ELC4438: Embedded System Design

ARM Embedded Processor

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Electrical and Computer Engineering

Baylor University

Intro to ARM Embedded Processor

- (UK 1990) Advanced RISC Machines (ARM) Holding

- Produce IP core and license to semiconductor companies

  → produce embedded MPU and MCU according to company strength

  – In electronic design a semiconductor intellectual property **core**, **IP core**, or **IP** block is a reusable unit of logic, cell, or chip layout design that is the intellectual property of one party. **IP** cores may be licensed to another party or can be owned and used by a single party alone.

- Semiconductor companies, e.g. TI, Samsung, Freescale, NXP, ST Semiconductor

ARM Embedded System Support

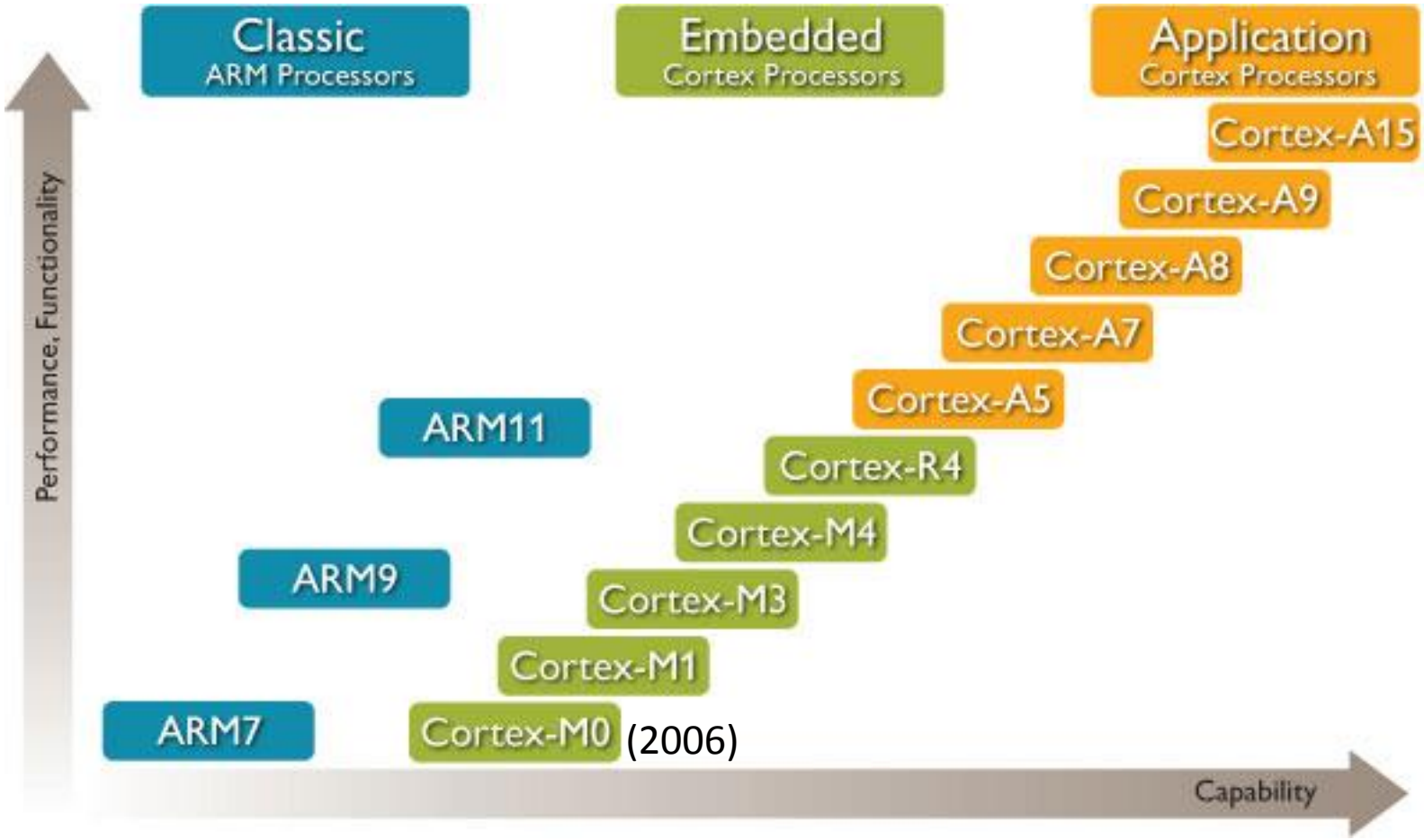
- Windows CE (Compact/Consumer/Connectivity/Companion – Electronics)
- µClinux (from Linux 2.0/2.4)
- pSOS
- VxWorks (US WindRiver 1983 realtime OS, used in F-16, FA-18, B-2, Patriot SAM, Pathfinder, etc.)
- µC/OS (open source, mostly C coded)
- Palm OS
- Windows 8

ARM Processor Feature

Typical RISC Feature:

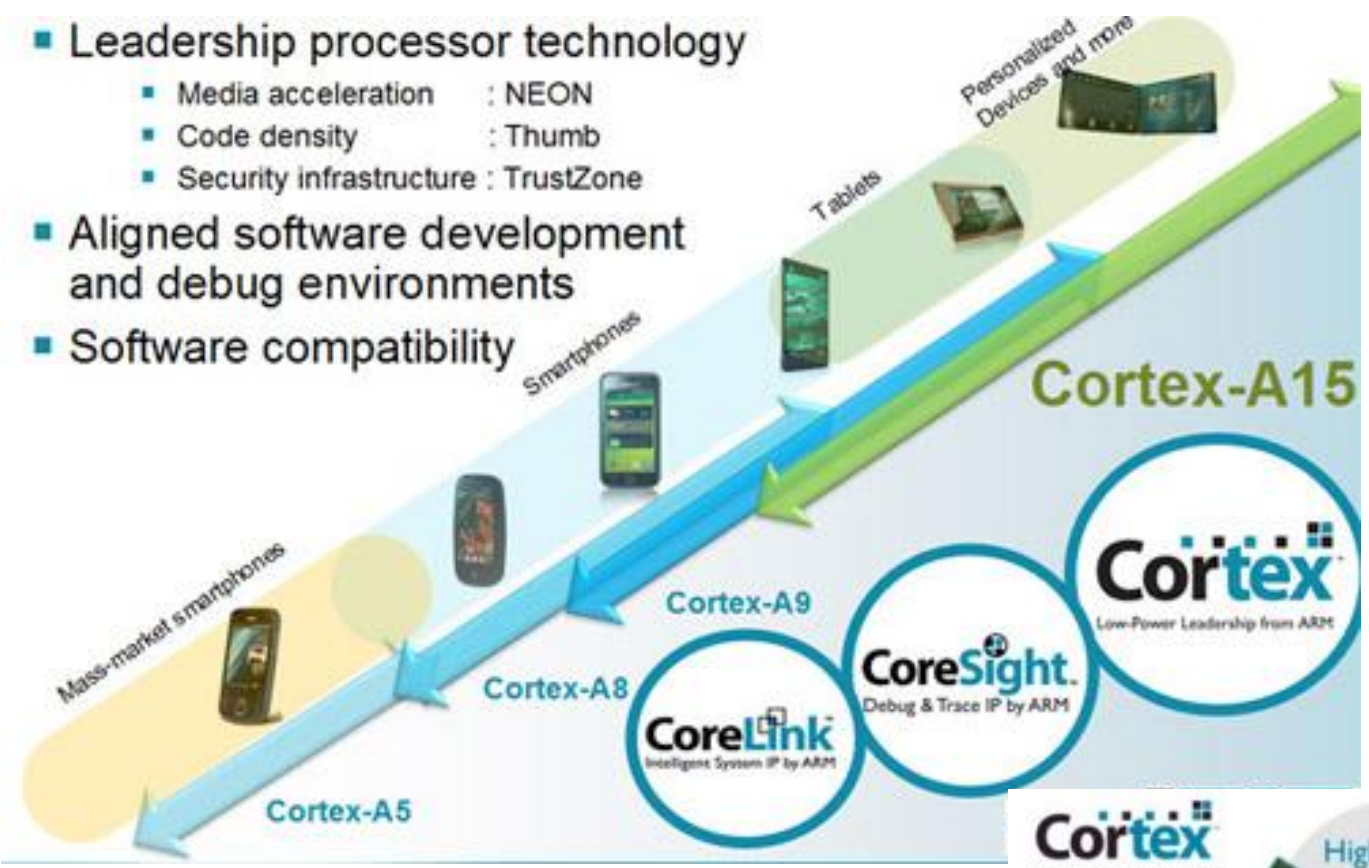
- Small volume, low power, low cost, high performance
- Use many registers, fast execution time of instructions
- Easy addressing methods, high-efficiency
- Most data operations done in registers
- 32-bit wordlength
- Embedded online simulator included

ARM Processor Series



- ARM [x] [y] [z] [T] [D] [M] [I] [E] [J] [F] [-S]
  - [x] series number ARM7, ARM9
  - [y] memory storage and protection ARM72
  - [z] high-speed buffer ARM720, ARM940
  - [T] Thumb instruction set
  - [D] Support JTAG online/on-chip testing
  - [M] Hardware Multiplier
  - [I] Embedded ICE Macrocell
  - [E] Enhanced DSP instructions
  - [J] Java accelerator Jazelle
  - [F] Floating point
  - [S] Source code, can be applied to EDA (Electronic Design Automation)

- Leadership processor technology
  - Media acceleration : NEON
  - Code density : Thumb
  - Security infrastructure : TrustZone
- Aligned software development and debug environments
- Software compatibility



ARM Cortex

- ARM Cortex-A: Consumer Entertainment Electronics, Wireless Product
  - Cortex-A9/A10 dual-core quad-cord 1GHz
  - Cortex-A15 quad-core 2.5GHz

