By Team F:
Tyler Dubuke, Matt Fortmeyer, Jeremy Hoffman, Elsa Luthi, Amanda Pennie, Michael Prindle, and Sylvia van der Weide

ARM - Cortex: Background and Summary

- ARM Product Family: ARM’s three largest product families are the Cortex-A family, the Cortex-R family, and the Cortex-M family
- “Neoverse” - Compute
- “Machine Learning” - AI and Machine Learning
- “SecurCore” - security applications
- Cortex families - scalable performance across a wide variety of chips

ARM Cortex - A Series

- “A” for “Application” - designed for performance-intensive applications running on a variety of systems
- The largest Cortex family; 16 chips as of the time of writing
- Smallest chip: Cortex-A5 - low cost, low power applications such as mobile computing
- Largest chip: Cortex-A76 - “laptop-class performance with smartphone efficiency”
- Cortex-A76E - “world’s first autonomous-class processor with integrated safety”
    - Used for autonomous vehicles

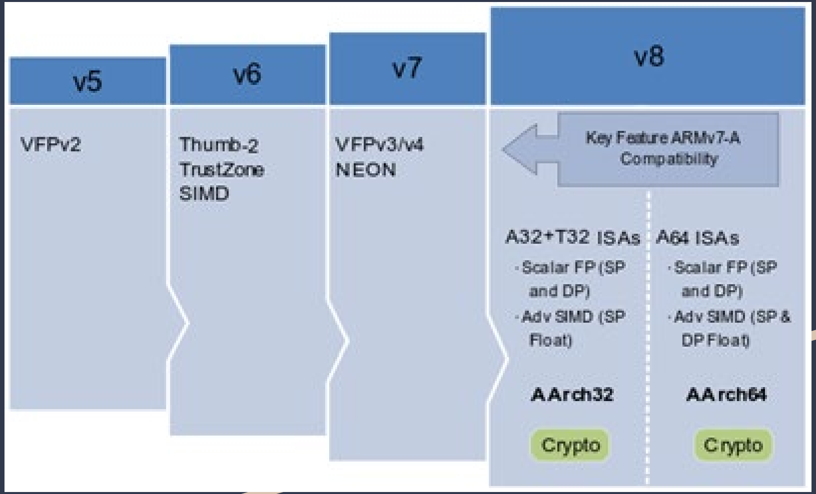
ARM Cortex - R Series

- “R” for “Real-time” - designed for difficult real - time applications and applications that are safety critical
    - Medical devices
    - Robotics
    - Avionics (fly-by-wire)
- Smallest ARM product family - 5 chips
- Smallest chip: Cortex-R4 - with deterministic microarchitecture and built in error handling, used for Hard Disk controllers and Automobile displays (i.e. dashboard)
- Largest chip: Cortex-R52 - higher performance safety critical applications
    - Advanced Driver Assistance Systems and Medical Robotics

ARM Cortex - M Series

- “M” for “Microcontroller” - Introduced by ARM to compete within the busy MCU market
- Used for traditional MCU applications
  - Household appliances
  - Displays
  - Game consoles
- Smallest chip: Cortex-M0 - low power, low cost, high battery life
  - Used for wearables and environmental sensors
- Largest chip: Cortex-M35P - high performance, increased security
  - Used for medical devices, industrial control, and large-scale smart lighting

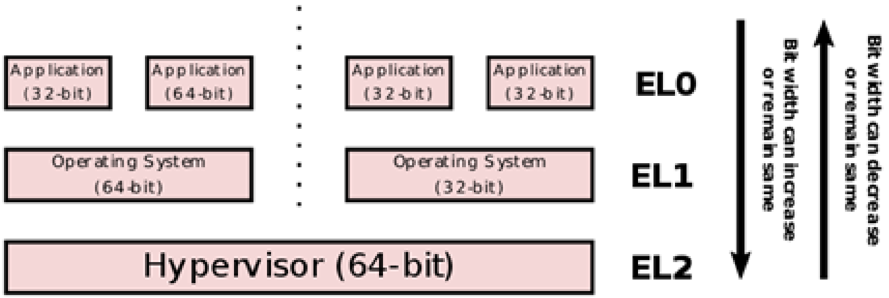
ARMv8 Overview



- Current ARM instruction set architecture
  - Introduced in 2011
- Introduced 64-bit operating capabilities
- Maintains backwards compatibility with ARMv7
- Has two main execution states
  - AArch32
  - AArch64
- Introduced hardware acceleration for cryptography
- Larger physical addresses
  - Processor can access beyond 4GB of physical memory

