Affordable Power for Workstation Applications

Intel® Pentium® III Processor
Intel® 840 Chipset

October 1999
Intel Corporation

Table of Contents

List of Figures

Executive Summary

e-Business growth demands that companies outpace competitors in new product and service development. Doing this requires the fastest possible workstations on designers' and analysts' desktops to speed creativity, design, visualization, and analysis. Intel-based workstations based on the new Intel® Pentium® III processor with advanced transfer cache, advanced system buffering, and multiprocessing give companies the performance and productivity they need to stay ahead. With AGP Pro graphics and the Intel® Scalable Bandwidth Technology of the Intel® 840 Chipset, workstation users are able to meet ever more stringent time-to-market pressures for efficient designs, attention-grabbing creativity, complex data visualizations, and in-depth analysis.

Intel's new entry-level workstation technology delivers the design performance required by new product and service developers worldwide. For example, the Pentium III processor provides an average 32 percent performance boost over legacy systems using AutoCAD* 2000 (see Figure 5).

In the Internet economy, products and services are being introduced at ever shorter intervals. No longer can a company make a product or provide a service in isolation. Collaboration is key to success. Intel-based workstations are driving down the cost of workstation ownership and becoming the creation and collaboration vehicles of choice. By using intranets and extranets, businesses are able to do rapid prototyping in a virtual, collaborative environment. This leads to better products produced faster. With powerful, low-cost workstations on designers' desks, suppliers can provide digital designs rather than just mockups. Once a product or service is designed, companies can use an integrated supply chain to get customers the right information while reducing overhead and increasing forecast accuracy.

Intel-based workstations are being used to bring many of these new products and services to market faster, with higher quality and reduced costs. Companies using Intel-based workstation get faster prototyping, faster virtual designs, the ability to manage their supply system online, and unprecedented price/performance. High-performance Pentium III processor-based workstations shorten the distance from thinking to seeing, from idea to success.

Intel® Pentium® III Processor Micro-architecture and Workstation Benefits

Today's new high-performance Intel Pentium III processor-based workstation allows Internet developers, product designers, and financial professionals to create, design, visualize, analyze, and collaborate with colleagues faster and more clearly than ever before. Processing speeds of up to 733 MHz, a new advanced transfer cache with advanced system buffering, and an enhanced front-side bus are among many features designed to accelerate performance for all workstation market segments.

The Intel Pentium III processor is designed to bring tremendous processing power and an attractive price-point to entry-level

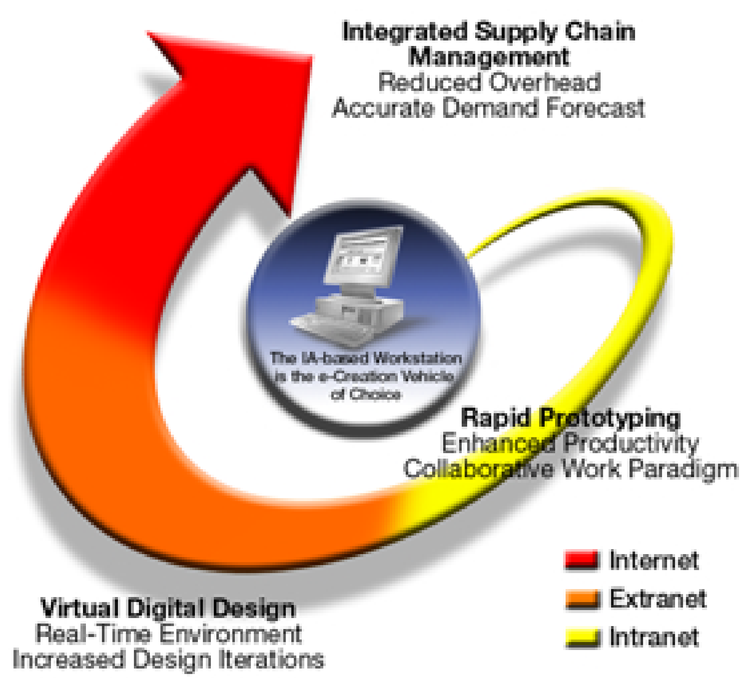

Figure 1. Effective e-Business collaboration with Intel® Architecture-based workstations, the e-Creation Vehicles of Choice

workstations. Design objectives included optimizing the use of Intel's new 0.18 micron semiconductor process, which provided significant performance improvements and headroom. Key design features include:

- Speeds of up to 733 MHz
- Advanced 256 KB Transfer Cache
- 32 KB non-blocking Level 1 cache to provide fast access to heavily used data
- Advanced System Buffering
- 133 MHz system bus designed to support the Intel 840 Chipset
- P6 Dynamic Execution micro-architecture including multiple branch prediction, data flow analysis, and speculative execution
- Dual Independent Bus (DIB) architecture increases bandwidth and performance

Some of these features are discussed here in detail.

