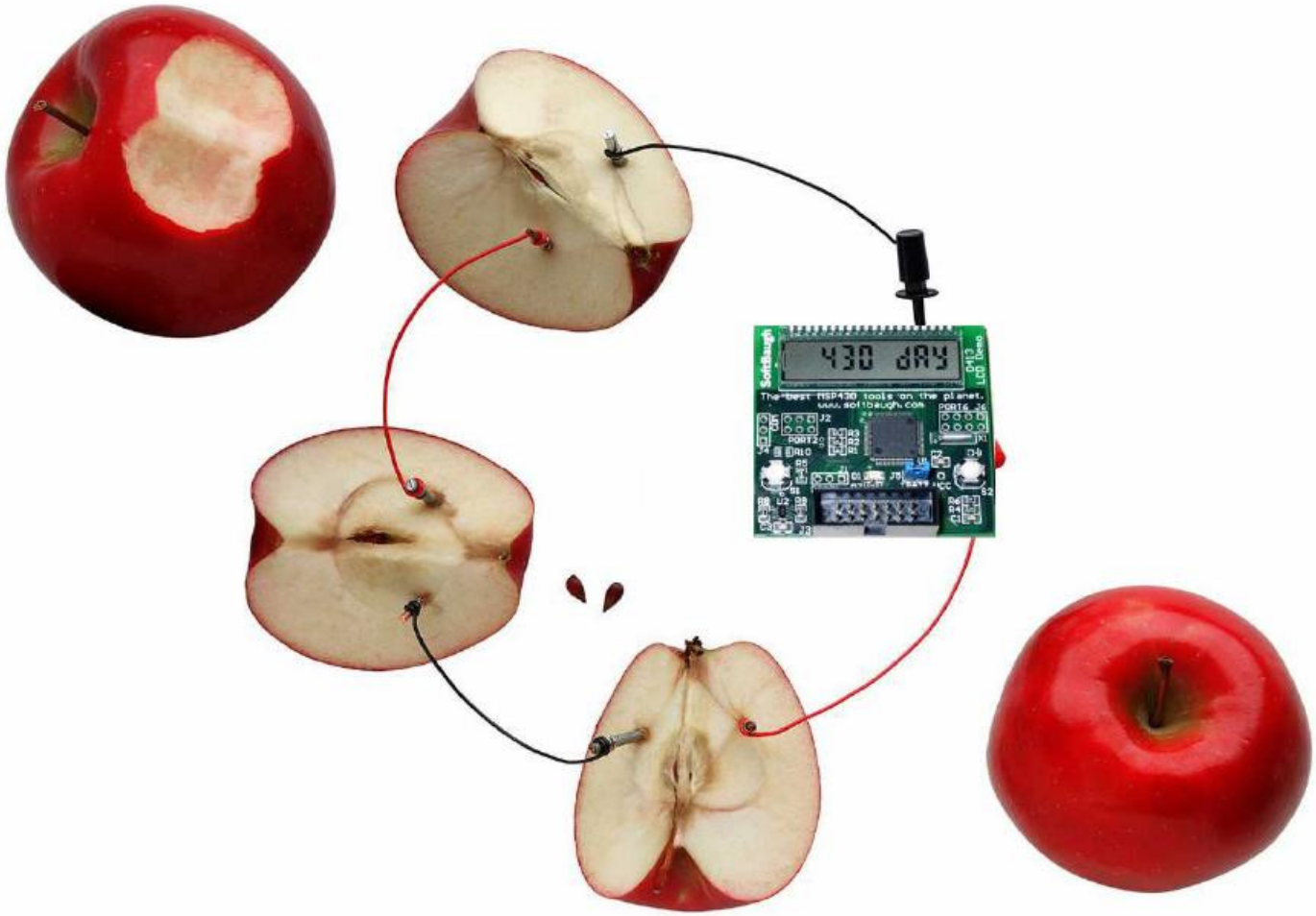
- Grace
- Capacitive Touch Solution

# 超低功耗特性



# *Ultra-Low Power* Is In Our DNA


- 超低功耗是MSP430最大的特点
- 外设的优化设计，降低功耗，同时最少地使用CPU
- 智能化的，低功耗的外设可以独立于CPU运行使用，从而使得系统尽可能长时间地处在低功耗模式
  www.ti.com/ulp

✓多种操作模式
- – 100 nA power down (RAM retained)
- – 0.3 µA standby
- – 110 µA / MIPS from RAM
- – 220 µA / MIPS from Flash

✓即时可稳定的高速时钟

✓1.8 - 3.6V 单电源供电

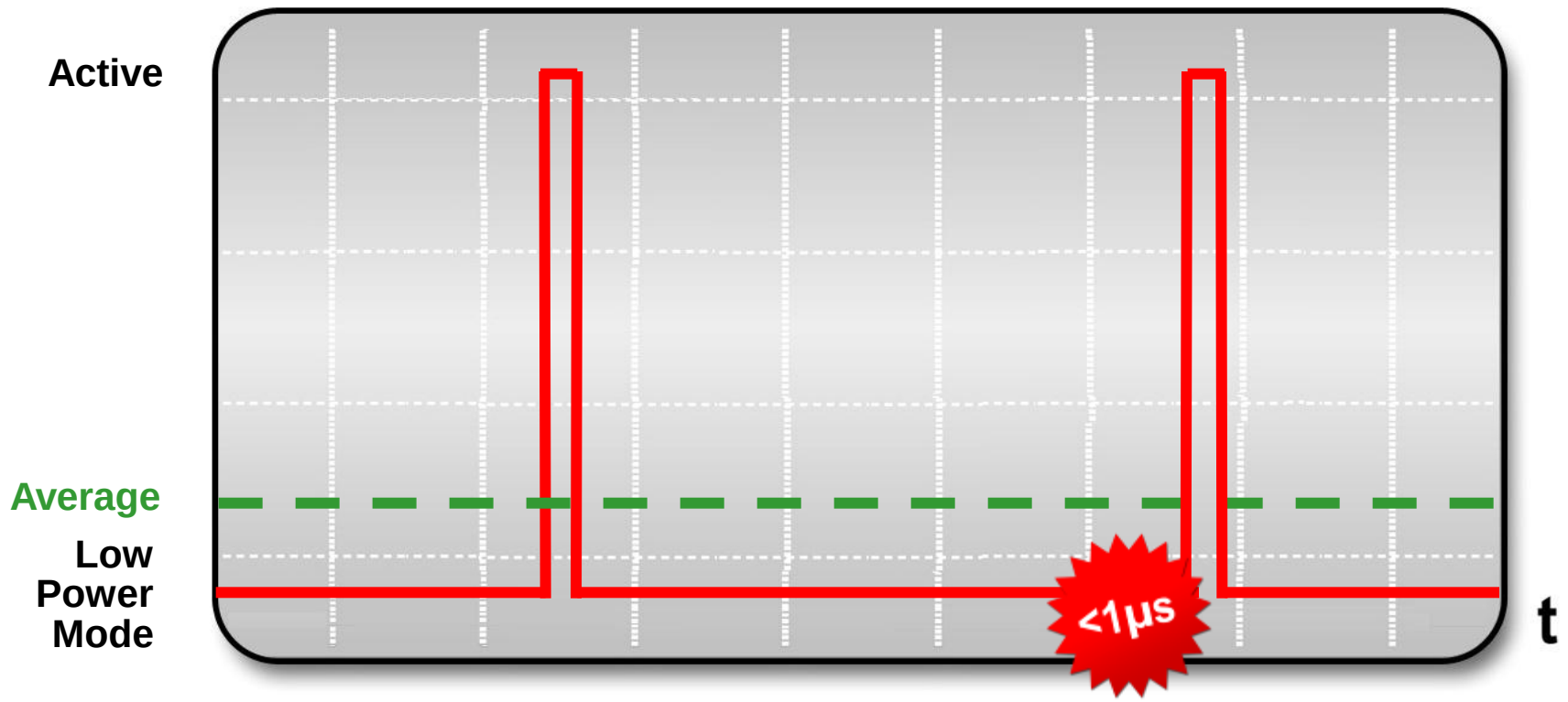
✓零功率，始终工作的BOR

✓<50nA 引脚漏电流

✓低功耗智能外设
- –ADC 自动搬运数据DTC
- –Timers 功耗极低
- –100 nA 模拟比较器

✓性能保证

# 超低功耗工作模式




- 最大限度地减少Active时间
- 尽量使处于Low Power Modes
- 按功能需求的中断型程序设计 <1µs 唤醒时间
- 零功耗，始终工作的欠压复位电路 (BOR)

