The Millennium Prize Laureate 2010

"For seminal contributions to the development of high performance microprocessors based on reduced instruction set (RISC) architecture and its implementation on silicon chips. This invention has enabled the revolution in mobile electronics. To date, more than 18 billion ARM-based chips have been manufactured and are used in ubiquitous computing applications, such as mobile phones, digital photography and video, music players, fixed and wireless networking, automobiles and health care, benefitting a large number of people all over the world."

Professor Stephen Furber

Professor of Computer Engineering, the University of Manchester, United Kingdom

Born March 1953 in Manchester, United Kingdom.

Timeline

1982 Acorn BBC Micro launched
1983 Acorn starts RISC Machine project with Furber as principal designer
1985 First ARM microprocessor produced
1987 ARM processor debuts as the first RISC processor for Acorn Archimedes desktop computer
1990 Advanced RISC Machines (ARM) spins out of Acorn and Apple Computers collaboration, Furber continues his research of low power computing as a professor at University of Manchester.
1998 ARM listed on the London Stock Exchange and NASDAQ. Over 50 million ARM powered products

shipped.
2010 20 billion ARM based chips manufactured

Creator of the ARM microprocessor

The 2010 Millennium Prize Laureate Steve Furber is the principal designer of the ARM 32-bit RISC microprocessor, an innovation that revolutionised mobile electronics. The ingeniously designed processor enabled the development of cheap, powerful handheld, battery-operated devices. In the past 25 years nearly 20 billion ARM based chips have been manufactured.

You may never have heard of ARM microprocessors, but probably use at least one every day. They tick inside our mobile phones, mp3-players, video recorders and home routers. Today ARM technology is used in more than 98 percent of the world's mobile handsets and over one-quarter of all electronic devices.

In 1985 Furber become the father of a microprocessor phenomenon - a single chip which did the same amount of work as other 32-bit microprocessors but used one tenth of their transistors - and consequently, one tenth of their electricity. Furber was the principal designer of the ARM 32 bit microprocessor at Acorn Computers.

The original design was simple and elegant. It exploited Reduced Instruction Set Computing (RISC) architecture. ARM was the world's first commercially available RISC microprocessor. It was initially used in the Acorn Archimedes personal computer released in 1987.

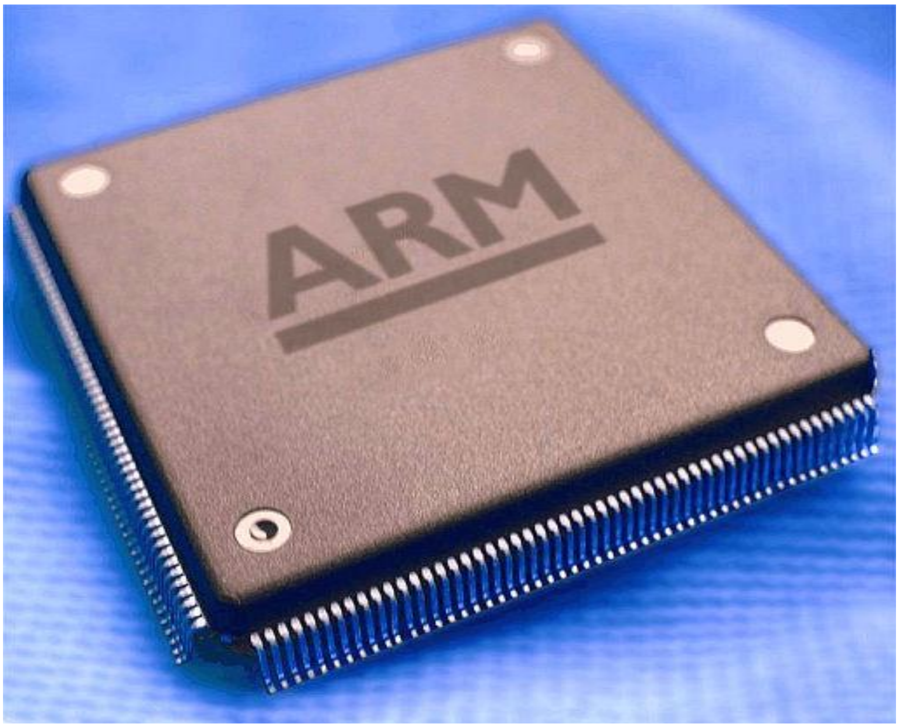
The relative simplicity of ARM processors made them suitable for low power applications. It is this that has allowed them to dominate the mobile and embedded electronics market as relatively low cost and small microprocessors and microcontrollers.

