Intel Architecture MMX™ Technology in Business Applications

June 1997

Order Number 243367-002
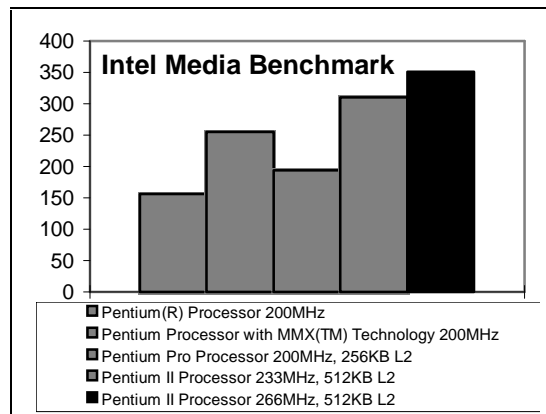
intel ®

CONTENTS

EXECUTIVE SUMMARY

MMX™ technology is Intel's most significant enhancement to the Intel Architecture in the last 10 years, and will enhance the performance of complex media-intensive and communications applications and enable new features and capabilities. MMX technology will have a long-term effect on mainstream business applications, especially as they continue to provide richer content. This trend will continue, and is being accelerated in large part by the mass move to Internet and Intranet technologies, and the inherently rich graphics- and media-intensive nature of these environments.

MMX technology embodies new instructions and data types. These instructions and data types can be used by any type of software, not just multimedia applications. Compression and decompression of files and/or rich content, graphical editing and manipulation, and complex file conversions are examples of common software functionality that will benefit from MMX technology. MMX technology will improve file transfer rates and network performance by enabling faster compression, decompression and smaller file sizes. Intel disclosed details about MMX technology over a year ago. Microsoft, Adobe, and other leading developers have invested significant resources optimizing applications[1] with MMX technology. Existing mainstream business applications are being revised with MMX technology additions and several announcements are expected shortly.

The benefits of MMX technology will continue to become widespread as more applications are designed to take advantage of this technology. MMX technology provides more productive environments, the ability to run more applications at one time, and prevents users from being bandwidth-limited on their systems, saving money in the long run. Software ranging from office applications to Internet/Intranet applications will run faster. For small businesses, MMX technology increases productivity with higher performance systems

for in-house development, reducing the need for expensive outsourcing. Across the board, for large corporations and small businesses, purchasing MMX technology-based systems today prepares your user base for the future, extends the lifecycle of PCs by providing the performance headroom for future applications, and reduces long-term capital costs.

By accelerating basic underlying operations (details below), MMX technology can yield a significant performance improvement, as in the 7x improvement[2] experienced by image processing applications. Intel first introduced the Pentium® processor with MMX technology and will continue to incorporate MMX technology into **all** future Intel Architecture microprocessors. The Pentium II processor, targeted at business desktop users, combines the Pentium Pro processor's 32-bit architecture with MMX media enhancement technology and systems are expected in the second quarter of 1997. Overall scores on the Intel Media Benchmark with the 266 MHz Pentium II processor with MMX technology show a 225%[3] increase over the 200 MHz Pentium processor.

Intel Media Benchmark

(bar chart showing values from approximately 150 to 350 on a scale of 0 to 400)

- ■ Pentium(R) Processor 200MHz
- ■ Pentium Processor with MMX(TM) Technology 200MHz
- ■ Pentium Pro Processor 200MHz, 256KB L2
- ■ Pentium II Processor 233MHz, 512KB L2
- ■ Pentium II Processor 266MHz, 512KB L2

Those in a position to specify and purchase systems for use with Internet technology need to look forward as they deploy the next wave of information systems. By mid-1998, **all** Intel microprocessors for PCs will incorporate MMX technology. To provide the most performance headroom for the future, corporations should

---

[1] Microsoft Internet Explorer*, Netshow*, NetMeeting* and Adobe Photoshop*, PhotoDeluxe* and several other MMX™ technology-optimized examples are discussed ahead.

[2] Based on the score improvement for Image Processing in the Intel Media Benchmark. See Appendix A for details.

[3] See Appendix A for details and selected individual scores.

evaluate and qualify new MMX technology-based systems.

Although this white paper cannot cover all software vendor efforts underway, it discusses:

- *How* MMX™ technology delivers higher performance

- *Where* this technology applies to business applications, and

- *Examples* of optimized applications available today.