# MSP430 低功耗工作模式


**CPU Off**
**DCO on**
**ACLK on**
45µA

**LPM0**

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

<1µs

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

**LPM4**
- RAM/SFR retained

<1µs

**Stand-by**
**DCO off**
**ACLK on**
0.3µA

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

**BOR is enabled in all modes**

Specific values vary by device

# 低功耗模式配置


| Reserved | V | SCG1 | SCG0 | OSC OFF | CPU OFF | GIE | N | Z | C |
|---|---|---|---|---|---|---|---|---|---|

R2/SR

| | | | | | | |
|---|---|---|---|---|---|---|
| Active Mode | 0 | 0 | 0 | 0 | | ~ 250uA |
| LPM0 | 0 | 0 | 0 | 1 | | ~ 35uA |
| LPM3 | 1 | 1 | 0 | 1 | | ~ 0.8uA |
| LPM4 | 1 | 1 | 1 | 1 | | ~ 0.1uA |

```
bis.w    #CPUOFF,SR          ; LPM0
```

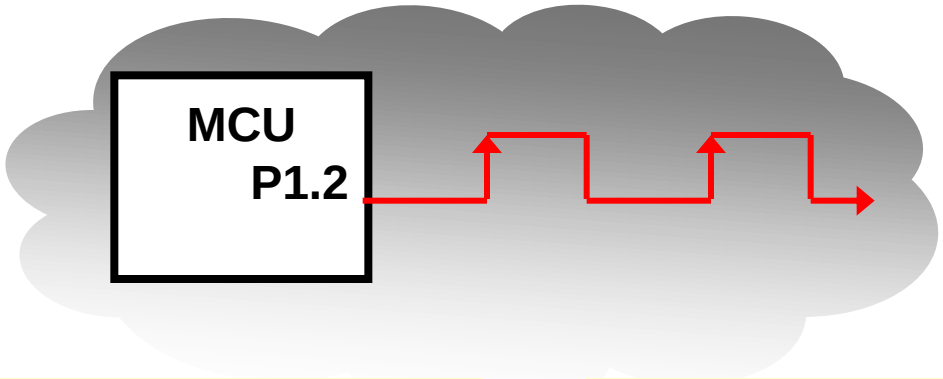
# 低功耗设计


使用低功耗模式十分简单

```
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
}
```

# 将软件功能移至由外设来完成



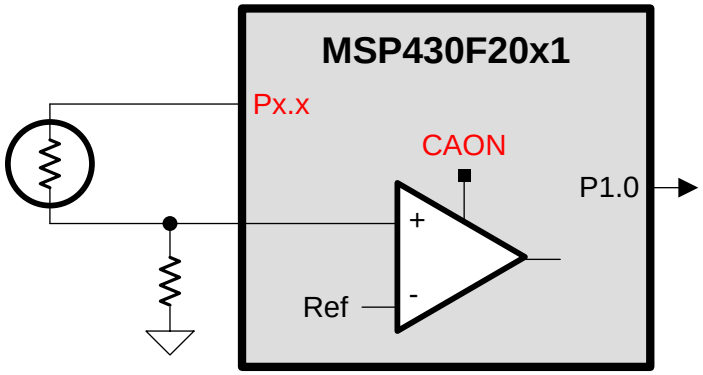

```
// Endless Loop
for (;;)
{
 P1OUT |= 0x04;   // Set
 delay1();
 P1OUT &= ~0x04; // Reset
 delay2();
}
```

**100% CPU Load**

```
// Setup output unit
 CCTL1 = OUTMOD0_1;
 _BIS_SR(CPUOFF);
```

**Zero CPU Load**

# 片上外设的电源管理

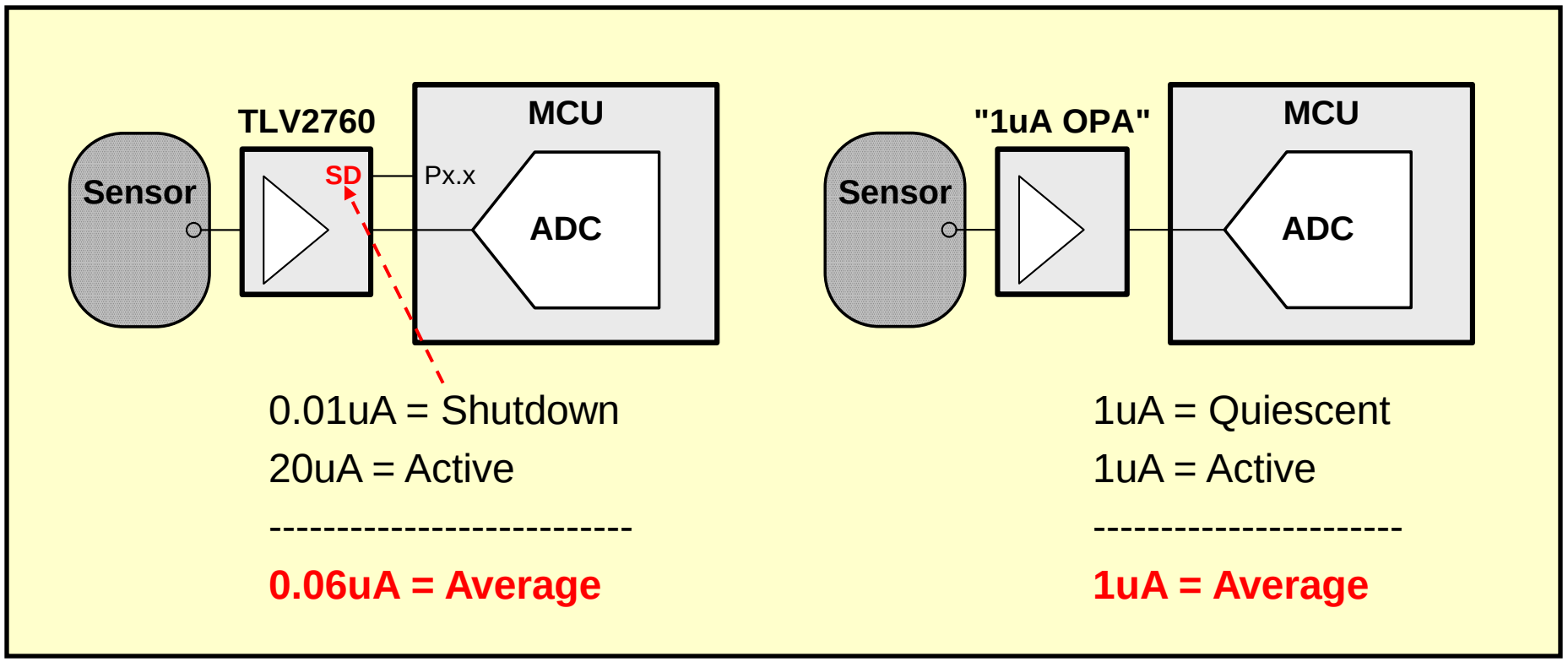



**Comparator_A**

| VCC | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|
| 2.2 V | | 25 | 40 | µA |
| 3 V | | 45 | 60 | |

```
P1OUT |= 0x02;                          // Power divider
CACTL1 = CARSEL + CAREF_2 + CAON;       // Comp_A on
if (CAOUT & CACTL2)
  P1OUT |= 0x01;                        // Fault
else
   P1OUT &= ~0x01;
P1OUT &= ~0x02;                         // de-power divider
CACTL1 = 0;                             // Disable Comp_A
```

