COMPAQ

White Paper

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Contents

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Comparison of Intel Pentium III and Pentium 4 Processor Performance

Abstract: This white paper summarizes key technology advancements in the Intel® Pentium® 4 processor compared with the previous-generation Intel Pentium III processor. Common benchmark workloads are discussed to provide an illustration of which areas of computing will benefit the most from this new architecture. Results of Compaq benchmark testing, comparing results for both processors, are included to demonstrate the performance gains realizable with the new processor.

Notice

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Introduction

This White Paper provides information useful in understanding the differences between the Intel® Pentium® 4 processor and the previous-generation Pentium III. A discussion is included about the architectural differences in the two processors and the performance benefits they provide. When evaluating performance, there is no single performance test ("benchmark") that can completely describe the performance of a complex system like modern microprocessor or personal computer. It is important to obtain the complete performance picture. In other words, the system should deliver high performance across the entire spectrum of applications such as productivity, multimedia, 3D and Internet. Each of these application categories caries a unique set of computation and data movement characteristics; thus it is important to realize how each class of application would benefit or not from the new architecture. It is also important to realize the investment protection delivered, where the new architecture will provide reasonable performance gain for current applications while providing headroom for future growth as more and more ISVs will fully take advantage of the new architecture. With that in mind, it is expected that there is a non-uniform gain in performance, as each class of current application lends itself more to the new architecture while others do not. Using the Compaq *Deskpro* EN platform equipped with 1 GHz Pentium III processor as the baseline, benchmark results of the new Compaq *Evo* D500 platform equipped with the 1.7 GHz Pentium 4 processor are presented as a comparison of the two architectures.

Comparison of Pentium 4 and Pentium III Architecture Benefits

As Internet and digital media become more pervasive in modern computing, the Pentium 4 processor is optimized for a new level of digital audio, video, photography and 3D performance. For corporate users, the Pentium 4 offers excellent performance with added headroom for future applications such as

- Java technology and XML, which will be increasingly enabled in Office XP, Windows® XP and Web services
- Enhanced 3D rendering for business analysis, video decompression for e-learning, and peer-to-peer interaction for improved collaboration
- Secure connections with support for latest encryption technology for data transfer and e-Commerce transactions.

How are these potential enhancements possible with this new processor? Let's explore the micro-architecture enhancements in the Pentium 4 processor:

Representing a breakthrough to a new level of computing, the Pentium 4 processor is a completely redesigned version of the earlier Intel IA32 processor architecture or Pentium III while maintaining backward compatibility with existing applications. This means the Pentium 4 processor protects user's current investment in existing applications while providing new optimized instructions, registers, and data structures for future applications.

The Pentium 4 processor is optimized for large data sets transfer and handling. This means the customer will see significantly improved performance over previous generation Pentium III processors in applications that handle and require large amounts of data. This will apply to all vertical applications and many horizontal applications, such as financial analysis applications, where handling large data sets is the norm. For a limited number of horizontal applications, such as Microsoft Word, performance is not enhanced and can even suffer, though differences are typically made up for by faster processor speeds enabled by the new processor architecture. However, it should be noted that the trend in office applications is for greater and greater usage of graphics. Use of graphics presupposes the existence of data-intensive graphics-generation applications, which benefit greatly (and noticeably to the user) from Pentium 4 enhancements. Moreover, as noted above, the trend is also to increasing use of java technology and XML in Office XP, Windows XP and Web services. Nevertheless, in the short term, if the customer’s need is primarily for office applications and there is a budget constraint, Pentium III may still offer an acceptable solution. However, the customer should be aware that Compaq expects that, in the near future, office applications will be handling much more data requiring the architectural advantages the Pentium 4 possesses.

Perhaps more important for the user is the fact that higher processor speeds from Intel will only be available in the future in the Pentium 4. The Pentium III will offer no further increases in processor speeds. (Intel will continue to refresh Celeron processors, however). This is illustrated in Figure 1, which shows the roadmap for of Intel processor technology. This means that regardless of the application, improvements in performance can only be obtained by greater processor speed available from Intel in the Pentium 4 processor.