Advanced Transfer Cache

The advanced transfer cache—previously known as the Level 2 cache—consists of micro-architectural improvements to provide a higher data bandwidth interface into the processor core. The advanced transfer cache performance is also completely scalable with the processor core frequency. The advanced transfer cache features:

- Full-speed 256 KB on-die Level 2 cache
- 8-way set associativity
- 256-bit data bus to the Level 2 cache
- Reduced latency interface to cache data (as compared to discrete caches)

The advanced transfer cache delivers significant performance benefits to workstation users. The increased bandwidth delivers 32 Bytes every two clocks (11.7 GB/sec at 733 MHz), is fully scalable with the core processor frequency, and enables full system bus utilization. There is a greater than four times reduction in CPU clock latency over the previous Pentium III processor version, which decreases the penalty of L1 cache misses and reduces snoop stalls. Lastly, the 8-way set associativity increases cache performance for real applications, providing a benefit for integer and workstation workloads.

Advanced System Buffering

Advanced System Buffering increases the utilization of the available bandwidth on the 133 MHz system bus, thus optimizing the fast system bus. It delivers a balanced increase in buffers to minimize bottlenecks. Advanced System Buffering provides:

- Six (6) fill buffers, providing a 50 percent increase in concurrent non-blocking data cache operations
- Eight (8) bus queue entries, allowing more outstanding memory/bus operations
- Four (4) writeback buffers, which reduce blocking during cache replacement operations and faster de-allocation times for multiple fill buffer

Intel® Internet Streaming SIMD Extensions

The Intel® Internet Streaming SIMD Extensions consist of 70 instructions, such as single instruction, multiple data for floating point, and additional SIMD-integer and cacheability control instructions. Streaming SIMD Extensions bring several benefits to workstation users and Internet applications:

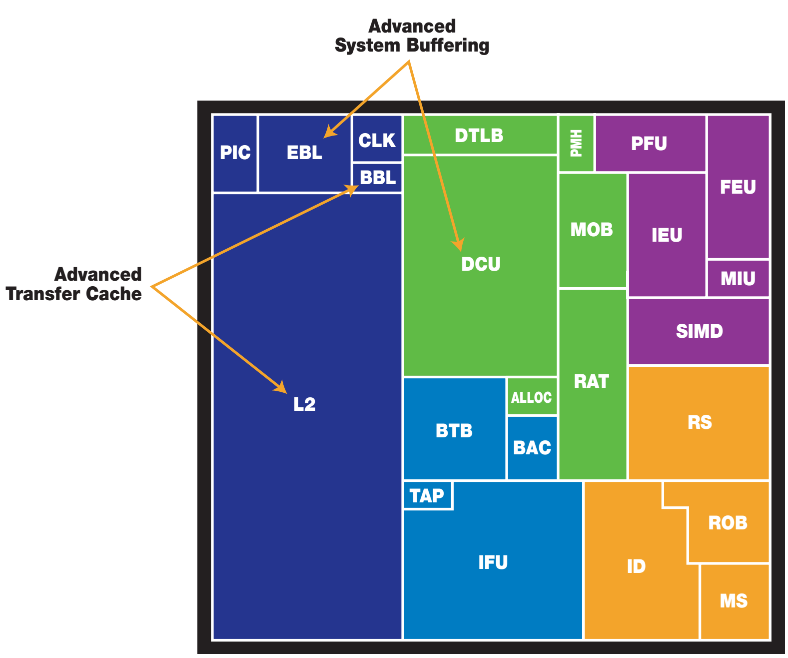

Figure 2. The new Intel® Pentium® III .18 micron microarchitecture

- Higher resolution and quality images can be viewed and manipulated
- Higher quality audio, MPEG2 video, and simultaneous MPEG2 encoding and decoding
- Reduced CPU utilization for speech recognition, as well as higher accuracy and faster response times

Dozens of independent software vendors support the Intel Streaming SIMD Extensions, using it to achieve significant application performance improvements.