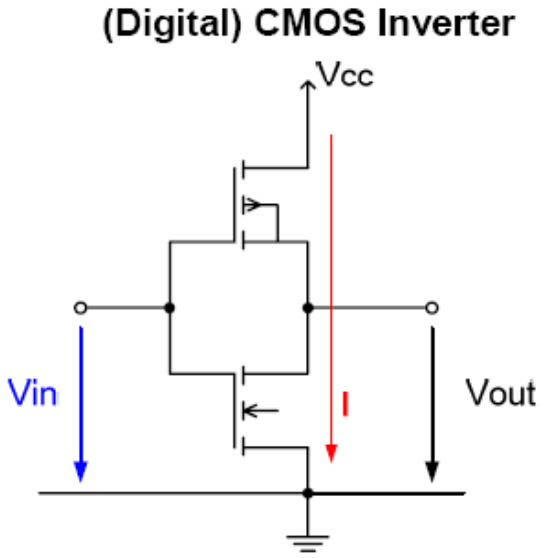
# 外部设备的电源管理

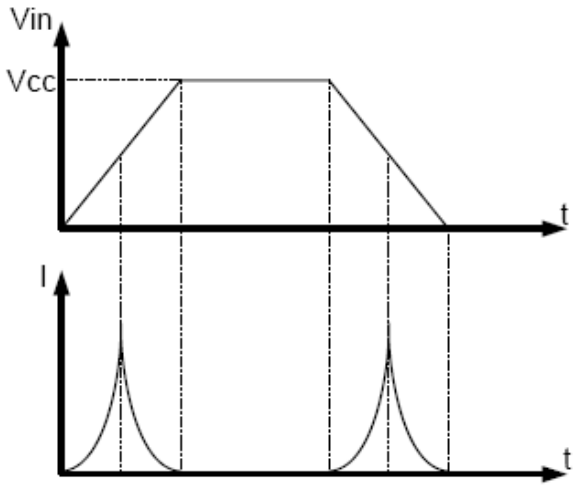



带有SHUTDOWN引脚的运放，总功耗可以降低20倍！

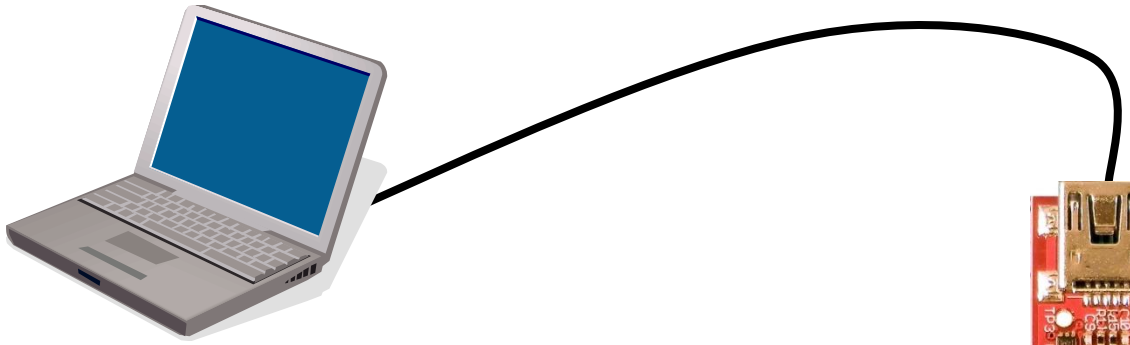
# 未用引脚接口——UserGuide

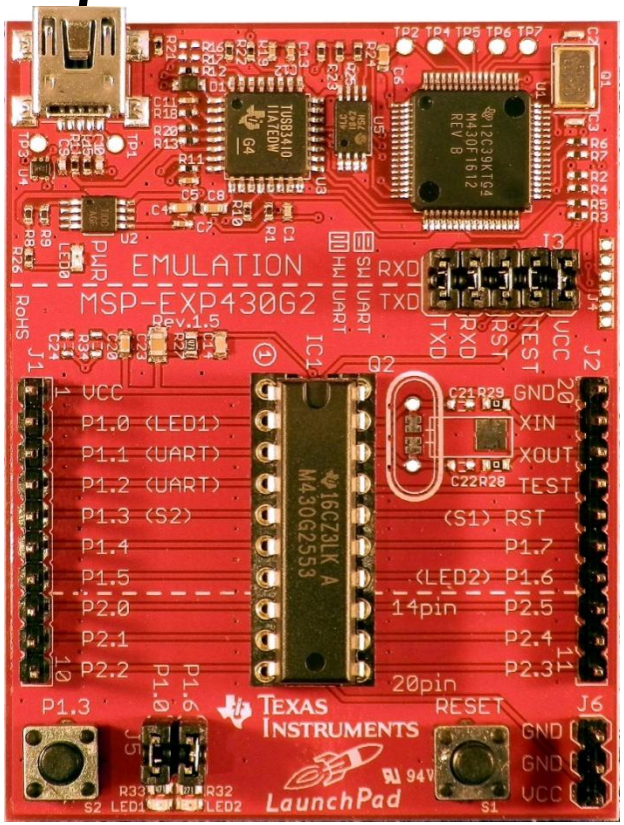

- 数字输入引脚需要注意电流击穿的影响
  - 如果输入引脚为浮动状态（未连接），则当输入电压在VIL和VIH之间时会产生击穿电流
- 未用的I/O 应当
  - 设置为输出
  - 通过外部电路与Vcc或地相连
  - 与上拉或下拉电阻相连



