**MSP430 Model Families Overview**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Model Series | Flash (KB) | RAM (KB) | GPIO | Max Clock | ADC | Timers | Key Features |
| MSP430G2xx | Up to 32 | Up to 2 | 10–24 | 16 MHz | 10-bit | 2 | Entry-level, LaunchPad support |
| MSP430F2xx | Up to 60 | Up to 4 | 16–48 | 16 MHz | 12-bit | 2 – 3 | Enhanced ADC, basic UART/SPI/I2C |
| MSP430F5xx/F6xx | Up to 512 | Up to 66 | 48–83 | 25 MHz | 12-bit | 4 – 7 | DMA, USB, real-time clock |
| MSP430FR2xx/FR4xx | Up to 64 | Up to 8 | 12–32 | 16 MHz | 10-bit | 2 – 3 | FRAM for better endurance |
| MSP430FR5xx/FR6xx | Up to 256 | Up to 32 | 32–83 | 24 MHz | 12-bit | 4 – 7 | High endurance FRAM, AES, low power |

**Protocols & Connectivity Support**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Protocol | Availability | Model Support | Max Connections | Notes |
| UART | Yes | All | 1 – 4 | Full-duplex |
| SPI | Yes | All | 1 Master, multiple Slaves | Depends on software |
| I2C | Yes | All | 1 Master, multiple Slaves | Shared bus |
| USB | Limited | MSP430F5xx/F6xx only | 1 Device | Device role only |
| CAN | No native | External via SPI or UART | - | Not on-chip |
| Wireless | No native | External via UART/SPI | - | Needs CC1101, CC2500, etc |

**Power Specifications**

|  |  |  |  |
| --- | --- | --- | --- |
| Operating Voltage | Sleep Current | Active Current | Wake Time |
| 1.8–3.6 V | ~0.1 µA | ~160 µA/MHz | ~1 µs |

MSP430s are designed for **ultra-low power** operation with aggressive sleep modes (LPM0–LPM4).

**GPIO & Connectivity Comparison Table**

|  |  |  |  |
| --- | --- | --- | --- |
| Feature | MSP430FR5994 | MSP430FR6989 | MSP430F2618S-HT |
| Total GPIO Pins | Up to 74 | Up to 83 | Up to 48 |
| Max Package Size | 100-pin QFP | 100-pin QFP | 64-pin TQFP (space-rated) |
| UART Modules | 2 × | 2 × | 2 × USCI\_A |
| SPI Modules | 2 × (configurable) | 2 × (configurable) | 2 × USCI\_B |
| I2C Modules | 2 × (configurable) | 2 × (configurable) | 2 × USCI\_B |
| Total eUSCI Modules  (SPI, UART & I2C) | 4 (2 A-type, 2 B-type) | 4 (2 A-type, 2 B-type) | 4 (2 A-type, 2 B-type) |
| USB Support | ❌ | ❌ | ❌ |
| Timers | 4 × 16-bit | 4 × 16-bit | 3 × 16-bit |
| ADC Channels | 8 ch, 12-bit SAR | 16 ch, 12-bit SAR | 12 ch, 12-bit SAR |
| DMA Channels | 6 | 6 | None |
| Capacitive Touch I/O | Yes (16 channels) | Yes (16 channels) | No |
| RTC Module | Yes | Yes | No |
| Watchdog Timer | Yes | Yes | Yes |
| External Oscillator | Yes (LFXT, HFXT) | Yes (LFXT, HFXT) | Yes |
| FRAM | 256 KB | 128 KB | No (uses Flash) |

**Feasibility for Satellite Use**

**Pros:**

1. **Low Power Consumption**: Critical for power-limited spacecraft.
2. **Fast Wake Time**: Useful for event-driven architectures.
3. **Radiation Tolerance (with Caveats)**:
   * FRAM models (FRxx) offer better resistance to **SEUs** than Flash.
   * Lower complexity reduces susceptibility.
4. **Simple Architecture**: Useful for hardened or fault-tolerant design.
5. **TI's Space-Grade MSP430F2618S-HT**: Available for Hi-Rel systems.

**Cons:**

1. **No Built-In Radiation Hardening (except space-grade variants)**:
   * Requires TMR (Triple Modular Redundancy) or watchdogs for reliability.
2. **16-bit CPU Limitations**:
   * May be underpowered for heavy OBC tasks (e.g., attitude control algorithms).
3. **Lack of Native CAN/RS-485/SpaceWire**:
   * Requires external transceivers or controllers.
4. **Memory Limitations**:
   * Larger OBCs or payloads (e.g., cameras, telemetry logs) may exceed onboard FRAM/Flash.
5. **No MMU or OS Support**:
   * Real-time OS like FreeRTOS can be run, but no MMU or virtualization support.

**Best Fit Use Cases in a Satellite**

|  |  |  |
| --- | --- | --- |
| Role | Feasibility | Notes |
| OBC | Moderate | Good for CubeSats with simple tasks. FRAM-based models recommended. |
| Telemetry Subsystem | High | Ideal due to low power, ADC support, and serial/I2C interfaces. |
| Power Management Unit (PMU) | High | ADCs, timers, and low power make it ideal. |
| Attitude Control | Low | Lacks DSP/FPU needed for control algorithms. |
| Communications Handling | Moderate | Needs external RF modules; SPI/UART manageable. |
| Thermal Monitoring | High | Works well with analog sensors, thermistors. |

**Abbreviations:**

**SEUs:** **(Single Event Upsets)** are a type of **radiation-induced error** that occurs when a **high-energy particle** (like a proton, neutron, or heavy ion) strikes a sensitive part of a microelectronic circuit and **flips a bit** in memory or a register.

**FRAM: (Ferroelectric Random-Access Memory)** is a type of non-volatile memory that combines the speed and flexibility of RAM with the **data retention** of Flash memory, and is particularly valued in embedded systems for its low power usage, endurance, and radiation resistance.

**eUSCI (Enhanced Universal Serial Communication Interface)**

The **eUSCI** is a **hardware communication module** found in newer MSP430 microcontrollers (especially the **MSP430FR5xx/6xx** families). It allows the microcontroller to communicate with other devices over standard serial protocols like **UART**, **SPI**, and **I²C**.