

# AMD Athlon™ Processor Architecture

**The World's First Seventh-Generation x86 Processor:  
Delivering the Ultimate Performance for Cutting-Edge  
Software Applications**

ADVANCED MICRO DEVICES, INC.  
One AMD Place  
Sunnyvale, CA 94088

## Introduction: The World's Most Powerful x86 Microprocessor

AMD Athlon™ processors are members of a new family of seventh-generation AMD processors designed to meet the computation-intensive requirements of cutting-edge software applications running on high-performance desktop systems, workstations, and servers. With the introduction of the AMD Athlon processor with performance-enhancing cache memory, AMD continues to deliver superior solutions for high-performance computing.

AMD Athlon processors are the world's most powerful x86 processors, outperforming Intel's Pentium® III processor and delivering the highest integer, floating point and 3D multimedia performance for applications running on x86 system platforms.<sup>1</sup> The AMD Athlon processors provide industry-leading processing power for cutting-edge software applications, including digital content creation, digital photo editing, digital video, image compression, video encoding for streaming over the Internet, soft DVD, commercial 3D modeling, workstation-class computer-aided design (CAD), commercial desktop publishing, and speech recognition. They also offer the scalability and “peace-of-mind” reliability that IT managers and business users require for networked enterprise computing.

AMD Athlon processors feature the industry's first seventh-generation x86 microarchitecture, which is designed to support the growing processor and system bandwidth requirements of emerging software, graphics, I/O, and memory technologies. The high-speed execution core includes multiple x86 instruction decoders, a dual-ported large 128KB split-L1 cache, a large 256KB<sup>2</sup> or 512KB L2 cache, three independent integer pipelines, three address calculation pipelines, and the x86 industry's first superscalar, fully pipelined, out-of-order, three-way floating point engine.

The AMD Athlon processor's microarchitecture incorporates enhanced 3DNow!™ technology, a high-performance cache architecture, and a 200MHz, 1.6-Gigabyte/sec system bus—the first bus of its kind for x86 system platforms. Based on the Alpha™ EV6 interface protocol licensed from Digital Equipment Corporation, the AMD Athlon processor system bus combines the latest technological advances, such as point-to-point topology, source synchronous packet-based transfers, and low-voltage signaling, to provide the most powerful, scalable bus available for any x86 processor.

AMD Athlon processors deliver superior system performance in cost-effective, industry-standard form factors. AMD Athlon processors are compatible with motherboards based on AMD's Socket A form factor, which leverage commonly available chassis, power supply, and thermal solutions. Additionally, AMD Athlon processors are

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<sup>1</sup> The AMD Athlon processor's industry-leading performance is supported by test results from a variety of integer, floating point, and 3D multimedia benchmarks. Visit [www.amd.com](http://www.amd.com) for the latest benchmark data.

<sup>2</sup> The AMD Athlon processor Model 4 includes an on-die, full-speed, 16-way, 256KB L2 cache.

manufactured on AMD’s robust 0.18-micron aluminum process technology at Fab 25 in Austin, Texas and on AMD’s leading-edge HiP6L 0.18-micron process technology featuring copper interconnects at the newest facility, Fab 30, in Dresden, Germany. The approximately 37-million-transistor new AMD Athlon processor has a die size of 120 mm<sup>2</sup> on 0.18-micron technology.