# Lab5: Low Power Mode






**Lab5**

- **Optimize Lab4 to implement LPM**

# Lab 5:


**Enter Low Power Modes with just *1 line of code*!**

```
_BIS_SR(_____);//Enter Low Power Mode;
```

# Lab 5:


**Enter Low Power Modes with just *1 line of code*!**

```
_BIS_SR(LPM0_bits + GIE);//Enter Low Power Mode;
```

中断使能

# Agenda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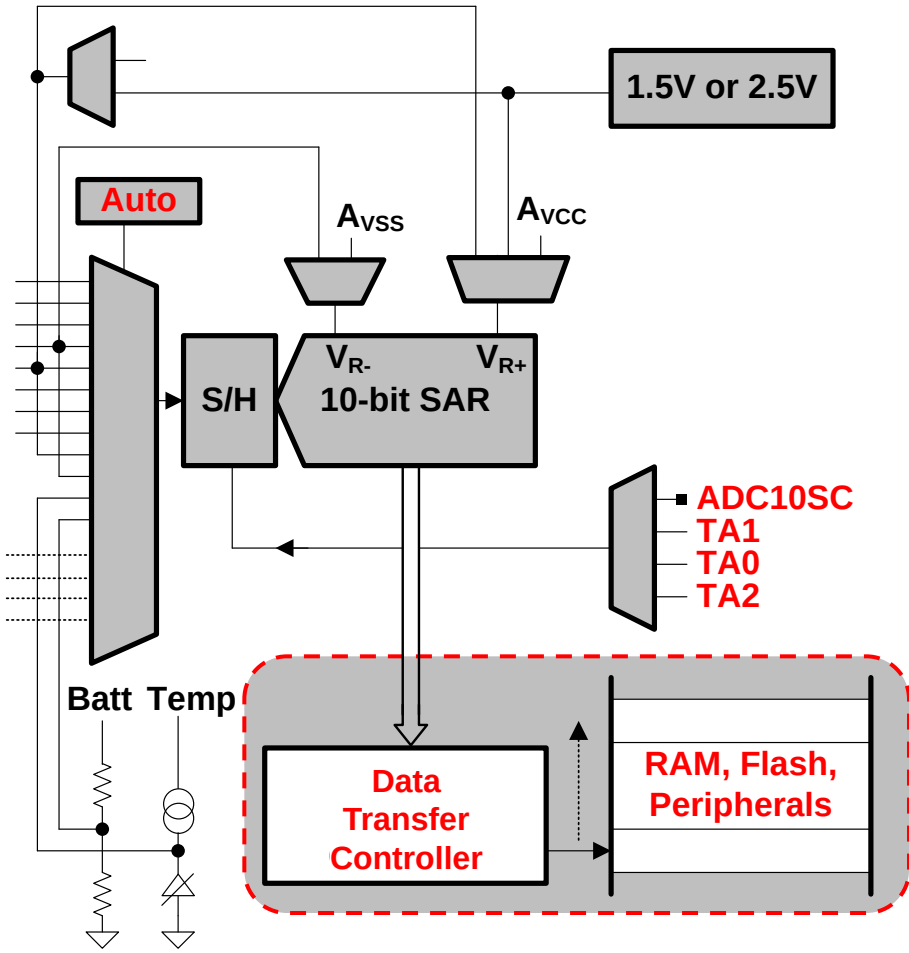
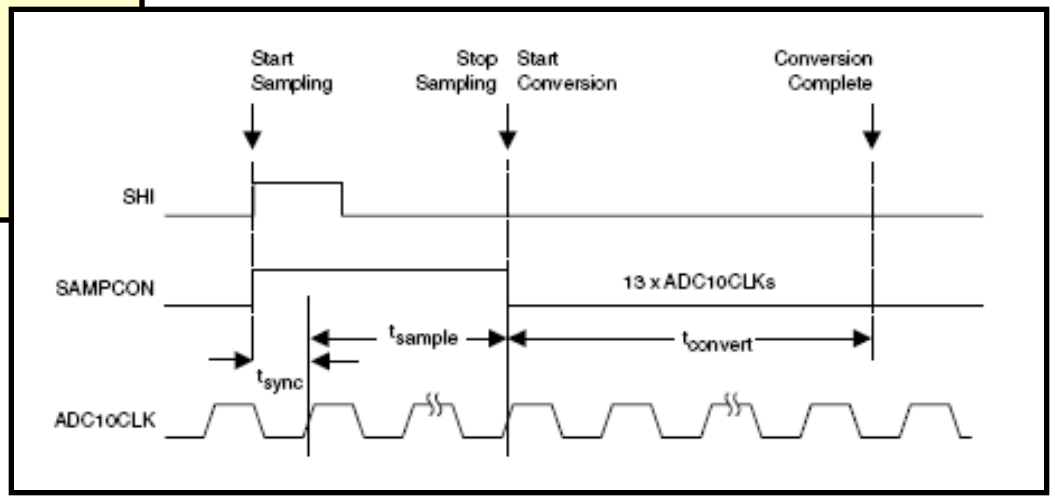
# 快速灵活的ADC10

- 10位 8 通道 SAR ADC
  - 6 个外部通道
  - Vcc和内部温度传感器
- 200 ksps+
- 可选的转换时钟
- 4中自动扫描模式
  - Single
  - Sequence
  - Repeat-single
  - Repeat-sequence
- 可选内部或外部参考电压
- 可由Timer-A触发
- 具有中断能力
- Data Transfer Controller (DTC)
- 自动断电模式

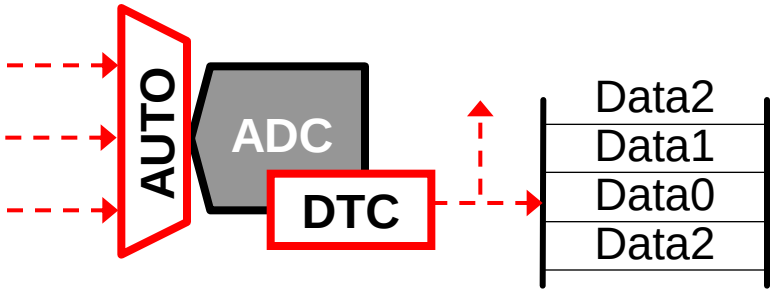


# 采样时序

- 参考电压建立时间约30uS
- 可选的保持时间
- 转换过程需13个时钟周期
- 多个时钟源
  - ADC10OSC (~5MHz)
  - ACLK
  - MCLK
  - SMCLK