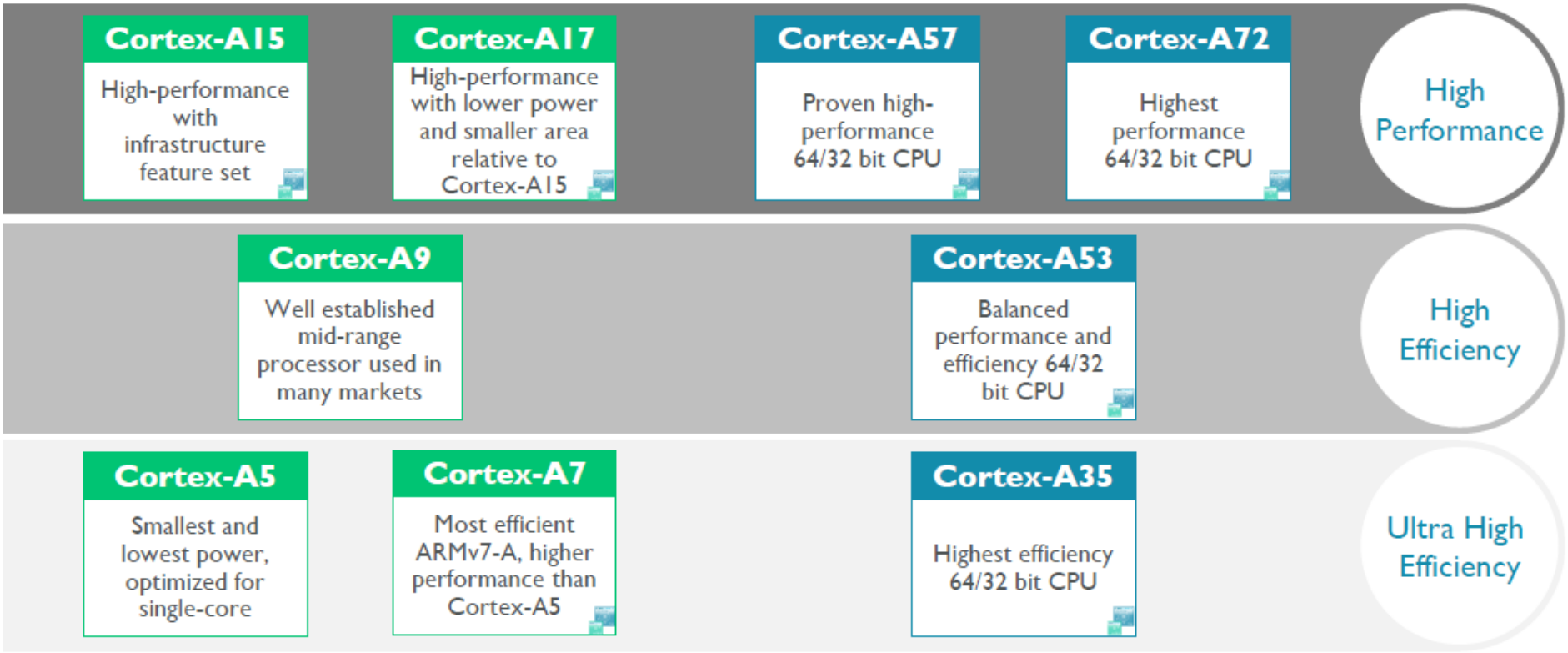
- ARM Cortex-A8 1 GHz
  - Sophisticated pipelining
  - Thumb-2 instruction set (32-bit and 16-bit)
  - NEON™ signal processing – H.264, MP3
  - Jazelle-RCT Java accelerator
  - JIT (Just in Time) and DAC (Dynamic Adaptive Compilation) Technologies
  - e.g. iPad, iPhone4 A4 processor is Cortex-A8 manufactured by Samsung

- The implementation of the Advanced SIMD (Single Instruction, Multiple Data) extension used in ARM processors is called NEON

- SIMD technology uses a single instruction to perform the same operation in parallel on multiple data elements of the same type and size

