MSP430 Ultra-Low-Power Microcontrollers
MSP430 Microcontrollers

Key Features

- **Ultra-low-power** architecture and flexible clock system extends battery life:
  - 0.1-µA RAM retention
  - <1-µA RTC mode
  - <250 µA/MIPS
- **Integrated intelligent peripherals** including wide range of high-performance analog and digital peripherals offload the CPU
- **16-bit RISC CPU architecture** enables new applications with industry leading code density
- **Easy to Get Started**: Complete development tools starting at only $20

MSP430 Modular Architecture

A 16-bit RISC CPU, peripherals and flexible clock system are combined by using a von-Neumann common memory address bus (MAB) and memory data bus (MDB). Partnering an optimized CPU with modular memory-mapped analog and digital peripherals, the MSP430 device offers solutions for today’s and tomorrow’s mixed-signal applications.

**Device Configuration**

- 1-kB to 256-kB ISP Flash
- RAM up to 16 kB
- 14- to 100-pin options

**Integrated Peripherals**

- 10-/12-bit SAR ADC
- 16-bit Sigma Delta ADC
- 12-bit DAC
- Comparator
- LCD driver
- Supply Voltage Supervisor (SVS)
- Operational amplifiers
- 16-bit and 8-bit timers
- LDO

**Ultra-Low Power**

- Zero-power Brown Out Reset (BOR)
- <1-µs clock startup
- <50-nA pin leakage

- Watchdog timer
- UART/LIN
- I²C
- SPI
- IrDA
- Hardware multiplier
- DMA controller
- Temperature sensor

16-Bit RISC CPU

- Optimized for C and assembler programming
- 16 general-purpose registers
- Compact core design reduces power and cost
- Up to 25 MIPS of performance available

The MSP430 MCU’s orthogonal architecture provides the flexibility of 16 fully addressable, single-cycle 16-bit CPU registers and the power of a RISC. The modern design of the CPU offers versatility using only 27 easy-to-understand instructions and seven consistent-addressing modes. This results in a 16-bit low-power CPU that has more effective processing, is smaller-sized, and more code-efficient than other 8-/16-bit microcontrollers. This will allow you to develop new ultra-low-power, high-performance applications at a fraction of the code size.

The MSP430 CPU core with sixteen 16-bit registers, 27 core instructions and seven addressing modes results in higher processing efficiency and code density.
Ultra-Low-Power Performance

The MSP430 is designed specifically for ultra-low-power applications. A flexible clocking system, multiple operating modes and zero-power always on brown-out reset (BOR) are implemented to reduce power consumption and dramatically extend battery life. The MSP430 BOR function is always active in all low-power modes to ensure the most reliable performance possible.

The MSP430 CPU architecture with 16 registers and 16-bit data and address buses minimize power consuming fetches to memory and a fast vectored-interrupt structure reduces the need for wasteful CPU software flag polling. Intelligent hardware peripheral features were also designed to allow tasks to be completed more efficiently independent of the CPU. Many MSP430 customers have developed battery-based products that will last for over 10-years from the original battery!

Ultra-Low Power Checklist:
- Multiple operating modes
  - 0.1-μA RAM retention
  - <1-μA RTC mode
  - <250 μA/MIPS
- Instant-on stable high-speed clock
- 1.8-V to 3.6-V operation
- Zero-power BOR
- <50-nA pin leakage
- CPU that minimizes CPU cycles per task
- Intelligent, low-power peripheral options

Ultra-Low Power Activity Profile

Ultra-fast 1-μs DCO start-up allows MSP430-based systems to remain in low-power modes for the longest possible interval – extending battery life. The DCO is fully user programmable.