# 自动扫描 + DTC 可实现性能提升




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

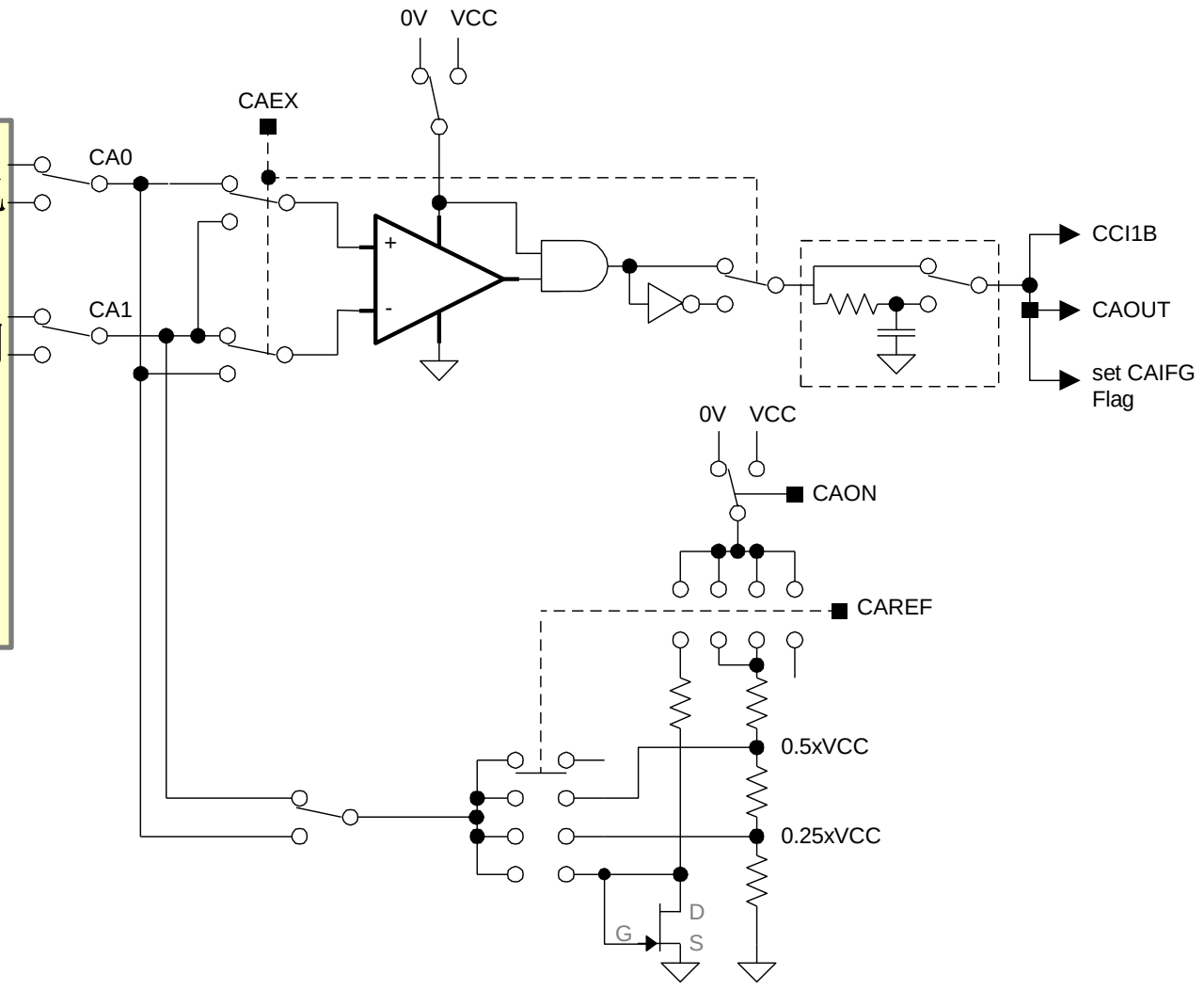
**70 个周期/样本**

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

全自动

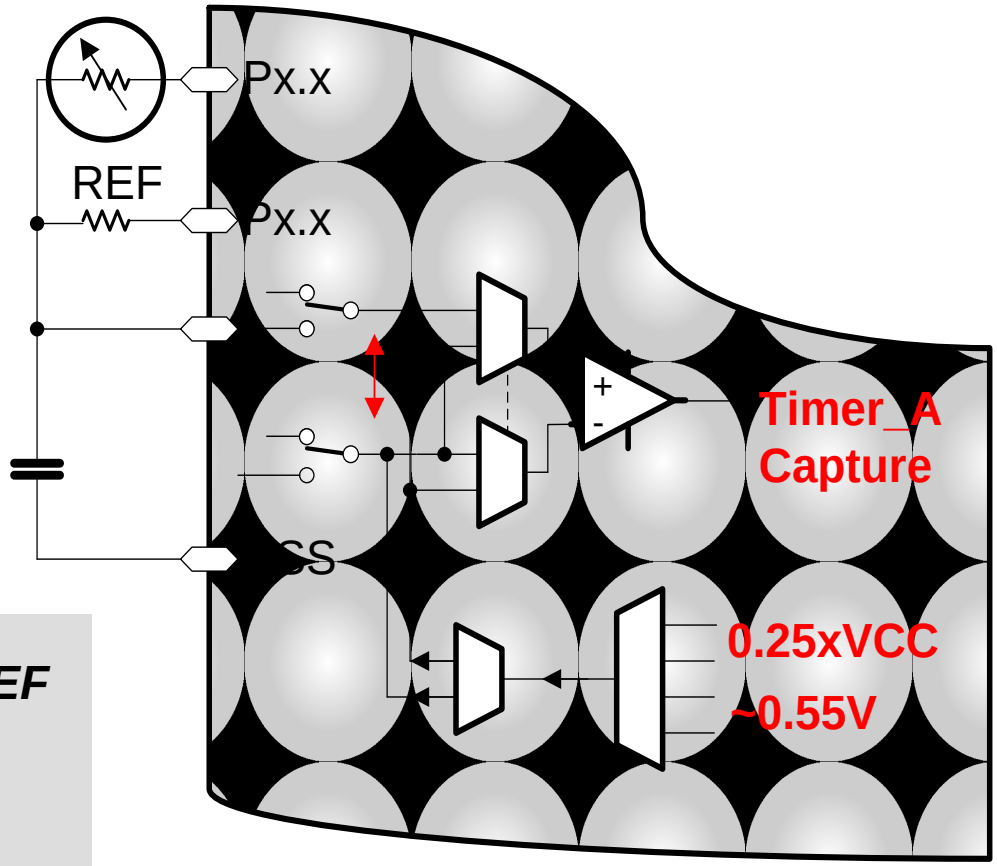
# Comparator_A

- 可用内部电压参考，也可从外部接入
- 内建低通滤波器可利用软件来选择开或关
- 多路输入选择开关
- 具有中断功能



# 基于比较器的Slope ADC

- 10 位以上的精度
- 非常适合电阻型传感器
- 超低成本应用
- 应用笔记 SLAA038



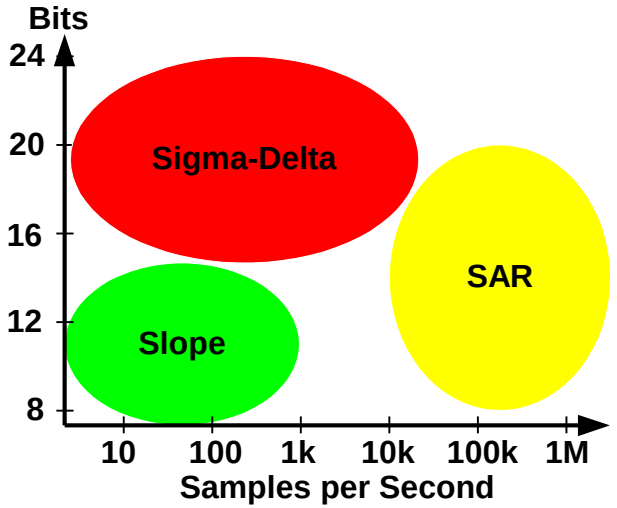

$$t\_x = R\_x \times C \times \ln \frac{VCAREF}{Vcc}$$

$$R\_NTC = 10k \times \frac{t\_NTC}{t\_10k}$$

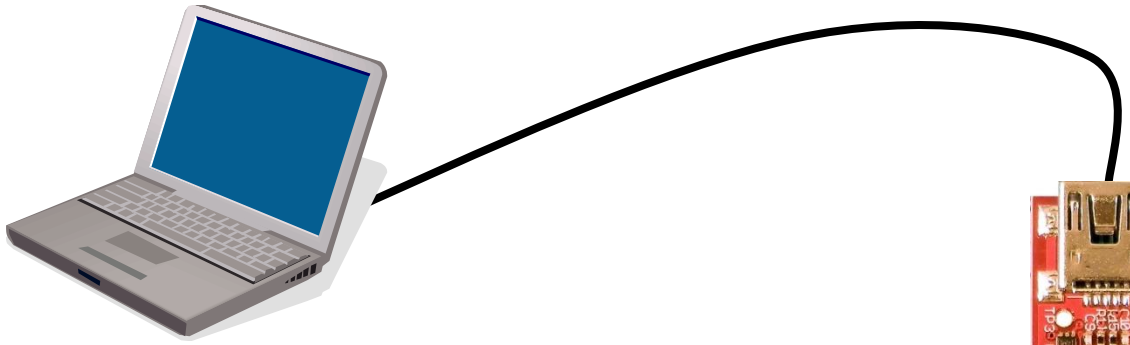
# 选择一款 MSP430 ADC

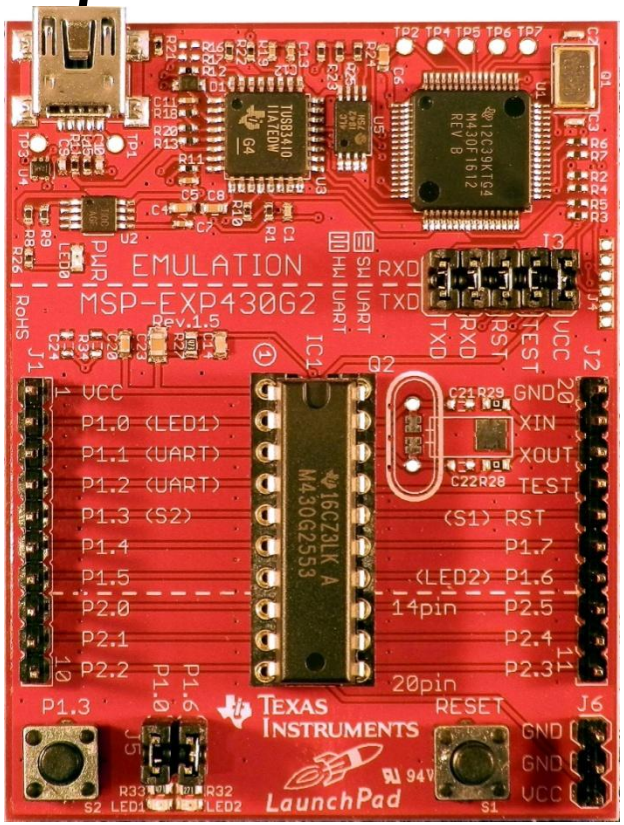

| | 通道数 | $f_{SAMPLE}$ (ksps) | | 分辨率 | SINAD (典型值) | $A_{IN}$ | 基准 | | | 触发 | 增益 | 特性 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 最小值 | 最大值 | | | | $Ref_{IN}$ | $Ref_{OUT}$ | $Ref_{I\_OUT}$ | | | |
| | | | | | | | | | | | | |
| **ADC10** | 8 | 34 | 200+ | 10 | 57 | Vss 至 Vref | 1.4-3.6 | 1.5/2.5V | +/-1mA | SW/定时器/计数器 | N/A | DTC |