**Table 1: Processor Architecture/Technology – Competitive Comparison**

	<b>AMD Seventh Generation</b>	<b>Intel Previous Generation</b>
Feature	AMD Athlon™ Processor	Pentium® III * Processor
Operations per clock cycle	9	5
Integer pipelines	3	2
Floating point pipelines	3	1
Full x86 decoders	3	1
L1 cache size	128KB	32KB
L2 cache size	Internal, 256KB	Internal, 256KB
System bus speed	200 MHz – 400+ MHz	100MHz to 133 MHz
Peak bus bandwidth	1.6 to 3.2 GB/s+	533 MB/s to 1.06 GB/s
Bus outstanding transactions	24 per processor	4-8 per processor
Clock technology	Source synchronous (Clock forwarding)	Common clock
3D enhancement instructions	Enhanced 3DNow!™ technology	SSE
- Total no. of instructions	45	71
- Single-precision FP SIMD	Yes	Yes
- 4 FP operations per clock	Yes	Yes
- Cache/prefetch controls	Yes	Yes
- Streaming controls	Yes	Yes
- DSP/comm extensions	Yes	No
Multiprocessing support	Yes, point-to-point	Yes, shared
Max. system processors	Unlimited (by chipset)	Unlimited (by chipset)
No. of transistors per die	~37 million	Up to ~28 million

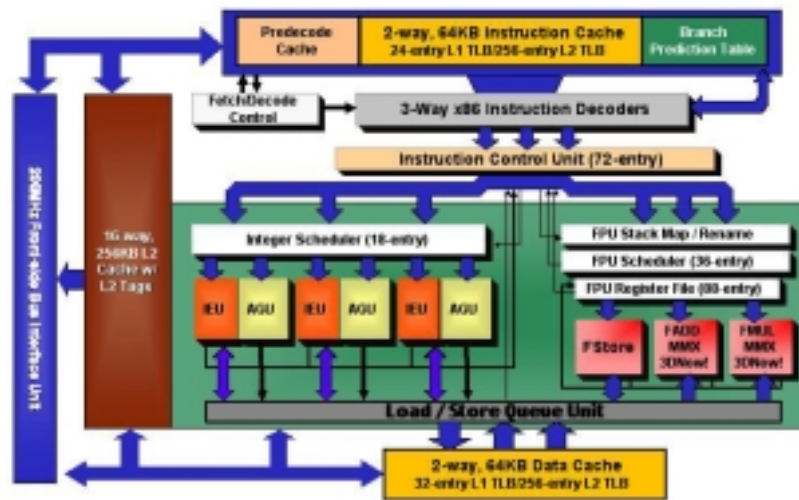
\* Includes estimates for the Intel 0.18-micron Pentium III processors.

## Superior Seventh-Generation AMD Athlon™ Processor Architecture

AMD Athlon processors are based on a seventh-generation x86 microarchitecture that is technologically superior to previous sixth-generation architectures, such as the Pentium III and Pentium III Xeon processors. (See Table 1, Competitive Comparison, on previous

page.) AMD Athlon processors feature a superpipelined, nine-issue superscalar microarchitecture optimized for high clock frequency. AMD Athlon processors have a large dual-ported 128KB split-L1 cache (64KB instruction cache + 64KB data cache); a full-speed on-die 256KB L2 cache; a large multi-level, 512-entry Translation Look-aside Buffer (TLB); a two-way, 2048-entry branch prediction table; multiple parallel x86 instruction decoders; and multiple integer and floating point schedulers for independent superscalar, out-of-order, speculative execution of instructions. These elements are packed into an aggressive processing pipeline that includes 10-stage integer and 15-stage floating point pipelines.

The innovative AMD Athlon processor architecture implements the x86 instruction set by internally decoding x86 instructions into fixed-length “Macro-Ops” for higher instruction throughput and increased processing power. AMD Athlon processors contain nine execution pipelines—three for address calculations, three for integer calculations, and three for execution of MMX™ instructions, 3DNow! technology, and x87 floating point instructions.



**Figure 1: AMD Athlon™ Processor Architecture Block Diagram**

AMD Athlon processors are binary-compatible with existing x86 software and backward compatible with applications optimized for MMX and 3DNow! instructions. Using a data format and single-instruction multiple-data (SIMD) operations based on the MMX instruction model, AMD Athlon processors can produce as many as four, 32-bit, single-precision floating-point results per clock cycle. The enhanced 3DNow! technology implemented in AMD Athlon processors include new integer multimedia instructions and

software-directed data movement instructions for optimizing such applications as digital content creation and streaming video on the Internet, as well as new instructions for DSP/communications applications.

