

# Understanding Processor Performance

**Jay Pickett**

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

## Understanding Processor Performance

To the end-user, the ultimate benefit of processor performance is how fast their applications run. Performance to them, simply put, is the amount of time it takes to perform a given task. With that in mind, the processor that performs a given task in the least amount of time has the highest performance. Increased performance implies reduced execution time. Historically, this has been measured through a variety of benchmarks. When comparing the performance of processors that execute the same instruction set, such as the x86 instruction set in PCs, performance is defined as: The work done by the processor in each clock cycle (represented as instructions per clock – IPC) times the number of clock cycles (represented by frequency) or:

$$\textit{Performance} = \textit{IPC} \otimes \textit{Frequency}$$

In the '286, '386, and '486 processor generations, the underlying architecture of the competing x86 processors was exactly the same; therefore IPC was equivalent among competing processors from several different companies. Since the IPC of these processors was essentially constant, performance was perceived as:

$$\textit{Performance} = \textit{Frequency}$$

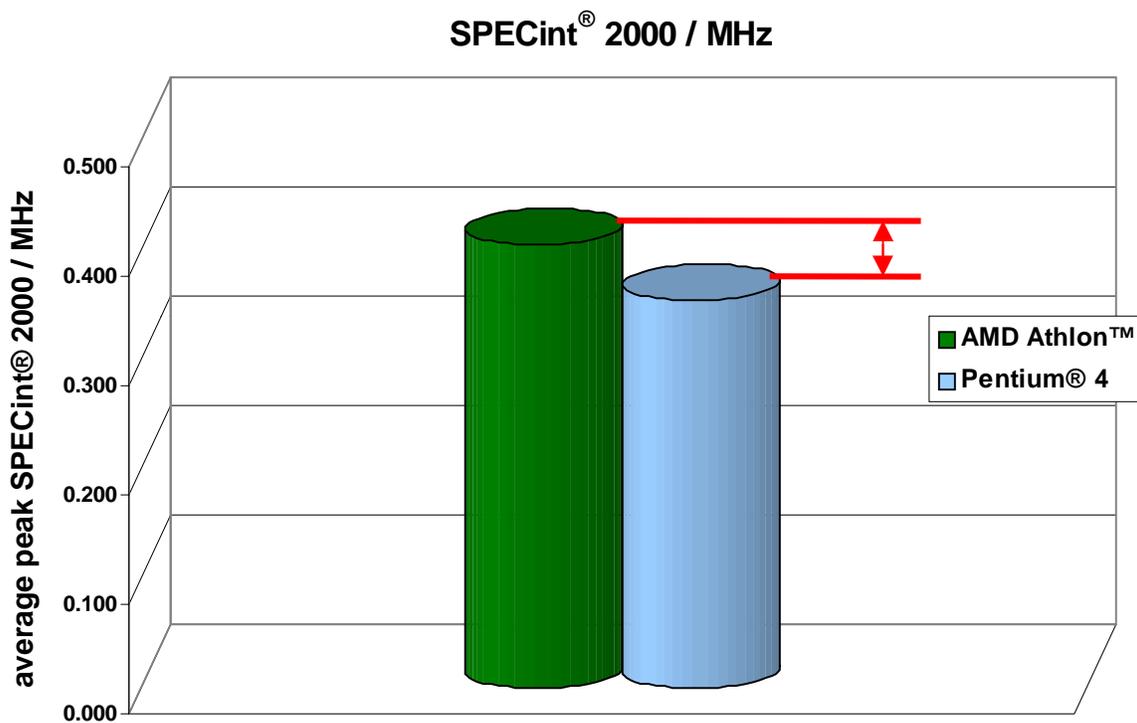
With those previous processor generations, the focus was purely on clock frequency (MHz) as the differentiating performance factor.

Starting with the fifth generation of x86 processors, the AMD-K5® processor and the Pentium® processor, this relationship was no longer true. AMD and Intel took different approaches to the internal architectures of these processors, even though they remained compatible with the x86 instruction set architecture. For the first time, IPC was different for competing processors running the same applications and benchmarks. Therefore, processor performance was defined as:

$$Performance = IPC \otimes Frequency$$

The end result showing that frequency (MHz) alone no longer determined processor performance.