| **ADC12** | 12 | 34 | 200+ | 12 | 68 | Vss 至 Vref | 1.4-3.6 | 1.5/2.5V | +/-1mA | SW/定时器/计数器 | N/A | 转换存储器 |
| **SD16** | 3 个独立 | 约 4 | | 16 | 85 | +/-600mV | 1.0-1.5 | 1.2V | +/-1mA | SW/计数器 | 至32倍 | 预加载 |
| **SD16_A** | 4 个复用 | 约 0.03 | 约 5 | 16 | 85 | +/-600mV | 1.0-1.5 | 1.2V | +/-1mA | SW/计数器 | 至32倍 | 缓冲输入 |

- 需要测量的电压范围是多少？
- 针对 $A_{IN}$ 的最大频率是多少？
- 分辨率是多少？
- 是否采用差分输入？
- 基准范围是多少？
- 是否具有多个通道？



# Lab6：应用ADC10






**Lab6：**

- 使用**ADC10**内部温度传感器测量温度
- **CCS** 新特性

# Lab 6:


```
 //Configure ADC10
// Choose ADC_Channel as Temp Sensor
ADC10CTL1 = _______ + ADC10DIV_3;
//Choose ADC_Ref_sourceCCTL1
ADC10CTL0 = _______ + ADC10SHT_3 + REFON + ADC10ON +ADC10IE;
```

# Lab 6:


```
 //Configure ADC10
// Choose ADC_Channel as Temp Sensor
ADC10CTL1 = INCH_10 + ADC10DIV_3;
//Choose ADC_Ref_sourceCCTL1
ADC10CTL0 = SREF_1 + DC10SHT_3 + REFON + ADC10ON +ADC10IE;
```

✓使用breakpoint进行断点调试
✓使用watch窗口查看变量

# 议程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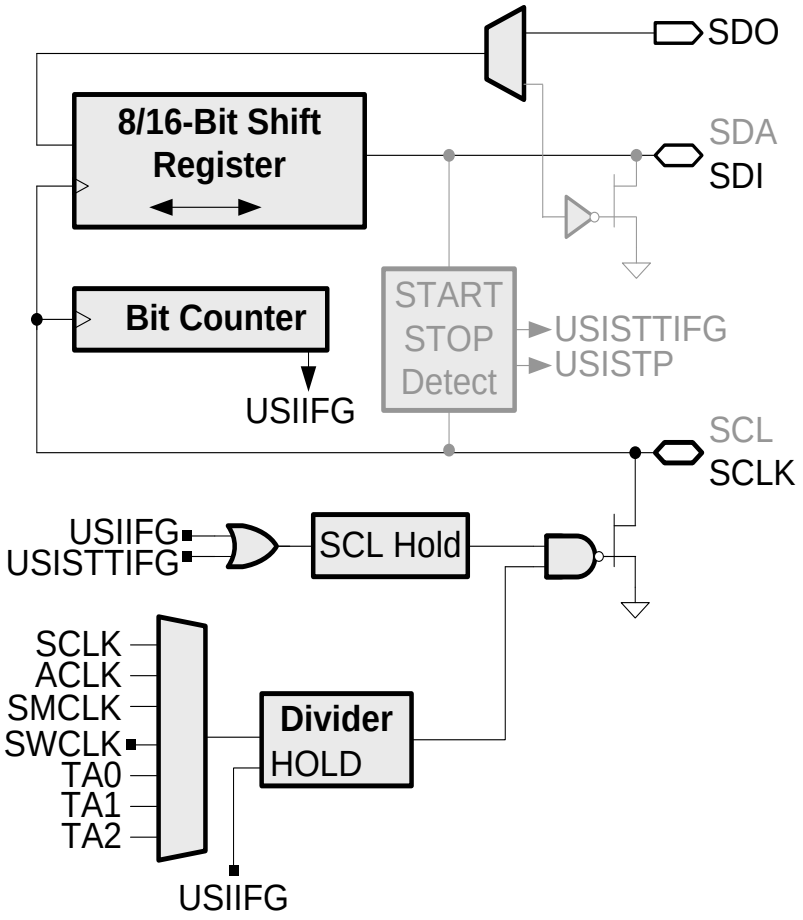
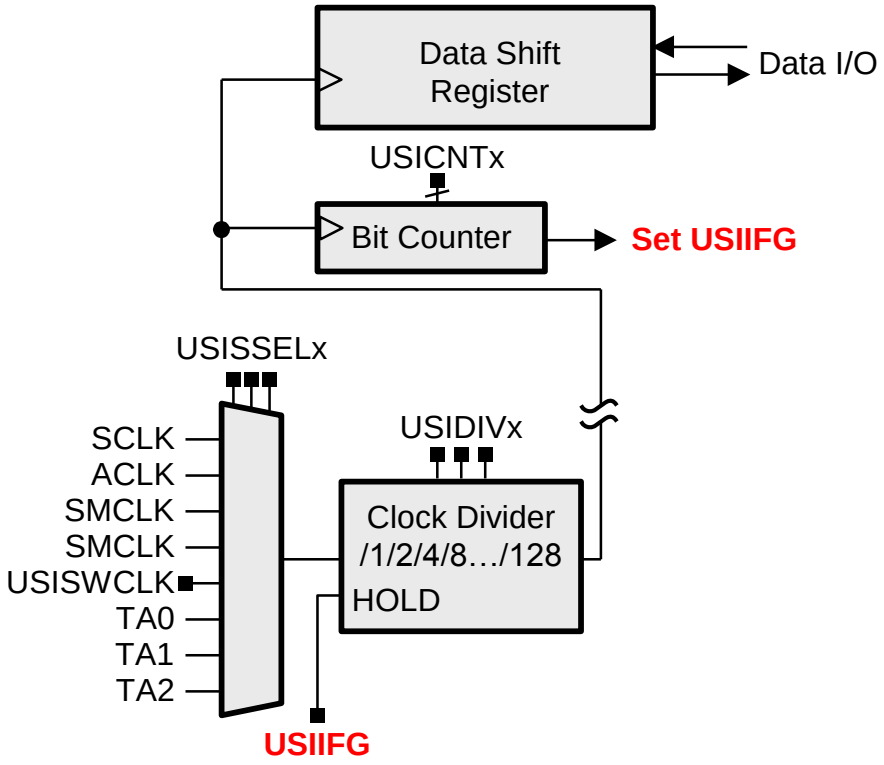
# USI