AArch32 vs AArch64

- 32-bit and 64-bit execution states
- AArch32 uses the traditional ARM exception handling model
- AArch64 has a simplified exception handling model
- AArch32 and AArch64 applications can run side by side on the same operating system
- Can change between the two states at the exception entry and exception exit points



ARMv8 Processors

- Two popular processors implement the ARMv8-A ISA
- Cortex-A53
  - Mid-range, low power processor
  - Extremely power efficient
- Cortex-A57
  - Higher end processor
  - Used for more intense processing
- These processors can be deployed independently or paired with each other for increased performance

NEON

- Expanded in ARMv8
  - Originally introduced in ARMv7
- Advanced SIMD Architecture designed for the ARM Cortex-A series
  - Single instruction stream, multiple data streams
- Primarily used for graphics, audio/video decoding, and UI processing

What is RISC?

- ARM (Advanced RISC Machine)
- Reduced Instruction Set Computer
- ARM processors are RISC
- 32-bit instruction set
- 3-data address instructions
- 16 General purpose registers
- The simplified design of RISC enables them to be more efficient at multi -core processing and easier coding for developers
- They do not have the same computing throughput as products of the x86 line, but sometimes can exceed the performance on applications that exist on both architectures

What is THUMB?

- A subset of RISC instructions
- 16-bit instruction set
- 2-data address instructions
- 8 General purpose registers
- Greater code density
- If used properly can lead to even better performance and power efficiency

What is JAZELLE?

- 8-bit instruction set
- Is an extension that allows arm processors to execute Java bytecode
- Not much information on how this is implemented in the ARM

Naming Scheme

Product Family	Feature	Example Use Cases
Cortex-A	**Highest Performance** Supreme performance at optimal power	Automotive Mobile Medical
Cortex-R	**Real-Time Processing** Reliable mission-critical performance	Automotive Industrial Cameras
Cortex-M	**Lowest Power, Lower Cost** Reliable mission-critical performance	Automotive Smart devices Secure embedded applications
Neoverse	**Maximum Performance, Maximum Efficiency** Revolutionary compute performance	Cloud Computing Edge Computing Network Infrastructure
Machine Learning	**Efficiency Uplift for All Devices** Project Trillium for unmatched versatility and scalability	Artificial intelligence Augmented reality Edge computing
SecurCore	**Tamper Resistant** Powerful solutions for security applications	Advanced payment systems SIM Smart cards

Naming Scheme (Before 2006)

- Prior to 2006, ARM had 5 different core families
  - ARM7, ARM8, ARM9, ARM10 and ARM11
- These cores had certain tags in their name which denoted certain features
  - ARM**XX** names tell you which family
    - ARM**9**20T
  - 'F' - core has a VFP (vector floating point) unit
    - ARM1136J(**F**)-S
  - 'T' - core is able to use thumb encoding
    - ARM1020**T**
  - 'T2' - core is able to use thumb2 encodings
    - ARM1156**T2**(F)-S
  - 'J' - core is able to use jazelle encodings
    - ARM1136**J**(F)-S

Naming Scheme (After 2006)

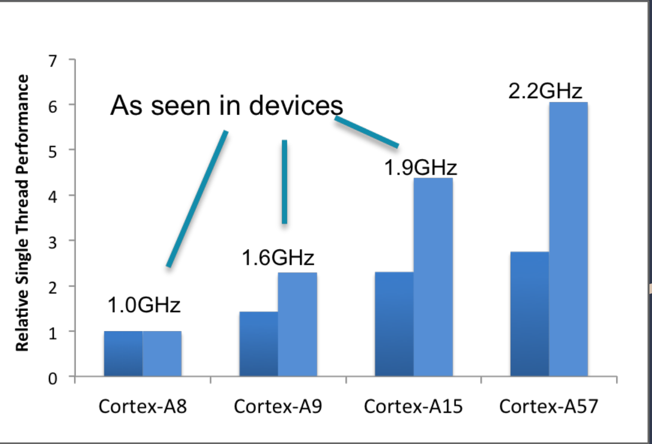
- After 2006, ARM started developing their cortex line
- Naming schemes now only include the letter denoting its family because VFP and Thumb are included in every model
  - Microcontroller
    - Cortex-M3
  - Real-time
    - Cortex-R4
  - Application
    - Cortex-A35

Benchmarks

ARM has increased the smartphone's CPU by **100x** and GPU performance by **300x** since 2009 bringing desktop-class PC performance into our hands.