With the seventh-generation AMD Athlon™ processors and Pentium 4 processors, architectural designs, and thus IPC, have clearly diverged.



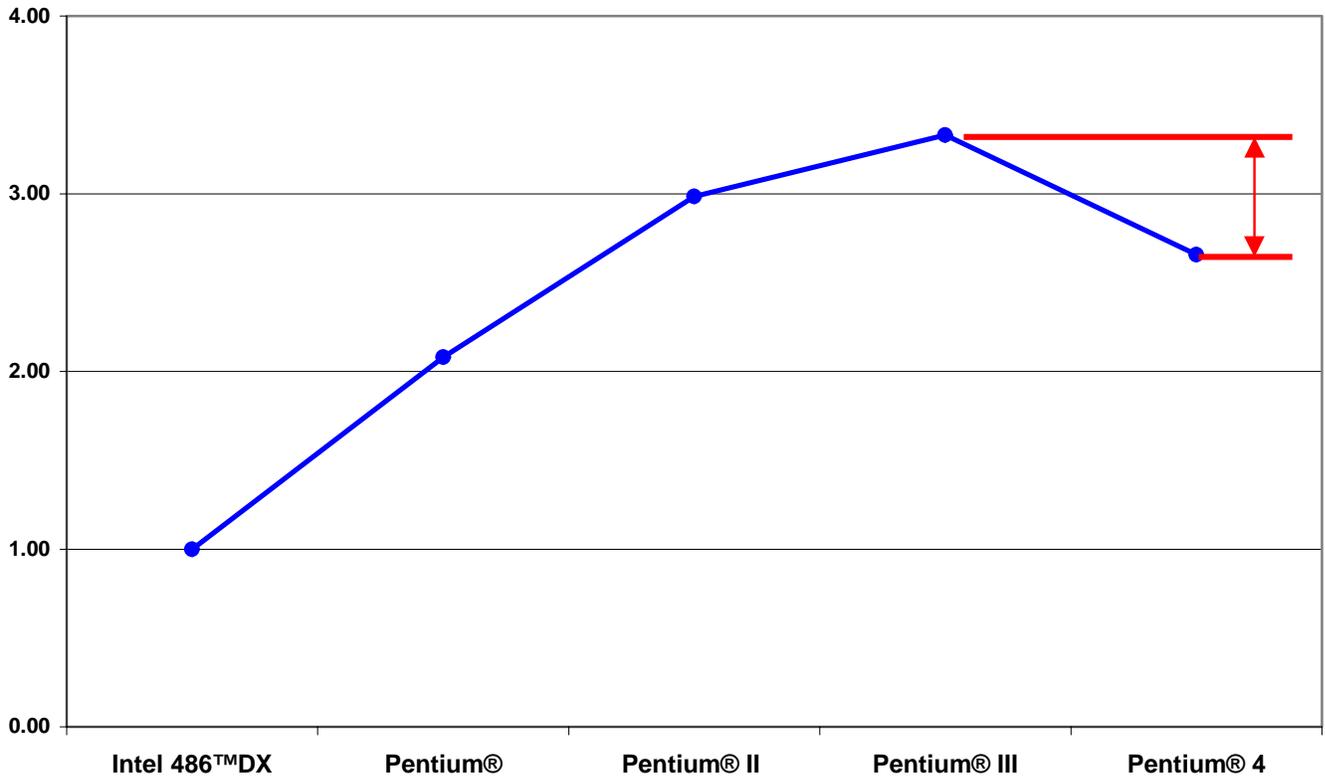
Now, more than ever, it is important to look at the combination of the amount of work being done per clock cycle as measured by IPC, and the operating frequency of the processor. Clearly, it is time to evaluate processors on the merits of their overall performance, not just their raw frequency alone.

Improvements in overall performance come from two different areas:

1. Frequency improvements
  - Technology has driven frequency improvements by enabling smaller geometries and faster transistors, commonly referred to as “process shrinks.”
  - Design has driven frequency improvements by enabling deeper pipelines with fewer gates per clock cycle, which can reduce the architectural performance.
2. Work per clock improvements
  - IPC has been improved by techniques such as superscalar architectures, dynamic instruction schedulers, larger on-chip caches, and advanced branch prediction.

