

MSP430 Family Architecture

CPE621 Advanced Microcomputer Techniques
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Technology

- Ultra low power
 - The MSP430 platform of ultra-low-power 16-bit RISC mixed-signal processors
 - 0.1 μA RAM retention
 - 0.8 μA real-time clock mode
 - 250 $\mu\text{A}/\text{MIPS}$ active
 - MSP430x5xx – new Flash-based family featuring the lowest power consumption
 - up to 25 MIPS with 1.8 to 3.6V operation starting at 12 MIPS
 - New features include an innovative Power Management Module for optimizing power consumption, an internally controlled voltage regulator, and 2x more memory than previous devices.
- Low power & high performance
 - TMS320C550x DSPs Industry's lowest power fixed-point DSP
 - Large on-chip memory
 - optimized FFT co-processor for faster, cost- and energy-efficient performance
 - One-half the power consumption of existing TMS320C55x™ DSPs
 - 6.8 μW^* in deep sleep mode (all peripheral clocks off)
 - 18/46 mW at 60/100 MHz
 - Applications: medical monitoring, noise cancellation headphones and portable audio/music recording

MSP430 Family

- **MSP430x1xx**
 - 1.8V to 3.6V operation
 - up to 60kB
 - 8MIPS with Basic Clock
 - from a simple low power controller with a comparator, to complete systems on a chip including high-performance data converters, interfaces and multiplier.
- **MSP430F2xx**
 - up to 16 MHz
 - an integrated $\pm 1\%$ on-chip very lowpower oscillator,
 - software-selectable, internal pullup/pull-down resistors
 - increased number of analog inputs
 - the in-system programmable Flash has also been improved with smaller 64-byte segments and a lower 2.2-V programming voltage
 - Available in low-pin count options.
- **MSP430x4xx**
 - up to 120kB/ Flash/ ROM 8MIPS with FLL + SVS
 - an integrated LCD controller
 - Several devices offer application-based peripherals to provide single-chip solutions for flow and electricity metering.
- **MSP430x5xx**
 - 12-25 MIPS with 1.8 to 3.6V
 - an innovative Power Management Module for optimizing power consumption
 - an internally controlled voltage regulator
 - 2x more memory than previous devices.

Introduction

- The Texas Instruments MSP430 series is an ultralow-power microcontroller family consisting of several devices featuring different sets of modules targeted to various applications. The microcontroller is designed to be battery operated for use in extended-time applications.
- Typical applications include embedded and sensor systems. Integrated timers make the configurations ideal for industrial control applications such as ripple counters, digital motor control, EE-meters, hand-held meters, etc. The hardware multiplier enhances the performance and offers a broad code and hardware-compatible family solution.

TI MSP430x1xx family features

- ❑ Ultralow-power architecture:
 - 0.1– 400 μ A nominal operating current @1 MHz
 - 1.8 – 3.6 V operation (2.5–5.5 V for C11x, P11x, and E11x devices)
 - 6 μ s wake-up from standby mode
 - Extensive interrupt capability relieves need for polling
- ❑ Flexible and powerful processing capabilities:
 - Seven source-address modes
 - Four destination-address modes
 - Only 27 core instructions
 - Prioritized, nested interrupts
 - No interrupt or subroutine level limits
 - Large register file
 - Ram execution capability
 - Efficient table processing
 - Fast hex-to-decimal conversion

TI MSP430x1xx family features #2

- ❑ Extensive, memory-mapped peripheral set including:
 - Integrated 12-bit A/D converter
 - Integrated precision comparator
 - Multiple timers and PWM capability
 - Slope A/D conversion (all devices)
 - Integrated USART(s)
 - Watchdog Timer
 - Multiple I/O with extensive interrupt capability
 - Integrated programmable oscillator
 - 32-kHz crystal oscillator (all devices)
 - 450-kHz – 8-MHz crystal oscillator (selected devices)
- ❑ Powerful, easy-to-use development tools including:
 - Simulator (including peripheral and interrupt simulation)
 - C compiler / Assembler / Linker
 - Emulators
 - Flash emulator kit
 - Evaluation kits
 - Device programmer
 - Application notes
 - Example code

TI MSP430x1xx family features #3

- Versatile ultralow-power device options including:
 - Masked ROM
 - OTP (in-system programmable)
 - Flash (in-system programmable)
 - EPROM (UV-erasable, in-system programmable)
 - -40°C to +85°C operating temperature range
 - Up to 64K addressing space
 - Memory mixes to support all types of applications