ARM Cortex-A (mobile application) processor product line spans several generations and three main product tiers

Benchmarks (Cortex A)



2005

Cortex-A8

First processor supporting armv7 -a architecture. Many partners thought it was overkill for mobile phones.

2007

Cortex-A9

First multi-core ARMv7 CPU, 25% higher instruction throughput per clock cycle than A8. Became the high end mobile CPU in late 2011.

2012

Cortex-A15

>50% increase in performance over the already powerful Cortex-A9. Allowed for larger physical address space, hardware virtualization support, and extended coherency

Benchmarks (Cortex A)

2013

Cortex-A12

New microarchitecture in a new CPU. Targets fast-growing mid-range mobile segment

2013

Cortex-A57

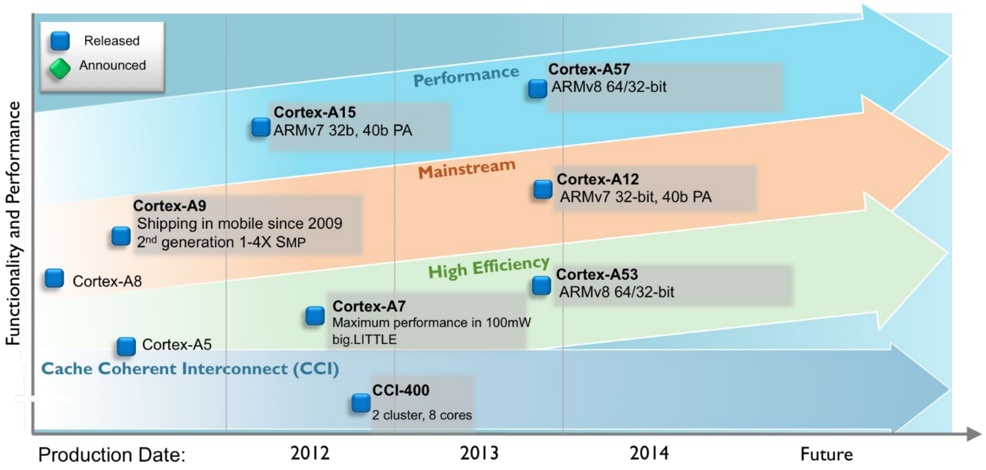
Increases performance per cycle by **20% to 40%** over the high performance Cortex-A15 CPU

2013

High Efficiency Product Line

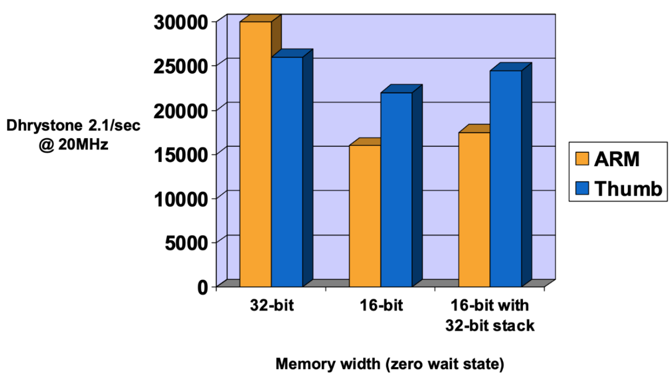
Cortex-A5 allowed the efficiency (performance per mW) to be the **highest** ARM had ever delivered for an applications processor
Cortex-A7 delivered **20%** more performance per cycle.
Cortex-A53 delivered more performance than the flagship CPU in the Cortex-A9

Benchmarks (Cortex A)