Furber's innovation has underpinned the rapid growth in mobile communications, which has opened up economic opportunities and enhanced the quality of life for billions in the developing and developed world.

Today about 98 percent of the more than one billion mobile phones sold each year use at least one ARM processor. The processors are also used extensively in other consumer electronics, including PDAs, digital media and music players, hand-held game consoles, calculators and computer peripherals such as hard drives and routers.

Picture: ARM-processor

Caption: *ARM microprocessors are embedded in most of the world's electronic devices, virtually every mobile phone made. In cars they are running systems like airbags, fuel injection and ABS.*



Keep it simple

The Central Processing Unit (CPU) or the processor is the portion of a computer system that carries out the instructions of a computer program, and is the primary element carrying out the computer's functions.

In the early days of the computer industry, programming was done in assembly language or machine code, which encouraged powerful and easy to use instructions. CPU designers tried to make instructions that would do as much work as possible.

For example, the original IBM PC processor, Intel 8088, had a highly complex instruction set with many instructions and addressing modes. In the Seventies a new "do-less" design strategy started to gain more and more popularity: instructions which did less might still provide high performances if this simplicity could be used to make instructions execute very quickly. The Reduced Instruction Set Computer (RISC) philosophy was to minimize the number of instructions by using a scheme called a compiler, which was designed to work very fast with just a few simple instructions.

In October 1983, Acorn Computers Ltd started its RISC Machine project. Furber was the principal designer of the new microprocessor for their next personal computer. The team completed development samples called ARM1 in 1985, and finished the first production systems, ARM2 the following year. ARM1 was the world's first commercially available RISC microprocessor, and possibly the simplest useful processor in the world, with only 25,000 transistors. This simplicity led to its excellent low-power needs, and yet it performed better than the Intel 286 processor used in the IBM PC.

Reducing the number of different instructions that a microprocessor can execute means it can execute them more quickly. The processor will be a lot simpler, cheaper to make and will use less power. These are the features which have made ARM chips so popular. They give the most processing power possible for a given amount of electricity. Thanks to a fundamentally simple and elegant design, ARM processors contain fewer components than the alternative solutions to getting the job done.

A steady success story

The Acorn RISC chip was first used in the revolutionary, but not terribly successful, Acorn Archimedes desktop computer. The low-power 32-bit processors proved far more valuable to the booming mobile device market. Interest in the ARM family was growing as more designers became interested in RISC. ARM's design was seen to match a definite need for low power consumption, low-cost RISC processors.

Since the early-Nineties, the success story of the ARM has grown slowly but steadily. The ARM has now become the standard processor for mobiles and now 98 percent of the more than one billion mobile phones sold each year use at least one ARM processor.

Today embedded systems are by far the largest market for processors: while a family may own one or two PCs, their car, mobile phones, and other devices may contain a total of dozens of embedded processors. ARM is the industry's leading provider of 32-bit embedded microprocessors, accounting for approximately 90 percent of all embedded 32-bit RISC processors.

ARM processors are used as the main CPU for most mobile phones, including those manufactured by Nokia, Sony Ericsson and Apple, many personal digital assistants and handhelds, like the Apple iPod and Nintendo DS as well as many other applications, including GPS, digital cameras, digital televisions, network devices and storage.

Chip manufacturers use ARM designs in thousands of different ways, often embedding the ARM processor on a chip with lots of other components. In fact, today it is not uncommon for all the components of a computer to be on the one chip, this has an acronym, SOC, or System On a Chip. An example of an SOC is the new Apple iPad tablet computer. This one chip contains an ARM-processor, graphics controller and all the electronics they need to make up a complete system.

"Hello World, I am ARM"

Whilst studying his PhD in aerodynamics at Cambridge in the Seventies, Furber joined a club for computer hobbyists, the Cambridge University Processor Group. "We started building computers for fun. My first machine used a Signetics 2650 microprocessor, had a full kilobyte of static RAM memory," Furber recalls.

