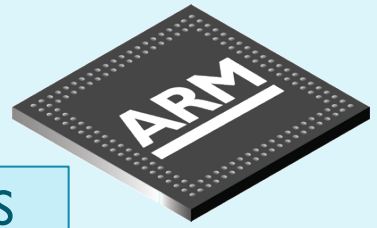
ARM's Cortex®-M and Cortex-R Embedded Processors

ARM Cortex® Processors: Scalability for Every Market

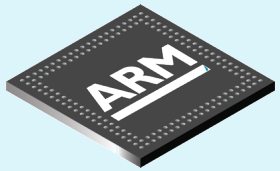
Cortex-A Processors



Rich OS

Highest performance

Cortex-R Processors

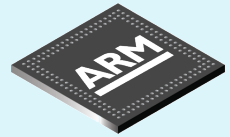


RTOS

Fast response / real-time control

Cortex-M Processors

DSP + MCU



Smallest footprint / lowest power

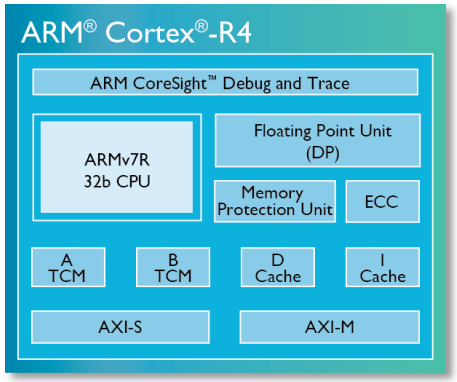
ARM

ARM Cortex®-R Real-Time Embedded Processors

Fast: High processing performance at high clock frequencies

Real-time: Deterministic processing always meets real-time constraints

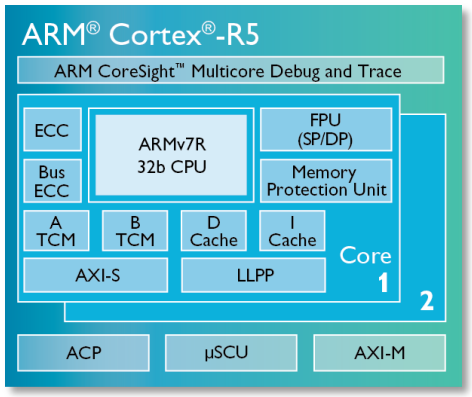
Reliable: Dependable with safety features and high error resistance



The real-time 'workhorse' with wide applicability

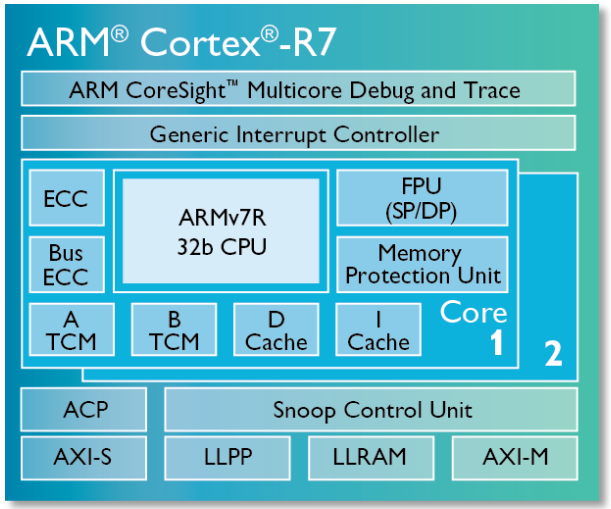
Tightly Coupled Memory for deterministic response

Memory Protection Unit



Dual core with accelerator coherency

Functional safety support



Extreme real-time performance, out-of-order execution

MultiProcessor Core with integrated interrupt controller

ARM

Cortex-R Series Summary

ARM CORTEX
Processor Technology

Cortex-R4/R5

>1552 DMIPS

@935MHz

2x Cortex-R5

>3104 DMIPS

@935MHz

Cortex-R7

>2500 DMIPS

@1GHz

2x Cortex-R7

>5000 DMIPS

@1GHz

- 90+ licensees of ARM Cortex-R processors
- Many of the leading HDD and SSD storage manufacturers
- The leaders in mobile handsets for baseband processing
- The best in safety-critical industrial and automotive systems
- >2 billion Cortex-R processors shipped

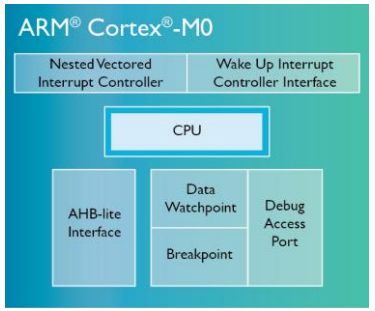
MARVELL
Infineon
ENTROPIC
TOSHIBA
LSI
BROADCOM
SPANSION
SAMSUNG
Texas Instruments
ARM

ARM Cortex®-M Processor Family

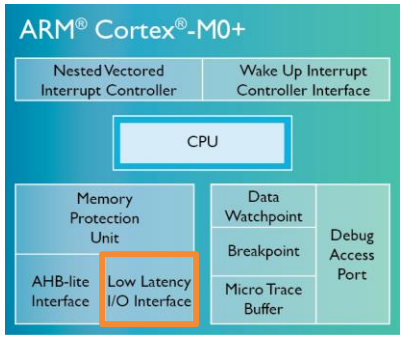
High Performance: Low interrupt latency and fast bitwise operations

Low Energy: The most energy-efficient 32-bit processors

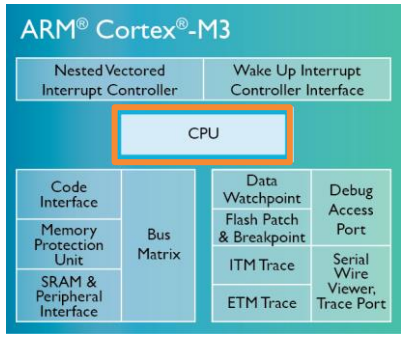
Low Cost: Low area, configurable with good code density



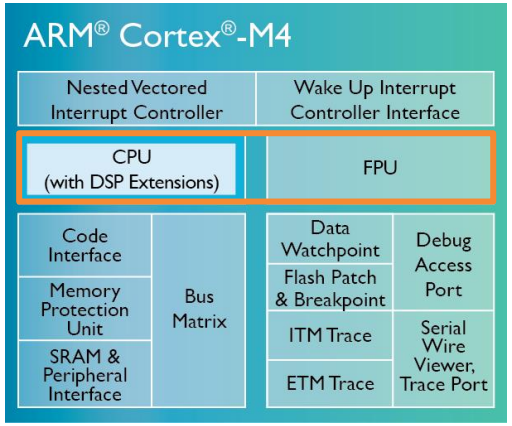
Lowest cost
Low power



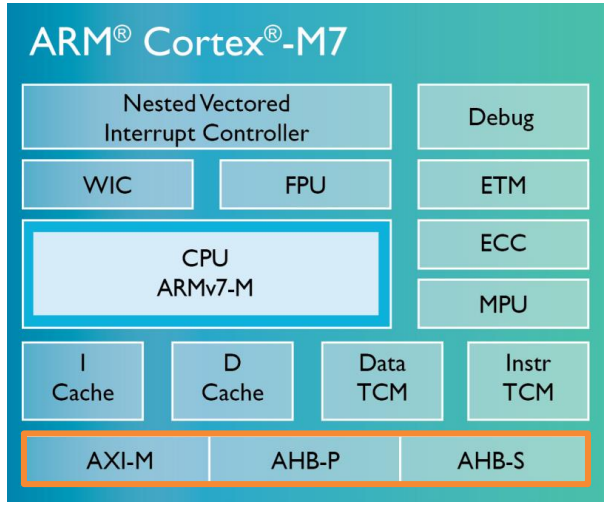
Lowest power
Outstanding energy efficiency



Performance efficiency
Feature rich connectivity



Digital Signal Control (DSC)
Processor with DSP
Accelerated SIMD
Floating point (FP)