ARM® Cortex®-A Current Portfolio

Q4 2015



ARM

ARM® Cortex®-R and Cortex-M Processor Portfolio

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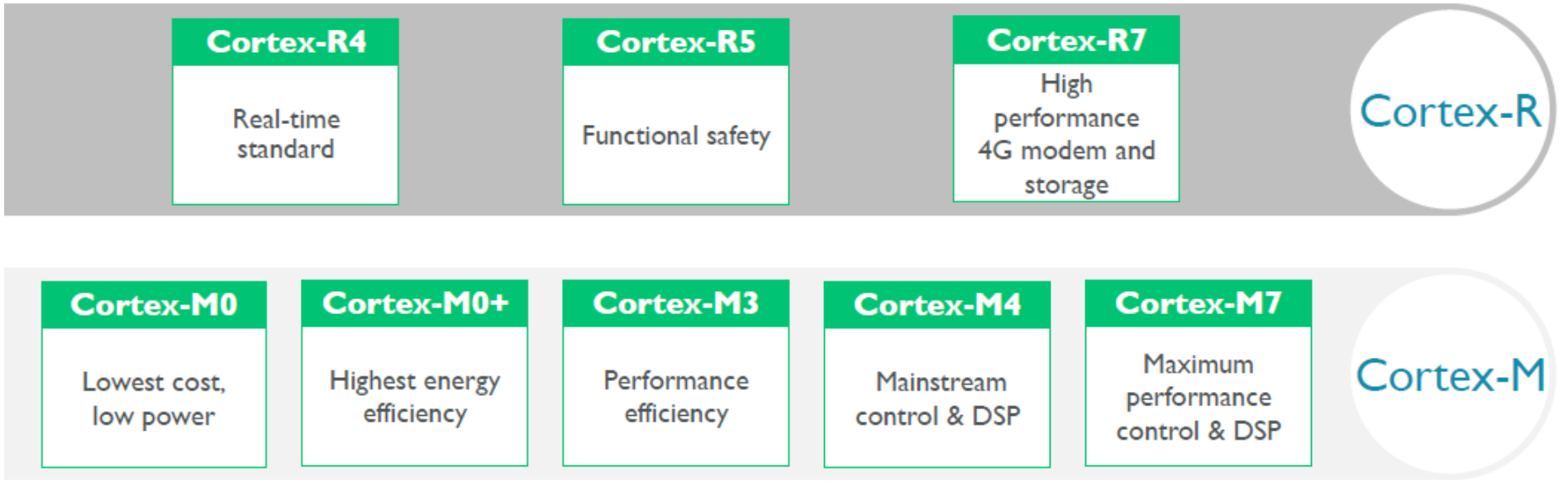
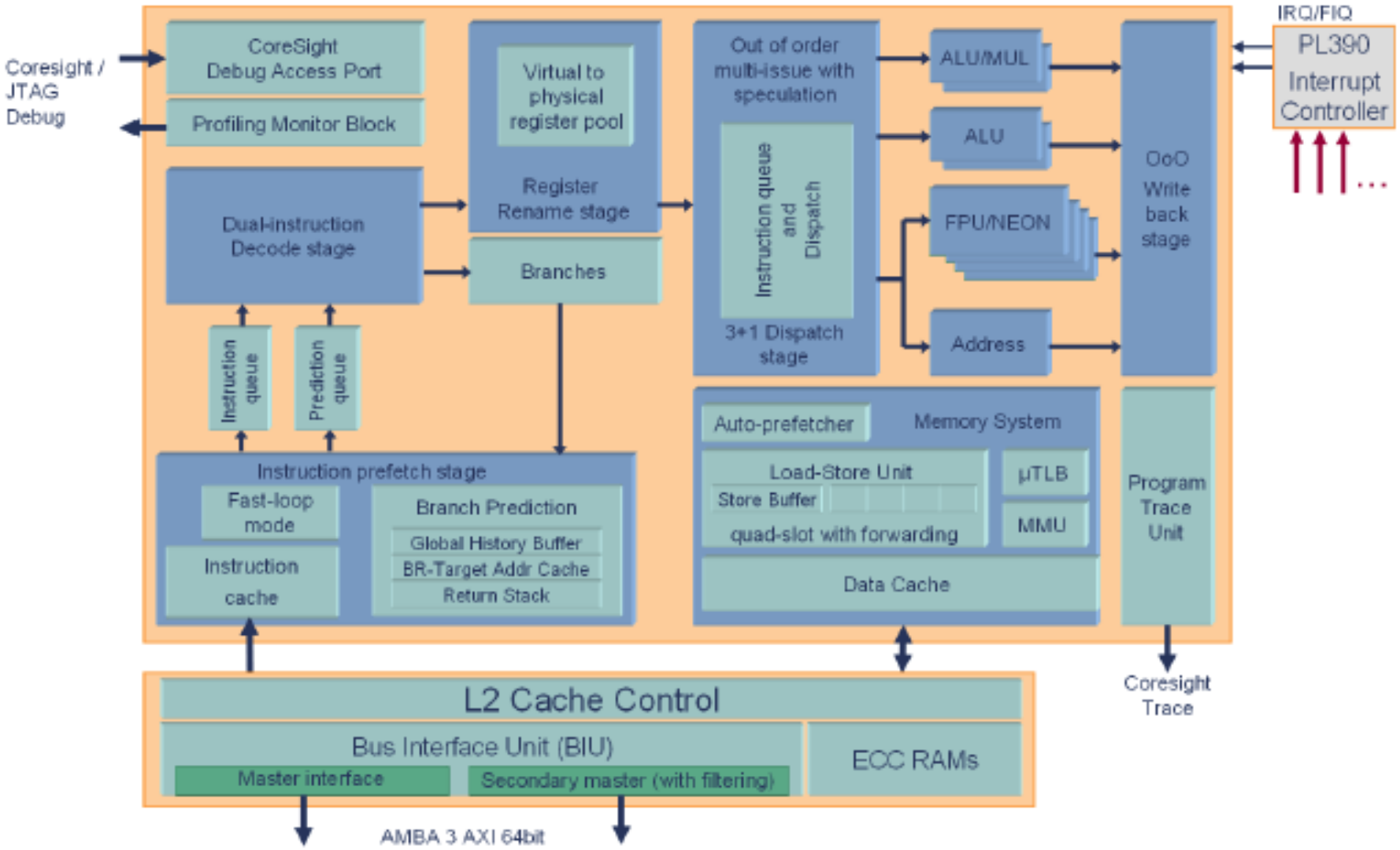
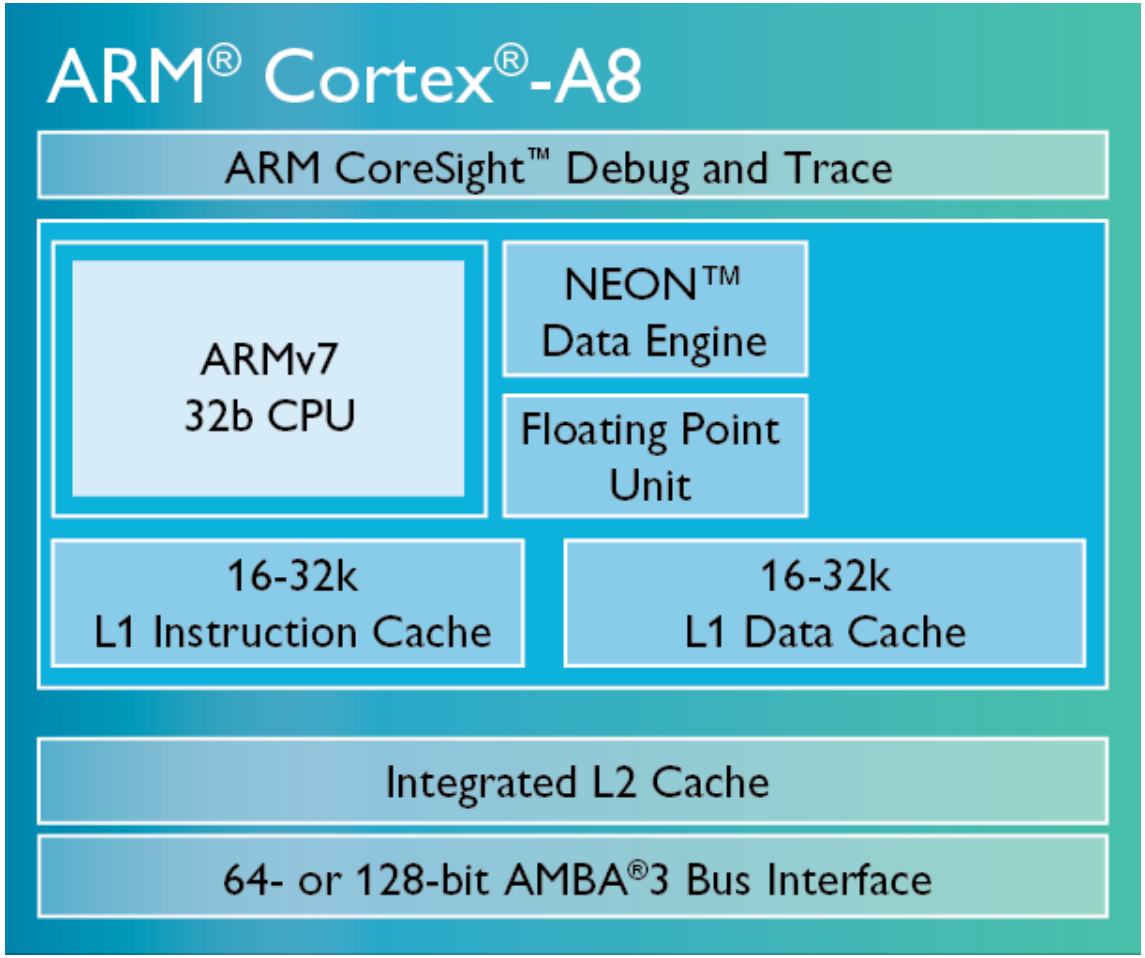