- MSP430G2xx1/2 器件
- 可变长度移位寄存器
- 支持 I2C
  - START/STOP 检测
  - SCL 在 START 之后保持
  - SCL 在计数器溢出之后保持
  - 丢失检测仲裁机制
- 支持 SPI
  - 8/16 位移位寄存器
  - MSB或LSB 优先可选
- 灵活的定时
- 中断驱动

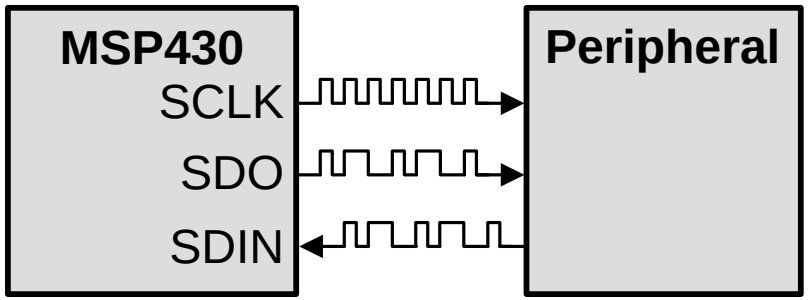


# USI的data IO

- 数据移位寄存器：可支持多达 16 位
- 发送与接收的位数受控于一个位计数器
- 发送与接收是同时进行的
- 数据 I/O 由用户定义：MSB 或 LSB 优先
- 位计数器在最后一个位之后自动停止计时并设定标记
- 无需数据缓冲



# USI 减低了 SPI 的 CPU 负荷




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

**425 个周期**

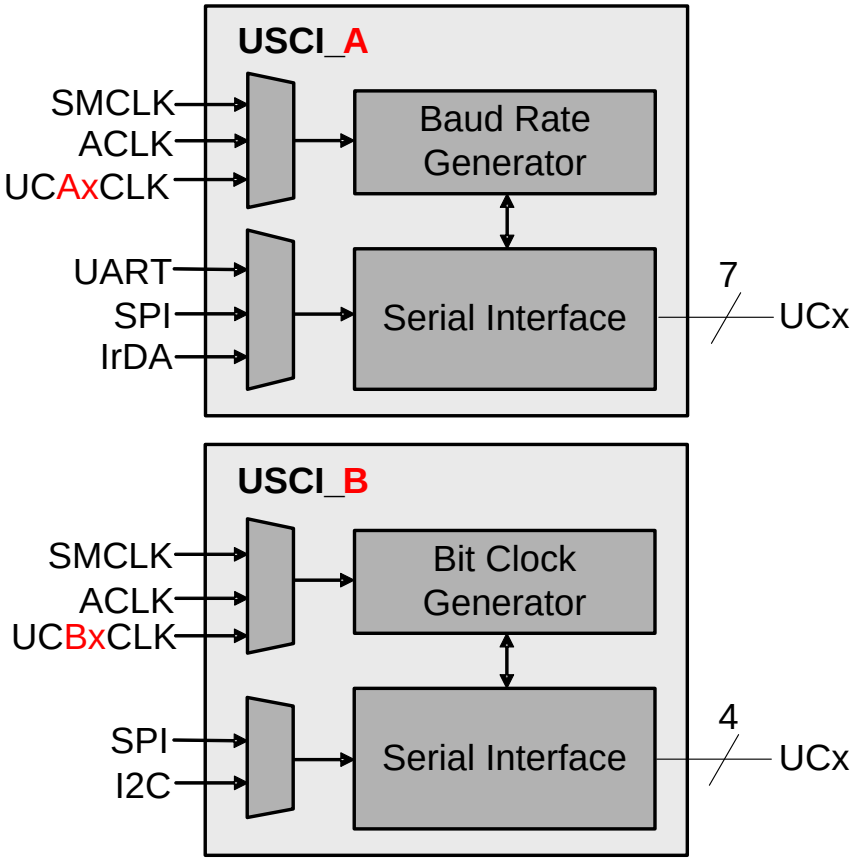
```
// Shift16_inout_USI
USISR |= DATA;
USICNT |= 0x10;
```

**10 个周期**

- I2C Slave从时钟边缘至数据寄存器的时间短至 4us
- 若使用纯软件解决方案，MCU几乎无法完成其他操作
- USI 硬件可实现实用和兼容的 I2C
- 代码可通过 MSP430 的相关网址获得

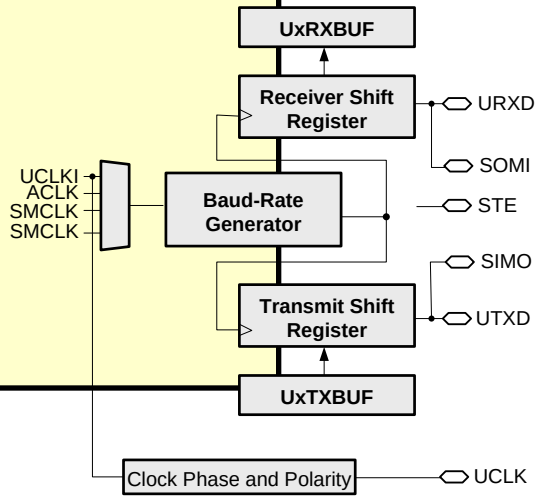
# USCI

- 专为超低功耗而精心设计：
  - 可从任意低功耗模式自动起动
- 两个专用模块：
  - USCI_A:
    UART 或 SPI
  - USCI_B:
    SPI 或 I2C
- 双缓冲发送 (TX) / 接收 (RX)
- 波特率/位时钟发生器：
  - 自动波特率检测
  - 灵活的时钟脉冲源
- 接收 (RX) 干扰抑制
- DMA 被启用
- 误差检测