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

Cortex-M Series Summary

ARM CORTEX
Processor Technology

Cortex-M0

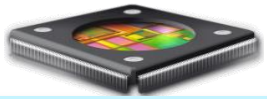
>42 DMIPS
@50MHz

Cortex-M0+

>46 DMIPS
@50MHz

Cortex-M3

>125 DMIPS
@100MHz



Cortex-M4

>250 DMIPS
@200MHz

Cortex-M7

>850 DMIPS
@400MHz

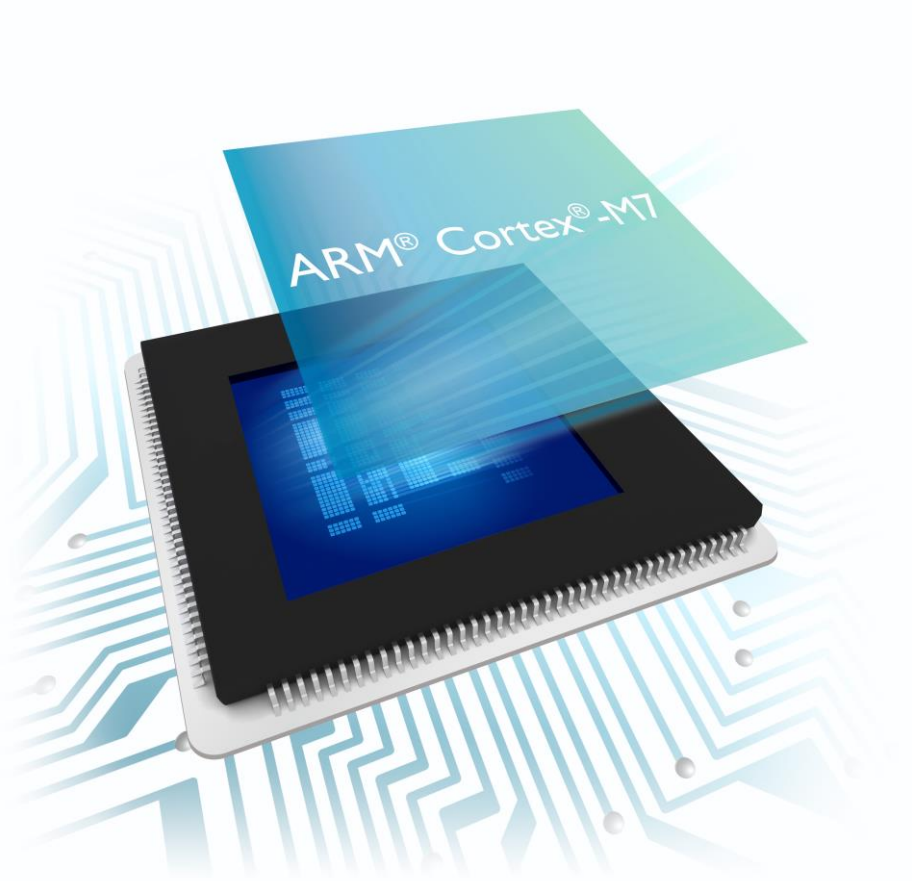
- 280+ licenses of ARM Cortex-M processors
- Over 3,000 Cortex-M processor-based devices
- Implemented as 'helper' coprocessors in SoCs
- >10 billion Cortex-M processors shipped

accent Integration, Accentuated
ANALOG DEVICES
Atmel
BROADCOM.
CYPRESS PERFORM
Texas Instruments
FUJITSU
TOSHIBA
Infineon
freescale semiconductor
Microsemi SoC Products Group
NORDIC SEMICONDUCTOR
NXP founded by Philips
RENESAS
SILICON LABS
DUST NETWORKS
nuvoTon
ARM

ARM's Cortex®-M7 and Cortex-R5 Processors

Cortex®-M7 Overview

- Performance
  - Achieving 5 CoreMark/MHz – 2000 CoreMark* in 40LP
  - Typical 2x DSP performance of Cortex-M4
- Versatility
  - Highly flexible system and memory interfaces
  - Designed for functional safety implementations
- Scalability and compatibility
  - Enables simple migration from any Cortex-M processor
  - Widest third-party tools, RTOS, middleware support



* CoreMark 1.0 : IAR Embedded Workbench v7.30.1 --endian=little --cpu=Cortex-M7 -e -Ohs --use_c++_inline --no_size_constraints / Code in TCM - Data in TCM

ARM

Cortex®-M7 Partner News

Atmel®

SAM70

SAM V71 Xplained Ultra Kit
Available now

- Launched new SAM70 series based on Cortex-M7 (300MHz)
- First devices have up to 384kB SRAM and 2MB Flash, AXI connection to large external memories
- Targeting Automotive, IoT and Industrial

freescale™

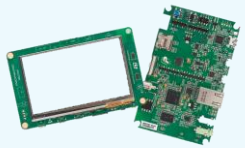
KV5x

- Launched Kinetis KV5x family based on Cortex-M7 at Embedded World 2015
- Now in preproduction, devices later this year
- Targeting advanced motor control and power conversion

life.augmented

STM32F7

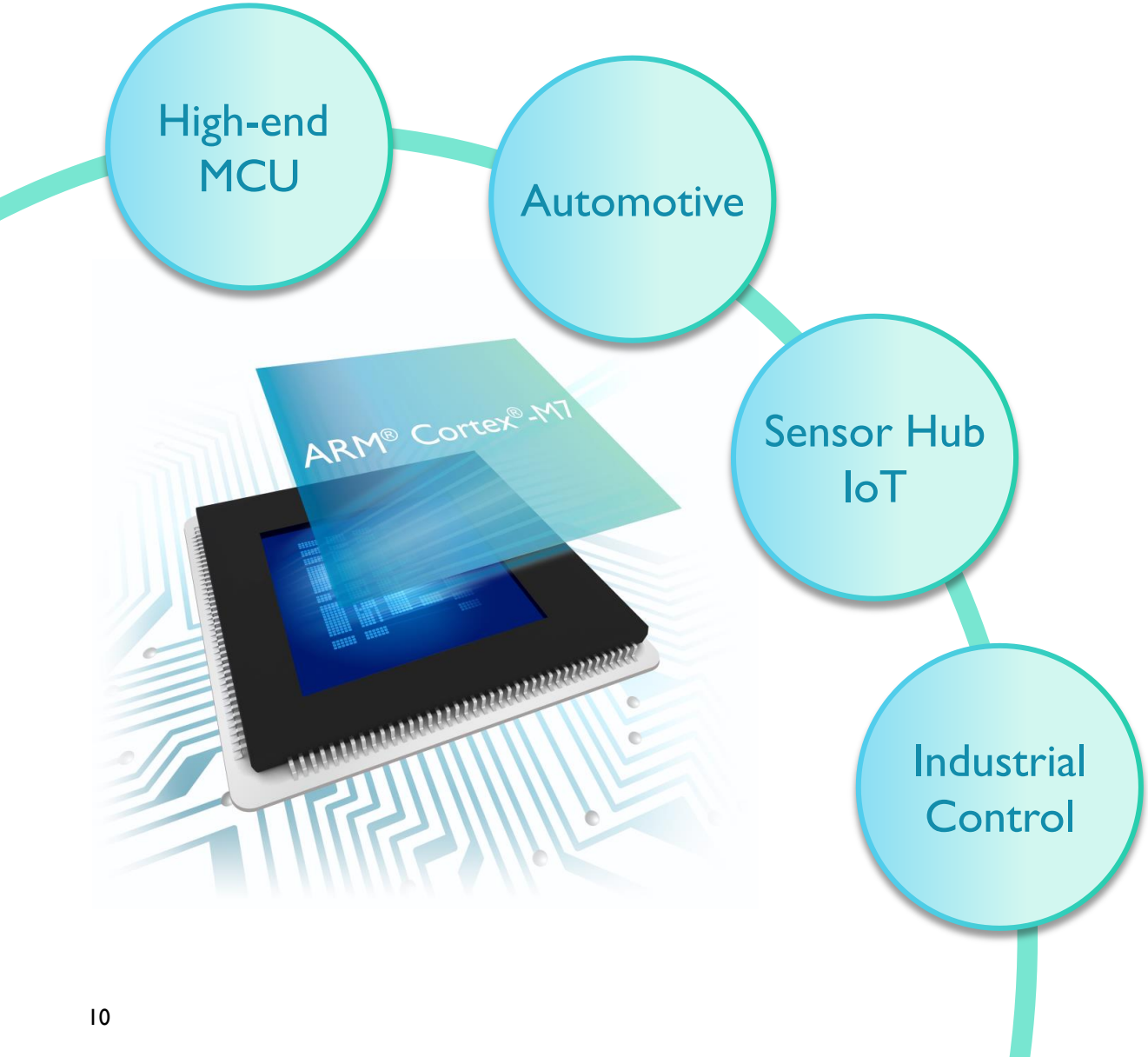
STM32F7 Discovery Board
Available now



- Launched full STM32F7 family of processors, now available to mass market
- 1MB Flash, 320kB SRAM, AXI connection to large external memories, 216MHz
- Targeting Audio, Home Automation, Medical, Industrial, Motor control
- Roadmap to faster devices on smaller process technology (400MHz)

ARM

Cortex®-M7 Target Applications



- High-end member of existing Cortex-M based MCU family
- Replacement for MCU + proprietary DSP
- Powerful sensor hub, capable of voice recognition, image processing
- Powerful processor for factory automation: motor control, PLC, servo control
- Flexible processor for automotive: dashboard, ABS, low-end gateway, transmission, convenience electronics

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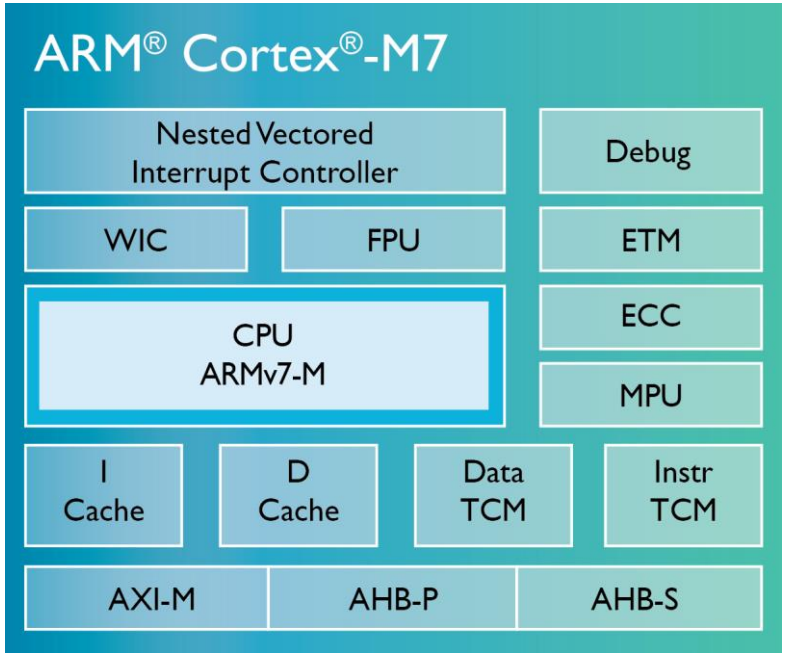
Cortex®-M7 Key Features (1)

