M01: Embedded Systems Architecture

1.2. TI Tiva Series MCUs

Ref:

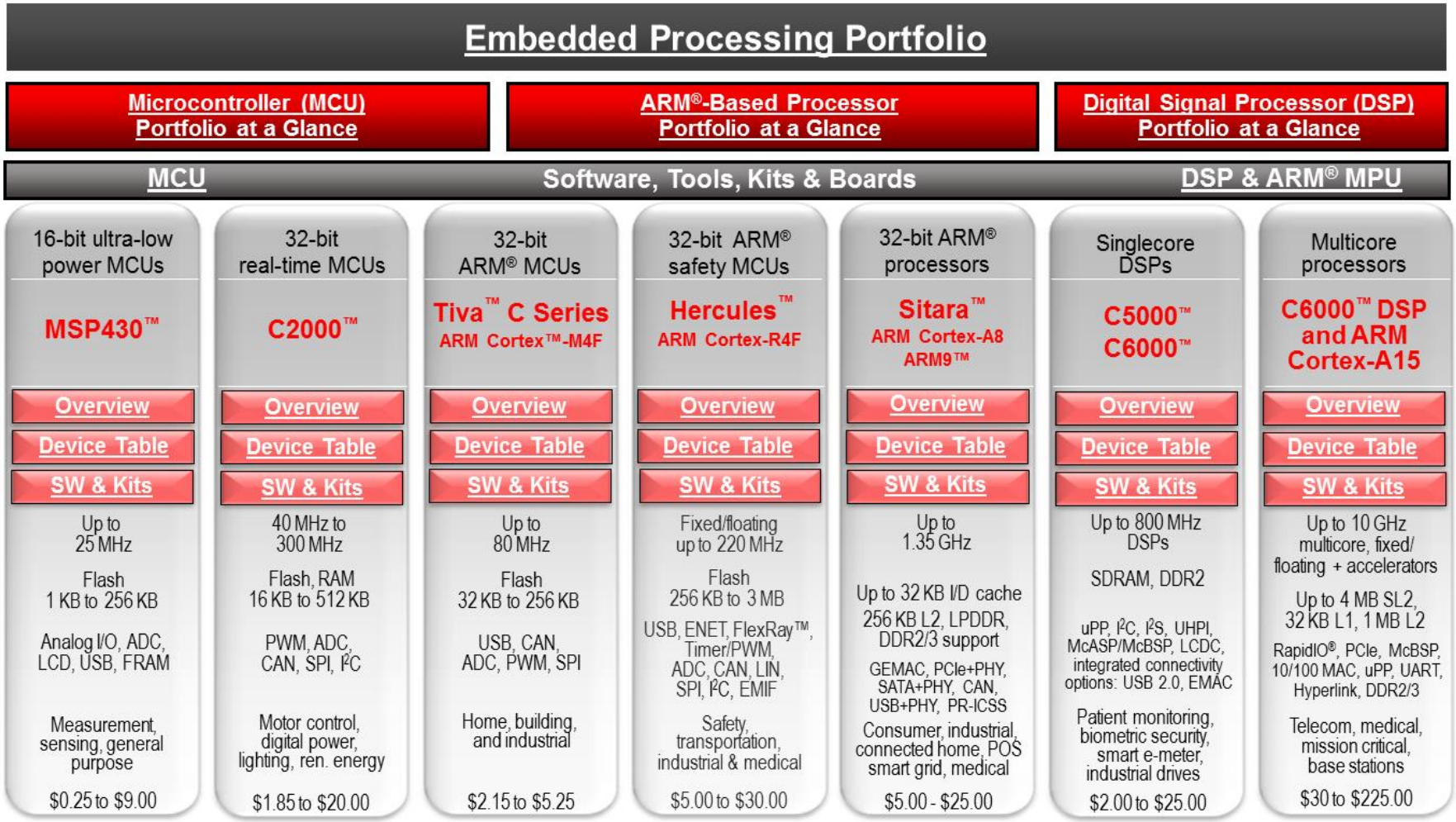
TI website, TTO workshop

J. Valvano, Embedded Systems: Shape the World.

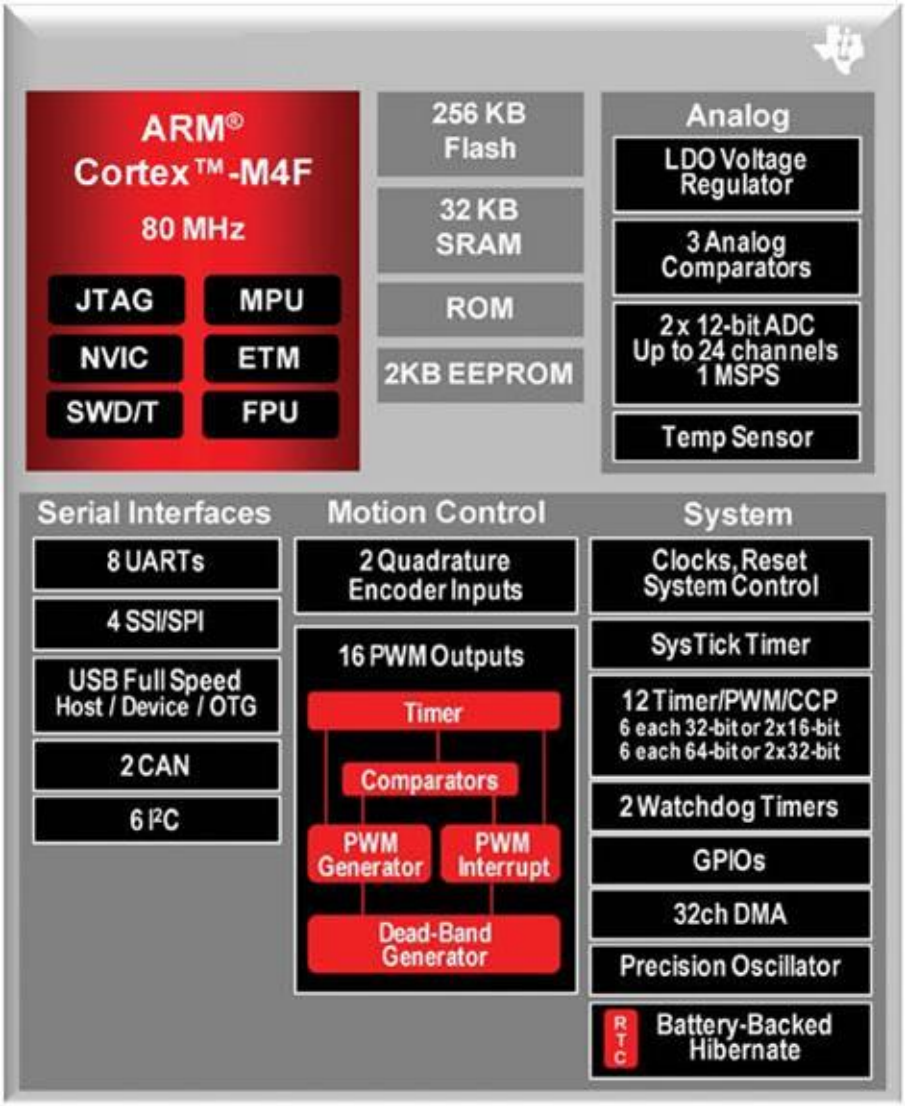
Texas Instruments

- Company Info:
  - 1930s: Oil and Gas
  - 1940s: Defense Electronics
  - 1950s: Integrated Circuits
  - 1970s: Microprocessors
  - 1980s: DSP
- Main Product Lines
  - Analog ICs: Power Amps, ADC, sensors, etc.
  - MCU: MSP430, TMS340C2000
  - DSP: TMS340C5000, C6000