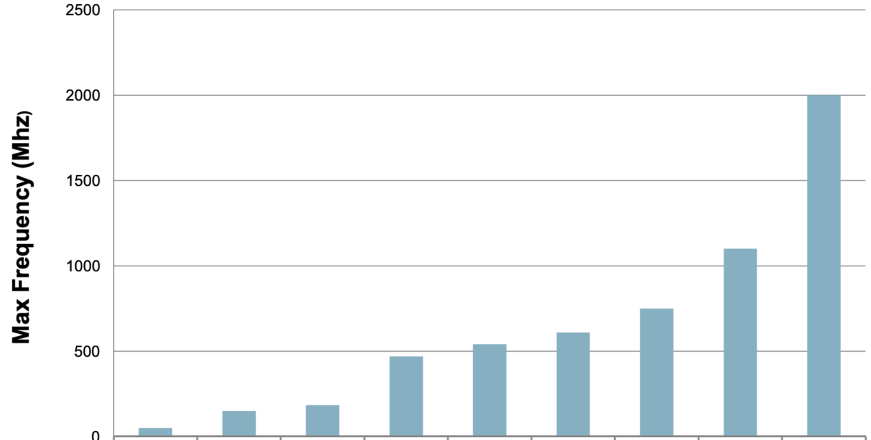


Performance Information

ARM and Thumb Performance



Relative Performance*



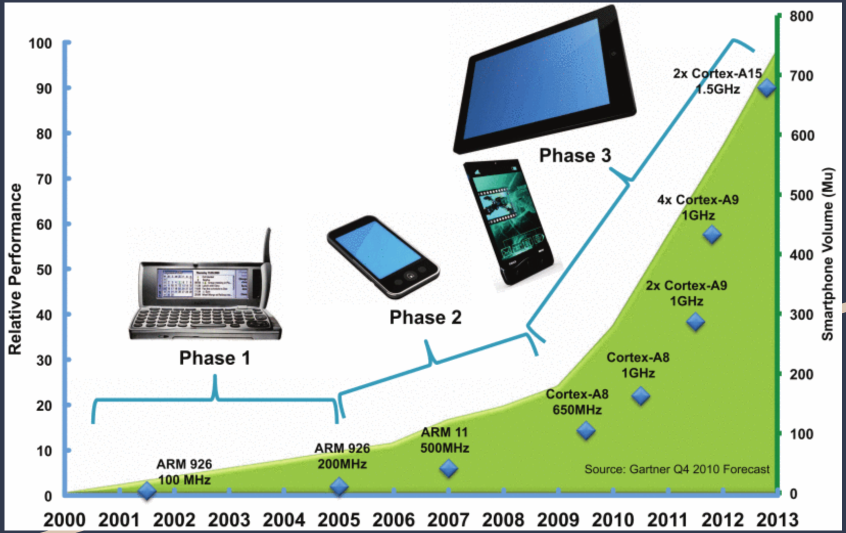
	Cortex-M0	Cortex-M3	ARM7	ARM926	ARM1026	ARM1136	ARM1176	Cortex-A8	Cortex-A9 Dual-core
Max Freq (MHz)	50	150	184	470	540	610	750	1100	2000
Min Power (mW/MHz)	0.012	0.06	0.35	0.235	0.36	0.335	0.568	0.43	0.5

*Represents attainable speeds in 130, 90, 65, or 45nm processes

Performance Information

- Past 30 years significant increase in technology
    - Functionality and competition
    - Cost
- Old computers
- Early phones
    - Contact list
    - Calling
    - Calculator
    - SMS
- Moore’s Law

Performance Information



- Smartphones
  - Always connected to the internet
  - Cloud access
  - Flash
  - Apps
- Current Technology
  - Multi-core
- Power efficient processing
- Issues
  - Batteries
  - Implementation
  - Transistors

Microprocessors for Laptops

GOAL:

- “Always On, Always Connected”
- Long battery life
- Low power usage
- Lightweight

Snapdragon 850 Mobile Compute Platform

- Announced at Computex in 2018
- Partnership between Qualcomm and Samsung to integrate Snapdragon X20 and Qualcomm AI into a device
- Stays connected via WiFi or LTE for constant access
- Battery life of 25 hours of continuous usage
- Allow for Windows 10 systems

Pinebook

64-bit ARM based open source notebook

Specifications:

- 1.2 GHz Quad-Core ARM Cortex A52
- 2 GB RAM
- 16 GB Flash
- Linux OS
- 2.3 lbs
- 10000 mAH battery

COST: $99

ASUS NovaGo TP370QL 2 - in - 1

Windows 10 OS

Specifications:

- Qualcomm® Snapdragon 835 Mobile Processor
- 4GB RAM
- 256GB storage
- 3.1 lbs, 0.6 inches thin
- 22 hours of video playback
- WiFi and 1Gps LTE connection

COST: $699

Microprocessors for smartphones and tablets

- Requirements
  - Small
  - Low Power
  - Handles hardware well
- Solution
  - System on a chip (SoC)

What is a System on a Chip?

- A single chip that integrates all the components of a computer within a single integrated circuit
- They are smaller and consume less energy than multi-chip systems
- Examples
  - Qualcomm Snapdragon
  - Samsung Exynos

Questions?