While Furber was finishing his studies, Herman Hauser came knocking on his door. He and Chris Curry were planning to form a company, which became Acorn Computers. They were looking for technical people who might be able to help them. "That was how I joined the embryonic Acorn."

One of his first major projects was designing the unexpectedly successful BBC Micro, a machine designed to accompany a computer literacy programme set up by the BBC. Ultimately, 1.5 million machines were sold in the UK.

Picture:
http://upload.wikimedia.org/wikipedia/commons/3/37/BBC_Micro.jpeg
***Caption**: The vast majority of UK schools used BBC Micros teaching IT skills in the 1980's.*

After the BBC Micro's success, it was clear that Acorn needed to build on that success with continued product development. For their next machine, Furber and his colleagues tested all the available 16-bit processors – and didn't like them. Having ruled out existing CPUs, it was clear to the developers that Acorn should seriously consider designing its own processor. It felt like mission impossible. Everybody knew that it had taken National hundreds of man-years of development effort to build their 16-bit microprocessor, and Acorn couldn't afford that - they only had 300 people at the time.

In late 1983, Furber started working closely with Sophie Wilson, who had developed the BASIC for the BBC Micro. Sitting at the office, not sure which way to go, Furber and Wilson were flipping through the Berkeley RISC papers. A group of graduate students had built a microprocessor with only a tiny percentage of the resources used by National. They then travelled to Phoenix to the Western Design Centre, the designer of the 6502 processor used in the BBC Micro. "We walked out of there saying to each other: If they can design a microprocessor, so can we!"

Their boss Hermann Hauser backed the crazy idea, and they started design work. It turned out it designing a microprocessor wasn't a black art: the microprocessor was just a piece of logic. The RISC idea proved to be a good one and 18 months later they had a working ARM 32 bit processor in their hands.

It was the birth of a microprocessor phenomenon. When the first ARM microprocessors arrived back from the manufacturer in 1985, they were put straight into the development system which was fired up. The screen reportedly displayed: 'Hello World, I am ARM', though Furber is unsure whether this is more myth than historical fact.

The first 32-bit ARM used only 25000 transistors, less than the eight-bit Z80-processor. "It was a really small and simple piece of design," Furber says. It was a low power chip as well. "It was one of the great accidents of history."

Low power was not a requirement, but keeping the chip low cost meant low-cost packaging, which meant plastic. It also meant they had to keep the power dissipation below a watt. Furber says the designers wanted to ensure that – and they did. ARM executed six million instructions per second and used only 0.1 watts of power.

Furber as a TV character

Furber is one of the leading developers of personal computing. Acorn boss Hauser said "Steve is one of the brightest guys I've ever worked with - brilliant and when we decided to do a microprocessor on our own I made two great decisions - I gave them two things which National, Intel and Motorola had never given their design teams: the first was no money; the second was no people. The only way they could do it was to keep it really simple."

After 25 years and 20 billion ARM processors, the success of the design is still magical. "We couldn't imagine selling millions of processors. And now it is billions. ARM was the right product at the right time. It was just perfect for the emerging system on chip -business in the early-Nineties."

Furber has been portrayed in a TV show with actor Sam Philips playing a young Furber in the BBC Four documentary drama Micro Men. Set in the eighties, it told about the rise of the British home computer market, particularly the rivalry between Sir Clive Sinclair, who developed the ZX Spectrum, and Chris Curry, the man behind the BBC Micro.

Mimicking the human brain

In 1990 Furber was appointed to Professor of Computer Engineering at Manchester University. He established a research group with interests in asynchronous logic design and power-efficient computing. Furber and his group continued to help the development of the ARM architecture.

In 2000 Furber's research group merged with the Parallel Architectures and Languages group to form the Advanced Processor Technologies group. Today his researchers are using ARM technology as a fundamental building block to model the human brain. The SpiNNaker project's architecture mimics the human brain's biological structure and functionality. The brain's hundred billion neurons together perform tasks beyond the capabilities of our most powerful computers. Understanding how the brain delivers this functionality might show how to build more resilient and energy-efficient machines.