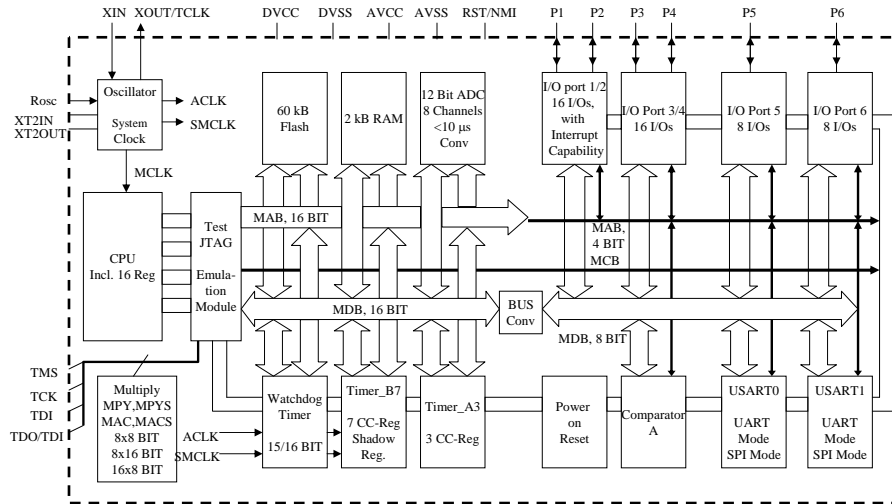
TI MSP430x1xx family peripherals

- Basic Clock System (on-chip DCO + one or two crystal oscillators)
- Watchdog Timer/General Purpose Timer
- Timer_A3 (16-bit timer with 3 capture/compare registers and PWM output)
- Timer_B7 (16-bit timer with 7 capture/compare registers and PWM output)
- 48 I/O pins
 - I/O Port 1, 2 (8 I/O's each, all with interrupt)
 - I/O Port 3, 4, 5, 6 (8 I/O's each)
- Comparator_A (precision analog comparator, ideal for slope A/D conversion)
- ADC12 (12-bit A/D)
- USART0
- USART1
- Hardware Multiplier

Family members

- MSP430F147 32KB +256B Flash, 1KB RAM
- MSP430F148 48KB +256B Flash, 2KB RAM
- MSP430F149 60KB +256B Flash, 2KB RAM

MSP430x14x Architecture



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MSP430 CPU

- 16-bit RISC like CPU
 - 1-5 cycles / instruction
 - Hardware multiplier
- 16 registers
- special registers
 - PC (Program Counter)
 - SP (Stack Pointer)
 - SR (Status Register)
 - CRx (Constant Generator)
- Orthogonal design
 - all registers accessed by the complete instruction set
 - 7 addressing modes
 - 51 (27) instructions

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MSP430 Memory

- Program memory
 - 16-bit memory access (MDB)
 - as many MAB bits as necessary
 - modules for reduced power consumption
 - data constants
- Data memory
 - 8/16 bit memory access
 - program can be loaded and executed from RAM
- Special Function Registers

New Family Members F1611

- Low Supply Voltage Range 1.8 V to 3.6 V
- Ultralow-Power Consumption: Active Mode: 330 μ A at 1 MHz, 2.2 V, Standby Mode: 1.1 μ A, Off Mode (RAM Retention): 0.2 μ A
- Wake-Up From Standby Mode in less than 6 μ s
- 16-Bit RISC Architecture, 125-ns Instruction Cycle Time
- Three-Channel Internal DMA
- 12-Bit A/D Converter With Internal Reference, Sample-and-Hold and Autoscan Feature
- Dual 12-Bit D/A Converters With Synchronization
- 16-Bit Timer_A With Three Capture/Compare Registers
- 16-Bit Timer_B With Three or Seven Capture/Compare-With-Shadow Registers
- On-Chip Comparator
- Serial Communication Interface (USART0), Functions as Asynchronous UART or Synchronous SPI or I2C™ Interface
- Serial Communication Interface (USART1), Functions as Asynchronous UART or Synchronous SPI Interface
- Supply Voltage Supervisor/Monitor With Programmable Level Detection, Brownout Detector
- MSP430F1611: 48KB+256B Flash Memory, 10KB RAM
- Available in 64-Pin Quad Flat Pack (QFP) and 64-pin QFN (see Available Options)