- High performance core with DSP capabilities
  - Six-stage dual-issue pipeline
  - Powerful DSP instructions and SP/DP Floating Point
  - **Best-in-class core for high-end MCU, or replace MCU+DSP with Cortex-M7**



- Flexible, memory system
  - Tightly-coupled memories for real-time determinism
  - 64-bit AXI AMBA4 memory interface with I-cache and D-cache for efficient access to external resources
  - **Enables MCUs to be built with access to large external memories and powerful peripherals**

* SP – Single Precision, DP – Double Precision

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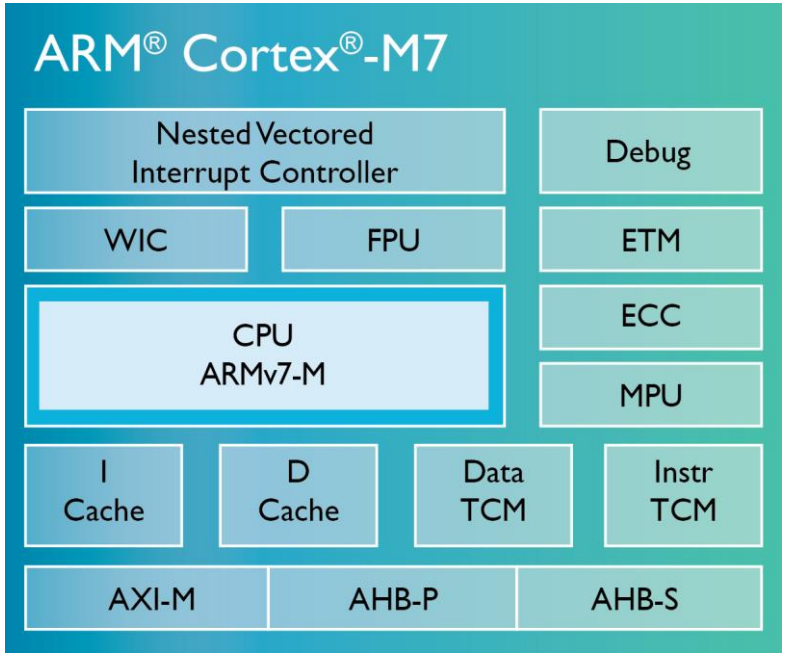
Cortex®-M7 Key Features (2)

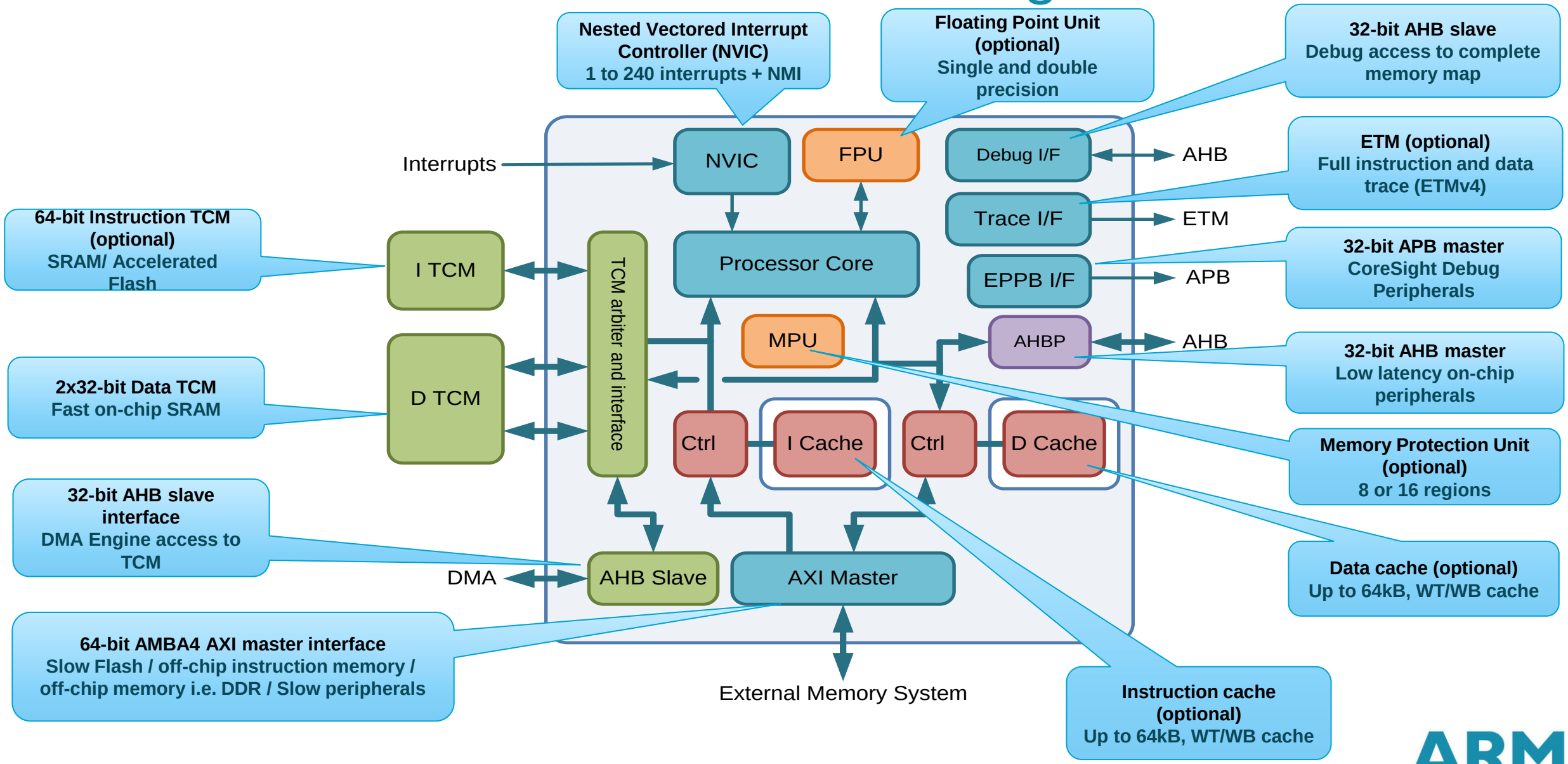
- ARMv7E-M architecture
  - 100% binary forwards compatibility from Cortex-M4
  - Key Cortex-M family processor characteristics: Ease of use, excellent interrupt latency
  - **Fast interrupt response for real-time systems, reuse code and system design from existing products to reduce development costs**



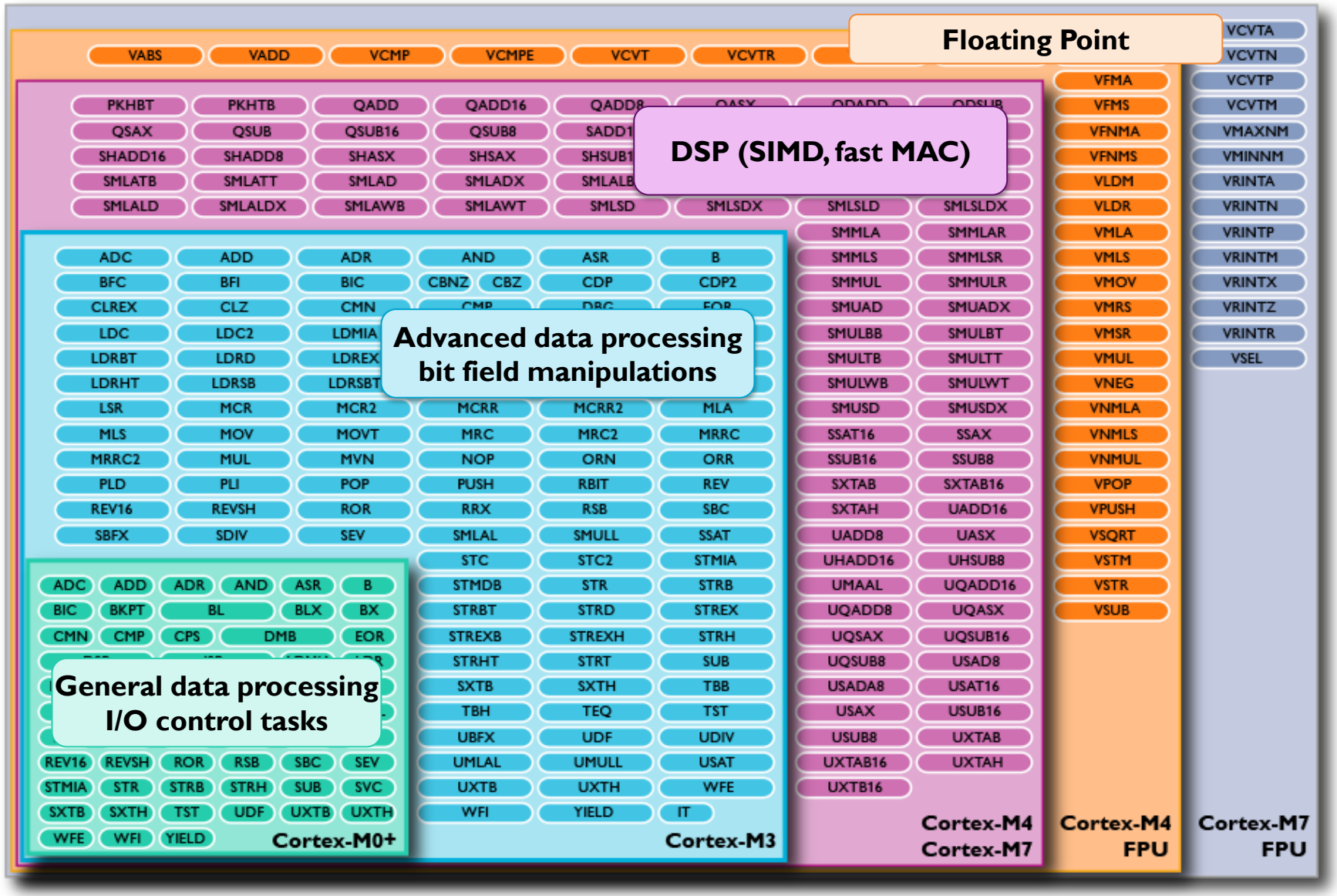
- Safety features
  - Memory ECC (SEC-DED), MPU, MBIST, lock-step operation, full data trace, safety manual
  - **Enables entry into safety-critical markets.**