One key point to recognize is that deeper pipelines alone translate into less work per clock cycle. This reduced work per clock cycle or reduced IPC can only be offset by improvements in other areas, such as branch prediction and cache hit rates. Taken to an extreme, processor performance can actually be reduced by forcing frequency improvements at the expense of IPC improvements. The Pentium 4 processor is the first Intel processor to step backward in IPC, or work performed per clock cycle.

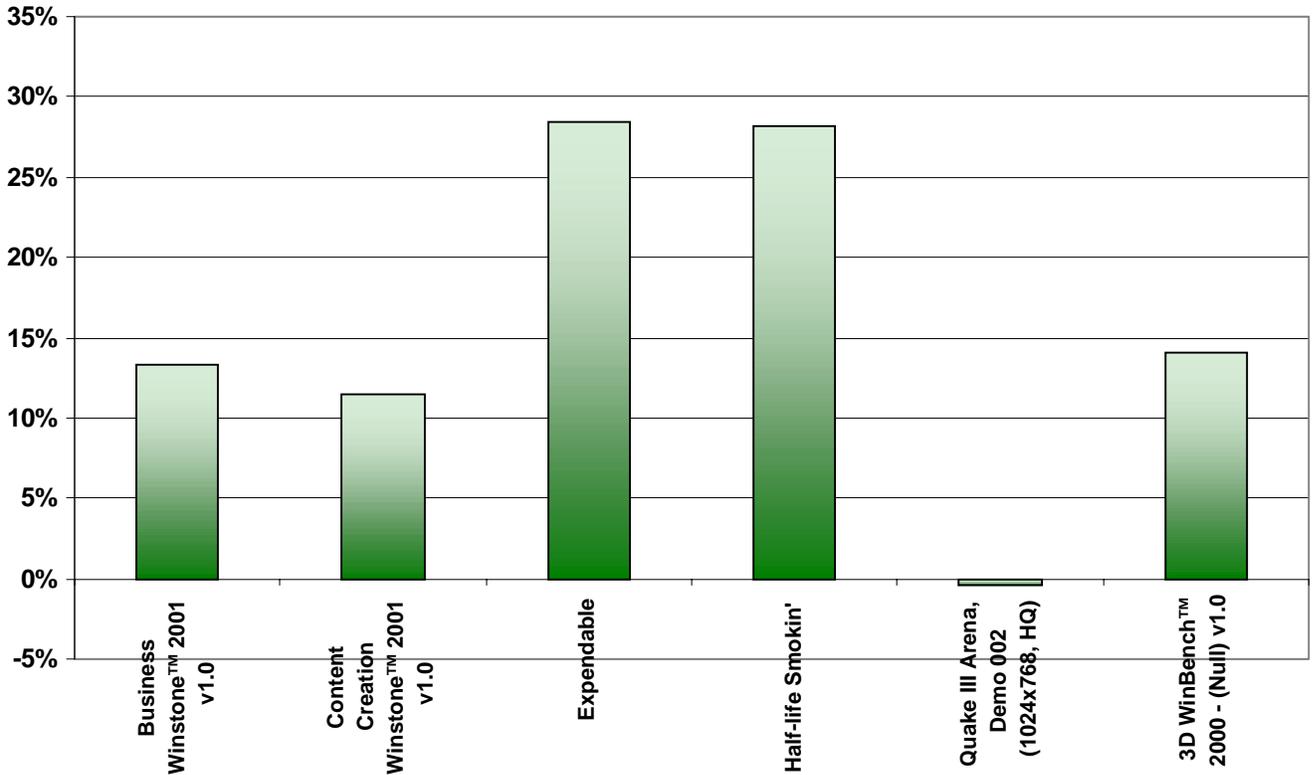
**SPECint<sup>®</sup> / MHz Performance**  
 (Normalized to the 486<sup>™</sup>DX)



Due to the reduction in work per clock cycle, the Pentium 4 processor must operate at significantly higher clock frequencies to produce better processor performance than previous-generation Pentium III processors.