Key Applications
- Utility metering
- Portable medical and instrumentation
- Low-power wireless applications
- Intelligent sensing
- Consumer electronics
- Security systems

Flexible Clock System
- Low-frequency auxiliary clock for ultra-low-power stand-by mode
- High-speed master clock for high-performance processing
- Stability over time and temperature

The MSP430 MCU clock system is designed specifically for battery-powered applications. Multiple oscillators are utilized to support event-driven burst activity. A low-frequency Auxiliary Clock (ACLK) is driven directly from a common 32-kHz watch crystal or the internal very low-power oscillator (VLO) – with no additional external components. The ACLK can be used for a background real-time clock self wake-up function. An integrated high-speed digitally controlled oscillator (DCO) can source the master clock (MCLK) used by the CPU and sub-main clock (SMCLK) used by the high-speed peripherals. By design, the DCO is active and stable in 1 μs (F2xx) or <6 μs (x1xx, x4xx, F5xx). MSP430 device-based solutions efficiently use 16-bit RISC CPU high performance in very short burst intervals. This results in very high performance and ultra-low power consumption.
The Next Generation: MSP430F5xx

The MSP430F5xx is the next generation technology platform for the MSP430 family and continues to expand on MSP430’s industry leadership in the ultra-low-power 16-bit MCU space. The 5xx family offers improved ultra-low-power performance with innovative new power conserving features such as adjustable core voltage and an integrated low-power LDO. Cutting edge power efficiency is available through an innovative power management system as well as record breaking performance at 160 μA/MIPS with 256-kB flash and 16-kB RAM. The 5xx also offers increased peripheral performance, significantly higher levels of integration and many new features designed for customer ease of use, all while remaining completely compatible with existing MSP430 families.

Ultra-Low Power
- 160 μA/MIPS
- 2.5-μA standby mode
- Integrated LDO, BOR, WDT+, RTC
- 12 MHz @1.8 V
- Wake up from standby in <5 μs

Increased Performance
- Up to 25 MHz
- 1.8-V ISP Flash erase and write
- Fail-safe, flexible clocking system
- User-defined Bootstrap Loader
- Up to 1-MB linear memory addressing

Innovative Features
- Multi-channel DMA supports data movement in standby mode
- Industry leading code density
- More design options including USB, RF, encryption, LCD interface

Get Started Now!

Getting started is easy with MSP430. MSP430 offers easy-to-use tools, free development software and hundreds of application notes and code examples to help get your design started.

Two main collateral pieces are needed for device documentation.
- Data Sheets for each specific device provide pin functions, internal signal connections and operational parameters. Datasheets can be obtained by going to the specific device web page.
- User Guides provide in-depth detailed technical information on the device peripherals. These are written for each family of the MSP430, including x1xx, x2xx and x4xx and the new F5xx.

Visit www.ti.com/msp430 for all the documentation and resources.

Flash-Based x5xx MCU Platform (Vcc 1.8-3.6V), Up to 25 MIPS (See www.ti.com/msp430 for additional information)

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<th>PMM, (BOR SVS, SVM LDO)</th>
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<th>Ch B: F1C/SPI</th>
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<th>MPY</th>
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New products are listed in bold red. Preview products are listed in bold blue.

www.ti.com/msp430
## MSP430 Microcontrollers

### Flash-Based F2xx MCU Platform (Vcc 1.8-3.6V), Up to 16 MIPS

(See [www.ti.com/msp430](http://www.ti.com/msp430) for additional information)

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### Flash/ROM-Based x4xx MCU Platform (Vcc 1.8-3.6V), Up to 8 MIPS (unless noted)

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**Notes:**
- Prices are quoted in U.S. dollars and represent year 2008 suggested resale pricing. All prices are subject to change. Customers are advised to obtain the most current and complete pricing information from TI prior to placing orders.
- TI may verify final pricing prior to accepting any order. New products are listed in bold red. Preview products are listed in bold blue.
### Flash/ROM-Based x1xx MCU Platform (Vcc, 1.8-3.6V), Up to 8 MIPS

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**New products are listed in bold red.**

## Selected Package Options for MSP430 Devices

**1**Prices are quoted in U.S. dollars and represent year 2008 suggested resale pricing. All prices are subject to change. Customers are advised to obtain the most current and complete pricing information from TI prior to placing orders. TI may verify final pricing prior to accepting any order.