New Family Members F2013

- Low Supply Voltage Range 1.8 V to 3.6 V
- Ultralow-Power Consumption, Active Mode: 220 μ A at 1 MHz, 2.2 V, Standby Mode: 0.5 μ A, Off Mode (RAM Retention): 0.1 μ A
- Ultrafast Wake-Up From Standby Mode in Less Than 1 μ s
- 16-Bit RISC Architecture, 62.5 ns Instruction Cycle Time
- Internal Frequencies up to 16MHz with 4 Calibrated Frequencies to \pm 1%
- Internal Very Low Power LF oscillator
- 32-kHz Crystal, External Digital Clock Source
- 16-Bit Timer_A With Two Capture/Compare Registers
- On-Chip Comparator for Analog Signal Compare Function or Slope A/D (MSP430x20x1 only)
- 10-Bit, 200-kSPS A/D Converter with Internal Reference, Sample-and-Hold, and Autoscan. (MSP430x20x2 only)
- 16-Bit Sigma-Delta A/D Converter with Differential PGA Inputs and Internal Reference (MSP430x20x3 only)
- Universal Serial Interface (USI), supporting SPI and I2C (MSP430x20x2 and MSP430x20x3 only)
- Brownout Detector
- Serial Onboard Programming, No External Programming Voltage Needed
Programmable Code Protection by Security Fuse
- MSP430F2013: 2KB + 256B Flash Memory 128B RAM
- Available in a 14-Pin Plastic Small-Outline Thin Package (TSSOP), 14-Pin Plastic Dual Inline Package (PDIP) and 16-Pin QFN

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New Family Members F5529

- Low Supply-Voltage Range: 1.8 V to 3.6 V
- Ultralow Power Consumption
 - Active Mode (AM): 200 μ A/MHz (Typ)
 - Standby Mode (LPM3 RTC Mode): 2.5 μ A (Typ)
 - Off Mode (LPM4 RAM Retention): 1.5 μ A (Typ)
 - Shutdown Mode (LPM5): 0.2 μ A (Typ)
- Wake-Up From Standby Mode in Less Than 5 μ s
- 16-Bit RISC Architecture, Extended Memory, up to 25-MHz System Clock
- Flexible Power Management System
 - Fully Integrated LDO With Programmable Regulated Core Supply Voltage
 - Supply Voltage Supervision, Monitoring, and Brownout
- Unified Clock System
 - FLL Control Loop for Frequency Stabilization
 - Low Power/Low Frequency Internal Clock Source (VLO)
 - Low Frequency Trimmed Internal Reference Source (REFO)
 - 32-kHz Watch Crystals (XT1)
 - High-Frequency Crystals up to 32 MHz (XT2)
- Timers
 - 16-Bit Timer TA0(5 CCR.), TA1&TA2 (3 CCR) TB0 (7 CCR)
- Two Universal Serial Communication Interfaces
 - Enhanced UART supporting & Auto-Baudrate Detection
- Synchronous SPI, I2C
- Comparator
- Three Channel Internal DMA

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MSP430 Typical Applications

Handheld Measurement

- Air Flow measurement
- Alcohol meter
- Barometer
- Data loggers
- Emission/Gas analyser
- Humidity measurement
- Temperature measurement
- Weight scales

Medical Instruments

- Blood pressure meter
- Blood sugar meter
- Breath measurement
- EKG system

Utility Metering

- Gas Meter
- Water Meter
- Heat Volume Counter
- Heat Cost Allocation
- Electricity Meter
- Meter reading system (RF)

Sports equipment

- Altimeter
- Bike computer
- Diving watches

Security

- Glass break sensors
- Door control
- Smoke/fire/gas detectors

Home environment

- Air conditioning
- Control unit
- Thermostat
- Boiler control
- Shutter control
- Irrigation system
- White goods (Washing machine,..)

Misc

- Smart card reader
- Taxi meter
- Smart Batteries

MSP430 Development Environment

- IAR Embedded Workbench
 - Full version
 - Baseline version (preferred)
 - Kickstart
- mspgcc
 - GCC compiler, no limitation
- TinyOS (Moteiv)
 - GCC compiler/UNIX/Cygwin
- Texas Instrument website, local documents
 - C:\ti\msp430\
 - CPE621 web site

MSP430 Embedded Workbench

- MSP430 documents
 - <http://www.ece.uah.edu/~jovanov/msp430/msp430.html>
- Documentation(local disk) \iar\ew23\430\doc\
 - ew430.pdf
 - Windows Workbench Interface Guide
 - cw430.pdf
 - C-Spy User's Guide
 - a430.pdf
 - MSP430 Assembler, Linker and Librarian Programmer's guide
 - cs430r.pdf
 - C-Spy ROM-Monitor Supplement

Documentation etc.

- MSP430 documents
 - <http://www.ece.uah.edu/~jovanov/msp430/>
 - <http://www.ti.com/sc/docs/products/micro/msp430/msp430.htm>
 - C:\Docs
- User manuals & Datasheet
- Development tools (eZ430)
 - <http://www.ti.com/corp/docs/landing/mcu/index.htm?DCMP=MSP430&HQS=Tools+OT+ez430>