ARM

ARM® Cortex® -M7 Processor Block Diagram



Powerful & Scalable Instruction Set



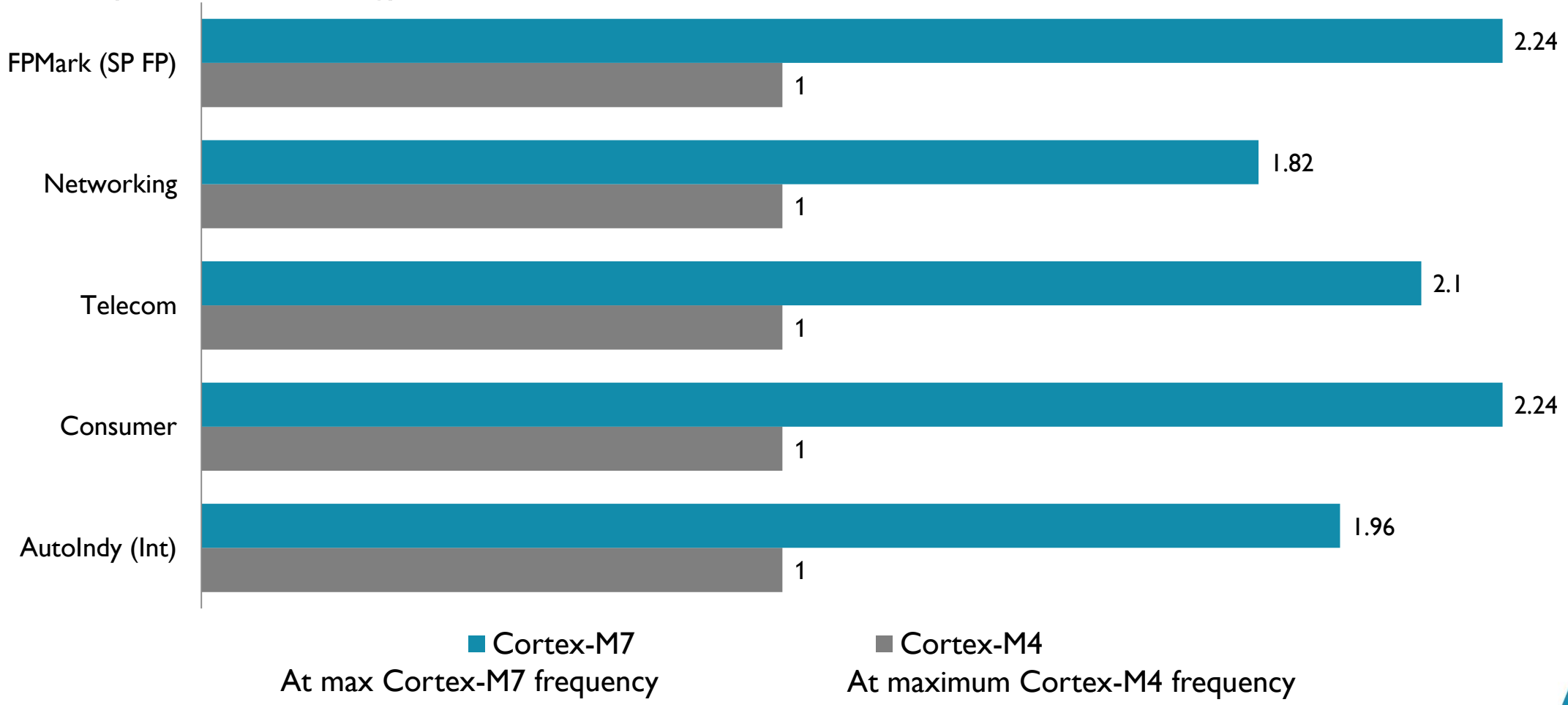
- Cortex®-M7 has the same powerful instruction set as Cortex-M4:

- Integer MAC instructions are all single-cycle
- SIMD instructions can work on 8-/16-bit quantities packed in to a 32-bit word
- Arithmetic can be signed/unsigned, saturating/non-saturating
- A few new FP instructions for FPv5

ARM

EEMBC

- Results are geo-mean of EEMBC IPC relative to Cortex®-M4 baseline
- Comparable memory systems – zero wait state memory for Cortex-M4, caches for M7
- Same process technology



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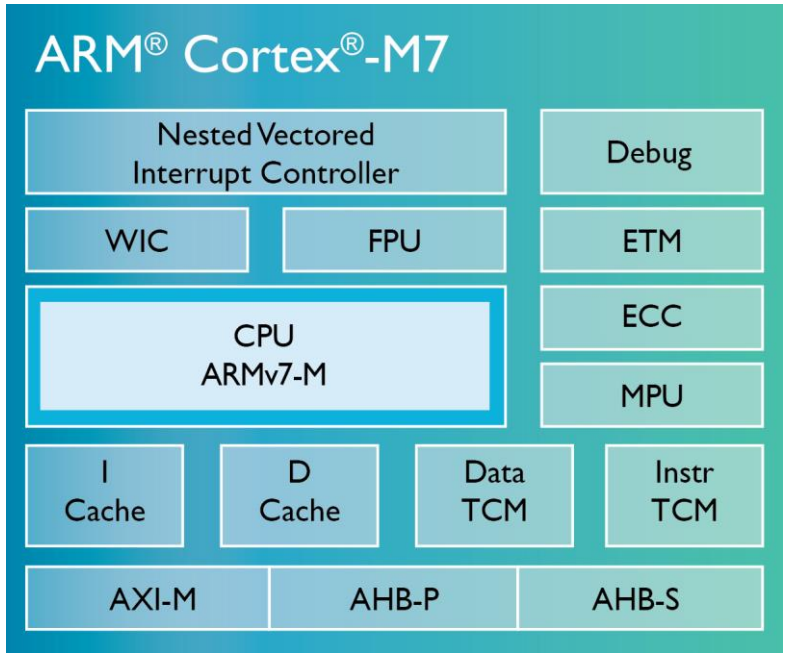
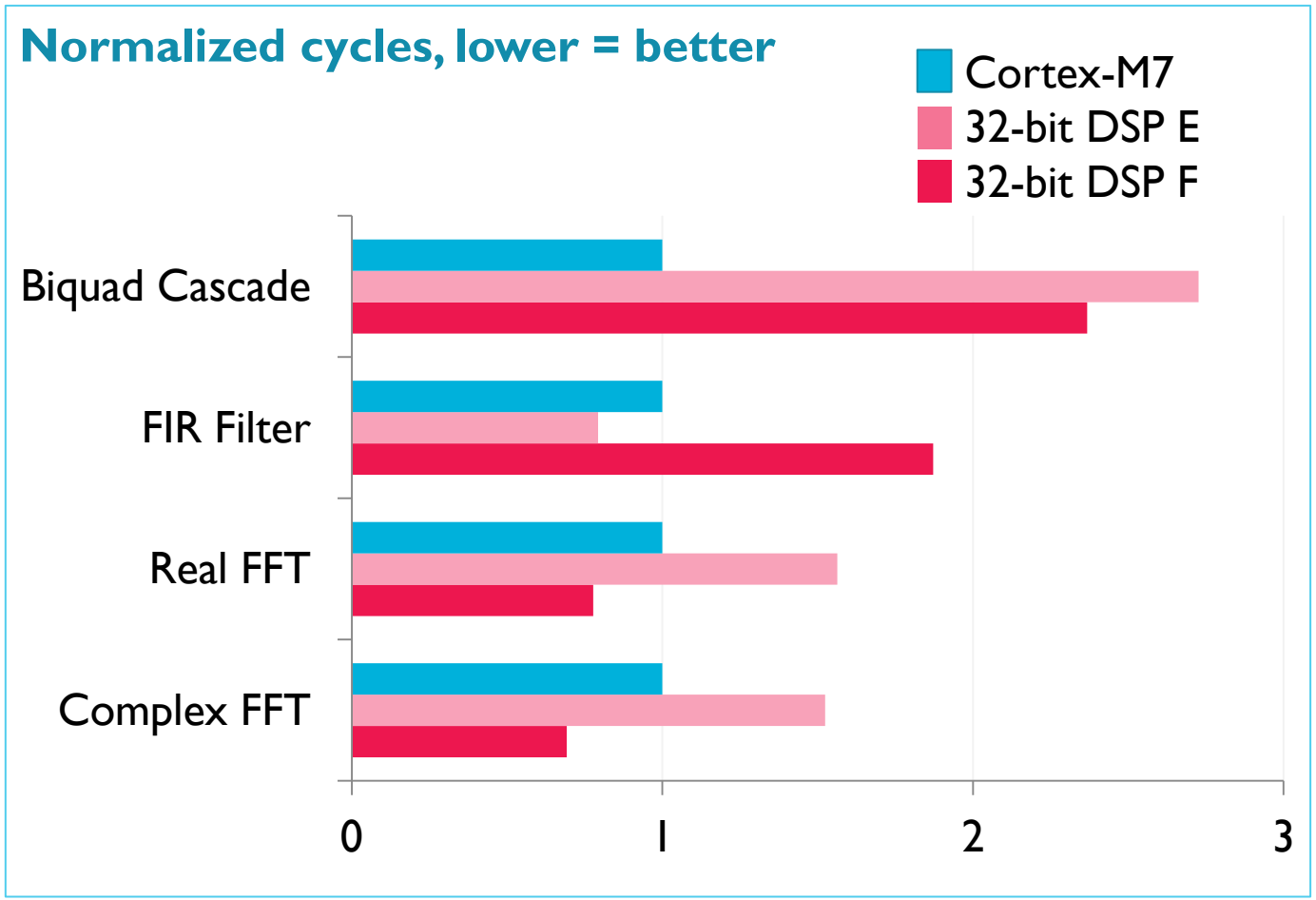
Cortex®-M7: Competitive with Popular DSPs