## New products are listed in bold red.

www.ti.com/msp430
Intelligent Peripherals

With purely software-driven functions, the CPU is 100% active and consuming power. Effectively utilizing peripherals allows the CPU to be turned off to save power or work on other activities to achieve the highest performance. MSP430 device peripherals are designed to require the least amount of software service. Additional hardware features allow CPU resources to focus more on differentiated application-specific features and less on basic data handling. Lower-cost systems can be implemented using less software and lower power.

Peripheral Overview

ADC10/ADC12 — The ADC10/12 module supports fast, >200ksps, 10- or 12-bit analog-to-digital conversions. The module features a 10 or 12-bit SAR core with 5, 8 or 12 input channels, sample select control, 1.5/2.5V reference generator and internal temperature sensor. ADC10 features a data transfer controller (DTC) and ADC12 features a 16 word conversion-and-control buffer. These added features allow samples to be converted and stored without CPU intervention.

BOR — The brown-out reset (BOR) circuit detects low supply voltages and reset circuit resets the device by triggering a POR signal when power is applied or removed. MSP430’s zero-power BOR circuit is continuously turned on, including in all low power modes.

Comparator_A/Comparator_A+ — The Comparator_A/Comparator_A+ module supports precision slope analog-to-digital conversions, supply voltage super vision, and monitoring of external analog signals for accurate voltage and resistor value measurement. The module features a selectable reference voltage generator and input multiplexer. (Comp_A+/A+)

DAC12 — The DAC12 module is a 12-bit, voltage output DAC featuring internal or external reference selection, programmable settling time for optimal power consumption and can be configured in 8- or 12-bit mode. When multiple DAC12 modules are present, they may be grouped together for synchronous update operation.

DMA — The direct memory access (DMA) controller transfers data from one address to another, without CPU intervention, across the entire address range. The DMA increases the throughput of peripheral modules and reduces system power consumption. The module features up to three independent transfer channels.

ESP430 (integrated in FE42x devices) — The ESP430CE1 module incorporates the SD16, hardware multiplier and ESP430 embedded processor engine for single-phase energy metering applications. The module performs metering calculations independent of the CPU.

FLASH — The MSP430 flash memory is bit-, byte-, and word-addressable and programmable. The main memory segment size is 512 bytes. Each MSP430 also has up to 256 bytes of Flash Information Memory for EEPROM emulation. Flash can be read, erased and written (100,000 cycles) through the JTAG debugging interface, the Bootstrap Loader, and in-system.

I/O — MSP430 devices have up to 12 digital I/O ports implemented, P1-P10. Each port has eight I/O pins. Every I/O pin is configurable for input or output direction, and can be individually read or written to. Ports P1 and P2 have interrupt capability. MSP430F2xx, 5xx and some 4xx devices feature built-in individually configurable pull-up or pull-down resistors.

LCD/LCD_A — The LCD/LCD_A controller directly drives LCD displays with automatic signal generation for up to 160 segments. The MSP430 LCD controller can support static, 2-mux, 3-mux, and 4-mux LCDs. The LCD_A module includes an integrated charge pump for contrast control.

MPY — The hardware multiplier module supports 8-/16-bit x 8-/16-bit signed and unsigned multiply with optional ‘multiply and accumulate’ functionality. It is a peripheral which does not interfere with CPU activities and can be accessed by the DMA. The MPY on new F47xx and F5xx devices features up to 32x32 bit operation.

OA — The MSP430 integrated operational amplifiers feature single supply, low current operation with rail-to-rail outputs and programmable settling times. Internal, programmable feedback resistors and connections between multiple op amps allow for a variety of software selectable configuration options including: unity gain mode, comparator mode, inverting PGA, non-inverting PGA, differential and instrumentation amplifier.

