WHITE PAPER

Introduction to ARM

Chris Shore/ATC-200 November 2012

Introduction

The world of ARM® technology can seem daunting at first. For a company which has only been around for just over 25 years, the sheer number and variety of products available which support one version or another of ARM's processor architecture is bewildering.

This paper accompanies a presentation, which is aimed at those who are attending ARM TechCon™ for perhaps the first time. I hope that it will provide a way in to the ever-expanding world of the ARM architecture and enable you to get more out of the wealth of material on show.

The presentations given at the show (the slides are available to download) contain all the information in this paper together with a brief technical introduction to the ARM architecture. This technical information is not included in the paper as it is widely available through other documentation which is freely available from the ARM website. See the section on further reading at the end.

It is perhaps useful to get some common misconceptions about ARM cleared up straight away…

ARM does not stand for anything
The processor was originally dubbed the "Acorn RISC Machine" and the company was originally called "Advanced RISC Machines" but, following flotation on the London stock market and the NASDAQ in 1998, changed its name officially to "ARM".

ARM does not manufacture chips
The original vision, shaped and driven by the first CEO, Sir Robin Saxby, was for a company which licensed processor IP, charging a licence fee for use of the design and then an associated royalty on all devices sold. This model, groundbreaking at the time, has since been adopted by a number of other leading players in what has become the semiconductor IP industry. ARM was there first!

ARM is a UK company and has its headquarters in Cambridge, UK
Although we do business on every continent (except Antarctica) and have offices in 14 countries, ARM was founded in the UK and maintains its headquarters there. We have major engineering facilities in UK, US, France, Norway, India and China.

We don't know everything our partners do with our products
We have, at last count, sold nearly 900 licences to a huge and diverse group of partner companies. They have been deployed in products in almost every target market, from smartphones to medical instruments, tablets to electronic toys, fridges to hard disk drives. It would be a herculean task to list or even count all the devices which have been built around ARM technology.

For a semiconductor company, we are very small
Traditionally, semiconductor manufacturers are immense concerns with large numbers of employees and huge fixed assets – mostly in the form of foundries. ARM, with its focus on designing and licensing IP, is very small in comparison. By maintaining that sharp focus on innovation and IP development, we are able to stay lean and nimble.

Key milestones

ARM's history goes back either 27 years or 21 years, depending on your starting point. The architecture itself is 26-years old, dating from April 26 1985 when Acorn Computers, a very successful personal computer manufacturer based in Cambridge, England received the first samples on a radical new processor it had designed for its next generation of desktop machines. Dubbed the "Acorn RISC Machine", it was the first incarnation of what became the ARM architecture. Many of its revolutionary design features are still found in today's ARM processors.

ARM the company was founded on 26 November 1990 as a joint venture between Apple, Acorn and VLSI. The goal of the company was to take Acorn's design and turn it into a design which could be licensed to semiconductor manufacturers. It is interesting to note that ARM has outlived two of its parents and is still very closely associated with the third.

ARM floated on the LSE and NASDAQ in a simultaneous joint listing on 17April 1998. It has since climbed into the FTSE-100 index of the 100 most valuable companies listed on the London Stock Exchange.

ARM's current success can be measured in many ways but perhaps the most staggering is the fact that over 33billion ARM processors have been shipped. ARM's partners are currently shipping at the rate of 8 billion cores per quarter.

Architecture evolution

Since its inception in Acorn's design in the mid 1980's, the ARM architecture has evolved significantly. The introduction of the Thumb® instruction set in 1995 proved a key innovation in realizing high performance at the same time as managing code density in a 32-bit design. Other key innovations are shown in the table, against the architecture in which they were introduced.

Architecture	Feature
ARMv4	Halfword and signed halfword/byte support System mode
ARMv4T	Thumb instruction set
ARMv5TE	Improved ARM/Thumb interworking Saturated arithmetic DSP MAC instructions Jazelle® Java acceleration (in ARMv5TEJ)
ARMv6	SIMD instructions Multi-processing extensions VMSAv6 virtual memory architecture Unaligned data support Thumb-2 technology (in ARMv6T2) TrustZone® (in ARMv6Z)
ARMv7	Architecture profiles v7-A, v7-R and v7-M NEON™ Virtualization Large Physical Address Extensions Thumb-only (ARMv6-M and ARMv7-M)

Processor families

Alongside the evolution of the architecture, the underlying implementation of the processors has also grown in complexity and diversity. From the simple three-stage pipeline on the ARM7TDMI®, to the 24-stage variable-length multi-issue out-of-order pipeline employed by the Cortex™-A15, ARM has introduced caches, virtual memory, prefetch and store buffers, data processing engines, memory protection, vectored interrupt controllers and more. These innovations ensure that ARM designs remain at the leading edge of embedded processor technology. And, underlying it all is our continued focus on power-efficiency.

The ARM Cortex range

The Cortex range of processor cores represents the current state-of-the-art in ARM's portfolio. All implement one of the profiles of the ARMv7 architecture.