P6 Dynamic Execution Microarchitecture

The Pentium III processor is built on the P6 Dynamic Execution microarchitecture delivering great performance to workstation users. Multiple branch prediction forecasts program execution through several branches, accelerating the flow of work to the processor and eliminating wait time. Data flow analysis finds data dependencies between instructions and creates an optimized, reordered schedule of instructions. Again, the result is less wait time for processors and more productive processing. Speculative execution allows this optimized schedule of instructions to execute randomly, ensuring that the processor's superscalar execution units remain busy and boosting overall performance.

Features for Testing and Performance Monitoring

The Intel Pentium III processor includes a number of features that facilitate performance monitoring and testing. The Built-In Self Test (BIST) provides single stuck-at fault coverage of the microcode and large logic arrays, as well as testing of the instruction cache, data cache, Translation Lookaside Buffers, and ROMs. The IEEE 1149.1 Standard Test Access Port and Boundary Scan mechanism enables testing of the Pentium III processor and system connections through a standard interface. There are internal performance counters for performance monitoring and even counting.

Benefits of Multiprocessing

The Pentium III processor utilizes a GTL+ bus that provides glueless support for up to two processors. This enables system integrators to use Pentium III processors to provide low-cost, two-way symmetric multiprocessing systems that deliver significant performance gains for multitasking systems and multithreaded applications. Benchmarks show that you can improve productivity up to 97 percent by configuring your Intel-based workstation with two processors (see Figure 8). The benefits of multiprocessor workstations come from multitasking and multithreading.

Multitasking

Multitasking is nothing more than running multiple applications at the same time on a computer. It could be multiple copies of an application or several different applications, but the important factor is that these applications run at the same time. At present, most people using workstations do this every day. The extent to which users benefit depends on how much time is spent doing concurrent execution of applications. With workstations based on the Intel Architecture, it doesn't take much time to cost-justify a dual-processor workstation. In many cases, the incremental Intel processor can be cost-justified in as little as four to eight work weeks. For more information, go to http://www.intel.com/go/workstations/, then click on "Multiprocessing" and check out the cost-justification calculator.

Multiprocessing capability is important to users of multiple, concurrently executing single-threaded applications. With long-running engineering simulations, analyses, graphics, image processing, and software compilations running on one processor in the background, multiprocessor workstation users can prepare reports, do spreadsheet calculations, and prepare presentations on a second processor in the foreground. Alternatively, multiple simulation or analysis runs can be done simultaneously on a multiprocessor workstation.

The Pentium III processor provides excellent multitasking workload performance, since its large advanced transfer cache allows large amounts of data to be stored locally and accessed quickly. Also, the high bandwidth, split-transaction system bus allows multiple processors to effectively share the system bus, increasing bus utilization and minimizing bus contention.

Multithreading

Multithreading is a programming technique that enables an application to take advantage of the processing power of a multiple-processor system configured as a single computer system. This allows applications to run parts of their workload in parallel, where possible. There are many different ways to exploit parallelism. Some of these include performing the same operation on different sets of data in parallel, performing various operations on independent sections of data, or separating the "number-crunching" part of an application from user-interface operations (which provides noticeable improvement in user interaction with the system). Multithreaded applications provide significantly more flexibility and efficiency in the allocation of resources to application software, and they represent the direction in which an increasing number of applications are moving.

Many applications are being written specifically to take advantage of multiple processors to provide the dramatic performance gains that help companies maintain their competitive edge. Currently, applications from such diverse disciplines as image processing, mechanical design automation, chemistry, fluid dynamics, finance, and video editing all have the capability of executing multiple threads using the multiprocessing capabilities of Pentium III processor-based workstations. As even more applications are developed to exploit the benefits of multithreading, multiprocessor workstations will provide an even more critical performance edge.

Intel® 840 Chipset and Workstation Benefits

If Intel only increased the performance of the processor, the CPU engine would outstrip the rest of the system-I/O, memory, graphics. To make sure that workstation users take full advantage of the power of the Pentium III processor, Intel has increased the bandwidth of its chipsets.