- Essential DSP features
  - Parallel execution of loads, stores and MAC
  - SIMD support, single-cycle MAC
  - Single and double precision floating point unit
  - Minimal loop overhead (branch predictor/BTAC)
  - Optimised DSP libraries

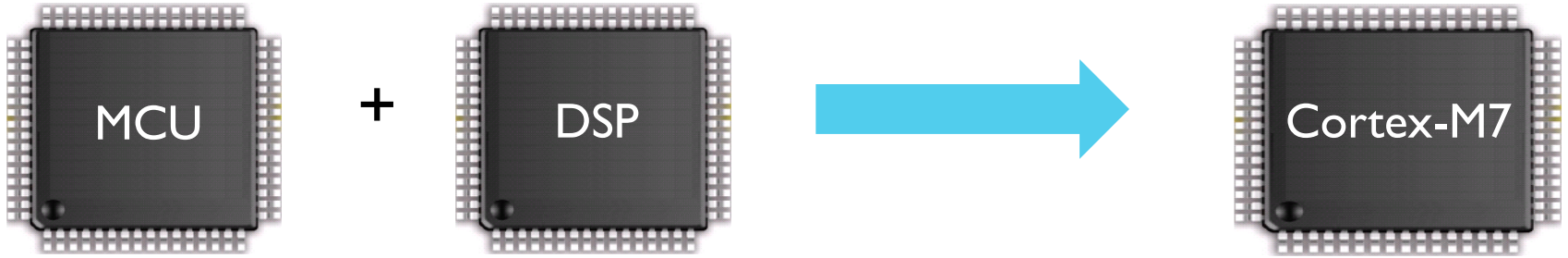


Consistently good performance across key DSP functions



ARM

Cortex®-M7 – Replacement for MCU+DSP



- **Trends:**
  - Convergence of MCU+DSP to DSC for cost reduction
  - Increased processing demands
  - Increasing consumer expectation of quality in portable devices
- **Example applications:**
  - Multi-channel audio / Dolby Audio
  - Advanced Motor Control
  - Factory Automation
  - Automotive
  - Image processing
  - Power conversions

Cortex-M7 Advantages:

- High performance core with fast DSP
- Compatibility with existing Cortex-M4 designs
- Flexible memory system

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Enabling More Capabilities for Feature-Rich Devices

2x More performance delivering improved flight management

Cortex®-M7
400 MHz

Cortex-M4
168 MHz

Source: 3DRobotics, PX4 autopilot ETH Zurich

- Finer degree of control
- Accurate speed measurement
- Finer GPS accuracy
- Secure telemetry radio

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Helping Drive Richer Audio Experiences

2x More performance delivering advanced sound processing

Cortex®-M7

DOLBY AUDIO Dolby Digital Plus (with post processing) 160 MHz

Cortex-M4

130 MHz

DOLBY AUDIO Dolby Digital

- 7.1 Multi-channel audio support
- More speaker EQ processing
- Capacity for decoders
- More connectivity options

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Cortex®-M7 in Automotive

- **Trends and challenges:**
  - Safety certification mandated in more regions
  - Convergence of functionality into fewer MCUs/ASSPs
  - Increasing user requirements and expectations

- **Typical Applications**
  - Dashboard in medium-range cars
  - Voice recognition
    (for Multimedia control functions)
  - Character recognition (eg Kanji)
  - "Convenience" features
    (eg intelligent headlight clusters)
  - Chassis, electric power steering, "steer-by-wire"
  - Automotive audio

Cortex-M7 Advantages:

- High performance core with fast DSP
- Safety features built in and safety manual
- Determinism with high performance
- Full trace via ETM

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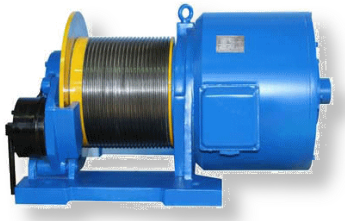
Cortex®-M7 in Industrial Control



- **Trends and challenges**
  - High performance control functions
  - Safety, reliability and conformance will become mandatory
  - 80-90% of cost is software, Cortex-M offers scalability and protects software investment
- **Typical applications:**
  - Factory Automation
    - Inverters, Servos
    - Programmable Logic Controllers
    - High-speed comms
  - Intelligent motor control

Cortex-M7 Advantages:

- Increased DSP performance for control functions
- Safety features built-in
- In-order pipeline gives performance with predictability
- TCMs and low interrupt latency: Interrupt response within 100ns required
- Scalability from Cortex-M3 through Cortex-M7 up to Cortex-A53

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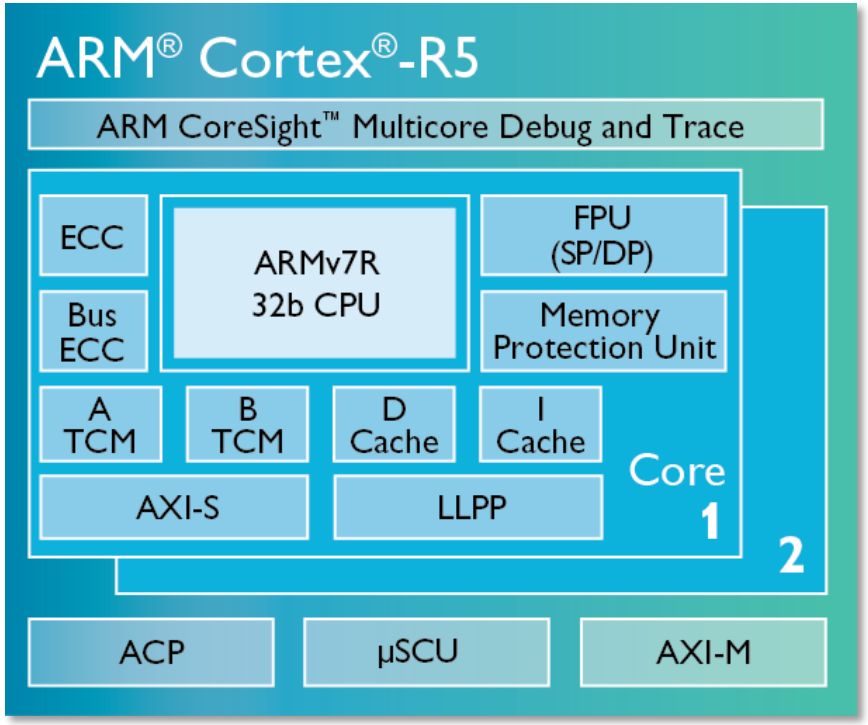
Cortex®-R5 Processor

Enhanced SoC integration with Low Latency Peripheral Port, Accelerator Coherency Port

- Fast high performance 1.66 DMIPS/MHz
  - Energy-efficient, eight-stage dual-issue pipeline
  - ARMv7R architecture - Thumb-2 / ARM instructions
  - Hardware divide, SIMD, SP or SP/DP FPU option
  - Harvard caches, 64-bit AMBA AXI-3 bus
- Deterministic and fast interrupt response
  - Unified Tightly-Coupled Memory system
  - Low Interrupt Latency microarchitecture
- Reliable with fault handling built into core