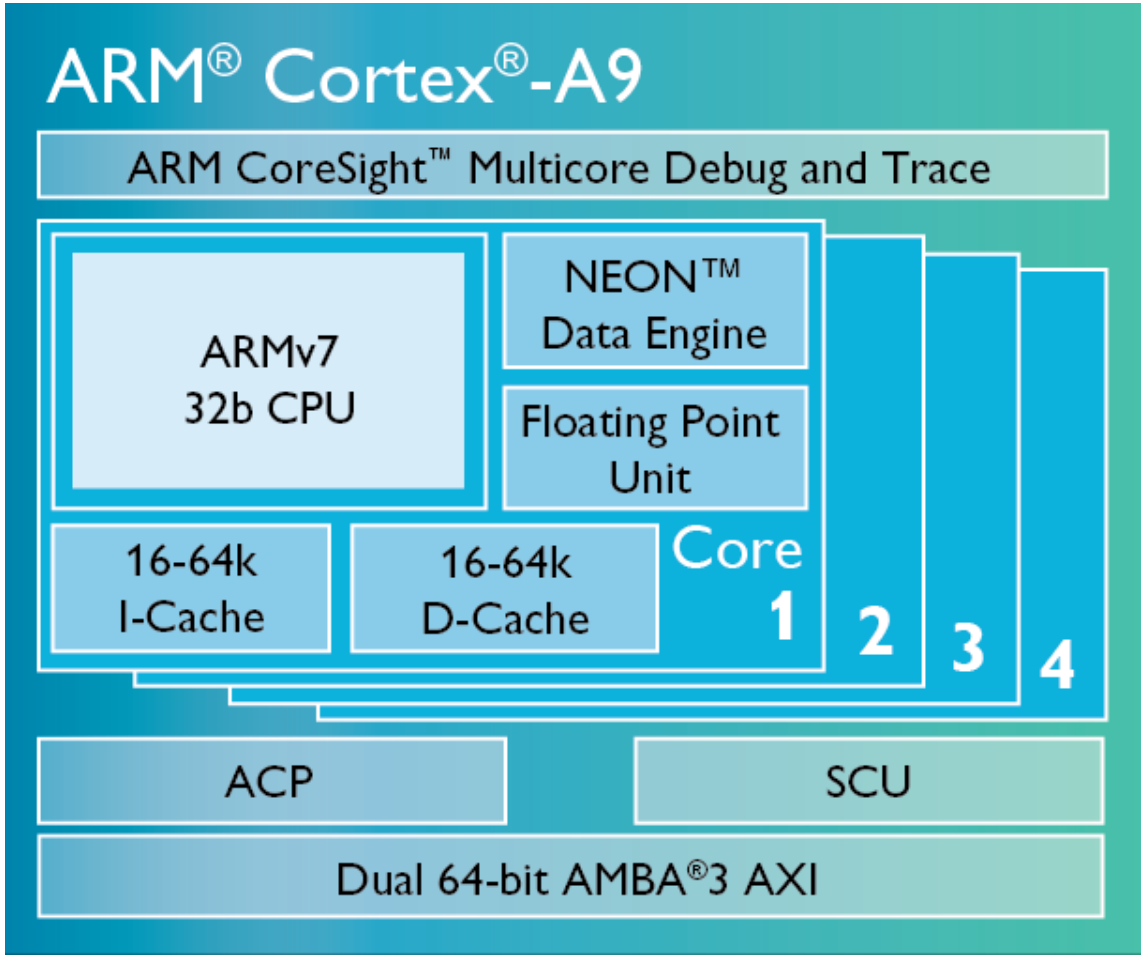
ARM

ARM Cortex-A8/A9



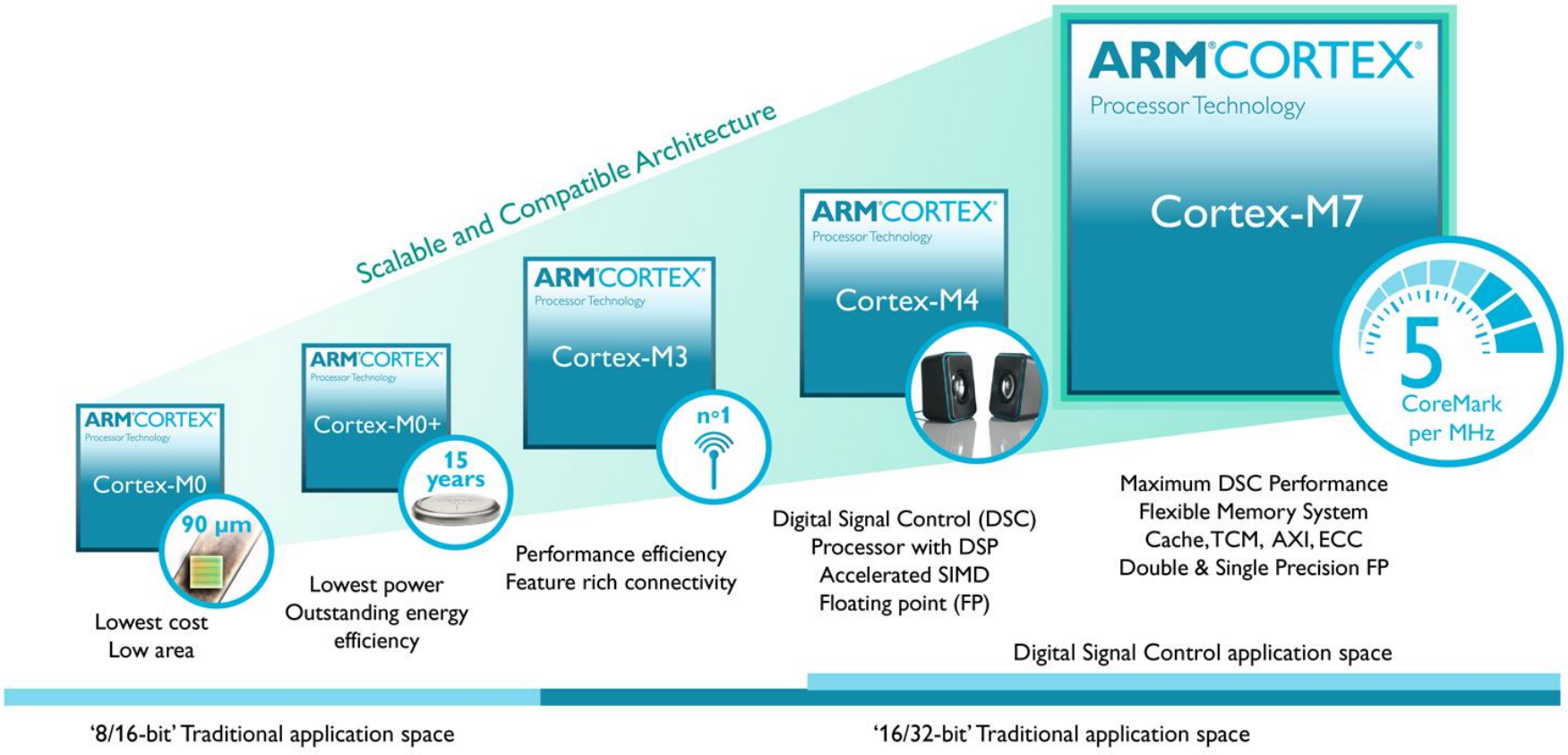


AMBA: Advanced Microcontroller Bus Architecture



ACP: Accelerator Coherency Port; SCU: Snoop Control Unit

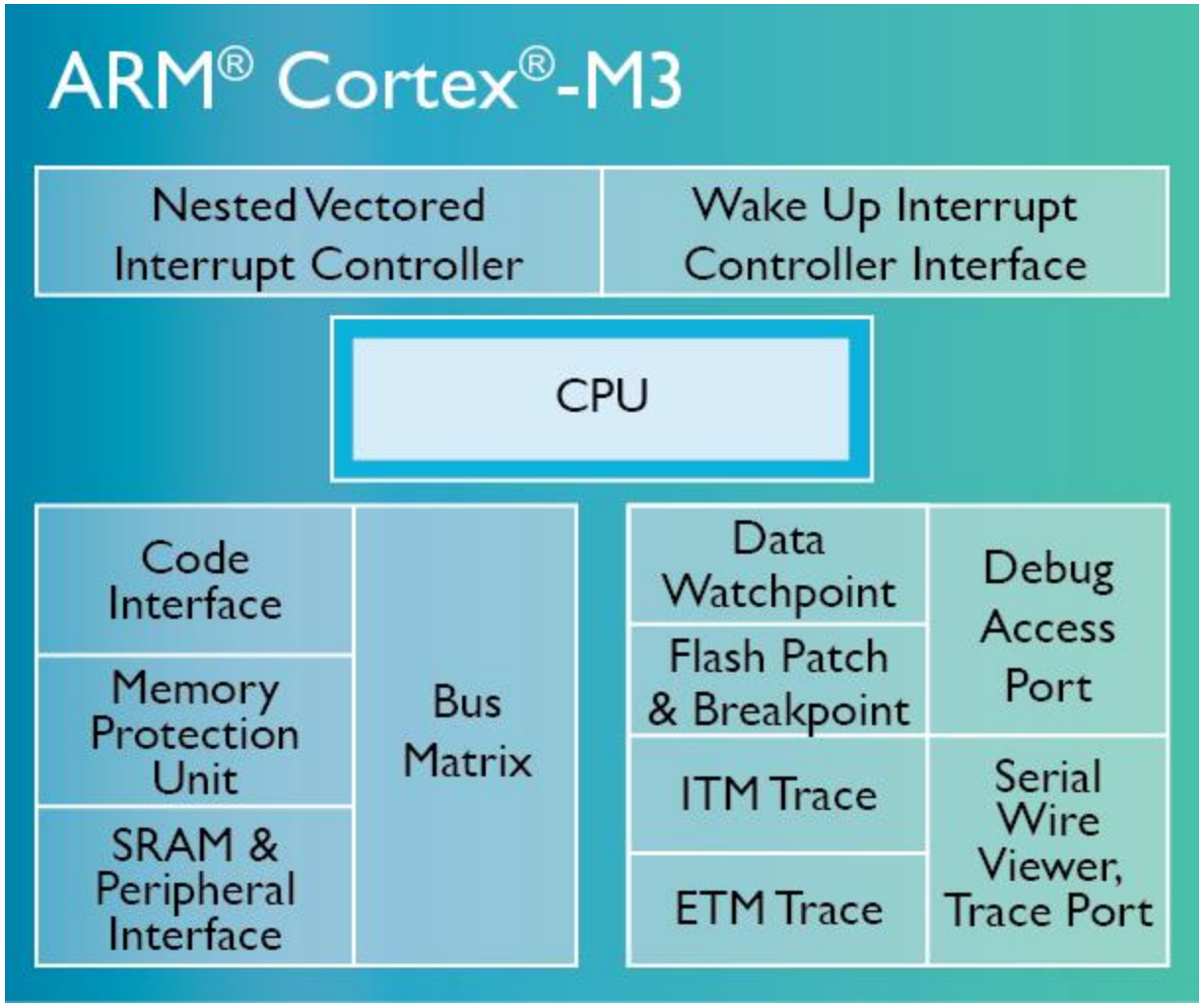
ARM Cortex-M


Scalable and Compatible Architecture
ARM CORTEX
Processor Technology
Cortex-M0
90 µm
Lowest cost
Low area
ARM CORTEX
Processor Technology
Cortex-M0+
15 years
Lowest power
Outstanding energy efficiency
ARM CORTEX
Processor Technology
Cortex-M3
n°1
Performance efficiency
Feature rich connectivity
ARM CORTEX
Processor Technology
Cortex-M4
Digital Signal Control (DSC)
Processor with DSP
Accelerated SIMD
Floating point (FP)
ARM CORTEX
Processor Technology
Cortex-M7
5
CoreMark
per MHz
Maximum DSC Performance
Flexible Memory System
Cache, TCM, AXI, ECC
Double & Single Precision FP
Digital Signal Control application space
'8/16-bit' Traditional application space
'16/32-bit' Traditional application space

