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 µMIPS 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 ±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 120 kB/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 μA nominal operating current @ 1 MHz
  - 1.8 – 3.6 V operation (2.5–5.5 V for C11x, P11x, and E11x devices)
  - 6 μs 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
Versatile ultralow-power device options including:
- Masked ROM
- OTP (in-system programmable)
- Flash (in-system programmable)
- EPROM (UV-erasable, in-system programmable)
- $-40^\circ C$ to $+85^\circ C$ operating temperature range
- Up to 64K addressing space
- Memory mixes to support all types of applications

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
MSP430 x14x Architecture

CPE 621 MSP430 Architecture

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

CPE 621 MSP430 Architecture
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 µA at 1 MHz, 2.2 V, Standby Mode: 1.1 µA, Off Mode (RAM Retention): 0.2 µA
- Wake-Up From Standby Mode in less than 6 µs
- 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 (AM): 220 µA at 1 MHz, 2.2 V
  - Standby Mode (LP0 Mode): 0.5 µA
  - Off Mode (RAM Retention): 0.1 µA
- Ultrafast Wake-Up From Standby Mode in Less Than 1 µs
- 16-Bit RISC Architecture, 62.5 ns Instruction Cycle Time
- 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-ksp/s 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 µA/MHz (Typ)
  - Standby Mode (LPM3 RTC Mode): 2.5 µA (Typ)
  - Off Mode (LPM4 RAM Retention): 1.5 µA (Typ)
  - Shutdown Mode (LPM5): 0.2 µA (Typ)
- Wake-Up From Standby Mode in Less Than 5 µs
- 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
## MSP430 Typical Applications

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

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

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

### Medical Instruments
- Blood pressure meter
- Blood sugar meter
- Breath measurement
- EKG system

### Sports equipment
- Altimeter
- Bike computer
- Diving watches

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

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### 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](http://www.ece.uah.edu/~jovanov/msp430/msp430.html)
- Documentation (local disk) \ia\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.ece.uah.edu/~jovanov/msp430/)
  - C:\Docs
- User manuals & Datasheet
- Development tools (eZ430)