### **AMD Athlon Processor Microarchitecture Summary:**

- The industry's first nine-issue, superpipelined, superscalar x86 processor microarchitecture designed for high clock frequencies
  - Multiple x86 instruction decoders
  - Three out-of-order, superscalar, fully pipelined floating point execution units, which execute all x87 (floating point), MMX and 3DNow! instructions
  - Three out-of-order, superscalar, pipelined integer units
  - Three out-of-order, superscalar, pipelined address calculation units
  - 72-entry instruction control unit
  - Advanced dynamic branch prediction
- Enhanced 3DNow! technology with new instructions to enable improved integer math calculations for speech or video encoding and improved data movement for Internet plug-ins and other streaming applications
- 200MHz AMD Athlon processor system bus (scalable beyond 400 MHz) enabling leading-edge system bandwidth for data movement-intensive applications
- High-performance cache architecture featuring a large split 128KB L1 cache, high-speed L2 cache of 256KB (full-speed, on-chip) dedicated snoop tags, and a large multi-level, 512-entry Translation Look-aside Buffer

## **High-Performance Cache Design**

The AMD Athlon processor's high-performance cache architecture includes an integrated dual-ported 128KB split-L1 cache with separate snoop port; an integrated full-speed, 16-way set-associative, 256KB L2 cache using a 72-bit (64-bit data + 8-bit ECC) interface; and a multi-level split 512-entry Translation Lookaside Buffer (TLB).

The AMD Athlon processor's large integrated full-speed L1 cache is comprised of two separate 64KB, two-way set-associative data and instruction caches which is four times larger than the Pentium III processor's L1 cache (128KB vs. 32KB). By featuring a larger L1 cache, applications running on AMD Athlon processors perform significantly faster since more instruction and data information is local to the processor. The data cache also has eight banks to provide maximum parallelism for running multiple applications. It supports concurrent accesses by two 64-bit loads or stores. The instruction cache contains predecode data to assist multiple, high-performance instruction decoders. Both instruction and data caches are dual-ported and contain dedicated snoop ports to eliminate all system

coherency traffic, common in systems with many devices, from interfering with application performance.

The AMD Athlon processor with performance enhancing cache memory includes an integrated, full-speed, 16-way set-associative, 256KB L2 cache. Previous AMD Athlon processors contain an L2 controller which operates at the maximum frequency compatible with the latest industry-standard SRAMs. By integrating the L2 cache onto the processor, the L2 cache always operates at the same frequency as the processor, thereby minimizing any delays incurred waiting for external data from a slower bus. The newer AMD Athlon processor's L2 cache is 16-way set-associative, twice that of the L2 cache of the Intel Pentium III processor (16-way vs. 8-way). Higher associativity dramatically improves application performance since more local application data resides in the high-speed L2 cache memory instead of system memory. Finally, the integrated L2 cache tags improves performance by quickly indicating whether critical application data is located within the L2 cache. Having integrated tags is especially important for processors which utilize external SRAMs for the L2 cache. If application data is determined not to reside in the L2 cache early enough, then the processor can immediately request this data from the slower system memory, instead of checking for this data in an external L2 cache first, and then, having to request this data from system memory.

The robust multi-level, 512-entry, split TLB cache significantly improves performance of systems configured with large physical memory or storage, typically found in server environments, by caching all important translation information used by operating systems and application software that access large physical memory or storage. Thus, the cache architecture of the AMD Athlon processor enables high instruction-execution rates by minimizing effective memory latency and system snoop responses, and it provides large spatial locality of data for transaction-based applications and multiprocessing operating systems. The architecture also supports high-bandwidth data transfers to and from the execution resources, and it contributes to significant performance gains and extremely fast operation of data-intensive software programs.