SCAN IF — The Scan F module is a programmable state machine with analog front end used to automatically measure linear or rotational motion with the lowest possible power consumption. The module features support for different types of LC and resistive sensors and for quadrature encoding.

SD16/SD16_A — The SD16/SD16_A module features up to three 16-bit sigma-delta A/D converters with an internal 1.2V reference. Each has up to 8 fully differential multiplexed inputs including a built-in temperature sensor. The converters are second-order oversampling sigma-delta modulators with selectable oversampling ratios of up to 1024 (SD16_A) or 256 (SD16).

SVS — The supply voltage supervisor (SVS) is a configurable module used to monitor the AVCC supply voltage or an external voltage. The SVS can be configured to set a flag or generate a POR reset when the supply voltage or external voltage drops below a user-selected threshold.

Timer_A/Timer_B — Timer_A and Timer_B are asynchronous 16-bit timer/counters with up to seven capture/compare registers and four operating modes. The timers support multiple capture/compare, PWM outputs, and interval timing and also have extensive interrupt capabilities.

USART — The universal synchronous/asynchronous receive/transmit (USART) peripheral interface supports asynchronous RS232 and synchronous SPI communication with one hardware module. The MSP430F15x and MSP430F16x USART module also supports F/C. The module supports programmable baud rate and independent interrupt capability for receive and transmit.

USCI — The universal serial communication interface (USCI) module features two independent channels which can be used simultaneously. The asynchronous channel (USCI_A) supports UART mode, SPI mode, pulse shaping for I2C, and automatic baud rate detection for LIN communications. The synchronous channel (USCI_B) supports F/C and SPI modes.

USI — The universal serial interface (USI) module is a synchronous serial communication interface with a data length of up to 16-bit and can support SPI and F/C communication with minimal software.
Embedded Emulation with MSP430 MCUs

- In-system development
- Subject your design to the exact same characteristics of the final application
- Non-obtrusive development and debug
- Common user software and physical interface
- Maintains signal integrity of microvolt analog signals

Today's applications operating at lower voltages, with tighter packaging and higher-precision analog, benefit greatly from the MSP430 MCU's in-system emulation approach. The MSP430 MCU's dedicated embedded emulation logic resides on the actual device itself and is accessed via JTAG (4-wire) or Spy-Bi-Wire (2-wire) using no additional system resources. Maintaining signal integrity is virtually impossible with cumbersome in-circuit emulators that are sensitive to cabling crosstalk. And, unlike abstract background debuggers, no time-sharing of system serial communication resources is required with embedded emulation on the MSP430 device. From the first day of development, firmware engineers can now unobtrusively develop and debug their embedded code with full-speed execution, breakpoints, and single steps in an application.

Advanced Debugging Using the Enhanced Emulation Module (EEM)

Every MSP430 includes advanced on-chip debug logic. The Enhanced Emulation Module (EEM) features support for both precision analog and full-speed digital debug. Depending on the device being used, the EEM provides different levels of debug features. Due to the common architecture and peripherals of the family of MSP430 devices, it's possible to use a device with the full version of the EEM for development and then easily migrate to a smaller device for final production, optimized for the application.

- 2-8 hardware breakpoints
- Complex breakpoints
- Embedded trace capability
- Break if read/write at specified address
- Protection of read/write areas within memory
- All timers and counters can be stopped (device dependent)
- Intelligent clock control keeps PWM generation, on-going ADC conversion or communication running, even if emulation is on hold
- Single step/step into and over/run in real-time
- Full support of all low-power modes
- Support for DCO dependencies such as temperature and voltage

Production Programming:

In-System Production Programming

JTAG: Programming through JTAG is supported with all MSP430 devices. A security fuse can be blown to sever JTAG access and prevent reverse engineering.
Spy-Bi-Wire: 2-wire debug/programming interface similar to JTAG for the new low-pin-count MSP430F2xx devices.
Bootstrap Loader: On all MSP430 devices (except MSP430F20xx), the bootstrap loader (BSL), is part of factory-masked ROM and can be implemented via a UART. Single devices are programmed either stand-alone or in-system. Program, verify, read out and segment erase are password protected.