The research project aims to deploy a million ARM processor cores in a massive parallel computer with the objective of modelling large systems of spiking neurons in biological real time. ARM processors are used like single transistors 20 years ago. Although the finished machine will pack a huge amount of processing power, it will still only model around one percent of the human brain, or around one billion neurons.

Professor Furber has high hopes for the machine. Researchers want to understand how the brain works, but also to build better processors. "There is a lot of interest in the way the biology does the information processing. The chip industry is increasingly facing some of the problems biology has solved. As we keep shrinking transistors, technology will be less reliable. In adult life we are losing one neuron per second, and yet the brain keeps working. If we can understand how it is achieved, that may have important benefits to microchip design."

Business ecosystem around ARM

Around the time of the ARM-processor's 25th birthday in May 2010, more than 20 billion ARMs will have been manufactured. ARM Holdings, still headquartered in Cambridge, England, dominates the mobile phone chip market.

Unlike other microprocessor corporations, ARM only licenses its technology as intellectual property (IP), rather than manufacturing its own CPUs. Partners use ARM IP designs to create and manufacture system-on-chip designs, paying ARM a license fee for the original IP and a royalty on every chip or wafer produced. The value of the chip sales by ARM' s many semiconductor licensees is expected to overtake the microprocessor sales of Intel, the world's leading processor company.

ARM Holdings is best known for its processors, although it also designs, licenses and sells software development tools, system-on-a-chip infrastructure and software.

The principal visible outlet for Furber's innovation has been the mobile phone handset although other uses of the high processing power and low energy consumption of the ARM processor include set top boxes, consumer and semi- professional still- and movie-cameras, digital televisions, gaming consoles and handheld gaming devices, fixed and wireless networking controllers, communications devices, hard disc drives, printers, Voice over IP devices, GPS, personal digital assistants, media players (including the iPod), as well as applications in automobiles and toys. All of these devices and applications benefit in one way or another from the unique engineering value of the ARM processor.

LINKS AND FURTHER READING

Publications

Steve Furber: ARM System-on-chip Architecture. Addison Wesley (2000). ISBN: 0-201-67519-6

Links

Professor Furber's The Advanced Processor Technologies research group
http://intranet.cs.man.ac.uk/apt/
Wikipedia article about ARM architecture http://en.wikipedia.org/wiki/ARM_processor

Companies

ARM Holdings http://www.arm.com

Curriculum Vitae of Stephen B. Furber

Education

1958-63	Rose Hill County Primary School, Marple, Cheshire
1963-70	Manchester Grammar School
1971-78	Cambridge University

Qualifications

BA (mathematics, 1st class) Cambridge University, 1974
PhD (aerodynamics) Cambridge University, 1980
Chartered Engineer and Chartered IT Professional Fellow, British Computer Society (BCS), 1997-
Fellow, Royal Academy of Engineering, 1999-
Fellow, Royal Society, 2002-
Fellow, Institution of Engineering and Technology (IET, formerly IEE), 2004-
Fellow, Institute of Electrical and Electronics Engineers (IEEE), 2005-
Member, Academia Europaea, 2008-

Prizes and awards

1995	British Computer Society Award (to research group) for Amulet1.
1995	Computing IT 'Gold' award for Technology Transfer - research group jointly with ARM Ltd for the Amulet programme.
2003	Royal Academy of Engineering Silver Medal
2004	Royal Society-Wolfson Research Merit Award, October 2004 - September 2009
2007	Institution of Engineering and Technology Faraday Medal, 2007
2008	CBE, " for services to computer science"

Previous employment and appointments

1978-81	Rolls-Royce Research Fellow at Emmanuel College, Cambridge
1981-90	Acorn Computers Limited, Cambridge, hardware designer, design manager, head of Advanced R&D
1997-99	Non-executive director of Cogency Technology, Inc. (A start-up company employing several former members of my research group with a mission to exploit self-timed design.)
2001-04	Non-executive director of Transitive Corporation (A Departmental spin-out company exploiting dynamic binary translation software.)
2001-04	Head of the Department of Computer Science, University of Manchester.
2004-06	Non-executive director of Silistix Ltd (A University start-up company established to exploit Network- on-Chip Technology developed in my research group.)