The AMD Athlon processor's cache architecture is the first to incorporate a system-based MOESI (Modify, Owner, Exclusive, Shared, Invalid) cache control protocol for x86 multiprocessing platforms. Since the system logic manages memory coherency throughout the system by specifying all cache state transitions, either using a MESI or MOESI cache coherency protocol, and by filtering out unnecessary processor snoops, AMD Athlon processors are designed to deliver exceptional performance in both uniprocessor and multiprocessor system configurations. The AMD Athlon processor cache architecture also supports error correction code (ECC) protection, which is a required feature for high reliability of business desktop systems, workstations, and servers. Thus, the AMD Athlon

processor's cache architecture provides the features required for high-performance computing from desktop to server configurations.

## The Industry's First 200-MHz System Bus for x86 Platforms

The 200MHz AMD Athlon processor system bus—the fastest front-side bus implementation for x86 platforms—leverages the high-performance Alpha™ EV6 system interface technology to significantly boost system performance and provide ample headroom for today's and tomorrow's applications. By licensing the Alpha™ EV6 interface from Digital Equipment Corp., AMD has answered an industry challenge to deliver a reliable, high-speed system interface that offers unprecedented performance for x86 platforms without sacrificing legacy x86 compatibility.

The flexible AMD Athlon processor system bus provides advanced features, such as source synchronous clocking for high-speed 200 to 400 MHz operation, point-to-point topology for peak data bandwidth independent of the number of processors, packet-based transfers for maximum transaction pipelining, large 64-byte burst data transfers, ECC protection of data and instructions, low-voltage swing signaling for low-cost motherboard implementations, and the ability to address more than 8 terabytes of physical memory.

The 200MHz system bus implemented in the AMD Athlon processor is capable of delivering a peak data transfer rate of 1.6 Gbytes/sec—compared to only 1.06 Gbytes/sec of today's Intel's P6 bus. AMD's 200MHz system bus also provides 64-byte burst transfers, while the Intel P6 bus supports only 32-byte transfers. With its source synchronous clocking capability, the AMD Athlon processor's front-side bus is scalable to operate beyond 400 MHz. The Intel P6 bus uses a common clock, which is limited in operating frequency due to transport delay limits. With source synchronous clocking, the sender of the data also sends a clock so that the transport delay is negligible. AMD's advanced system bus technology, along with the Socket A infrastructure, enables a cost-effective and scalable system superior to that of Slot 1/Slot 2-based systems. (See the "AMD Athlon Processor System Bus" white paper for more details.)



**Table 2: 200-MHz AMD Athlon™ Processor System Bus Advantages**

	<b>AMD Seventh Generation</b>	<b>Intel Previous Generation</b>
Feature	AMD Athlon™ Processor	Pentium® III Processor
Number of pins	242	242
Bus operating frequency	200 MHz – 400 MHz +	100 MHz to 133 MHz
Data bus width	64 bits	64 bits
Data bus integrity	8-bit ECC	8-bit ECC
Clock technology	Source synchronous	Common
Peak bandwidth	1.6 to 3.2 GB/s+	533MB/s to 1.06 GB/s
Multiprocessing	Yes, point-to-point	Yes, shared
Max. system processors	Unlimited (by chipset)	Unlimited (by chipset)
Dedicated snoop channel	Yes	No
Cache Control Policy	MOESI or MESI	MESI
Outstanding transactions	24 per processor	4-8 per processor
Machine check architecture	Yes	Yes
Physical memory support	8 TB*	64 GB
Burst transaction size	64 byte	32 byte

\*The size of supported physical memory depends on the specific processor and chipset implementation.

The AMD Athlon processor system bus offers a significant advantage for multiprocessor systems: it is a high-frequency point-to-point bus, with no conflicting traffic, rather than a shared bus as used in the P6 bus architecture (see Table 2). Other advanced system features that enable the AMD Athlon processor system bus to deliver superior multiprocessor performance include a dedicated snoop port to reduce snoop traffic interruptions, large 64-byte cache line transfers (twice the size of Slot 1 or Slot 2 designs), MOESI cache control protocol, and 8-bit error ECC data integrity. By combining AMD’s system bus and high-performance cache design, the AMD Athlon processor can manage transaction-based applications with ease and enable superior data throughput for data-intensive applications, such as video or web servers and transaction-based systems.