The Intel® 840 Chipset manages traffic from I/O drives, memory, graphics, and the processor(s). The Intel 840 Chipset delivers a performance leap in each of these categories for workstation users. It supports dual processors, a 133 MHz front-side bus, two memory channels for 3.2 GB/sec throughput, AGP 4X graphics with the AGP Pro 50/110 graphics card, and dual PCI bus. It delivers significantly increased system bandwidth over its predecessors in the key areas of memory, I/O and graphics subsystems. This bandwidth delivers outstanding performance in multiprocessor systems, while also enabling the use of high-bandwidth peripherals through a 533 MB/sec PCI-64 bus and a high performance AGP port.

Processor Support

The Intel 840 Chipset supports the latest Pentium III processors. It can support dual-processing configurations using a 133 MHz system bus.

I/O

The Intel 840 Chipset embodies a new interconnect architecture (Intel Accelerated Hub Architecture) that transitions the PCI bus to a peripheral role in favor of the use of high-speed low pin-count buses. This new architecture doubles or quadruples aggregate bandwidth in every critical area over that of its predecessor, the 440GX. The Accelerated Hub Architecture provides up to 800 MB/sec of I/O bandwidth, supporting both 32-bit and 64-bit PCI segments. It also supports the 133 MHz processor system bus introduced on the Pentium III processor; the Pentium III has an enhanced bus interface and is capable of fully exploiting this bandwidth.

Memory

The Intel 840 Chipset supports the next-generation memory technology, Direct Rambus* DRAM (RDRAM*). Two Rambus channels provide the highest memory bandwidth in any high-volume Intel-based platform. The Direct Rambus interface represents a new approach to memory interfacing. The 12 address bits, 4 control bits and 64 data bits of a conventional memory array are replaced by a single 16-bit bi-directional bus, clocked on both edges of a high-speed 400 MHz clock and providing maximum data transfer rates of 1.6 GB/sec per device. The bus now carries commands to the memory, and transfers data in both directions in response to these commands. The lower pin count of the Rambus interface allows designers to accept a more challenging electrical design task in exchange for relatively simple, easily-manufactured designs that can deliver high data rates with a minimum component count. The low pin count allows channels to be easily added to a controller, providing a practical method to scale bandwidth for several generations of chipset. This is manifested in the Intel 840 Chipset, which uses two memory channels.

Initial Direct Rambus memory modules will be available with transfer rates of 600, 700 and 800 MHz and will be designated as PC600 and PC800 memory respectively. The Intel 840 Chipset supports PC600 & PC800 to enable system and memory manufacturers to optimize performance, yield and cost.

Graphics

AGP Pro, an extension of the AGP specification, provides more power and cooling capability to the graphics subsystem. This support system enhancement permits the design of graphics cards with powerful processors and large memory capacities; otherwise, the signals and the protocols remain identical to those in the original AGP specification.

The AGP architecture was developed to address the ever-increasing bandwidth needs of graphics accelerators. The initial implementation, AGP 2X, delivered double the bandwidth of PCI. Consequently, it was connected directly to the memory controller to avoid total overload of the PCI bus. AGP Pro supports the transfer rates supplied by the AGP 2X or AGP 4X specification and power requirements up to 110 Watts. The additional graphics bandwidth provided by AGP 4X demands a corresponding increase in main memory bandwidth, delivered by the use of the 3.2 GB/sec Direct Rambus interface. In conjunction with the Pentium III processor with Internet Streaming SIMD Extensions and AGP Pro, the Intel 840 Chipset opens up new opportunities for advanced graphics systems.

The Intel® 840 Chipset Architecture

Previous generation chipsets used the PCI bus to connect the north and south bridges of the chipset. However, with the Intel 840 Chipset, the PCI bus has been moved to become an extension of the I/O Controller Hub. The Intel Accelerated Hub Architecture is used to connect the Memory Controller Hub to the I/O Controller Hub and PCI-64 Controller Hub. The hub architecture partitions the system into three major components. It is distinguished by its use of a very high-bandwidth, reduced pin-count interface called the hub interface. The hub interfaces provide increased bandwidth of 266 MB/sec and 533 MB/sec with just 16 pins and 25 pins, respectively. Its bandwidth and architecture allows the chipset to deal effectively with isochronous data without the bottlenecks associated with the PCI protocols. This bandwidth is achieved through the use of very high clock rates, differential signaling on the strobe line, a reference voltage signal that guarantees reliable switching, and a compensation signal that allows the chip to match its buffer characteristics to those of the printed circuit board.