TI Embedded Processors



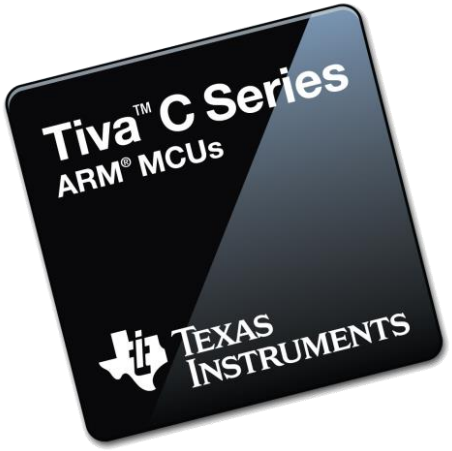
Tiva TM4C123G



- **Processor:** ARM Cortex-M4F, 80 MHz Clk
- **Memory:** EEPROM, ROM, SRAM, FLASH,
- **Serial ports:** UART, SSI/SPI, CAN, I2C
- **Analog:** Voltage regulator, comparator, ADC, temperature sensor
- **Control:** Timer, I/Q inputs, comparator, PWM, GPIO
- **System:** Low power modes, SysTick timer,

M4 Core and Floating Point Unit

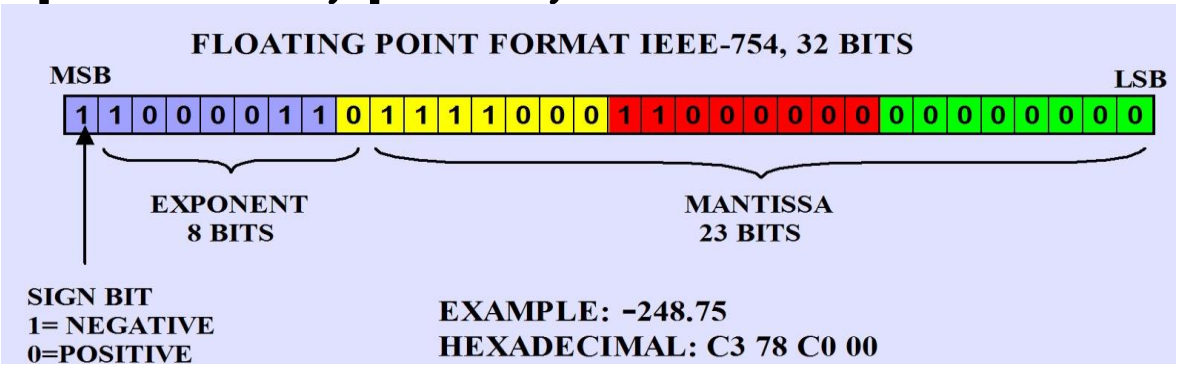
- 32-bit ARM® Cortex™-M4 core
- ISA: Thumb2 16/32-bit code:
  - 26% less memory & 25 % faster than pure 32-bit
- System clock frequency up to 80 MHz
- Flexible clocking system
  - Internal precision oscillator
  - External main oscillator with PLL support
  - Internal low frequency oscillator
  - Real-time-clock through Hibernation module



- Saturated math for signal processing: 100 DMIPS @ 80MHz
- Atomic bit manipulation. Read-Modify-Write using bit-banding
- Single Cycle multiply and hardware divider
- Unaligned data access for more efficient memory usage
- IEEE754 compliant single-precision floating-point unit
- JTW and Serial Wire Debug debugger access: ETM (Embedded Trace Macrocell) available through Keil and IAR emulators

IEEE754 Floating-Point Arithmetic

- A floating-point format is specified by:
  - a base (also called *radix*) *b*, which is either 2 (binary) or 10 (decimal) in IEEE 754;
  - a precision *p* (sign + mantissa);
  - an exponent range from *emin* to *emax*, with *emin* = 1 − *emax* for all IEEE 754 formats.
- An Example: b=2, p=24, emax=127