Single or dual core configuration

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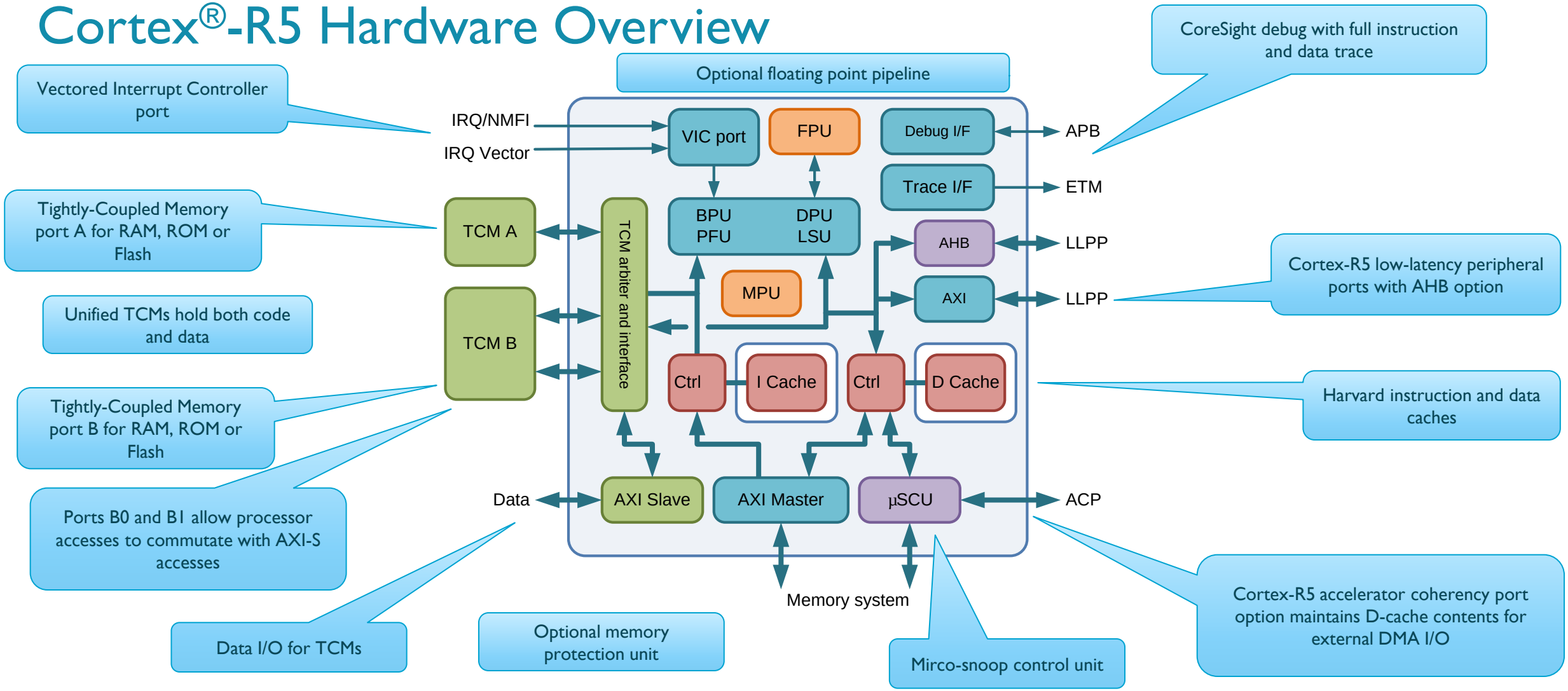
Cortex®-R5 Hardware Overview



- Synthesis config: Caches, TCMs, AXI-S, FPU, MPU, break/watch-points, ECC/Parity, lock-step
- R5 only: ACP/µSCU, AHB-LLPP, SP-only FPU, split-lock

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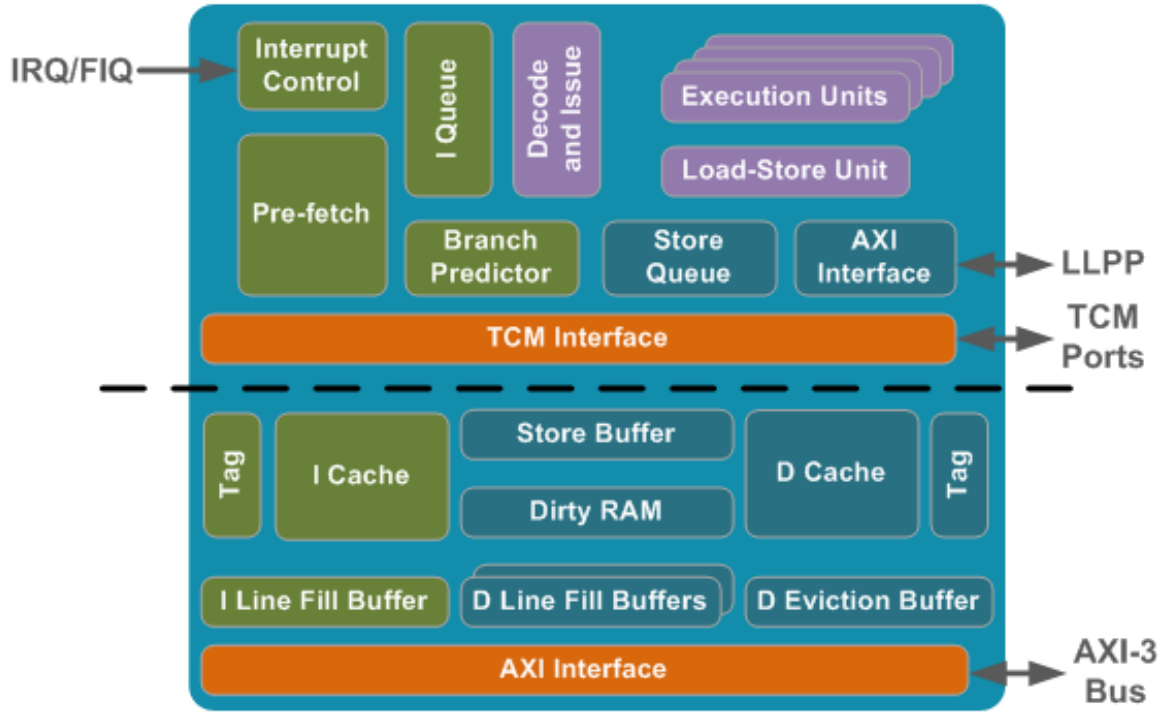
Cortex®-R5 Bounded Real-Time Response

- Superscalar execution throughput
  - Cache line buffers minimise stalling while waiting for L2 memory system
- Low Interrupt Latency mode
  - Fast interrupt response abandons pending and restartable memory operations
- Tightly Coupled Memory
  - Static Level-1 memory system for locally held code and data
    e.g. Interrupt service routines
- Low Latency Peripheral Port
  - Introduced in Cortex-R5
  - Direct paths to LSU and store queue avoid delays in caches and AXI-Main



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Safety in Embedded Processors

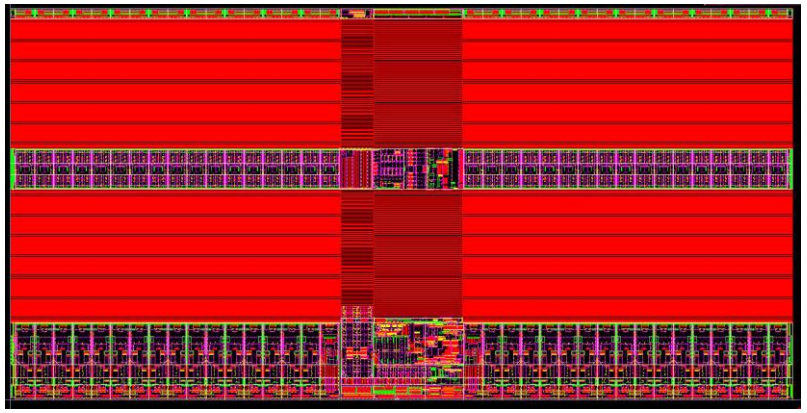
Reliability Requirements in Wider Range of Embedded Systems

- Traditional markets
  - Automotive
  - Industrial Control

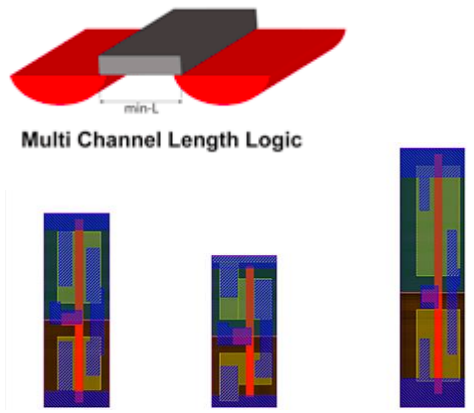
- Emerging markets
  - Infrastructure / Smart Cities
  - Medical
  - Home gateway / communication infrastructure

- Increasing reliance on embedded systems to continue functioning when errors occur
- Higher chance of errors at advanced nodes, in larger memories and in bigger programs

Typical Technical Requirements



Memory



Logic

Software

- Reducing the possibility of errors
- Detection of errors
- Correction of errors
- Robustness – reducing single points of failure

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Cortex®-M7 Functional Safety Support