Intel® Pentium® III Processor Benchmarks

Accelerating Creation, Design, Visualization and Analysis for e-Business

Design

- **AutoCAD 2000*/CADALYST99***

  AutoCAD 2000*, a product of Autodesk, Inc., is the base platform for a family of Autodesk products for the mapping, mechanical, architectural and civil/

AGP Pro Graphics

The AGP Pro specification enables high-performance graphics cards that contain larger numbers of specialized components. AGP Pro 50 supports cards that draw up to 50 watts of power, and AGP Pro110 supports power requirements of up to 110 watts. Some of the performance components typically integrated into these board designs include:

- Larger memory for texture, depth, and display data
- Faster geometry processors for calculating transform movements, set-up data, and lighting values of polygons
- Faster rasterizers for filling in polygons with texture data
- Higher resolution frame buffers for output display

AGP Pro defines the electrical/mechanical/thermal specification, not AGP bus speed. AGP Pro cards can be either AGP 2X or AGP 4X. The AGP bus is scalable-1X, 2X and now 4X, independent of AGP Pro. The AGP bus bandwidth increases from PCI at 132 MB/sec to AGP 4X at 1 GB/sec.

survey/land and entry-level design markets. The benchmark, C99 version 2.1 2D/3D, which was created by CADALYST Magazine* (http://www.cadonline.com/ cadbench.htm), shows the graphics performance improvement realized in AutoCAD 2000. The benchmark measures 2D and 3D performance of typical end user functions on eight different drawings by generating metrics of indices.

Creation

- **Microsoft Windows* Media Encoder* 4.0**

  Microsoft Windows* Media Encoder* 4.0 from Microsoft Corp. encodes audio and video content into an Advanced Streaming Format (ASF) stream. The content can be from a live source or an existing .avi, .wav, or .mp3 file. The output from Microsoft Windows Media Encoder is a stream of information that can be heard or viewed with Microsoft Windows Media Player or sent to a Windows Media Player server for multicasting or storage. This application tests the MPEG-4 Video Codec using 30-second 320 x 240.

- **3D StudioMAX***

  3D StudioMAX* is a popular 3D modeling and animation software from Autodesk's Multimedia division called Kinetix*. It is a 32-bit, multithreaded application written exclusively for Microsoft Windows NT*. The results reported here are based on a workload-developed version 3.0 of 3D StudioMAX. The current workload is only one example of an infinite combination of functions that a user could exercise in the 3D StudioMAX environment.

  3D StudioMAX's strength lies in using plug-ins to extend its baseline feature set. The workload does not feature any additional plug-in besides the default plug-ins that ship with 3D StudioMAX. However, an attempt was made to include a wide variety of operations that may be expected to be commonly exercised. The workload has 13 sessions, where each session features a different set of operations or features in 3D StudioMAX.

Visualize and Analyze

- **SPEC95***

  SPEC95* is a set of integer and floating-point benchmarks produced by the Standard Performance Evaluation Corporation. SPEC95 provides a standard for comparing compute-intensive workloads on different computer systems. SPEC95 consists of two suites of benchmarks: SPECint95 for measuring and comparing compute-intensive integer performance, and

The Intel® OR840 Workstation Board

When the Intel Workstation Products Group decided to build an entry-level workstation board, they had specific goals in mind. First, they wanted performance that provides workstation users with a viable solution to their performance needs. Performance had to be superior to that in products available in the consumer and business desktop arena. Second, they wanted a board with standard ATX dimensions (9.6" x 12"), which would increase the number of available chassis and keep costs down. Finally, they wanted to keep overall system costs down.

The team chose the Intel 840 Chipset to help meet each of these goals on what became the Intel® OR840 workstation board. The Intel 840 Chipset offers dual RDRAM channels for a whopping 3.2 GB/sec of memory performance. This is two times the memory performance offered on the latest desktop products and four times the performance of previous-generation products. This gave the team the performance they were looking for. In addition, the dual RDRAM channels allowed designers to put 4 RIMM sockets on the board offering additional memory scalability and flexibility.

The Intel 840 Chipset also helped the team hit its size and cost targets. The flexible Intel 840 Chipset architecture gave them choices in crafting their solution. The team chose not to use the 64 bit PCI controller or the memory repeater hubs offered with Intel 840 Chipset. As a result, they achieved their ATX form factor goal and kept costs down.