Present appointments

1990-	ICL Professor of Computer Engineering, Department of Computer Science, University of Manchester
1994-	Non-executive director of Manchester Informatics Ltd. (A subsidiary of Manchester Innovation, Ltd., the University's exploitation company.)
2000-	Non-executive director of Cogniscience Ltd. (A University start-up company established to channel funds from Providence Investments Limited and the University Challenge Fund into my hardware neural network research.)

Creative or innovative work

BBC microcomputer (1981): I was the principal architect of the hardware of this product, and designed and supervised the implementation of the gate arrays. 1.25 million BBC microcomputers (including derivatives) have been sold. The BBC micro earned Acorn a Queen's Award for Technology.
BBC micro 2nd processors (1982): I designed the hardware and laid out (on a Ferranti ULA) the 'Tube'

inter- processor communication component used on all of the BBC micro 2nd processors (6502, Z80, 32016, ARM) and designed the 6502 2nd processor card.
Acorn Electron (1983): This was a cost-reduced BBC micro, using 12 chips in place of the 100+ on the bigger machine. I was responsible for the hardware system design and the logic design for the Ferranti ULA which was the core of the design.
ARM1 32-bit RISC microprocessor (1983-85): I designed the hardware organization and logic of the ARM processor, and supervised the VLSI implementation. The ARM also earned Acorn a Queen's Award for Technology, and led ultimately to the formation of ARM Limited in 1990, which under the leadership of Sir Robin Saxby has become the world-leading supplier of 32-bit embedded processor core designs. By the end of 2007 over 10,000 million ARM cores had been shipped world-wide, making the ARM the highest volume 32+ bit microprocessor by a very large margin.
Acorn Archimedes (1985-87): I was responsible for the hardware architecture of the chip set that forms the basis of this product, and designed the logic of the memory controller chip (MEMC) and the ARM2 processor.
ARM3 (1987-89): I supervised the engineer responsible for designing the first ARM processor with cache memory.
AMULET1 (1991-94): An asynchronous implementation of the ARM microprocessor, and the first asynchronous implementation of a complete processor architecture. I led the research group and designed the hardware organization and logic. AMULET1 gained the 'Gold' for Technology Transfer in the 1995 Computing IT awards (the award going jointly to ARM Limited and the University of Manchester), and gained a 1995 BCS Award.
AMULET2e (1993-96): An asynchronous embedded system chip incorporating a 2nd generation asynchronous ARM core (AMULET2), 4 Kbytes or cache/RAM and a flexible memory interface. First silicon was delivered in October 1996. I led the research group and contributed to various low-level design features. (The high-level design owed a lot to AMULET1.) The total design effort was estimated to be 12 man-years.
AMULET3H (1996-2000): An asynchronous embedded processing subsystem; the first commercial use of the AMULET technology and the world's first commercial application of an asynchronous 32-bit processor. Production has not taken place due to the commercial partner's financial problems. I led the research group and contributed to various aspects of the design.
SPA (2000-2003): A prototype smart card chip developed to demonstrate the merits of asynchronous technology in enhancing the resistance of a chip to non-invasive attacks such as power and electromagnetic analysis. The chip incorporated two fully synthesized asynchronous ARM cores with different back-end technologies in order that security comparisons could be made. I led the research group and contributed to design reviews.
SpiNNaker (2005-): This is an ambitious, high-profile project to build a million ARM cores into a parallel supercomputer for large-scale neural modelling. It has attracted considerable funding and some media attention, which will presumably grow when we have working prototype chips…

Patents

1994	UK patent application 9400381.1: "Data Memory and Processor Bus" with W. H. Oldfield (arising from my consultancy work with ARM Ltd).
1996	UK patent application 9604367.4: "Dynamic Logic Pipeline Control".
1999	UK patent application 9924310.7: "Scalable Neural Network Architecture".
	UK patent application 9924312.3: "Duplex Communications System".
	UK patent application 9924585.4: "Viterbi Decoder" with L.E.M. Brackenbury, M. Cumpstey and P. Riocreux.
2002	UK patent application 0207372.4: "A Sparse Distributed Memory Based upon N-of-M Codes".
2005	UK patent application 0524126.0: "Multicast Communications Router".