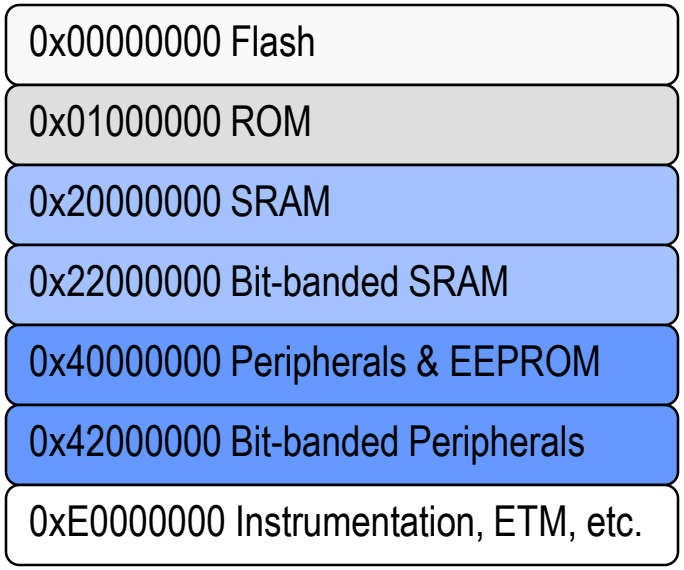
Basic Formats of IEEE 754

Name	Common name	Base (b)	Precision Bits (p)	Exponent bits (q)	E min	E max	Notes
binary16	Half precision	2	11		−14	+15	not basic
binary32	Single precision	2	24		−126	+127	
binary64	Double precision	2	53		−1022	+1023	
binary128	Quadruple precision	2	113		−16382	+16383	
binary256	Octuple precision	2	237		−262142	+262143	not basic
decimal32		10	7		−95	+96	not basic
decimal64		10	16		−383	+384	
decimal128		10	34		−6143	+6144	

How to convert? https://www.wikihow.com/Convert-a-Number-from-Decimal-to-IEEE-754-Floating-Point-Representation

TM4C123GH6PM Memory

- 256KB Flash memory
  - Single-cycle to 40MHz
  - Pre-fetch buffer and speculative branch improves performance above 40 MHz
- 32KB single-cycle SRAM with bit-banding
- Internal ROM loaded with TivaWare software
  - Peripheral Driver Library
  - Boot Loader
  - Advanced Encryption Standard (AES) cryptography tables
  - Cyclic Redundancy Check (CRC) error detection functionality
- 2KB EEPROM (fast, saves board space)
  - Wear-leveled 500K program/erase cycles
  - Thirty-two 16-word blocks
  - Can be bulk or block erased
  - 10 year data retention
  - 4 clock cycle read time



TM4C123GH6PM Peripherals

- **Battery-backed Hibernation Module**
  - Internal and external power control (through external voltage regulator)
  - Separate real-time clock (RTC) and power source
  - VDD3ON mode retains GPIO states and settings
  - Wake on RTC or Wake pin
  - Sixteen 32-bit words of battery backed memory
  - 5 µA Hibernate current with GPIO retention. 1.7 µA without
- **Serial Connectivity**
  - USB 2.0 (OTG/Host/Device)
  - 8 - UART with IrDA, 9-bit and ISO7816 support
  - 6 - I^2C
  - 4 - SPI, Microwire or TI synchronous serial interfaces
  - 2 – CAN bus

TM4C123GH6PM Peripherals

- **Two 1MSPS 12-bit SAR ADCs**
  - Twelve shared inputs
  - Single ended and differential measurement
  - Internal temperature sensor
  - 4 programmable sample sequencers
  - Flexible trigger control: SW, Timers, Analog comparators, GPIO
  - VDDA/GNDA voltage reference
  - Optional hardware averaging
  - 3 analog and 16 digital comparators
  - µDMA enabled