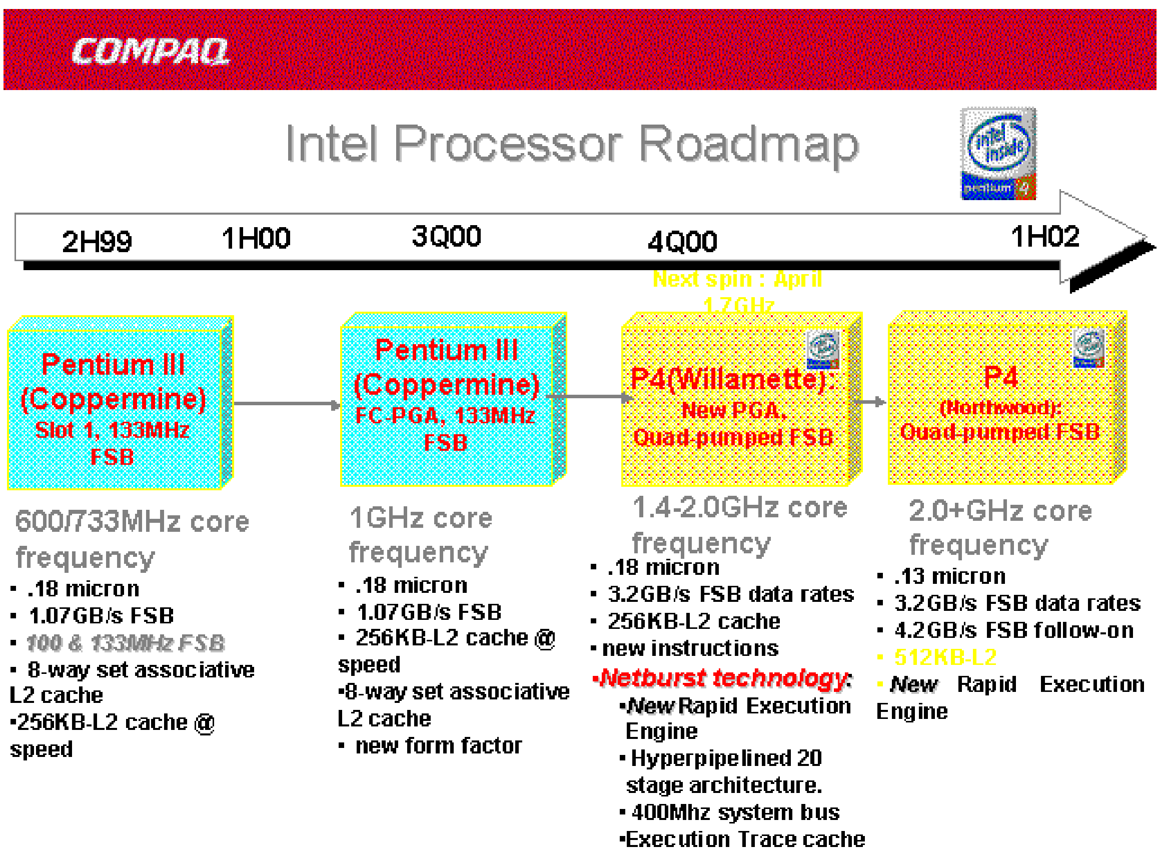


Figure 1: Roadmap of Intel Processor Evolution

On the surface, the architecture of this new class of Pentium 4 processor looks the same as the Pentium III, but after one drills further down, the Pentium 4 is significantly enhanced to give better levels of performance in terms of frequency and instructions execution per clock. These are the two variables that measure the level of how fast an application executes and is defined in the following performance equation:

Performance = MHz (Frequency) x Instructions executed per clock (IPC)

The Pentium 4 processor addresses the two variables in the performance equation with the new underlying silicon/logic implementation of what Intel calls NetBurst micro-architecture. The NetBurst micro-architecture more specifically attacks the frequency and IPC variables of the performance equation with its advanced 0.18μm (and 0.13μm shortly after) silicon process technology, its redesigned architecture of the complete instruction pipeline, its execution engine, and its extension to the existing instruction set. As we move forward through this paper, the benefits of this is will be more clearly explained

More detailed information can be found after the summary section.