Three appendices detail **tools**, **performance benchmarks** and additional **technical details**.

INTEL MMX™ TECHNOLOGY OVERVIEW

The definition of MMX technology resulted from a focused joint effort between Intel's microprocessor architects and developers from leading software companies. A wide range of software applications were analyzed, including graphics, audio and video, compression and decompression algorithms, speech recognition, image processing, conferencing and others. Advanced computer-aided engineering tools were used to identify the most compute-intensive routines. Despite the diversity of applications, the analysis revealed several underlying commonalties. Many algorithms used multiple repetitive loops and operated on small data quantities. While these loops occupied less than 10% of the overall application code, they accounted for up to 90% of the execution time. These analyses fed the design of MMX technology, which boosts the performance of these frequently executed common functions with new instructions and enhanced hardware execution capabilities.

New MMX technology instructions allow several small data quantities to be concatenated into a single larger quantity, permitting rapid, parallel computations on multiple data quantities at once. For example, graphics information is commonly represented in small, 8-bit, byte-sized quantities. Previously, manipulating 8 bytes of graphics data required 8 repetitions of a single instruction. The same manipulation can now be performed with a single MMX technology instruction, operating on all 8 bytes simultaneously. The result: an 8x improvement in execution time. This speedy, parallel processing of combined data quantities is termed the Single Instruction Multiple Data

(SIMD) model, in contrast to the older, less-efficient scheme where a single instruction operated on a single piece of data. To provide maximum flexibility, 57 new 'MMX technology instructions' and 4 new data types were added[4]. These features result in many more calculations performed for each clock cycle of the processor, yielding faster execution times and higher performance[5].

To accelerate the adoption of this advanced technology, the Intel Architecture MMX technology instruction set was designed and implemented in a transparent way that requires no changes to existing operating systems.

NOTE

All existing software continues to run correctly, without modification, on Intel microprocessors that incorporate MMX technology.

MMX™ TECHNOLOGY'S KEY BUSINESS BENEFITS: PERFORMANCE AND APPLICATION VIABILITY

MMX technology brings several tangible benefits to business users. These benefits span the spectrum of increasing overall application, system, and network performance, to expanding and bringing more power to the Internet/Intranet, to making innovative new media-rich and communications applications viable in mainstream business.

MMX™ Technology Benefits Application, System and Network Performance

The powerful parallelism inherent in MMX technology permits highly efficient processing and reduced processor utilization for compute-intensive tasks on large data files (common in image, audio/video data, etc.) without sacrificing system performance. This unleashes processing power for other concurrent or

---

[4] See Appendix B for more technical details.

[5] See Appendix A for performance benchmark details.

background activities like network operations. For example, while an image is being decompressed with the aid of MMX technology, or downloaded from the web, other applications can execute in parallel without degraded performance. Not only does this increase application and overall system performance, but network performance is enhanced, since the processor now has more time to service network requests while executing multiple host or server (and therefore network-serviced) applications.

Rapid compression and smaller file sizes due to improved compression ratios combine to reduce network traffic even further, benefiting all network users. This also benefits mobile laptop users using modems by reducing file transfer time, connect-time and storage space requirements. Reduced processor utilization by an application lets all users experience faster system and network response times. As a result, users become more productive since they spend less time waiting on compute-intensive tasks. In the future, Accelerated Graphics Port (AGP) technology will further enhance MMX technology-based 3D graphics performance.

MMX™ Technology Makes New Business Applications Viable

MMX technology benefits were never intended to be restricted to a handful of applications. Instead, Intel designers focused on accelerating the basic 'nuts and bolts' functions required by a very wide array of software. This allows MMX technology to improve the performance of a diverse range of applications. Many of these applications are directly tied to new capabilities in business software, especially in Internet/ Intranet applications. Some examples where MMX technology is expected to have the greatest impact are:

- Audio and video-enabled applications in web plug-ins, interactive training, customer self-service, real-time audio and video streaming and videoconferencing

- High-performance image processing, 3D graphics and data visualization, web publishing and content creation

- Intelligent content-based searches of large graphics, audio and video databases

- CAD/CAM model viewing and manipulation

- Security applications, video scene detection, face/fingerprint recognition and watermarking technology

Intranet-based employee training, for example, a natural extension of traditional computer-based training, is enhanced by audio and video components where MMX technology vastly improves the performance of underlying compression, decompression and playback algorithms. The resulting richer training content keeps audiences interested, leading to more effective training and retention.

