Microcontrollers

- Highly configurable (programmable)
  - One circuit fits many different applications
  - One chip serves several functions
- Analog and digital I/O
  - Can serve as bridge
- Inexpensive
  - starts at ~ $0.50
  - $10 (or more) for higher performance (more memory, IO pins)
- Many applications
  - Toothbrush (timer)
  - Flashlight (intensity)
  - Washing machine
  - Multimeter
  - Embedded webserver
  - Wireless sensor networks
  - Security system
  - Medical devices (e.g. pacemaker)
  - Utility metering
  - PC peripherals
  - ...

Many vendors and choices. Characteristics:

- performance
- power dissipation
- peripherals
  - analog, digital IO
  - RS-232, USB, I2C, ...
  - TCP/IP (Ethernet)
- Cost: $0.50 ...
- Support (development system)
Example: TI MSP430

Device Configuration
- 1-KB to 120-KB ISP Flash
- RAM up to 10 KB
- 14- to 100-pin options

Ultra-Low Power Checklist:
- Multiple operating modes
  - 0.1-μA power down
  - 0.8-μA standby
  - 250-μA / MIPS @ 3 V
- 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
- Low-power peripheral options
### MSP430 Instruction set

<table>
<thead>
<tr>
<th>Opcode</th>
<th>Source</th>
<th>Ad</th>
<th>B/W</th>
<th>As</th>
<th>Destination</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0 1 0 0</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>MOV Move source to destination</td>
</tr>
<tr>
<td>0 1 0 1</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>ADD Add source to destination</td>
</tr>
<tr>
<td>0 1 1 1</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>ADDC Add source and carry to destination</td>
</tr>
<tr>
<td>1 0 0 0</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>SUB Subtract source from destination (with carry)</td>
</tr>
<tr>
<td>1 0 0 1</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>CMP Compare (pretend to subtract) source from destination</td>
</tr>
<tr>
<td>1 0 1 1</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>DADD Decimal add source to destination (with carry)</td>
</tr>
<tr>
<td>1 0 1 0</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>BIT Test bits of source AND destination</td>
</tr>
<tr>
<td>1 1 0 0</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>BIC Bit clear (dest &amp; src)</td>
</tr>
<tr>
<td>1 1 0 1</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>BIS Bit set (logical OR)</td>
</tr>
<tr>
<td>1 1 1 0</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>XOR Exclusive or source with destination</td>
</tr>
<tr>
<td>1 1 1 1</td>
<td>source</td>
<td>Ad</td>
<td>B/W</td>
<td>As</td>
<td>destination</td>
<td>AND Logical AND source with destination (dest &amp; src)</td>
</tr>
</tbody>
</table>
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.

Multiple Oscillator Clock System

Very Low-Power Oscillator (VLO)

ACLK 32 kHz

Low-Power Peripherals

32.768 Hz

MCLK 100 kHz - 16 MHz

CPU and Peripherals
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
- Watchdog timer
- UART/LIN
- I²C
- SPI
- IrDA
- Hardware multiplier
- DMA controller
- Temperature sensor
### Selected Package Options for MSP430 Devices

<table>
<thead>
<tr>
<th>Package Type</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-pin PW (TSSOP)</td>
<td>(6.00, 6.50)</td>
</tr>
<tr>
<td>14-pin N (PDIP)</td>
<td>(6.00, 5.00)</td>
</tr>
<tr>
<td>16-pin RSA (QFN)</td>
<td>(6.00, 8.80)</td>
</tr>
<tr>
<td>22-pin DGV (TVSOP)</td>
<td>(6.00, 7.00)</td>
</tr>
<tr>
<td>26-pin PW (TSSOP)</td>
<td>(6.50, 11.50)</td>
</tr>
<tr>
<td>26-pin DW (SOIC)</td>
<td>(6.50, 13.00)</td>
</tr>
<tr>
<td>26-pin RGE (DFN)</td>
<td>(6.50, 13.00)</td>
</tr>
<tr>
<td>28-pin DW (SOIC)</td>
<td>(6.50, 13.00)</td>
</tr>
<tr>
<td>28-pin PW (TSSOP)</td>
<td>(6.50, 13.00)</td>
</tr>
<tr>
<td>32-pin RHB (QFN)</td>
<td>(6.00, 11.50)</td>
</tr>
<tr>
<td>38-pin DA (TSSOP)</td>
<td>(6.00, 11.50)</td>
</tr>
<tr>
<td>48-pin RHA (QFN)</td>
<td>(6.00, 15.00)</td>
</tr>
<tr>
<td>48-pin RGZ (QFN)</td>
<td>(6.00, 15.00)</td>
</tr>
<tr>
<td>48-pin DL (SSOP)</td>
<td>(6.00, 15.00)</td>
</tr>
<tr>
<td>64-pin RGC, RTD (QFN)</td>
<td>(6.00, 16.00)</td>
</tr>
<tr>
<td>64-pin PM, PAG (LOFP/TOFP)</td>
<td>(6.00, 16.00)</td>
</tr>
<tr>
<td>80-pin PN (LOFP)</td>
<td>(6.00, 16.00)</td>
</tr>
<tr>
<td>100-pin PZ (LOFP)</td>
<td>(6.00, 16.00)</td>
</tr>
<tr>
<td>113-pin ZOW (BGA)</td>
<td>(6.00, 16.00)</td>
</tr>
</tbody>
</table>

#### 24-pin RGE (QFN)

![24-pin RGE (QFN)](image)

#### 113-pin ZQW (BGA)

![113-pin ZQW (BGA)](image)
**Digital IO**

- Digital I/O port
- Pin sharing
- Port direction

  - Output:
    - Open collector
    - Pull-up resistor
    - Push-pull output stage
    - Example: LED

  - Input:
    - Input current
    - Interrupts

**Analog IO**

- Analog versus digital signals
- D/A conversion
  - Example: pulse density modulation (dimmer)