Case for Performance

Applications generally can be divided into two classes: **1) floating-point-based applications** that are memory- and bandwidth- intensive and, **2) integer-based and basic office productivity applications**. Recalling the performance equation mentioned above, the IPCs achievable by the above two classes of applications vary greatly due to the variation of branches in application code. This variation of branches affects the predictability of code flow. A higher probability of correct prediction yields a higher potential IPC and, therefore, higher performance. Floating-point-based multimedia applications tend to have branches that are very predictable and thus have a higher IPC potential. As a result, these applications scale very well with frequency and benefit greatly from the new architecture of the Pentium 4. However, integer-based and basic office productivity applications tend to have more random branches in application code, thus are more difficult to predict. The result is less efficient use of the Pentium 4 architecture on these applications. However, since Pentium 4 processors are available at higher frequencies than Pentium III, performance is still enhanced according to the performance equation.

SYSmark 2001

SYSmark2001 is a suite of application software and associated benchmark workloads developed by Applications Performance Corporation (BAPCO). It is a tool that measures system performance on popular business-oriented applications in the Microsoft Windows operation system. SYSmark contains twelve (12) application workloads that are divided into two categories: Office Productivity and Internet Content Creation.

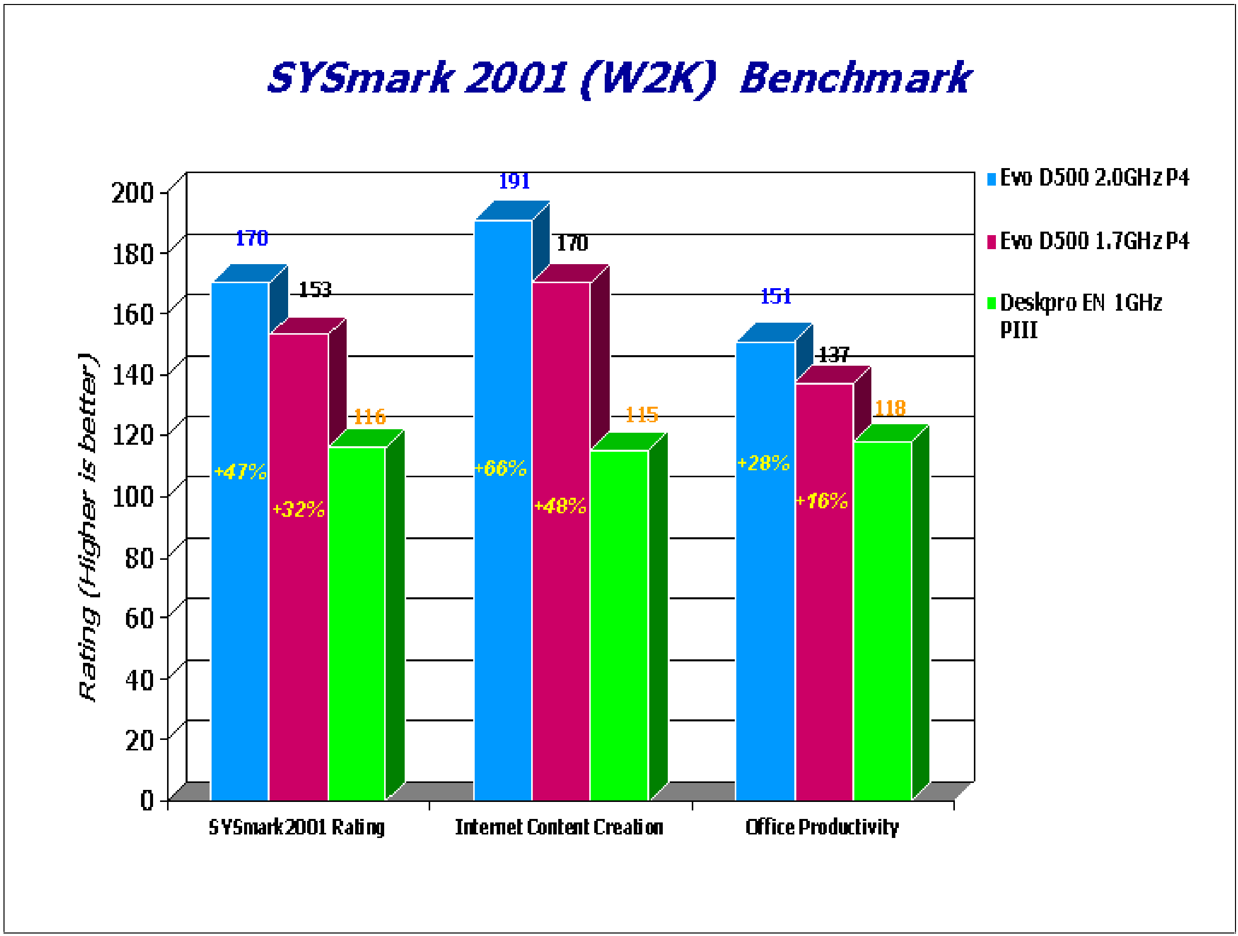
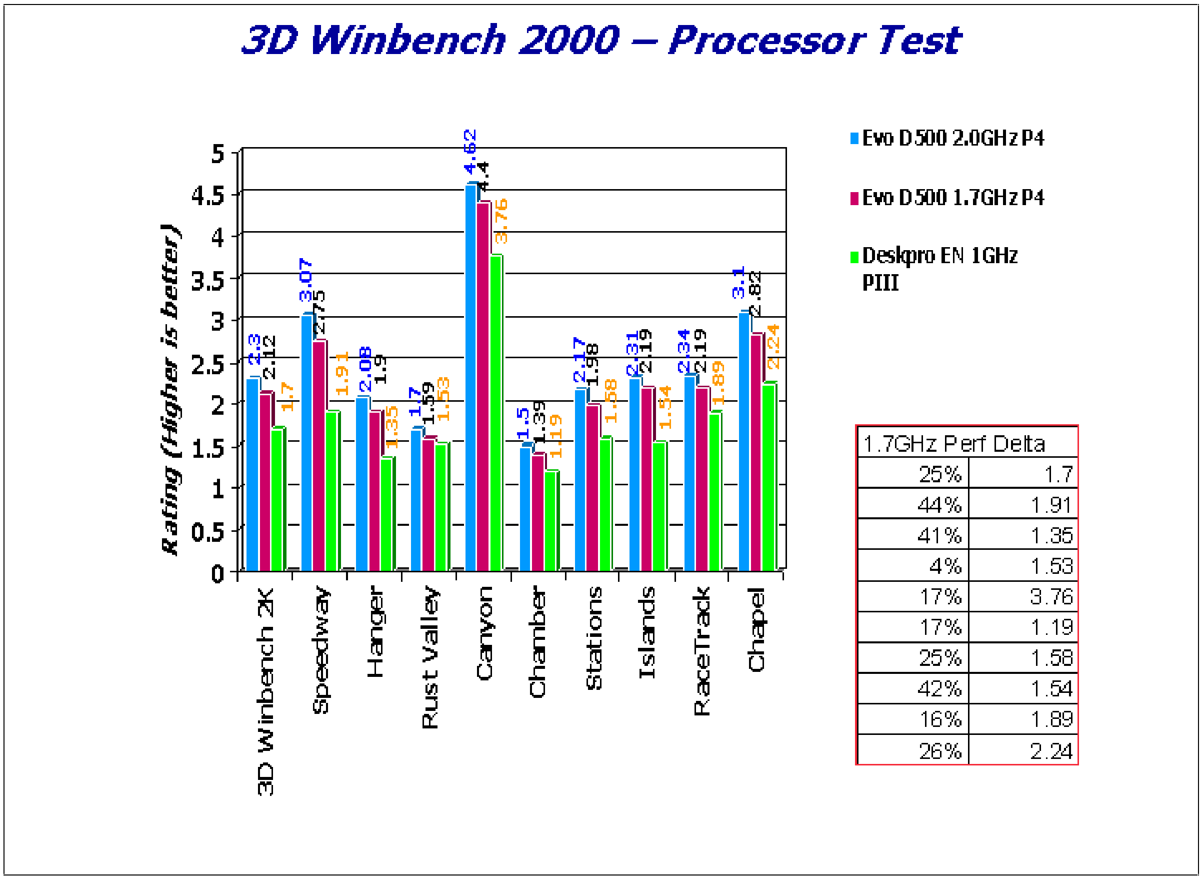


Figure 2: Comparison of Pentium III with Pentium 4 in SYSmark 2001 Benchmark Tests

Figure 2 clearly illustrates the Pentium 4 performance advantages over Pentium III. It is also clear that performance gains in the Office Productivity workload are less dramatic when compared to Internet Content Creation workload. In the Internet Content Creation workload, where the typical workload is streamed in nature (Windows Media Encode for example), the application tends to have branches that are very predictable resulting in performance that scales very well with frequency and benefits greatly from the new architecture of the Pentium 4.