Ultimately, the AMD Athlon processor system bus gives system designers the flexibility to design a broad range of reliable, powerful x86 system platforms, from high-end desktop systems to uniprocessor and multiprocessor workstations and enterprise servers. When powered by the AMD Athlon processor, these platforms will be able take advantage of high-bandwidth peripherals, such as digital video, cable modems, ADSL, IEEE-1394, and Gigabit Ethernet, without limiting system performance.



## Leading-Edge Floating Point and 3D Multimedia Technology

The AMD Athlon processor offers the most powerful, architecturally advanced floating point engine ever delivered in an x86 microprocessor. The AMD Athlon processor's three-issue, superscalar floating point capability is based on three pipelined, out-of-order floating point execution units, each with a 1-cycle throughput. The AMD Athlon processor's floating point engine offers twice the peak x87 floating point computation rate and three times the peak floating point instruction rate of the Pentium III processor, and its FP performance rivals that of many RISC processors used in workstations and servers. (For more details, see the "AMD Athlon Processor Floating Point Capability" white paper.

The three execution units (Fmul, Fadd, and Fstore) in the AMD Athlon processor's floating point pipeline handle all x87 (floating point) instructions, MMX instructions, and enhanced 3DNow! instructions. Using a data format and single-instruction multiple-data (SIMD) operations based on the MMX instruction model, the AMD Athlon processor can deliver as many as four 32-bit, single-precision floating point results per clock cycle.

The AMD Athlon processor includes an enhanced version of 3DNow! technology designed to take 3D multimedia performance to new heights. The enhanced 3DNow! technology implemented in the AMD Athlon processor includes AMD's original 21 3DNow! instructions (the industry's first x86 instruction set to use superscalar SIMD floating point techniques to accelerate 3D performance), as well as the following 24 additional instructions:

- ❑ 12 instructions that improve multimedia-enhanced integer math calculations used in such applications as speech recognition and video processing
- ❑ 7 instructions that accelerate data movement for more detailed graphics and new functionality for Internet browser plug-ins and other streaming applications, enabling a richer Internet experience
- ❑ 5 DSP instructions that enhance the performance of communications applications, including soft modems, soft ADSL, MP3, and Dolby Digital surround sound processing. This DSP functionality is unique to the AMD Athlon processor and not supported by Intel's Pentium III processor.

In enhancing 3DNow! technology, AMD kept the instruction set design simple, yet powerful. AMD's goal in designing the additional 3DNow! instructions was to provide powerful SIMD performance while enabling ease of implementation for software developers. The relatively few instructions of enhanced 3DNow! technology allow developers to adopt this technology and optimize their applications quickly. (See the "Enhanced 3DNow! Technology for the AMD Athlon Processor" white paper for more details.)

The AMD Athlon processor's superscalar floating point engine can significantly boost the performance of FP-intensive applications for desktop systems and workstations. Applications that have been optimized for enhanced 3DNow! technology will run even faster on AMD Athlon processor-based platforms. Performance benefits include higher resolution at the same frame rates or higher frame rates for digital video or action games, higher-quality digital video, more realistic 3D sound, and a richer Web experience. Examples of applications that stand to benefit from the leading-edge floating point and 3D multimedia processing capabilities of the AMD Athlon processor include:

- ❑ Advanced imaging software for processing digital imaging
- ❑ Enhanced Internet browsing using next-generation browser features
- ❑ Architectural 3D rendering systems
- ❑ CAD/CAE software packages
- ❑ Near real-time MPEG-2 video encoding/editing for higher quality video
- ❑ Speech recognition in Web browsing and word processing
- ❑ Financial modeling and trading software
- ❑ Realistic 3D software, including 3D games and flight simulators.

## Socket A Infrastructure Support

The AMD Athlon processor is designed to enable high-performance computing solutions for desktop, workstation, and server configurations. The Socket A infrastructure designed for the AMD Athlon processor is based on optimized, high-performance platforms. As a result, systems built using the AMD Athlon processor can use common system-level mechanical components, as well as system assembly techniques. AMD Athlon processor-based systems also can use all available cases, heatsinks, fans, and other basic system components.