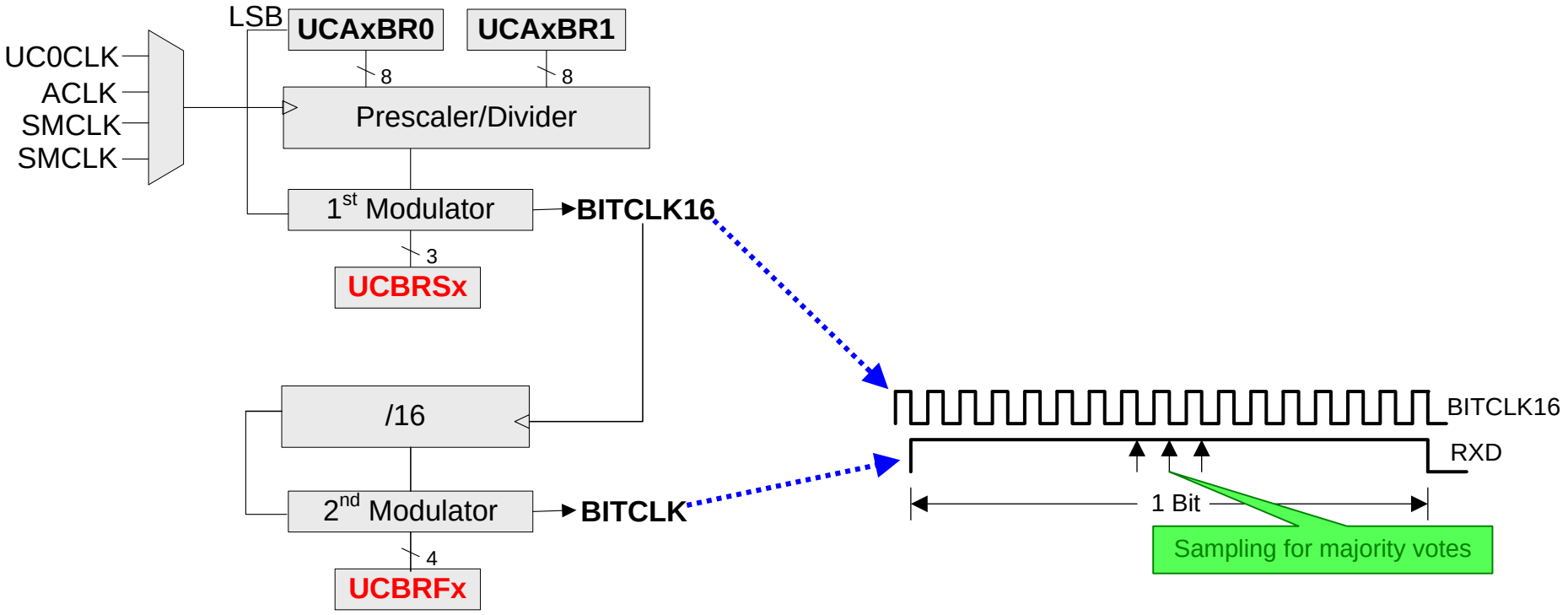
# USCI 增强型特性


- 最新标准 MSP430 串行接口
- 可从任意低功耗模式 (LPM) 实现自动时钟起动
- 两个独立的通信模块
- 异步通信模式
  - UART 标准和多处理器协议
  - 具有自动波特率检测功能的 UART（支持 LIN）
  - 两个调制器支持 n/16 位定时
  - IrDA 位整形编码器与解码器
- 同步通信模式
  - SPI（主控器和从动器模式，三线和四线式）
  - I2C（主控器和从动器模式）

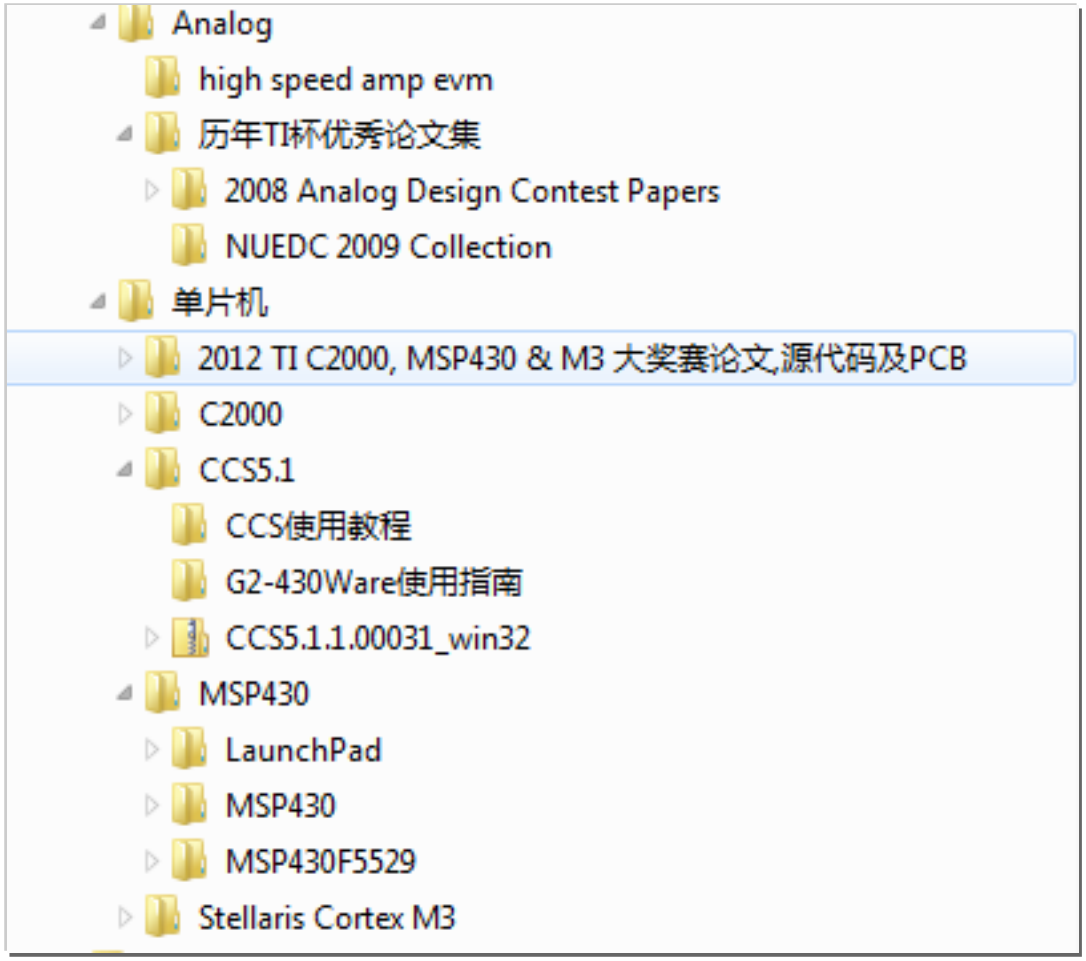


# USCI 波特率发生器

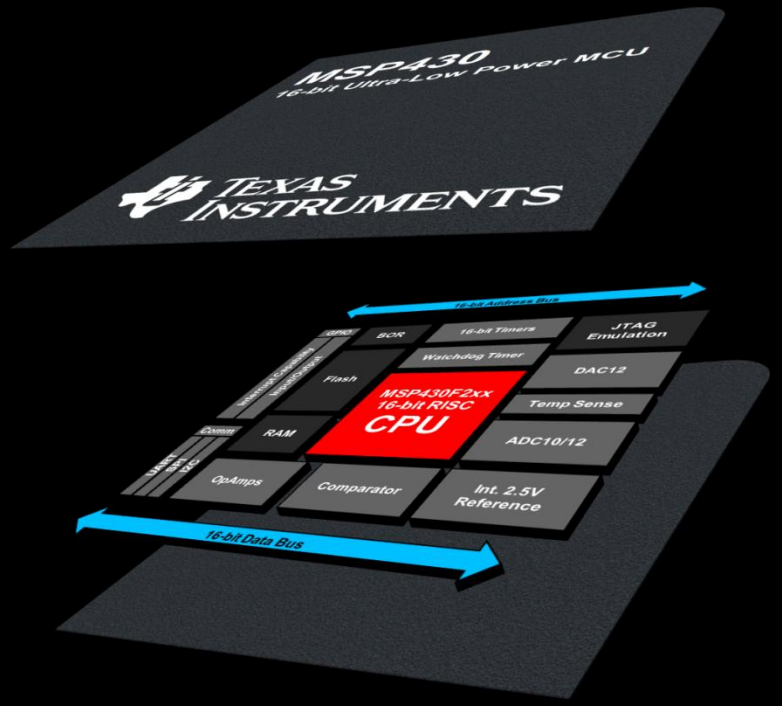
- 过采样波特率发生
- 两个调制器
  - **UCBRSx 和 UCBRFx**
- 采用 **BITCLK16** 进行 **RX** 采样



# TI teaching ROM 资料



# Thank you!




Texas Instruments