TM4C123GH6PM Peripherals

- **0 - 43 GPIO**
  - Any GPIO can be an external edge or level triggered interrupt
  - Can initiate an ADC sample sequence or µDMA transfer directly
  - Toggle rate up to the CPU clock speed on the Advanced High-Performance Bus
  - 5-V-tolerant in input configuration (except for PB0/1 and USB data pins when configured as GPIO)
  - Programmable Drive Strength (2, 4, 8 mA or 8 mA with slew rate control)
  - Programmable weak pull-up, pull-down, and open drain
- **Memory Protection Unit (MPU)**
  - Generates a Memory Management Fault on incorrect access to region

TM4C123GH6PM Peripherals

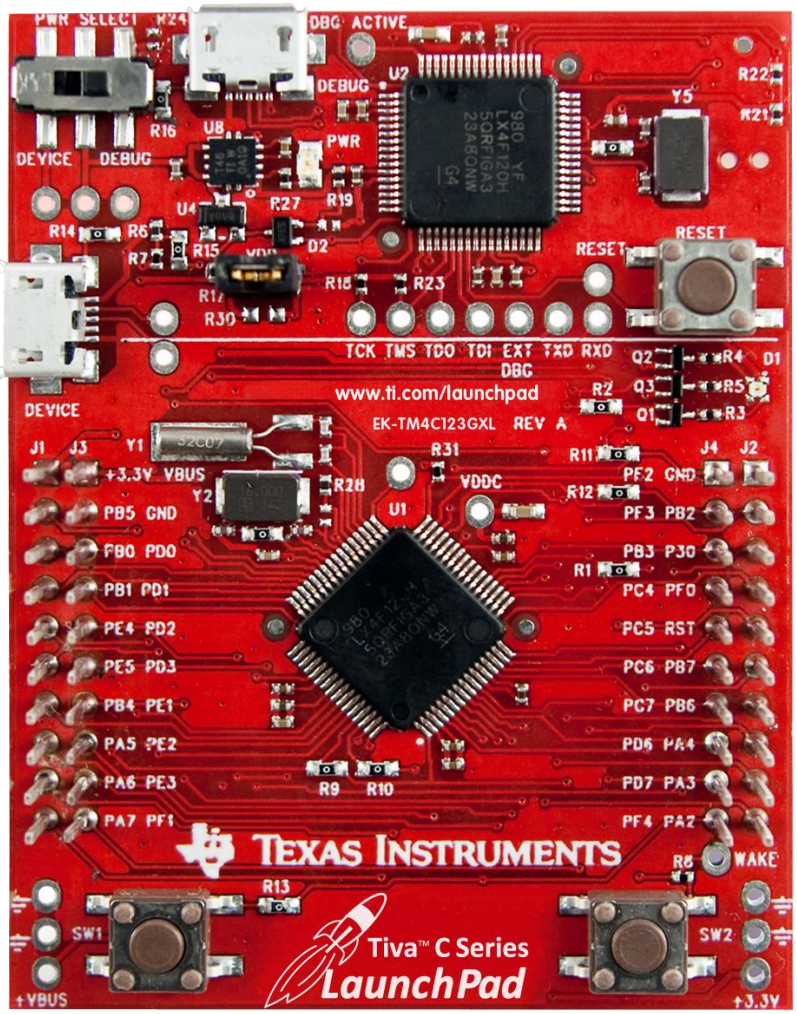
- **Timers**
  - 2 Watchdog timers with separate clocks
  - SysTick timer. 24-bit high speed RTOS and other timer
  - Six 32-bit and Six 64-bit general purpose timers
  - PWM and CCP modes
  - Daisy chaining
  - User enabled stalling on CPU Halt flag from debugger for all timers
- **32 channel µDMA**
  - Basic, Ping-pong and scatter-gather modes
  - Two priority levels; Interrupt enabled
  - 8,16 and 32-bit data sizes