Cortex®-M7 Support for Functional Safety

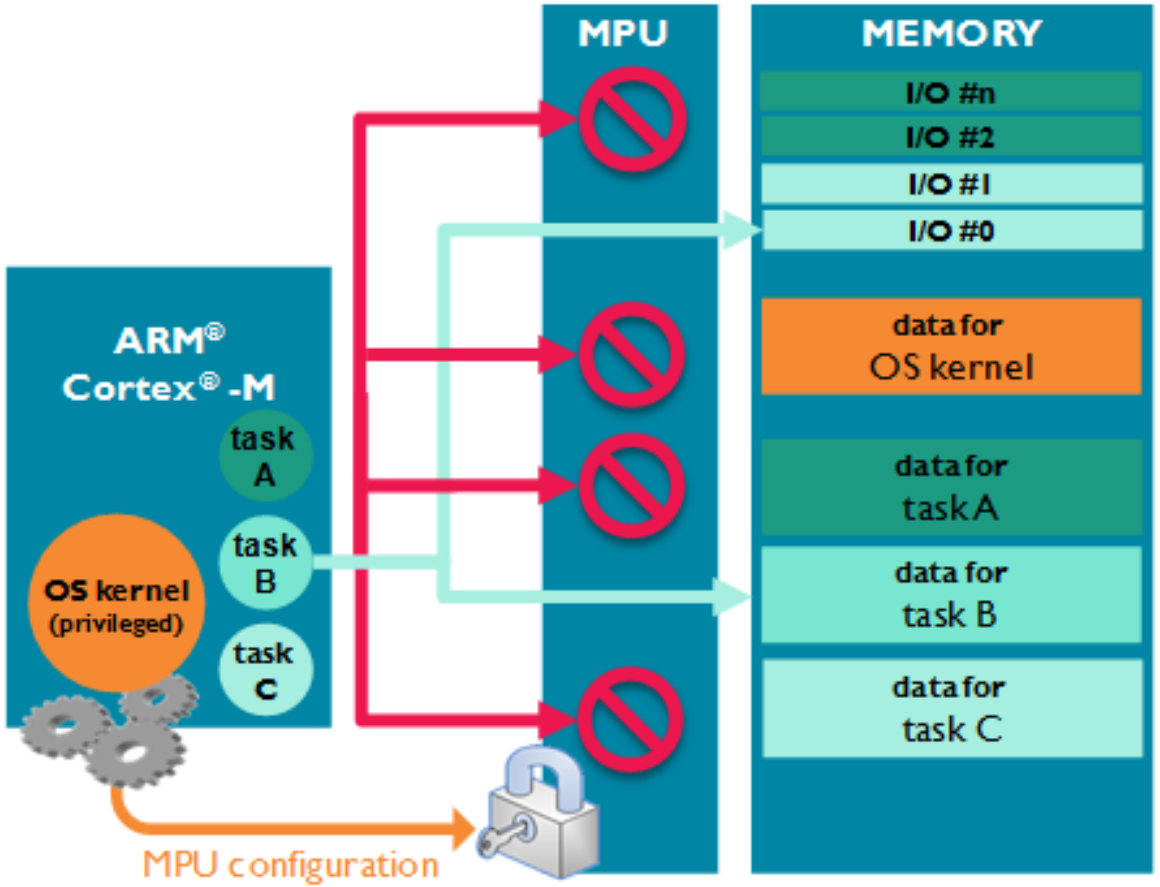
In accordance with ISO 26262, IEC 61508 etc.

- Cortex-M7 incorporates fault detection and control features
  - ECC for detection and correction of random faults in cache RAMs
  - Dual-Core Lock-Step option detects random faults in processor logic
  - Memory Protection Unit to detect systematic faults in software
  - On-line MBIST interface allows scrubbing of memory for errors whilst applications are running
- Features necessary for microcontrollers targeting automotive and industrial applications
- Safety Package will be released later in 2015

ARM

Cortex®-M Processor Features to Support Reliability

- Fault exceptions
  - HardFault (available on all Cortex-M processors)
  - Configurable faults on ARMv7-M architecture : Usage Fault, Bus Fault, Memory Management Fault
- Non-Maskable Interrupt (NMI)
  - Highest priority exception
  - Watchdog / BOD (Brown Out Detection)
  - Cannot be disabled
- Memory Protection Unit (MPU)
  - Use by RTOS to configure memory access permissions and memory attributes
  - Optional, programmable



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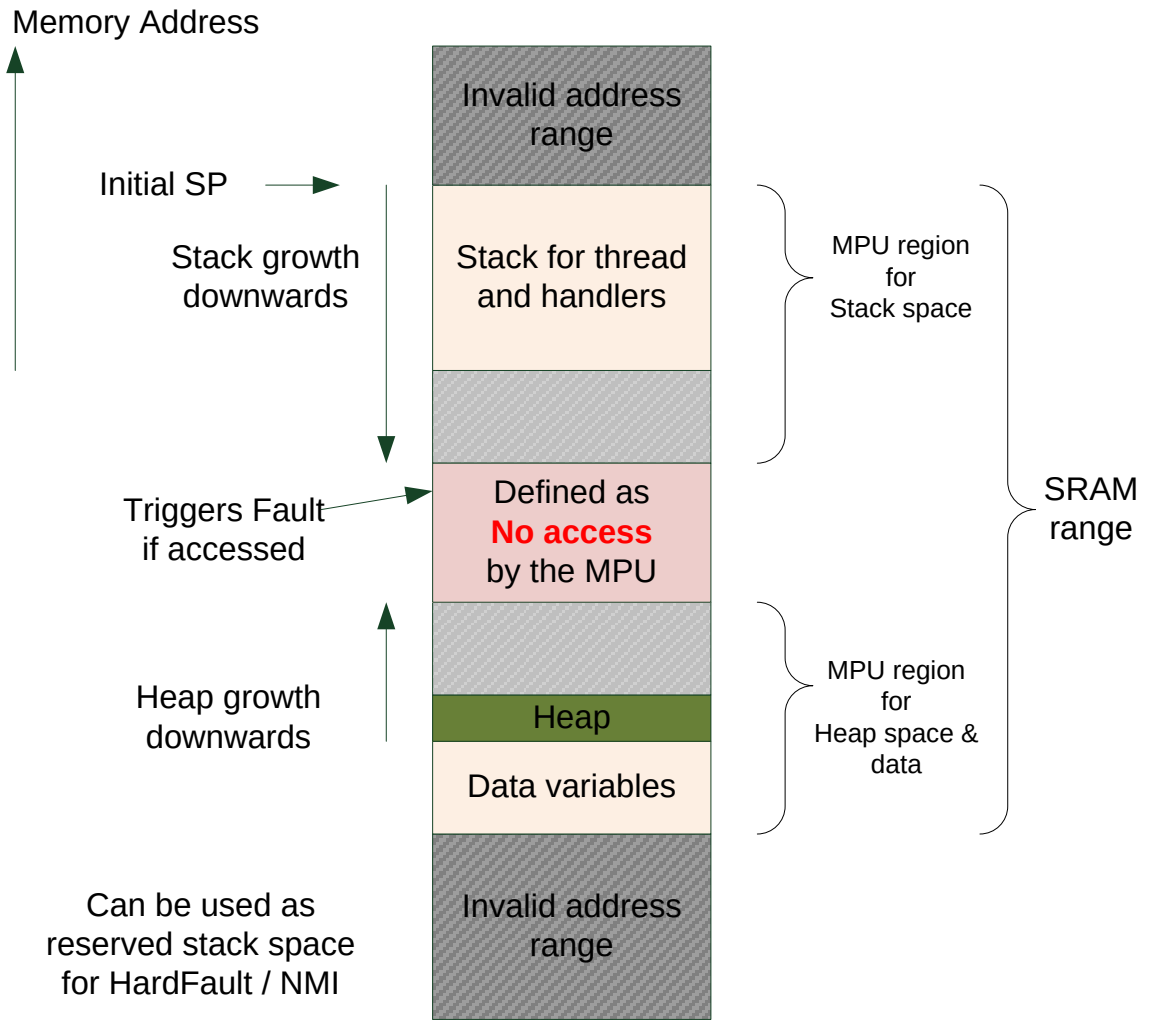
Example – Stack Protection

- Stack overflow is a common cause of embedded system failure
  - Software developer's mistakes
  - Unforeseeable workload
- Detection methods at runtime
  - Use MPU to define accessible RAM space
  - Stack limit by placement
  - Use stack checking feature in RTOS

  (Checks at context switches and/or OS ticks)



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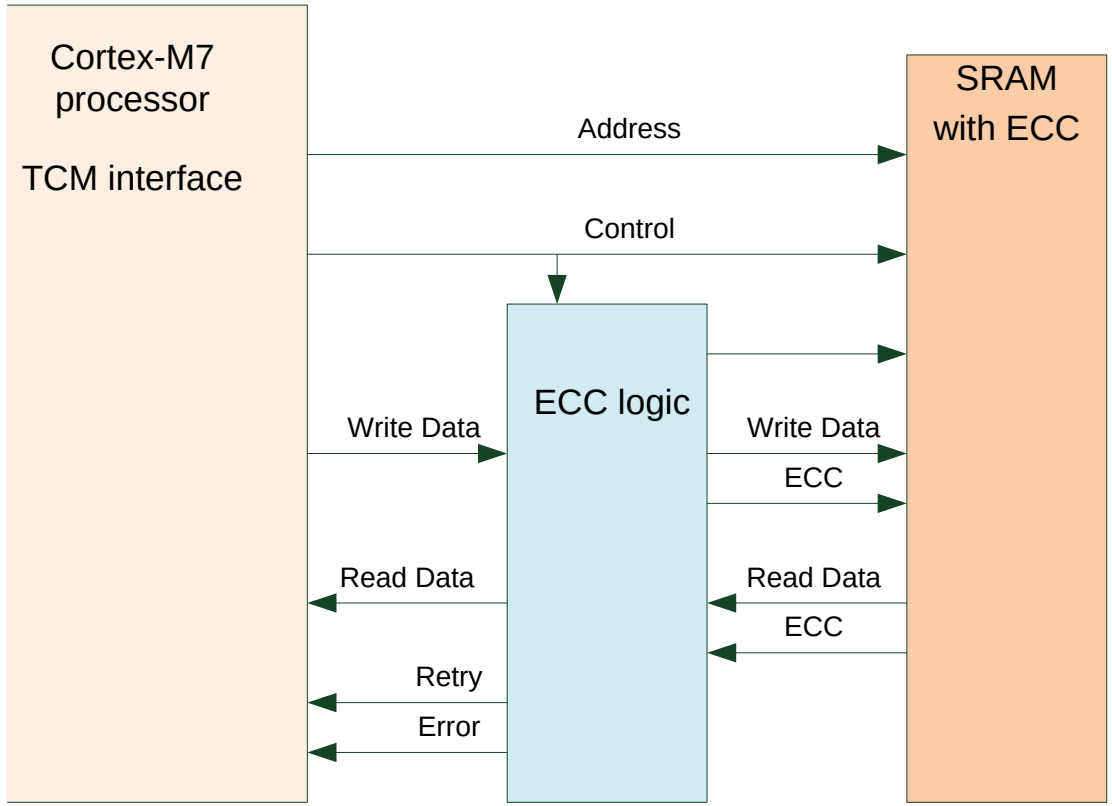
ECC on TCM Interfaces