Different approaches can be taken to optimize processor performance. AMD has worked to maintain a balanced approach to optimizing processor performance by increasing the amount of work done per clock cycle (IPC), and improving the operating frequency at the same time. Using this approach, the AMD Athlon processor delivers superior performance across a broad range of applications, even when compared to the Pentium 4 processor running at a considerably higher frequency. The following graph illustrates this point with a wide array of benchmarks run on two different processor architectures with a 300 MHz difference in frequency.

**1.4GHz AMD Athlon™ vs. 1.7GHz Pentium® 4  
% Performance Advantage**



Without a doubt, processor performance is no longer determined by frequency alone. AMD believes the Pentium 4 processor will continue to be forced to drive frequency to remain competitive with the AMD Athlon processor in terms of real-world application performance. For that reason, actual application performance must be the differentiator between processors.

**AMD Overview**

AMD is a global supplier of integrated circuits for the personal and networked computer and communications markets with manufacturing facilities in the United States, Europe, Japan, and Asia. AMD, a Fortune 500 and Standard & Poor's 500 company, produces microprocessors, Flash memory devices, and support circuitry for communications and networking applications. Founded in 1969 and based in Sunnyvale, California, AMD had revenues of \$4.6 billion in 2000. (NYSE: AMD)

## Configuration Statement

Windows® Me - No Service Packs or updates installed.

AMD Athlon™ processor-based system: Hardware: Motherboard: Gigabyte 7DX (Board Rev. 4.0, BIOS version F2ha), Chipset: AMD-760™ Chipset, Memory: PC2100 CAS-2 (DDR SDRAM), Qty (2), 128MB DIMM Modules (256MB total), Hard Drive: IBM Deskstar 30.7GB UDMA 100 (Model DTLA-307030), Network Card: Allied Telesyn AT2700TX PCI 10/100, Sound Card: Creative Labs SoundBlaster Live!, Video Card: Leadtek Winfast GeForce2 Ultra 64MB DDR memory. Drivers: AGP Miniport: Windows® Me - provided by operating system, EIDE Drivers: Windows Me - Via Bus Mastering v2.1.50.1 (provided by chipset vendor), Network Card: Windows Me - driver provided by operating system, Sound Card: Windows Me - emu10k1.vxd v4.11.01.0711 - provided by vendor Creative Labs, Video Card: v4.12.01.0650 - provided by vendor nVidia.

Pentium® 4 processor-based system: Hardware: Motherboard: Intel D850GB (i850 chipset, BIOS version GB85010A.86A.0058.P12 1.23 MB 13 Apr. 2001), Memory: PC800 (RDRAM®), Qty. 2, 128MB RIMM Modules (256MB total), Hard Drive: IBM Deskstar 30.7GB UDMA 100 (Model DTLA-307030), Network Card: Allied Telesyn AT-2700TX, GB85010A.86A.0058.P12.0104021715, Sound Card: Creative Labs SoundBlaster Live!, Video Card: Leadtek Winfast GeForce2 Ultra 64MB DDR memory. Drivers: AGP Miniport: Installed from CD provided with motherboard (version information not available), EIDE Drivers: Intel 82801BA ICH2 6.10.011 2.52 MB 19 Apr. 2001 (DMA enabled in Device Manager), Network Card: Windows Me - driver provided by operating system, Sound Card: Windows Me - driver provided by operating system, Video Card: nVidia Detonator version 6.50, INF Driver: Intel 82801BA ICH2 2.60.001 1.63 MB 13 Nov. 2000.

AMD, the AMD Arrow logo, AMD Athlon and combinations thereof, are trademarks, and AMD-K5 is a registered trademark of Advanced Micro Devices, Inc. Pentium is a registered trademark of Intel Corporation. Business Winstone and 3D WinBench are trademarks and Winstone is a registered trademark or trademark of Ziff-Davis Corporation in the United States and other jurisdictions. This test was performed without independent verification of Ziff-Davis and Ziff-Davis makes no representations or warranties as to the results of the test. SPECint is a registered trademark of Standard Performance Evaluation Corporation in the United States and other jurisdictions. Other product names used in this publication are for identification purposes only and may be trademarks of their respective companies.