For further information on JTAG and bootstrap loader, go to www.ti.com/msp430appnotes and download Application Notes SLAA149, SLAA089 and SLAA096.

ROM and Flash

For high-volume customers, masked ROM and factory programmed Flash devices can be ordered. The ROM process takes approximately 8-12 weeks from the receipt of a customer's verified code to the production of the first silicon. Flash devices take approximately 6-8 weeks. A customer-specific coded part number will be released.

Production Programming

MSP430 devices may also be programmed by TI's MSP-GANG430 or manual and automated production programming systems from third party vendors such as:

BPM Microsystems www.bpmmicro.com
Data I/O www.dataio.com
Elprotronic www.elprotronic.com
SoftBaugh www.softbaugh.com
Hardware Development Tools

Debugging & Programming Interfaces

TI offers USB and Parallel Port Flash Emulation Tools (FET) supporting complete in-system development for JTAG (4 wire) and Spy-Bi-Wire (2 wire – USB only). Programming, assembler /C-source level debug, single stepping, multiple hardware breakpoints, full speed operation and peripheral access are all fully supported in-system. This interface can be used with any development board with a JTAG header.

The MSP-GANG430 is a Flash device programmer which can program eight targets simultaneously using a JTAG connection either as a stand-alone programmer or in a development environment.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>PC Port</th>
<th>Contents Include</th>
<th>Devices Supported</th>
<th>Price (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP-FET430UIF</td>
<td>USB</td>
<td>Interface only</td>
<td>All</td>
<td>$ 99</td>
</tr>
<tr>
<td>MSP-GANG430</td>
<td>Serial</td>
<td>Production programmer</td>
<td>All (8 devices at one time)</td>
<td>$ 199</td>
</tr>
</tbody>
</table>

\(^1\)Price per unit in U.S. dollars.

Development Kits

MSP430 Development Kits come with everything required to complete an entire project including a socketed target board, a Flash Emulation Tool (FET) debugger and programming interface, cables and free code limited Code Composer Essentials (16 kB) and IAR (4 kB) software. All MSP-FET430Uxx Development Kits come with a MSP-FET430UIF USB Debugging and Programming Interface and an xx-pin target board unless otherwise noted.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Contents Include</th>
<th>Devices Supported</th>
<th>Price (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP-FET430U14</td>
<td>Interface and target board</td>
<td>14-pin PW (TSSOP)</td>
<td>$ 149</td>
</tr>
<tr>
<td>MSP-FET430U28</td>
<td>Interface and target board</td>
<td>20-/28-pin PW (TSSOP)</td>
<td>$ 149</td>
</tr>
<tr>
<td>MSP-FET430U38</td>
<td>Interface and target board</td>
<td>38-pin DA (TSSOP)</td>
<td>$ 149</td>
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<tr>
<td>MSP-FET430U23x0</td>
<td>Interface and target board</td>
<td>MSP430F23x0 40-pin RHA (QFN)</td>
<td>$ 149</td>
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<tr>
<td>MSP-FET430U48</td>
<td>Interface and target board</td>
<td>48-pin DL (SSOP)</td>
<td>$ 149</td>
</tr>
<tr>
<td>MSP-FET430U64</td>
<td>Interface and target board</td>
<td>64-pin PM (LQFP)</td>
<td>$ 149</td>
</tr>
<tr>
<td>MSP-FET430U80</td>
<td>Interface and target board</td>
<td>80-pin PN (LQFP)</td>
<td>$ 149</td>
</tr>
<tr>
<td>MSP-FET430U100</td>
<td>Interface and target board</td>
<td>100-pin PZ (LQFP)</td>
<td>$ 149</td>
</tr>
<tr>
<td>MSP-FET430U5x100</td>
<td>Interface and target board</td>
<td>100-pin PZ (TQFP)</td>
<td>$ 149</td>
</tr>
<tr>
<td>MSP-TS430P25x100</td>
<td>Target board only</td>
<td>100-pin PZ (TQFP)</td>
<td>$ 49</td>
</tr>
</tbody>
</table>

\(^1\)Price per unit in U.S. dollars.