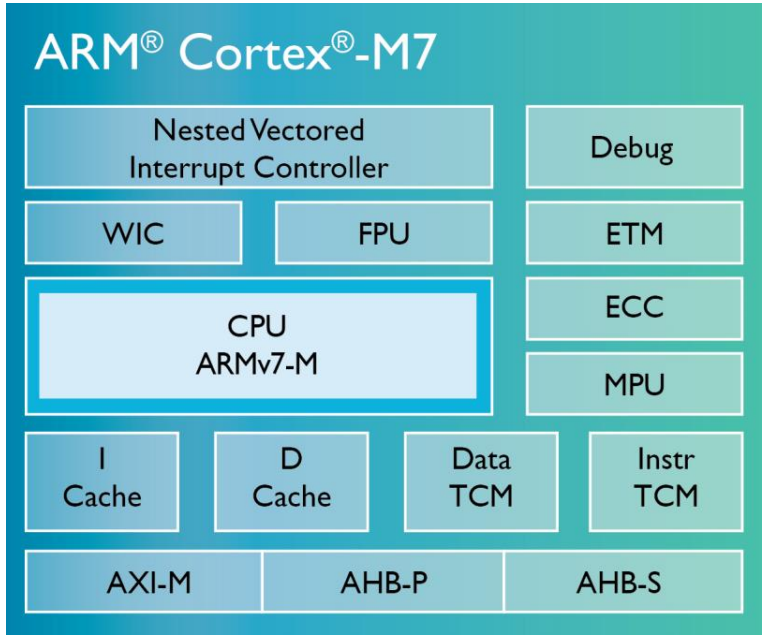
- Tightly Couple Memory (TCM) interfaces support optional ECC
  - ECC scheme defined by chip designers
  - RETRY and ERROR signals
- RETRY signal
  - Assert 1 cycle after read data
  - Give ECC logic chance to correct data
- ERROR signal
  - After retry, if error cannot be corrected
  - Result in bus fault exception



ARM

Cache ECC Support

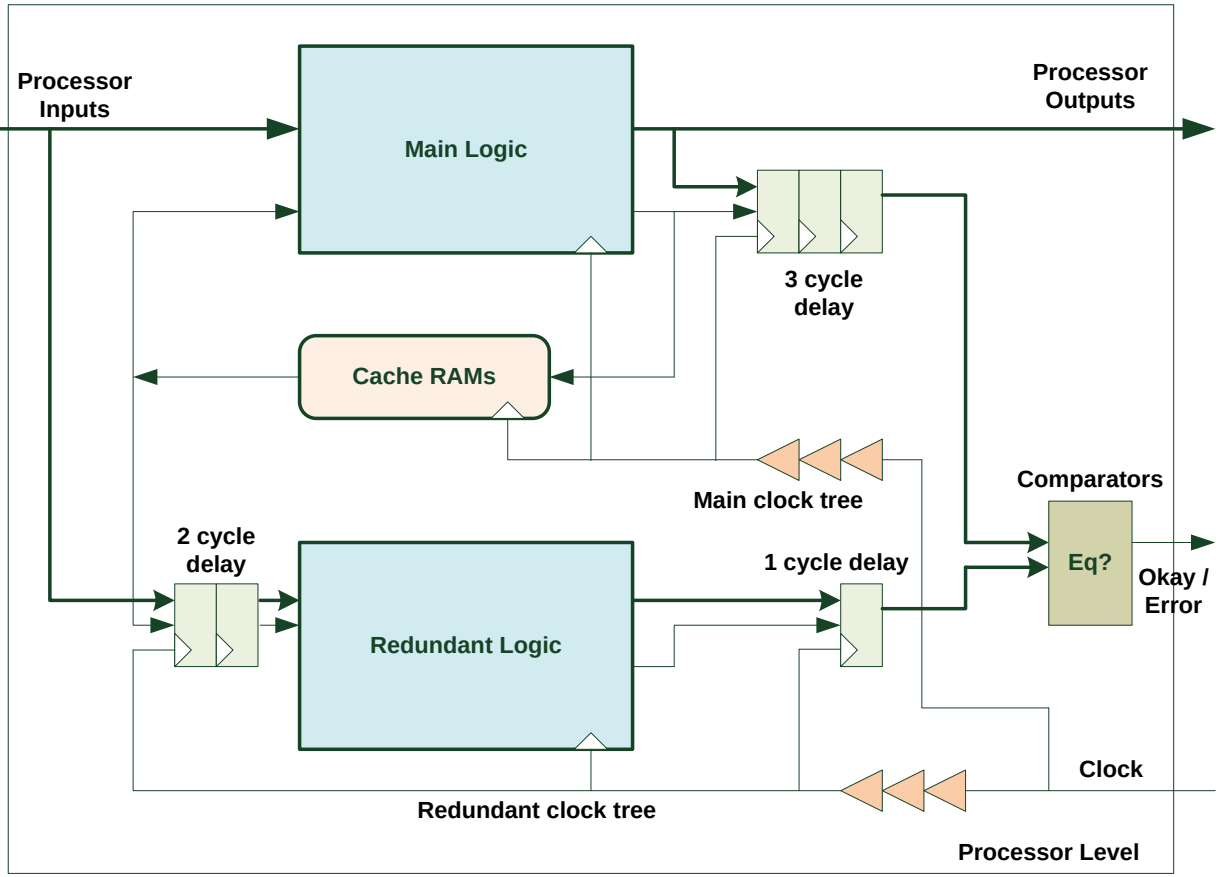
- Handled internally inside Cortex®-M7 processor
  - Optional
  - ECC initialized as part of cache invalidate during cache enabling
  - Cached data is **corrected on the fly with clean and invalidate**
  - Un-correctable errors trigger fault if in data cache & dirty
    (Instruction and clean data can be discarded)
- I-Cache, D-Cache error bank registers
  - Indication of cache memory error locations
  - Cache lines can be locked down to prevent them from being used
- Additional signals for cache error monitoring / handling



ARM

Dual Core Lock Step Support on Cortex®-M7 Processor

- Duplicate logic only
  - Cache and TCM are protected by ECC
  - Outputs are compared
- Skewed operation to prevent common mode failures
- Potentially can use different logic implementations between the two
  - Prevent common mode failures
  - Lower power implementation for redundant logic (not in critical path)



Example DC-LS, customers can modify top level comparators

ARM

Cortex®-M7 Safety Documentation Package contents

- Essential documentation to support designing Cortex-M7 products for safety-related markets
- Three key documents within the Safety Documentation Package:

- Safety Manual
  - Overall description of functional safety activities within ARM
  - Product specific aspects of functional safety
  - Overview of safety architecture
  - Description of fault detection and control mechanisms
  - Summary of safety analysis results
- Failure Modes and Effects Analysis Report
  - Block and sub-block level partitioning
  - Estimated failure rate distributions
  - Sample quantitative analysis
- Development Interface Report
  - Identification of safety-lifecycle aspects applicable to ARM and IP integrator

ARM

Cortex®-R5 Functional Safety Support

Dependable Systems with Cortex®-R4/R5

- Cortex-R4/R5 have many features to enable safe processing
  - Cortex-R5 has optional Safety Documentation Package
- Memory Protection Unit detects unauthorized address accesses
- Data and address protection integrated within processor architecture
  - ECC or Parity on Level-1 memories. Parity on selected busses
  - Cortex-R5 has extended ECC support to all AXI and AHB busses, incl. ACP
- ECC offers advanced Single Error Correction or Double Error Detection
  - Automated memory error correction integrated into processor pipeline
  - Support for external ECC logic, e.g. in a Flash memory controller
- Processor incorporates error counting and logging for diagnostics
- Optional redundant core configuration for lock-step operation
  - Cortex-R5 allows static switching between lock-step and twin core operation

ARM

ARM Compiler 5 Support for Functional Safety

- Compiler Safety Package for software development in safety markets
  - Industrial control, automotive, medical, transportation, military and others

Qualification Kit

- Development process docs
- Safety manual
- Defect report
- Test report

Extended Maintenance

- Five year commitment
- Technical support
- Critical defect fixes

Functional Safety Certified

- TÜV SÜD certification
- ISO 26262 (ASILD)
- IEC 61508 (SIL3)

- Access to the Safety Package provided with DS-5 Ultimate and Keil MDK Pro
  - Valid DS-5 or MDK support and maintenance entitlement enables extended maintenance
  - Compiler installation is an add-on to the standard product installation

ARM

ARM Cortex®-M and Cortex-R Embedded Processors

Cortex-M

Cortex-M4
Mainstream
Control & DSP

Cortex-M7
Maximum Performance
Control & DSP

Cortex-M0
Lowest cost
Low power

Cortex-M0+
Highest energy
efficiency

Cortex-M3
Performance
efficiency

Cortex-R

Cortex-R7
High performance
4G modem and storage

Cortex-R4
Real-time standard

Cortex-R5
Functional safety
package

Thank You

ARM