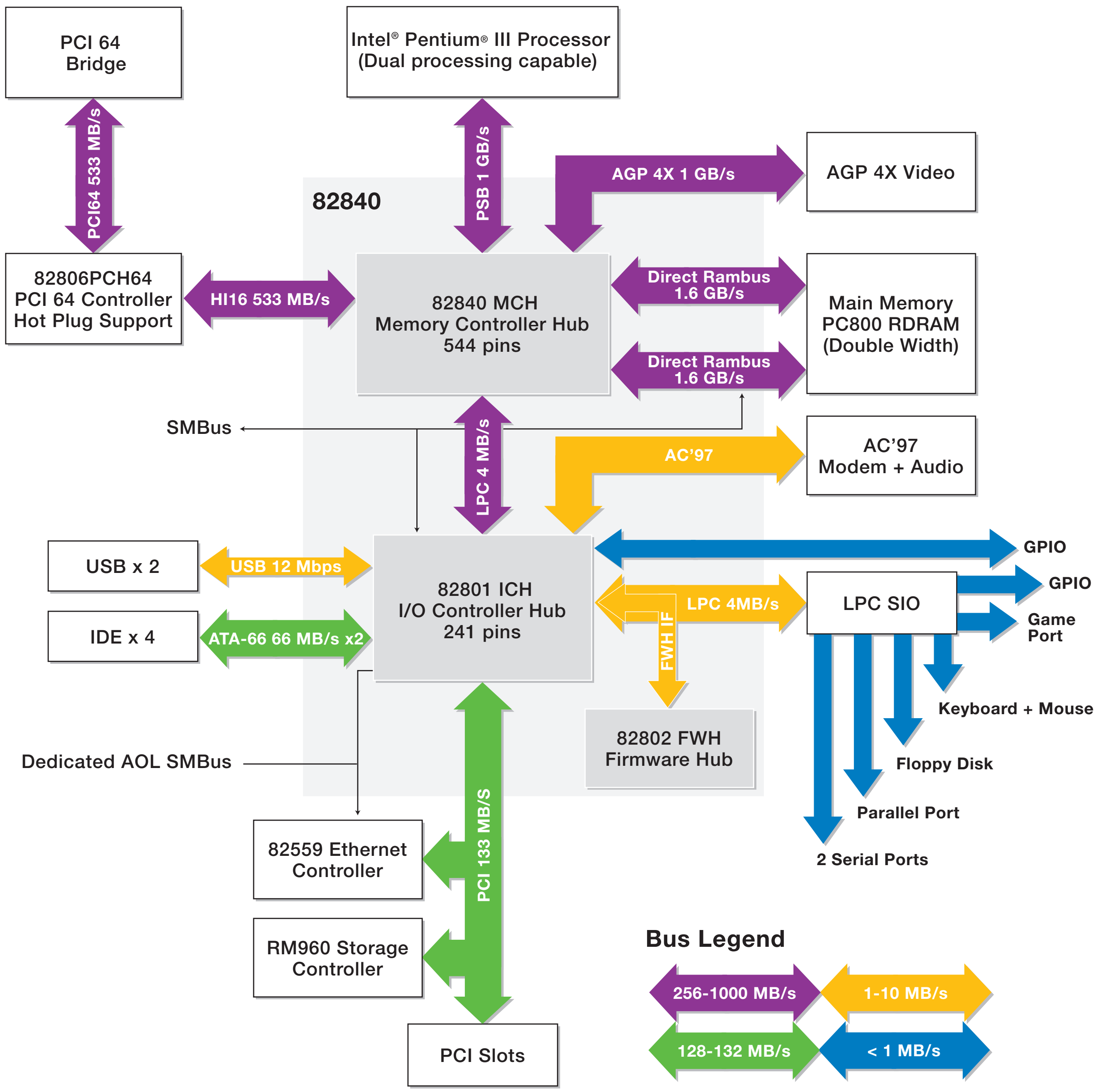

Figure 3. The Intel® 840 Chipset system architecture design

SPECfp95 for measuring and comparing compute-intensive floating-point performance. The two suites provide component-level benchmarks that measure the performance of the computer's processor, memory architecture and compiler.

Multiprocessing

- **SPECint_rate95 and SPECfp_rate95**

  SPECint_rate95 and SPECfp_rate95 peak results execute two copies of the respective benchmark components at the same time and measures the resulting throughput on Pentium III processors. These are dual-purpose benchmarks. Whereas SPECint95 and SPECfp95 measure compute-intensive performance, SPECrate is a capacity measure. It is not a measure of how fast a system can perform any task; rather it is a measure of how many of those tasks that system completes within a specified time interval.