TM4C123GH6PM Peripherals

- **Nested-Vectored Interrupt Controller**
  - 7 exceptions and 71 interrupts with 8 programmable priority levels
  - Tail-chaining and other low-latency features
  - Deterministic: always 12 cycles or 6 with tail-chaining
  - Automatic system save and restore
- **Two Motion Control modules. Each with:**
  - 8 high-resolution PWM outputs (4 pairs)
  - H-bridge dead-band generators and hardware polarity control
  - Fault input for low-latency shutdown
  - Quadrature Encoder Inputs (QEI)
  - Synchronization in and between the modules

EK-TM4C123G LaunchPad

- ARM® Cortex™-M4F
  64-pin 80MHz TM4C123GH6PM
- On-board USB ICDI
  (In-Circuit Debug Interface)
- Micro AB USB port
- Device/ICDI power switch
- BoosterPack XL pinout also supports
  legacy BoosterPack pinout
- 2 user pushbuttons
  (SW2 is connected to the WAKE pin)
- Reset button
- 3 user LEDs (1 tri-color device)
- Current measurement test points
- 16 MHz Main Oscillator crystal
- 32 kHz Real Time Clock crystal
- 3.3V regulator
- Support for multiple IDEs



IDE Tools for Tiva Series MCUs

	mentor embedded	IAR SYSTEMS	ARM KEIL An ARM® Company	Code Composer Studio
Eval Kit License	30-day full function. Upgradeable	32KB code size limited. Upgradeable	32KB code size limited. Upgradeable	Full function. Onboard emulation limited
Compiler	GNU C/C++	IAR C/C++	RealView C/C++	TI C/C++
Debugger / IDE	gdb / Eclipse	C-SPY / Embedded Workbench	µVision	CCS/Eclipse-based suite
Full Upgrade (2012 price)	99 USD personal edition / 2800 USD full support	2700 USD	MDK-Basic (256 KB) = €2000 (2895 USD)	445 USD
JTAG Debugger		J-Link, 299 USD	U-Link, 199 USD	XDS100, 79 USD

Several Other Microcontrollers

	8051	PIC	AVR	ARM
Bus width	8-bit for standard core	8/16/32-bit	8/32-bit	32-bit mostly also available in 64-bit
Communication Protocols	UART, USART,SPI,I2C	PIC, UART, USART, LIN, CAN, Ethernet, SPI, I2S	UART, USART, SPI, I2C, (special purpose AVR support CAN, USB, Ethernet)	UART, USART, LIN, I2C, SPI, CAN, USB, Ethernet, I2S, DSP, SAI (serial audio interface), IrDA
Speed	12 Clock/instruction cycle	4 Clock/instruction cycle	1 clock/ instruction cycle	1 clock/ instruction cycle
Memory	ROM, SRAM, FLASH	SRAM, FLASH	Flash, SRAM, EEPROM	Flash, SDRAM, EEPROM
ISA (Instruction Set Architecture)	CLSC	Some feature of RISC	RISC	RISC
Memory Architecture	Von Neumann architecture	Harvard architecture	Modified	Modified Harvard architecture
Power Consumption	Average	Low	Low	Low
Families	8051 variants	PIC16,PIC17, PIC18, PIC24, PIC32	Tiny, Atmega, Xmega, special purpose AVR	ARMv4,5,6,7 and series
Community	Vast	Very Good	Very Good	Vast
Manufacturer	NXP, Atmel, Silicon Labs, Dallas, Cyprus, Infineon	Microchip Average	Atmel	Apple, Nvidia, Qualcomm, Samsung Electronics, TI.
Cost (as compared to features provide)	Very Low	Average	Average	Low
Other Feature	Known for its Standard	Cheap	Cheap, effective	High speed operation Vast
Popular Microcontrollers	AT89C51, P89v51, etc.	PIC18fXX8, PIC16f88X, PIC32MXX	Atmega8, 16, 32, Arduino Community	LPC2148, ARM Cortex-M0 to ARM Cortex-M7.