Architecture	Processors
ARMv7-A	Cortex-A5, Cortex-A5MP
	Cortex-A7
	Cortex-A8
	Cortex-A9, Cortex-A9MP
	Cortex-A15
ARMv7-R	Cortex-R4
	Cortex-R5
	Cortex-R7MP
ARMv7-M	Cortex-M3
	Cortex-M4
	Cortex-M1 (FPGA)
	Cortex-M0 (ARMv6-M)
	Cortex-M0+

More processors are added to the range all the time, providing an unrivalled choice of power, performance, area and functionality in a single, upwards-compatible architecture.

Architecture profiles

The ARMv7 architecture is divided into “profiles”. Each profile is targeted at a specific class of applications.

Architecture	Features	Target market
ARMv7-A	Full virtual memory support Highest performance at low power Platform OS support NEON multimedia extensions TrustZone Virtualization Large Physical Address Extensions	Smartphones Digital TV and STB
ARMv7-R	Memory protection Low latency interrupt mode Predictable, real-time performance	Hard real-time applications Hard disk drive controllers Engine management systems Baseband processors
ARMv7-M	Lowest gate count entry point Deterministic, predictable behavior Microcontroller-like interrupt handling	Deeply embedded applications General purpose microcontrollers

For more details on the architecture, processor cores and their target application markets, please refer to the ARM website.

Supporting products

As well as processor cores, ARM produces a range of supporting technologies and products. These include ARM Physical IP, ARM Mali™ Graphics Processing Units, AMBA® on-chip interconnect bus standards and IP, CoreSight™ debug infrastructure and the DS-5™ (ARM Developer Studio) range of software development tools and models.

Details on all of these products can be found on the ARM website.

Getting started with ARM

ARM's customers are a diverse bunch! Your interaction with ARM depends on what you are trying to achieve.

- **Chip designers**

  Engineers designing chips using ARM's processor and supporting IP need to enter into a contractual license agreement with ARM in order to get access to the IP. There are several classes of license, ranging from a Single-Use Design License (which entitles the licensee to design and have manufactured a single product based on a particular processor core) to a subscription license (which allows manufacture on a number of designs based on a range of cores, usually from a single processor architecture or family).

  The variation in types, terms and coverage of licenses is enormous and you are advised to consult the ARM processor licensing team for further details. Contact information is, as usual, on the website.

  ARM provides a full range of design services, training and technical support products for licensees.

- **Product designers**

  Those designing products using ARM chips (but not actually designing and fabricating those chips themselves) usually source devices direct from an existing ARM licensee. These can range from custom, application-specific parts (ASSP or ASIC) to standard off-the-shelf parts which can be sourced via a distributor.

  These parts vary hugely in application, purpose and functionality. Often there are many possible variations on a single part, offering choices of e.g. memory type and size, processor speed, cost, power consumption, form factor etc.

  When sourcing parts from an ARM licensee, your relationship is with the manufacturer rather than with ARM. That usually means that technical support, boards, board support packages and other assistance will come from the manufacturer.

- **Software developers**

  The largest group of ARM "users" by far is the worldwide community of software developers working on ARM processor-based platforms. These range from low-level developers (board support packages, hardware abstraction layers, deeply embedded real-time software) to developers writing applications to run under platform OSs such as Linux®, Android™, and Windows Mobile etc.

  For all these groups, the ARM range of software development tools are a powerful solution. Purchasers of ARM tools receive technical support direct from ARM while they have a valid support contract. The ARM portfolio of technical training courses covers

software development for all current processors, as well as more advanced subjects as NEON and software optimization.

ARM Accredited Engineer

You might like to have a look at our newly-launched engineer accreditation program. This offers engineers the opportunity to take a CBT exam and gain the title of “ARM Accredited Engineer”. Full details, together with the full syllabus for the examination and a list of reference documentation, are online at www.arm.com/aae.

Further reading

There is a large amount of further information available for download direct from ARM's website. The following is just a small sample.

Cortex-A Series Programmer's Guide, ARM DEN 0013B
Essential reading for users of any of the Cortex-A processors.

ARMv7-AR Architecture Reference Manual, ARM DDI 0406B

ARMv7-M Architecture Reference Manual, ARM DDI 0403B
The definitive references for the architecture and instruction sets.

Instruction Set Quick Reference Cards (ARM, Thumb-2, VFP, NEON)
Handy reference cards which can be downloaded and printed out.

DS-5 User Guides

ARM Compiler Toolchain User Guides

Mali GPU Development Tools

Keil uVision User's Guide
All the user guides and reference documentation for ARM's software development tools.

Application Notes & Tutorials
A large range of helpful articles and tutorials on a range of common topics.

Processor Technical Reference Manuals
The definitive reference documentation for all processors

There is also a wide variety of books available on various aspects of the ARM world. All should be available from the bookseller of your choice.

The Definitive Guide to the ARM Cortex-M0
Joseph Yiu, published by Newnes, ISBN 978-0-12-385477-3

The Definitive Guide to the ARM Cortex-M3
Joseph Yiu, puiblished by Newnes, ISBN 978-1-85617-963-8

ARM Assembly Language: Fundamentals and Techniques
Bill Hohl, published by CRC press, ISBN 978-1439806104

ARM System-on-Chip Architecture
Steve Furber, published by Addison Wesley, ISBN 978-0201675191

ARM System Developer's Guide
Sloss, Symes & Wright, published by Morgan Kaufmann, ISBN 978-1558608740