Tech Report C20003184
Unclassified

29 Jan 2024

APEX STANDARDS

RISC-V's Ascent to Standardization in the Semiconductor Industry

RISC-V, which originally began as a project at the University of California, Berkeley to create an open-source computer system based on RISC principles, has evolved significantly since its inception. Initially designed for academic use, it was introduced to the public in 2015, marking a new paradigm in the CPU architecture landscape. Distinct from its predecessors, RISC-V stands out for its simplicity. By eliminating status registers and reducing the number of instruction formats, it streamlines the instruction decoder, making it more straightforward and efficient. This architectural design, coupled with its inherent virtualizability and modularity, allows for *application-specific* optimizations. Although currently lagging behind established counterparts in performance, these features make RISC-V particularly well-suited for embedded systems.

The history of CPU architectures provides context for RISC-V's emergence. Intel's x86 architecture, launched in 1978, has seen substantial evolution, incorporating out-of-order execution, microoperations, multithreading, and SIMD operations, which altogether cemented its market dominance. ARM, starting in 1983, has followed a similar path of continuous enhancement, optimizing its architecture for power efficiency, a critical feature for embedded devices.

While RISC-V may be younger than established architectures, its design philosophy embraces a fundamental shift - streamlined, customizable processing cores. This opens doors to a collaborative and innovative ecosystem. In an industry often bogged down by generic solutions, RISC-V stands out by enabling users to adapt and optimize for their specific requirements.

This ability to customize shines brightest in highly specialized, energy-sensitive applications like AI, large language models (LLMs), wearables, and the Internet of Things (IoT). Imagine tailoring RISC-V to efficiently handle the specific parallel processing needs of AI and LLMs, potentially with fewer transistors than ARM-based solutions. This translates to lower power consumption and faster operation - crucial assets in energy-hungry AI domains. For wearables and IoT devices, RISC-V's compact and energy-efficient nature is truly game-changing. These gadgets demand minimal power consumption while still delivering capable processing. RISC-V's flexibility allows manufacturers to craft chips that perfectly fit these needs, unlike the “one-size-fits-all” approach of ARM. As such, RISC-V architectures can function with fewer transistors compared to ARM. This becomes a major advantage in embedded systems like Bluetooth controllers, camera chips, and keyboards, where compactness and efficiency reign supreme. In such scenarios, RISC-V's lean and efficient design outshines the bulkier, more complex ARM architecture.

While ARM currently dominates in high-end smartphones, laptops, and computers, RISC-V is expected to increasingly take over the embedded market and low-end devices. Its broader market coverage means RISC-V will likely dominate areas where ARM is currently less present or absent.

However, it's essential to recognize ARM's ongoing growth in sectors like PC and High-Performance Computing (HPC), as evidenced by Apple's M1 (2020) and Nvidia's Grace superchips (2023). ARM's path of dominance in these areas is likely to continue for the next decade. Nonetheless, the versatility and efficiency of RISC-V suggest it may start appearing in smartphones and other consumer devices within that same timeframe, highlighting its potential to reshape various segments of the technology market.

Aspect	x86	ARM	RISC-V
IPR	Proprietary, owned by Intel and AMD.	Proprietary, owned by Arm Holdings.	Open-source ISA, community-driven.
Licensing	Exclusive, only available to Intel and AMD.	Flexible, with various licensing options.	Royalty-free, open for all to use and modify.
Market Attitudes	Established, trusted in PC/server markets.	Expanding, popular in mobile and growing in server/PC.	Innovative, gaining traction in new markets.
Supporters	Intel, AMD, OEMs like Dell, HP.	Qualcomm, Apple, Samsung.	Nvidia, Western Digital, global research community, diverse Chinese industries.
Market Share	Dominant in desktop, laptop, and server markets.	Dominant in mobile, growing in other areas.	Small but growing, especially in embedded and research.
Trends	Stable in traditional markets, challenged by ARM in efficiency.	Growing presence in PCs and servers, challenged by RISC-V's flexibility.	Rapid growth in specialized markets, open-source advantage.
Geopolitical Implications	Strong US presence, affected by US trade policies.	UK-based, affected by international trade and acquisitions (e.g., Nvidia's attempted purchase).	Neutral, Switzerland-based governance aimed at global collaboration.
Verticals	General computing, enterprise, gaming.	Mobile, IoT, automotive, increasingly PCs and servers.	IoT, embedded systems, automotive, industrial automation.