- **Windows* Media Encoder***

  Microsoft Windows Media Encoder 4.0 is executed here as part of Intel's Business Application Launcher version 1.2 in a dual processing mode.

The Nature of Benchmarks

The advantages of the Intel Pentium III processor are borne out in the performance of systems running standard benchmarks. Benchmarks provide a means of comparing the performance of different systems, their goal being to provide insight into how an application will run on a given system.

Two types of benchmarks are important in evaluating performance:

- Component benchmarks measure the performance of specific elements in a computing system: the processor, hard drive, or geometry accelerator. These benchmarks exercise particular system components by executing programs which themselves utilize mainly one component. For example, processor speed benchmarks are processor-bound programs, which make little use of memory and I/O resources. Since applications utilize all system components to varying degrees, it's important to take care in making application performance assumptions from component benchmark results.

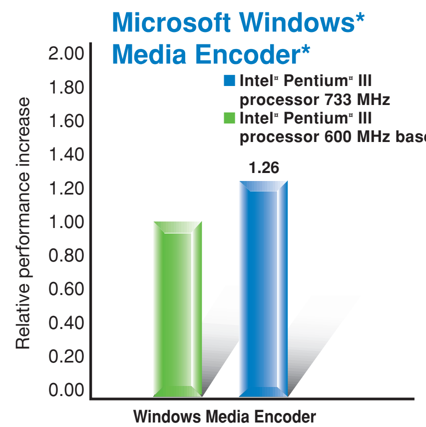

Figure 4. The new Intel® Pentium® III processor 733 MHz on a new Intel® 840 Chipset-based platform compared to the Intel® Pentium® III processor 600 MHz on a 440GX AGPset-based Intel validation platform.

Source: Results performed by Intel. Please refer to the Performance Report Notice at the end of this document. For system configuration, see Benchmark System Configurations at the end of this document.

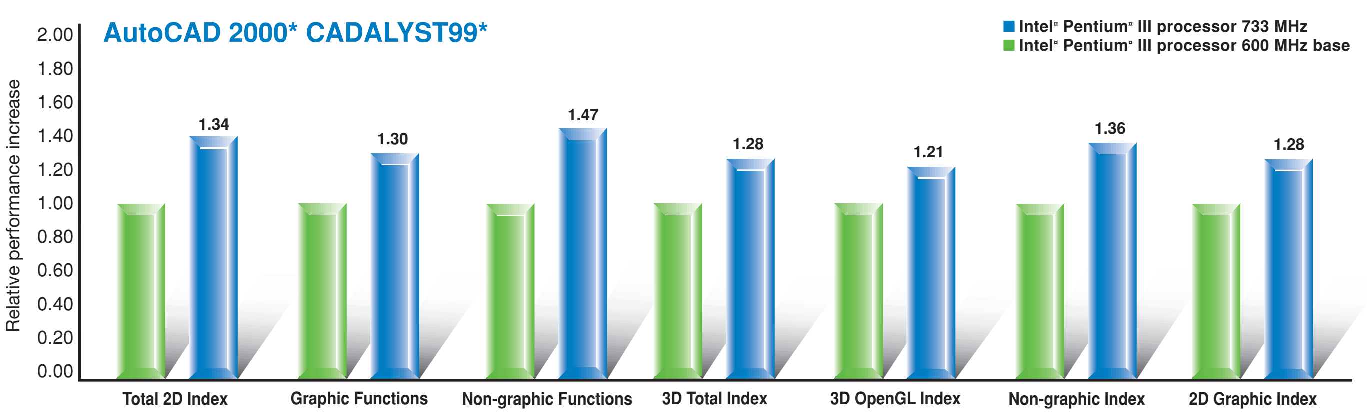

Figure 5. The new Intel® Pentium® III processor 733 MHz on a new Intel® 840 Chipset-based platform compared to the Intel® Pentium® III processor 600 MHz on a 440GX AGPset-based Intel validation platform.