AMD and its development partners are delivering a full line of optimized infrastructure products (chipsets, motherboards, drivers, and BIOS) that support the AMD Athlon processor. To provide the initial infrastructure for AMD Athlon processor-based platforms, AMD has developed the AMD-750™ chipset, a complete system logic solution featuring system and peripheral bus controllers designed to deliver enhanced performance for the AMD Athlon processor. Major third-party chipset suppliers, including VIA Technologies, Acer Laboratories Inc. (ALi), and SiS are delivering high-performance chipsets optimized for AMD Athlon processors.

Optimized BIOS support for the AMD Athlon processors is available by leading third-party suppliers, including American Megatrends, Inc., Award Software International, and Phoenix Technologies. All major motherboard vendors provide production availability of high-quality, high-performance motherboards. With AMD's release of the AMD Athlon

processor reference logic board design and chipset to infrastructure partners, AMD has set the stage for high-volume, cost-effective production of Socket A infrastructure based on the 200MHz AMD Athlon processor system bus.

## Summary: Powering the Next Generation in Computing Platforms

AMD Athlon processors use the latest microarchitecture innovations and system bus technology to deliver the industry's highest performance for x86-compatible platforms. Current AMD Athlon processor-based systems include high-end desktop products and uniprocessor workstations and servers. Future AMD Athlon processor-based systems are planned to include scalable, high-performance multiprocessing workstation and server platforms. The size of the multiprocessing system is determined by the chipset architecture and is designed to match the platform's computation needs. Forthcoming optimized chipsets are planned to enable multiprocessing system designs based on 2, 4, 8 or more AMD Athlon family processors.

AMD Athlon processors are compatible with x86 versions of Microsoft® Windows®, including Windows 98, Windows NT® and Windows 2000, as well as other leading operating systems, such as Unix, Linux, OS/2 Warp, and Novell NetWare. The processors are also compatible with the existing installed base of more than 60,000 x86 software packages. In addition, numerous existing and forthcoming software packages are either currently optimized or planned to be optimized for enhanced 3DNow! technology and other architectural features implemented in AMD Athlon processors.

High-performance AMD Athlon processor platforms provide a new level of performance and data movement capabilities for the next generation of computation-intensive software for the growing fields of digital imaging, the Internet, enterprise computing, CAD/CAE packages, scientific/technical applications, and 3D gaming.

## AMD Overview

AMD (NYSE: AMD) is a global supplier of integrated circuits for the personal and networked computer and communications markets. AMD produces microprocessors, flash memories, and integrated circuits for telecommunications and networking applications. The world's second-leading supplier of Windows compatible processors, AMD has shipped more than 120 million x86 microprocessors, including more than 90 million Windows compatible CPUs. Founded in 1969 and based in Sunnyvale, California, AMD has sales and marketing offices worldwide and manufacturing facilities in Sunnyvale; Austin, Texas; Dresden, Germany; Bangkok, Thailand; Penang, Malaysia; Singapore; and Aizu-Wakamatsu, Japan. AMD had revenues of \$2.9 billion in 1999.

## Cautionary Statement

This White Paper contains forward-looking statements, which are made pursuant to the safe harbor provisions of the Private Securities Litigation Reform Act of 1995. Forward-looking statements are generally preceded by words such as "expects," "plans," "believes," "anticipates," or "intends." Investors are cautioned that all forward-looking statements in this white paper involve risks and uncertainties that could cause actual results to differ materially from current expectations. Forward-looking statements in this white paper about the AMD Athlon processor involve the risk that AMD will not be able to produce the processor in the volume required by customers on a timely basis; that AMD may not be successful in developing an infrastructure to support the processor; that third parties may not provide infrastructure solutions to support the processor; that the processor will not achieve customer and market acceptance; and that software applications will not be optimized for use with the processor. We urge investors to review in detail the risk and uncertainties in the company's Securities and Exchange Commission filings, including the most recently filed Form-10K.

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