Table 1 The Changing Faces of Processor Market – Industry Supporters and Trends

Feature	x86	ARM	RISC-V	RISC-V's Implementation on Massive MIMO
Instruction Set Type	CISC with some RISC features	RISC	RISC	Simplified instruction set allows for optimized, streamlined Massive MIMO processing.
Flexibility	Limited, mostly via microcode updates	Custom instructions with ARMv8.1-M	Highly customizable with custom extensions	Tailored instructions can enhance specific processing needs of Massive MIMO, improving overall performance.
SIMD Extensions	AVX, AVX2, AVX-512	NEON	Vector extension (RVV) under development	RVV enables efficient handling of parallel data streams crucial for Massive MIMO.
FMA Instructions	Yes, widely supported	Yes, in most modern cores	Zfinx (F) extension	Zfinx provides fused multiply-add (FMA) instructions for efficient floating-point computations
Multi-Threading	Hyper-Threading (Intel)	Big.LITTLE architecture, ARM DynamIQ	Hardware multithreading (HMT)	HMT can manage multiple data streams, essential for Massive MIMO's spatial multiplexing.
Floating-Point Precision	Up to double precision (64-bit)	Up to double precision (64-bit)	Up to double precision (64-bit), quad-precision proposed	High precision is key for accurate signal processing in Massive MIMO systems.
Cryptographic Instructions	AES-NI and other dedicated instructions	Cryptography Extension (ARMv8-A)	Not standard, left to custom extensions	Customizable cryptographic instructions provide flexibility for secure Massive MIMO communication protocols.
DSP Extensions	Limited, generally rely on SIMD	Yes, especially in ARM Cortex-R series	DSP extensions available	DSP extensions can optimize signal processing tasks, a core component of Massive MIMO operations.
Bit Manipulation	BMI1 and BMI2 instruction sets	Arm Bit Manipulation Extension	Bit manipulation extension (RVB)	Efficient bit-level operations can optimize encoding/decoding processes in Massive MIMO.
Out-of-Order Execution	Widely supported in modern x86 processors	Supported in high-performance cores	Depends on implementation, not inherent to ISA	Improves processing efficiency for complex algorithms used in Massive MIMO.
Hardware Virtualization	Advanced virtualization support (Intel VT-x, AMD-V)	Virtualization support in ARMv8-A	Support varies by implementation	Facilitates flexible and scalable Massive MIMO deployments, especially in cloud-RAN architectures.
Cache Coherency	Complex cache hierarchies with coherency protocols	Coherent interconnects like ARM's AMBA	Cache coherency mechanisms are implementation-specific	Ensures data integrity and speed in high-throughput Massive MIMO operations.

Table 2 evaluates the implementation of Massive MIMO technology in 5G/6G, concentrating on the essential features that are common across different architectures. It points out that RISC-V might face some challenges because it doesn't have the advanced, ready-to-use libraries that x86 or ARM do—libraries that took years to develop and optimize. However, it also highlights RISC-V's potential to outperform the others thanks to its straightforward design. This simplicity could allow for more tailored optimizations by developers, without the burden of pre-existing library overhead that x86 and ARM systems have.

The processor architecture field is currently embroiled in intellectual property and licensing battles, notably the lawsuit between Arm Holdings and Qualcomm. This dispute stems from Qualcomm's use of chip technology, following its acquisition of Nuvia, which was developed under Arm's licensing agreements. As Arm, a SoftBank subsidiary, proceeds with its initial public offering begun in September 2023, it counts significantly on royalties from Qualcomm. Arm's approach to business, centered around two main licensing agreement types—Technology License Agreements (TLA) and Architectural License Agreements (ALA)—faces a shift as Qualcomm seeks to develop custom processors, thereby altering its royalty payments to Arm. This strategy has far-reaching implications for the competitive landscape of the US chip design industry, particularly in light of the CHIPS Act of 2022 aimed at strengthening US semiconductor manufacturing. If Arm's lawsuit leads to the discontinuation of Nuvia's advancements, it could affect a crucial innovation pathway, impacting US competitiveness and security.

In stark contrast, RISC-V exemplifies a trend towards open-source architecture. RISC-V International moved its headquarters to Switzerland in 2020, seeking a politically neutral base to foster unhindered global collaboration, a move away from the proprietary disputes exemplified by Arm and Qualcomm. These evolution may impact various facets, including licensing practices, management of intellectual property, and the position of global technological leadership. These changes could have far-reaching effects across the spectrum of manufacturing, design, and usage of semiconductor technology.

In the current market, x86 and ARM architectures are predominant in high-end and mid-range electronic devices. However, RISC-V is emerging as a formidable contender, especially due to its adaptability, efficiency, and open-source nature. This makes it particularly suitable for custom solutions, which is a growing demand in the industry. RISC-V's unique attributes have enabled it to make inroads into the low and mid-end markets in less than a decade time.

The future trajectory of RISC-V is not solely dependent on its technical advancements. It will also be shaped by broader economic, environmental, and geopolitical factors. These elements collectively underscore RISC-V's growing importance as a key architectural player in the dynamically evolving computing landscape.