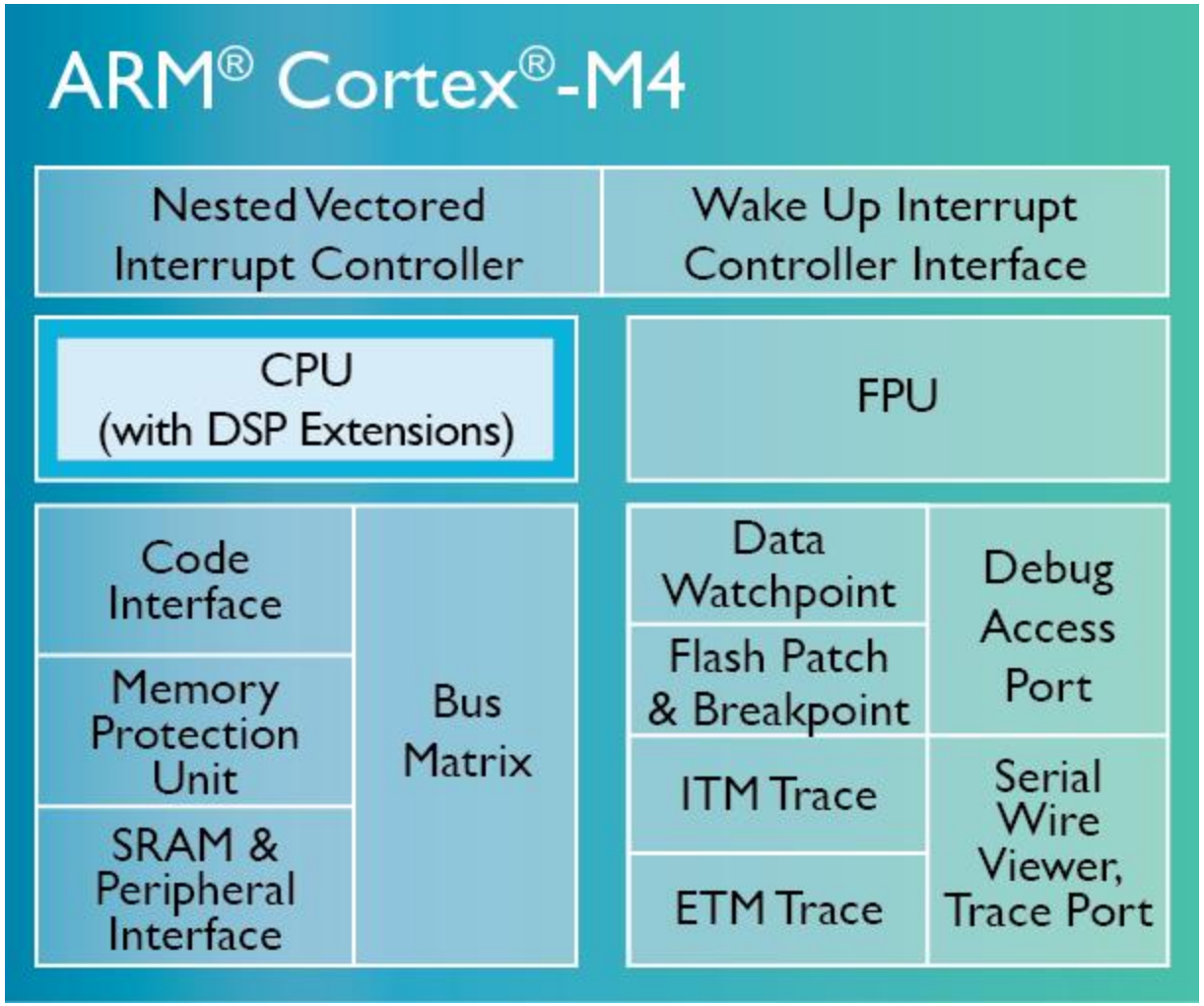
ARM Cortex-M

Cortex-M0	Cortex-M0+	Cortex-M3	Cortex-M4	Cortex-M7
Touchscreen controller	IoT sensor node	Activity trackers and basic wearables	Smart metering and sensor fusion	High-end audio headset or soundbar
Power management	Bluetooth smart transceiver	Wifi transceiver	High-performance motor control	Automotive (transmission, body electronics, low-cost infotainment)

ARM Cortex-M3 Processor



ARM Cortex-M4 Processor



ARM Cortex-M4 Processor

Energy efficient digital signal control

- The Cortex-M4 processor has been designed with a large variety of highly efficient signal processing features

- The Cortex-M4 processor features extended single-cycle multiply accumulate (MAC) instructions, optimized SIMD arithmetic, saturating arithmetic instructions and an optional single precision Floating Point Unit (FPU).

ARM Cortex-M4 Processor

Responsiveness and low power

- The Cortex-M4 has integrated sleep modes and optional state retention capabilities which enable high performance at a low level of power consumption.
- The processor executes the Thumb-2 instruction set for optimal performance and code size.
- The Cortex-M4 Nested Vectored Interrupt Controller is highly configurable at design time to deliver up to 240 system interrupts with individual priorities, dynamic reprioritization and integrated system clock.

ARM Cortex-M4 Features

ISA Support	Thumb / Thumb-2
DSP Extensions	Single cycle 16/32-bit MAC Single cycle dual 16-bit MAC 8/16-bit SIMD arithmetic Hardware Divide (2-12 Cycles)
Floating Point Unit	Single precision floating point unit IEEE 754 compliant
Pipeline	3-stage + branch speculation
Performance Efficiency	Without FPU: 1.25 / 1.52 / 1.91 DMIPS/MHz* With FPU: 1.27 / 1.55 / 1.95 DMIPS/MHz*

* Dhrystone **MIPS** (Million Instructions per Second), or **DMIPS**, is a measure of computer performance relative to the performance of the DEC VAX 11/780 minicomputer of the 1970s.

ARM Cortex-M4 Features

Memory Protection	Optional 8 region MPU with sub regions and background region
Interrupts	Non-maskable Interrupt (NMI) + 1 to 240 physical interrupts
Interrupt Priority Levels	8 to 256 priority levels
Wake-up Interrupt Controller	Up to 240 Wake-up Interrupts
Sleep Modes	Integrated WFI and WFE Instructions and Sleep On Exit capability. Sleep & Deep Sleep Signals. Optional Retention Mode with ARM Power Management Kit
Bit Manipulation	Integrated Instructions & Bit Banding
Debug	Optional JTAG & Serial-Wire Debug Ports. Up to 8 Breakpoints and 4 Watchpoints.
Trace	Optional Instruction Trace (ETM), Data Trace (DWT), and Instrumentation Trace (ITM)