New products are listed in bold red.

[www.ti.com/msp430]
eZ430: MCUs Made Easy
Designing with the world’s lowest-power MCU just got even easier with the eZ430 family of low-cost development tools starting at only $20! These platforms contain all the required hardware and software in a portable USB stick enclosure and include a free 16-kB code-limited version of Code Composer™ Essentials (CCE) which provides full emulation with the option of designing a stand-alone system or detaching the removable target board to integrate into an existing design.

Experimenter Boards
This innovative kit feature the largest MSP430 devices with additional hardware components to take advantage of the high level of analog integration available for easy system evaluation and prototyping. These are ideal for learning the MSP430 architecture, testing the capabilities and range available peripherals and include integrated headers for plugging in low-power RF modules (CCxxxxEMK).

### eZ430 Tools and Experimenter Boards

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Contents Include</th>
<th>Devices Included</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>eZ430-F2013</td>
<td>Interface and target board</td>
<td>MSP430F2013</td>
<td>$20</td>
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<tr>
<td>eZ430-F2012</td>
<td>3 target boards</td>
<td>MSP430F2012</td>
<td>$10</td>
</tr>
<tr>
<td>eZ430-RF2500</td>
<td>Interface, (2) target boards, battery board</td>
<td>MSP430F2274, CC2500</td>
<td>$49</td>
</tr>
<tr>
<td>eZ430-RF2500T</td>
<td>Target board, battery board</td>
<td>MSP430F2274, CC2500</td>
<td>$20</td>
</tr>
<tr>
<td>eZ430-RF2480</td>
<td>Interface, (3) target boards, 2 battery boards</td>
<td>MSP430F2274, CC2480</td>
<td>$99</td>
</tr>
<tr>
<td>MSP-EXP430FG4618</td>
<td>Board only (FET sold separately)</td>
<td>MSP430FG4618, MSP430F2013</td>
<td>$99</td>
</tr>
</tbody>
</table>

*Price per unit in U.S. dollars.

### Software Development Tools

Texas Instruments and third party developers offer Integrated Development Environments (IDE) to program all MSP430 devices. Full C-compilers are available enabling customers to develop and debug code in seconds. Free, code-limited versions of IAR Embedded Workbench Kickstart and TI Code Composer™ Essentials are also available for download.

**Third Party IDEs include:**
- GCC [mspgcc.sourceforge.net](http://mspgcc.sourceforge.net)
- HT Soft [www.htsoft.com](http://www.htsoft.com)
- IAR [www.iar.com](http://www.iar.com)
- Imagecraft [www.imagecraft.com](http://www.imagecraft.com)
- Phyton [www.phyton.com](http://www.phyton.com)
- Quadravox [www.quadrovox.com](http://www.quadrovox.com)
- Rowley [www.rowley.co.uk](http://www.rowley.co.uk)
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**Internet**

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support.ti.com

TI Semiconductor KnowledgeBase Home Page
support.ti.com/sc/knowledgebase

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Internet/Email support.ti.com/sc/pic/americas.htm

**Europe, Middle East, and Africa**

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- International +49 (0) 8161 80 2121
- Russian Support +7 (49) 95 98 10 701

**Note:** The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

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                  Domestic www.tij.co.jp/pic

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  - Hong Kong 800-96-5941
  - India 1-800-425-7888
  - Indonesia 001-803-8861-1006
  - Korea 080-551-2804
  - Malaysia 1-800-80-3973
  - New Zealand 0800-446-934
  - Philippines 1-800-765-7404
  - Singapore 800-886-1028
  - Taiwan 0800-006800
  - Thailand 001-800-886-0010

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