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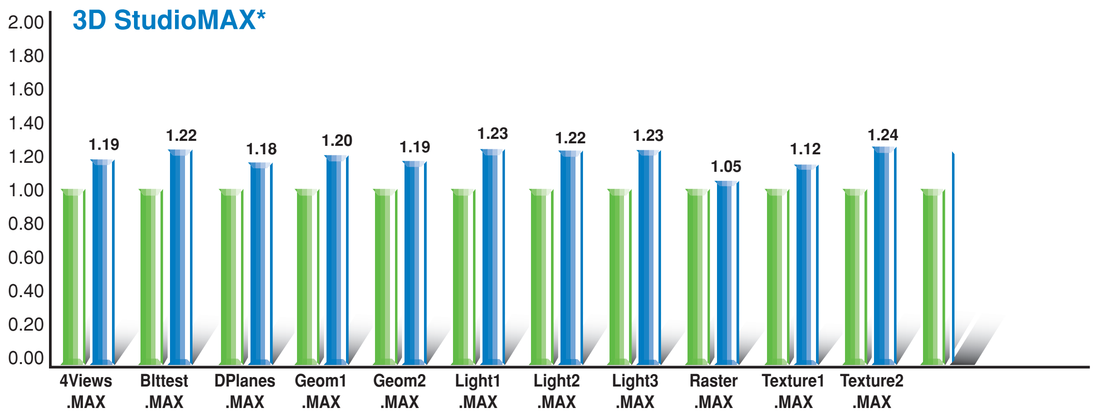

- Application benchmarks measure the performance of applications that are run by users. Because application benchmarks measure the overall performance of the various components of a system working together, they can be a more accurate predictor of the performance that users will see with their applications. Although application benchmarks are better predictors of application performance, it is important to carefully evaluate the similarities and differences between the real workload and that executed by the benchmark.
- Performance as reported by standard benchmarks is likely to vary from the observed performance on real workloads for two reasons:
- Benchmark results published by Intel are measured on specific systems and components using specific hardware and software configurations. Differences between Intel's configurations and other configurations will yield varying results. Differences in application and benchmark software revisions, compilers, and operating system versions may also affect measured performance.

- Application benchmarks may or may not exercise the system and the application in ways that are representative of the way an application is actually used. This includes not only the application features that are executed, but also the size and the nature of the data sets they manipulate as well. The best way to predict performance is to run the actual application and workload on the target system.

The Pentium III processor is designed for demanding workstation applications. Many workstation application benchmarks utilize small data sets compared to what can be expected in real workloads. When the same benchmark applications are executed with more realistic data sets, one can usually expect a greater performance advantage. This ensures growing room for both future releases of workstation applications as well as for their data sets.

Benchmark System Configurations

Hardware

Processor	Intel® Pentium® III Processor 600 MHz	Intel® Pentium® III Processor 733 MHz
L2 Cache	512 KB	256 KB Advanced Transfer Cache
Motherboard or System	Tyan S1837UANG Thunderbolt*	OR840
Memory Size and Type	PC100 SDRAM, 512 MB, ECC Enabled	PC800 RDRAM, 512 MB, ECC Enabled
Graphics Adapter (2D/3D)	3DLabs Oxygen VX1 32 MB AGP 2x (Internet Streaming SIMD optimized)	
Graphics driver for Windows NT* 4.0	2.14-0919 driver for Windows NT* 4.0 with NT service pack 4 installed	
Resolution /Colors	1024 x 768 true color (60 Hz) for all benchmarks except SPECviewperf 6.1.1	
Hard Disk	Seagate Cheetah* ST39102LW 10,000 rpm SCSI, 9.1 GB	
Disk Controller	Adaptec AHA2940U2W SCSI/PCI	
CD ROM Drive	Toshiba 32x XM-6201B SCSI CD-ROM Drive	
Network Interface Card	Intel Pro 100b PCI Ethernet LAN Adapter	

Operating System / Software

Windows NT* 4.0	Windows NT* 4.0 build 1381 NTFS partition with Service Pack 4 installed
SPECint95 C Compiler	Intel C Compiler v.4.5 Plug In† (Internet Streaming SIMD optimized)
SPECfp95 FORTRAN Compiler	Intel FORTRAN Compiler v.4.5 Plug In (Internet Streaming SIMD optimized)

†Binaries created with Intel pre-release Intel® Pentium® III processor compiler

References

The following Web sites provide further information on the various benchmarks whose results are reported in this paper:

- **CADALYST*/AutoCAD 2000***
  http://www.cadonline.com/cadbench.htm
- **3D StudioMAX***
  http://www.ktx.com
- **Microsoft Windows* Media Encoder***
  http://www.microsoft.com
- **SPEC95* and SPEC_rate95**
  http://www.spec.org

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SPEC Benchmark Test Notice

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