3D WinBench 2000 – Processor Test

3D WinBench 2000 measures system–level 3D performance, including CPU and graphics subsystem. To understand the processor 3D performance, this benchmark suite includes the Processor Test which measures the CPU-intensive portion of the 3D graphics pipeline – geometry and setup stage.



1.7GHz Perf Delta	
25%	1.7
44%	1.91
41%	1.35
4%	1.53
17%	3.76
17%	1.19
25%	1.58
42%	1.54
16%	1.89
26%	2.24

Figure 3: Comparison of Pentium III and Pentium 4 in 3D Winbench 2000 Processor Test

To display 3D objects on a 2D computer screen, it is much easier to represent 3D objects as a collection of polygons (usually triangles) than as curved surfaces. The larger the number of triangles used to represent the 3D object, the more closely the approximation of the mathematical description resembles the 3D object. The process of breaking up a 3D object into triangles is called *tessellation* and involves an enormous number of floating-point vector calculations. Objects in the real world have material properties and reflectivity and these impact how the objects interact with light, the more lighting from various sources and angles, the more realism to the object/scene. Again, calculations of light effects on 3D objects require large numbers of complex floating-point vector calculations. The CPU index performance gain in the 3D Winbench 2000 – Processor Test, benchmark, illustrated in Figure 3, resulted from the increase in floating-point performance of the Pentium 4 processor.

Summary

The Pentium 4 architecture offers significant innovations compared to earlier Pentium III technology. These innovations lead to breakthroughs in performance that are measured and substantiated by testing reported in this white paper.

The Pentium 4 processor is optimized for large data sets transfer and handling, so customers will see significantly improved performance over previous generation Pentium III processors in applications that handle and require large amounts of data. Floating-point-based multimedia applications tend to have branches that are very predictable and thus have a higher IPC (Instructions executed Per Clock) potential. Integer-based and basic office productivity applications tend to have more random branches in application code, thus are more difficult to predict. This means the IPC potential is not high, but the fact that Pentium 4 is available in higher frequencies than Pentium III results in increased performance with these applications.

It is important for the user to note the fact that higher processor speeds from Intel will only be available in the future from the Pentium 4. The Pentium III will offer no further increases in processor speeds. (Intel will continue to refresh Celeron processors, however). At some point, regardless of the application, improvements in performance can only be obtained by greater processor speed. The customer should be aware that Compaq expects that, in the near future, office applications will be handling a lot more data, thus resulting in the need for increased processing power and efficiency that the Pentium 4 offers.

Additional Micro-Architecture Detail

Figures 4 and 5 provide an overview of the micro-architectures of the Pentium III and Pentium 4 processors respectively.

