ISSN 2278-8808 IMPACT FACTOR: 1.38
An International Peer Reviewed
SCHOLARLY RESEARCH JOURNAL
FOR INTERDISCIPLINARY STUDIES
SRJIS

ACORN RISC MACHINE

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ARM is a reduced instruction set computer (RISC) instruction set architecture (ISA) developed by ARM Holdings. It was named the *Advanced RISC Machine* and, before that, the *Acorn RISC Machine*. The ARM architecture is the most widely used 32-bit instruction set architecture in numbers produced. Originally conceived by Acorn Computers for use in its personal computers, the first ARM-based products were the co-processor modules for the BBC series of computers.

Features and applications: In 2005 about 98% of the more than one billion mobile phones sold each year used at least one ARM processor. As of 2009 ARM processors accounted for approximately 90% of all embedded 32-bit RISC processors and were used extensively in consumer electronics, including personal digital assistants (PDAs), tablets, mobile phones, digital media and music players, hand-held game consoles, calculators and computer peripherals such as hard drives and routers.

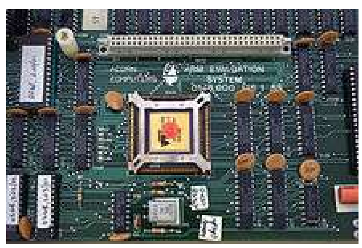
Licensees: The ARM architecture is licensable. Companies that are current or former ARM licensees include Alcatel-Lucent, Apple Inc., AppliedMicro, Atmel, Broadcom, Cirrus Logic, CSR plc, Digital Equipment Corporation, Ember, Energy Micro, Freescale, Intel (through DEC), LG, Marvell Technology Group, Microsemi, Microsoft, NEC, Nintendo, Nuvoton, Nvidia, Sony, NXP (formerly Philips Semiconductor), Oki, ON Semiconductor, Psion, Qualcomm, Renesas, Samsung, Sharp, Silicon Labs, STMicroelectronics, Symbios Logic, Texas Instruments, VLSI Technology, Yamaha, Fuzhou Rockchip, and ZiiLABS. In addition to the abstract architecture, ARM offers several microprocessor core designs, including the ARM7, ARM9, ARM11, Cortex-A8, Cortex-A9, and Cortex-A15. Companies often license these designs from ARM to manufacture and integrate into their own system on a chip (SoC) with other components like RAM, GPUs, or radio basebands (for mobile phones).

System-on-chip packages integrating ARM's core designs include Nvidia Tegra's first three generations, CSR plc's Quatro family, ST-Ericsson's Nova and NovaThor, Silicon Labs's Precision32 MCU, Texas Instruments's OMAP products, Samsung's Hummingbird and Exynos products, Apple's A4, A5, and A5X chips, and Freescale's i.MX. Companies can also obtain an ARM *architectural license* for designing their own, different CPU cores using the ARM instruction set. Distinct ARM architecture implementations by licensees include AppliedMicro's X-Gene, Qualcomm's Snapdragon and Krait, DEC's StrongARM, Marvell (formerly Intel) XScale, and Nvidia's planned Project Denver.

History: After achieving success with the BBC Micro computer, Acorn Computers Ltd considered how to move on from the relatively simple MOS Technology 6502 processor to address business markets like the one that would soon be dominated by the IBM PC, launched in 1981. The *Acorn Business Computer* (ABC) plan required a number of second processors to be made to work with the BBC Micro platform, but processors such as the Motorola 68000 and National Semiconductor 32016 were unsuitable, and the 6502 was not powerful enough for a graphics based user interface. Acorn would need a new architecture, having tested all of the available processors and found them wanting. Acorn then seriously considered designing its own processor, and their engineers came across papers on the Berkeley RISC project. They felt it showed that if a class of graduate students could create a competitive 32-bit processor, then Acorn would have no problem. A trip to the Western Design Center in Phoenix, where the 6502 was being updated by what was effectively a single-person company, showed Acorn engineers Steve Furber and Sophie Wilson that they did not need massive resources and state-of-the-art R&D facilities. Wilson set about developing the instruction set, writing a simulation of the processor in BBC Basic that ran on a BBC Micro with a second 6502 processor. It convinced the Acorn engineers that they were on the right track. Before they could go any further, however, they would need more resources. It was time for Wilson to approach Acorn's CEO, Hermann Hauser, and explain what was afoot. Once the go-ahead had been given, a small team was put together to implement Wilson's model in hardware.