Pentium III

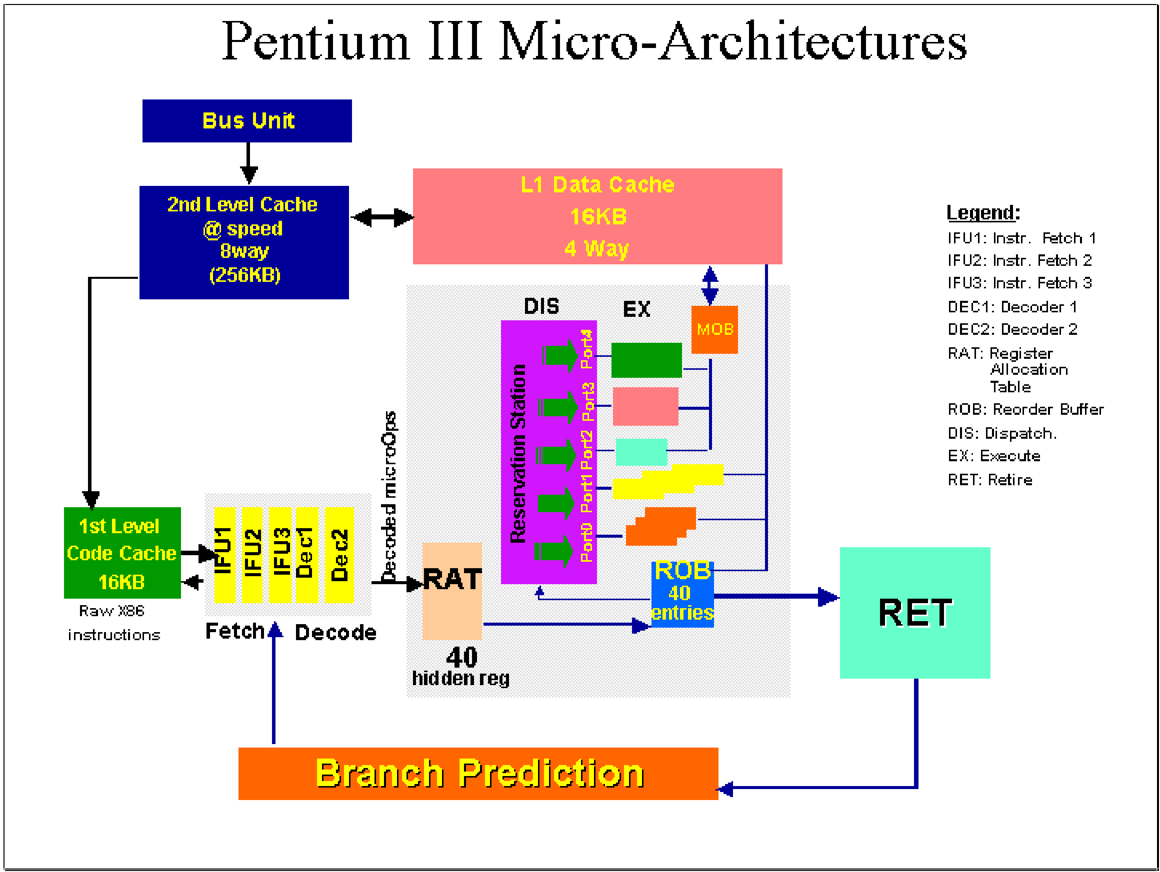


Figure 4: Pentium III Micro-Architecture Overview

Pentium 4

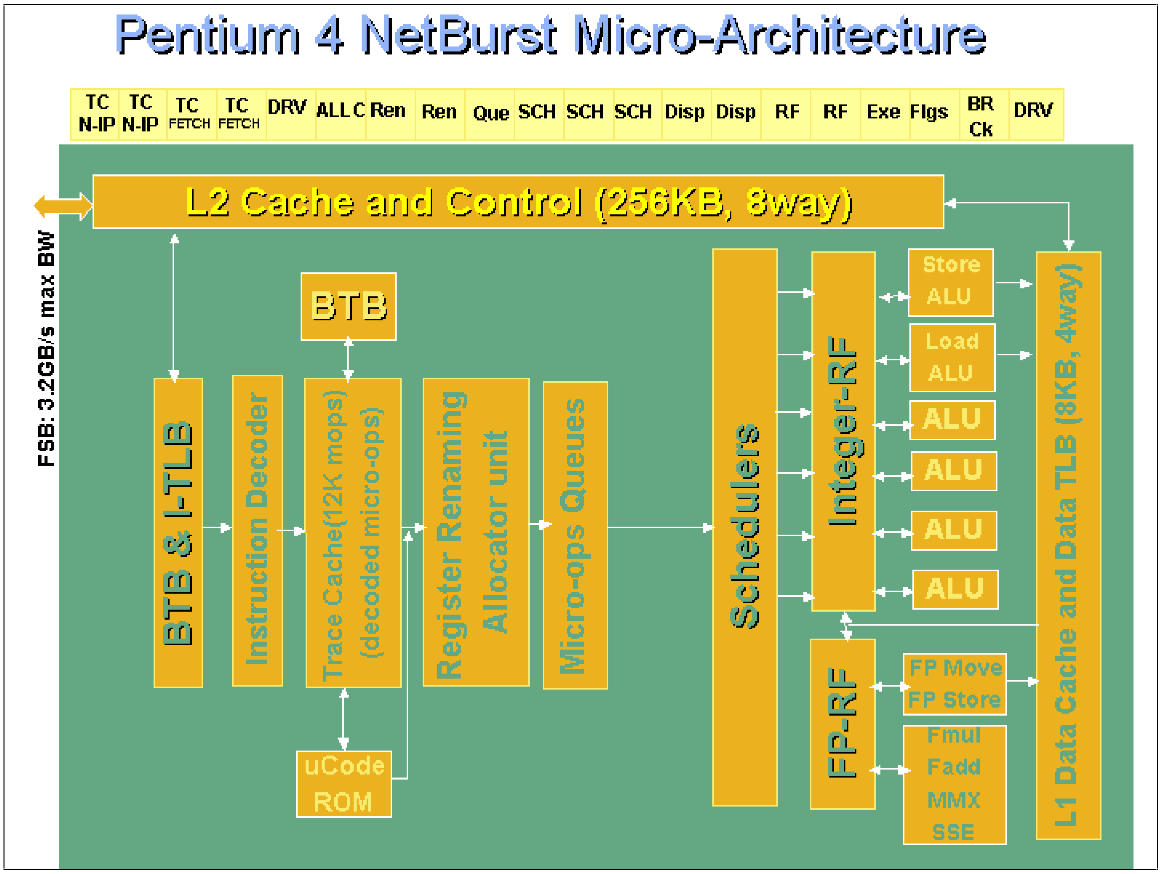


Figure 5: Pentium 4 NetBurst Architecture Overview

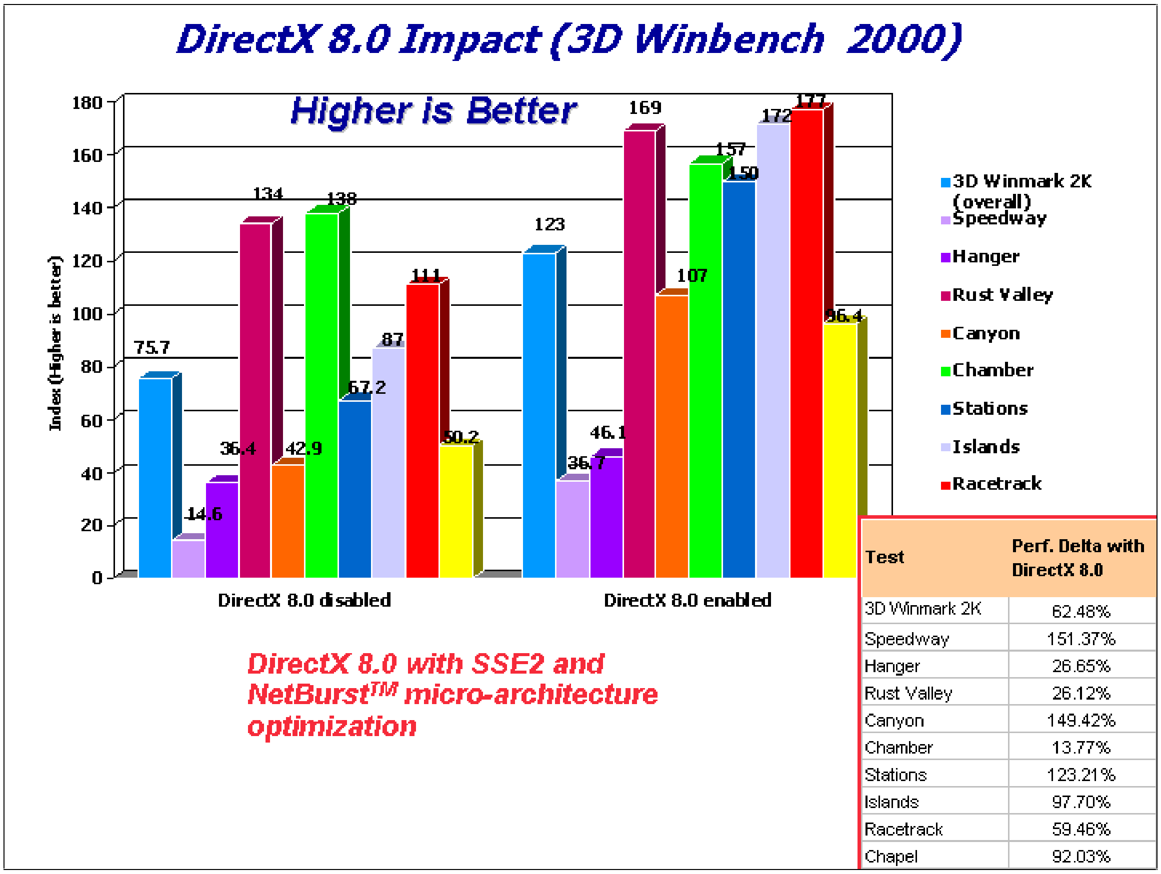
Again, the NetBurst micro-architecture attacks the frequency and IPC variables of the performance equation with its advanced 0.18µm (and 0.13µm shortly after) silicon process technology, its redesigned architecture of the complete instruction pipeline, its execution engine, and its extension to the existing instruction set, which is as follows:

- 20-Stage Pipeline as compared to a 10-stage Pipeline in the Pentium III – smaller workload per stage but at significantly faster execution time
- Execution Trace Cache to remove the long latency associated with the instruction decoder from the main execution loop in the Pentium III
- Rapid Execution Engine where multiple Arithmetic Logic Units (ALUs) are executed twice as fast as the core frequency, resulting in higher execution throughput, reduced execution latency, and extension of the total of execution ports to seven (7) as compared to five (5) in the Pentium III
- Advanced Transfer Cache with much higher throughput at 54.4GB/s for a 1.7 GHz Xeon (32 bytes x one transfer per clock x 1.7 GHz) to feed the data-hungry execution units as compared to 16GB/s throughput at 1 GHz in the Pentium III

- Advanced Dynamic Execution with very wide windows of instructions (126 instructions versus 42 instructions in the Pentium III) from which the execution units can choose to execute, thus avoiding dependency stalls that would prevent execution units from doing useful work. In addition, 4KB of branch target buffer (as compared to 1KB in the Pentium III), and a multilevel advanced branch prediction algorithm to keep detail on the history of past program branches, thus reducing by approximately 33% the mis-predictions rate as compared to the Pentium III.
- 400 MHz System Bus with enhancements to signaling scheme and bus protocols, thus featuring data bandwidth and bus transfer efficiencies much higher than those of the Pentium III, as follows:
  - 200% data bandwidth improvement (3.2GB/s ***(8 bytes x 400 Mtransfers/s)*** versus 1.06 GB/s ***(8 bytes x 133 Mtransfers/s)***)
  - 17% latency improvement for first critical data read
  - 46% latency improvement for 64-byte read
  - 25% latency improvement for data write
  - 64% latency improvement for 64-byte write
  - New cycles every two clocks at 200 MHz versus every three clocks at 133 MHz
  - 200% snoop bandwidth improvement (3.2GB/s ***(64 bytes/2 clocks @ 100 MHz)*** versus 1.06GB/s ***(32 bytes/4clocks @ 133 MHz)***).
  - Higher concurrent requests
  - Faster interrupt servicing (bus message versus I/O cycles)
- Streaming Single Instruction Multiple Data Extension 2 (SSE2) with 144 new instructions that deliver 128-bit SIMD integer arithmetic operation and 128-bit SIMD Double-Precision Floating Point to reduce the number of instructions to complete a task or program, effectively increasing IPCs.

Impact of DirectX 8.0

Optimized usage of SSE/SSE2 extension and code flow optimization to take advantage of the new NetBurst micro-architecture, allow graphic drivers to make use of DirectX 8.0 programmable vertex and pixel shaders to produce significant performance gains as illustrated in Figure 6.



Test	Perf. Delta with DirectX 8.0
3D Winmark 2K	62.48%
Speedway	151.37%
Hanger	26.65%
Rust Valley	26.12%
Canyon	149.42%
Chamber	13.77%
Stations	123.21%
Islands	97.70%
Racetrack	59.46%
Chapel	92.03%

Figure 6: DirectX8 Performance Improvements