A Conexant ARM processor used mainly in routers

Acorn RISC Machine: ARM2: The official *Acorn RISC Machine* project started in October 1983. VLSI Technology, Inc was chosen as silicon partner, since it already supplied Acorn with ROMs and some custom chips. The design was led by Wilson and Furber, and was consciously designed with a similar efficiency ethos as the 6502. It had a key design goal of achieving low-latency input/output (interrupt) handling like the 6502. The 6502's memory access architecture had allowed developers to produce fast machines without the use of costly direct memory access hardware. VLSI produced the first ARM silicon on 26 April 1985 – it worked the first time and came to be termed ARM1 by April 1985. The first "real" production systems named ARM2 were available the following year.



The ARM1 second processor for the BBC Micro

Its first practical application was as a second processor to the BBC Micro, where it was used to develop the simulation software to finish work on the support chips (VIDC, IOC, MEMC) and to speed up the operation of the CAD software used in developing ARM2. Wilson subsequently rewrote BBC Basic in ARM assembly language, and the in-depth knowledge obtained from designing the instruction set allowed the code to be very dense, making ARM BBC Basic an extremely good test for any ARM emulator. The original aim of a principally ARM-based computer was achieved in 1987 with the release of the Acorn Archimedes. In 1992 Acorn once more won the Queen's Award for Technology for the ARM. The ARM2 featured a 32-bit data bus, a 26-bit address space and twenty-seven 32-bit registers. Program code had to lie within the first 64 Mbyte of the memory, as the program counter was limited to 24 bits because the top 6 and bottom 2 bits of the 32-bit register served as status flags. The ARM2 had a transistor count of just 30,000, compared to Motorola's six-year older 68000 model with 68,000. Much of this simplicity comes from not having microcode (which represents about one-quarter to one-third of the 68000) and, like most CPUs of the day, not including any cache. This simplicity led to its low power usage, while performing better than the Intel 80286. A successor, ARM3, was produced with a 4 KB cache, which further improved performance.

Apple, DEC, Intel, Marvell: ARM6, StrongARM, Xscale: In the late 1980s Apple Computer and VLSI Technology started working with Acorn on newer versions of the ARM core. The work was so important that Acorn spun off the design team in 1990 into a new company called Advanced RISC Machines Ltd. Advanced RISC Machines became ARM Ltd when its parent company, ARM Holdings plc, floated on the London Stock Exchange and NASDAQ in 1998.

The new Apple-ARM work would eventually turn into the ARM6, first released in early 1992. Apple used the ARM6-based ARM 610 as the basis for their Apple Newton PDA. In 1994, Acorn used the ARM 610 as the main central processing unit (CPU) in their Risc PC computers. DEC licensed the ARM6 architecture and produced the StrongARM. At 233 MHz this CPU drew only one watt (more recent versions draw far less). This work was later passed to Intel as a part of a lawsuit settlement, and Intel took the opportunity to supplement their ageing i960 line with the StrongARM. Intel later developed its own high performance implementation named XScale which it has since sold to Marvell.

Licensing: The ARM core has remained largely the same size throughout these changes. ARM2 had 30,000 transistors, while the ARM6 grew only to 35,000. ARM's business has always been to sell IP cores, which licensees use to create microcontrollers and CPUs based on this core. The original design manufacturer combines the ARM core with a number of optional parts to produce a complete CPU, one that can be built on old semiconductor fabs and still deliver substantial performance at a low cost. The most successful implementation has been the ARM7TDMI with hundreds of millions sold. Atmel has been a precursor design center in the ARM7TDMI-based embedded system. ARM licensed about 1.6 billion cores in 2005. In 2005, about 1 billion ARM cores went into mobile phones.By January 2008, over 10 billion ARM cores had been built, and in 2008 iSuppli predicted that by 2011, 5 billion ARM cores will be shipping per years. As of

January 2011, ARM states that over 15 billion ARM processors have shipped. The ARM architectures used in smartphones, personal digital assistants and other mobile devices range from ARMv5, in obsolete/low-end devices, to the ARM M-series, in current high-end devices. ARMv6 processors represented a step up in performance from standard ARMv5 cores, and are used in some cases, but Cortex processors (ARMv7) now provide faster and more power-efficient options than all those prior generations. ARMv7 also mandates a hardware floating point unit, which has ABI and performance impact. In 2009, some manufacturers introduced netbooks based on ARM architecture CPUs, in direct competition with netbooks based on Intel Atom. According to analyst firm IHS iSuppli, by 2015, ARM ICs are estimated to be in 23% of all laptops. In 2011, HiSilicon Technologies Co. Ltd. licensed a variety of ARM technology to be used in communications chip designs. These included 3G/4G basestations, networking infrastructure and mobile computing applications.