Standard office suites and presentation software will benefit from MMX technology when integrating high quality graphic images or audio/video components into documents and presentations for greater impact. Industry analysts often point to the proliferation of media-rich business applications, which is precisely where MMX technology will best be applied.

MMX™ TECHNOLOGY IN BUSINESS APPLICATIONS: CATEGORIES AND EXAMPLES

Imaging Application Acceleration with MMX™ Technology

The Intel Media Benchmark[6] shows that MMX technology-optimized imaging applications experience exceptional gains in performance: a 266 MHz Pentium II processor delivers over seven times the performance of a 200 MHz Pentium processor on the imaging component of this benchmark. The exploding use of images in business presentations, sales collateral, product catalogs, brochures, newsletters and publishing requires efficient image management and manipulation tools. Existing tools can efficiently search, sort and operate on alphanumeric data, but graphic images can only be treated as binary large objects. As such,

---

[6] See Appendix A for details and selected individual scores.

searches can only be performed on textual file descriptors, instead of actual image content.

MMX technology now permits enhanced intelligent search capabilities. For example, Virage's Image Engine* uses MMX technology to search and sort based on an images' intrinsic visual attributes (i.e., by color, structure, texture and color composition) and to accelerate image comparison and large image database traversal. Image capturing, compressing, editing, sharing, archiving, indexing, retrieving and advanced print drivers require a great deal of data manipulation which can be accelerated by MMX technology. Image manipulation functions like filtering, compositing, alpha-blending, chroma-keying, anti-aliasing and color space conversion algorithms are compute-hungry functions suited for coding with MMX technology instructions. Popular applications like Adobe Premiere*, Photoshop*, PhotoDeluxe*, and AfterEffects* applications are all optimized for MMX technology. Adobe's PhotoDeluxe delivers performance gains of up to 200% when working with large images and adding special effects to photographs[7]. Microsoft's Picture It!* incorporates MMX technology to allow high quality photo imaging on desktop systems.

By improving the performance and reducing the execution time for complex filters, MMX technology reduces the number of iterations and thus, the amount of time spent achieving a desired result. For example, a 50-second reduction in manipulating an image seems trivial by itself, but quickly becomes significant for typical users who may make such manipulations numerous times. The acceleration provided by MMX technology allows trial-and-error by novice users, making advanced capabilities possible for non-specialists and small businesses. For experts, this performance allows the creative process to not be interrupted, allows the flow of ideas to continue, and hastens and improves the end-results.

How MMX™ Technology Benefits Compression and Decompression

Media-intensive data is typically quite large and requires compression for practical storage and network or web transmission. Compression and decompression algorithms are broadly used in audio, video and graphics applications for efficient storage and rapid transmission of large data files. MMX technology can significantly

improve the performance of these algorithms. Compression ratio improvements imply smaller compressed image, audio or video files for transmission, reducing network traffic and thereby improving network performance for all users in the organization. Through new data types and instructions, MMX technology greatly speeds byte-level compression. Coding the underlying algorithms with MMX technology enables a performance increase of up to 3x for JPEG compression and up to 5x for JPEG decompression[8]. These optimizations are being widely proliferated into various business applications currently in development. Pegasus' PICTOOLs* toolkits use MMX technology for faster image compression and decompression and see up to a 2x to 3x performance improvement over non-optimized versions.

Video, Communications and Conferencing Applications

MMX technology addresses some of the barriers to real-time video streaming over the Internet and corporate Intranets. Real-time streaming media permits viewing and/or listening while files download from the web, instead of waiting for complete file transfers. For example, Microsoft's NetShow* 2.0 is an easy, powerful application for streaming multimedia across the Internet and Intranet. Netshow 2.0 supports a wide variety of industry standard codecs which demonstrate significant gains with the use of MMX technology.

Effective, practical video communications require high quality image transmission and frame rates which can be difficult to achieve over low bandwidth communication infrastructures. MMX technology enhances software-only compression optimized for delivering high-quality video over existing networks and corporate LANs. High compression ratios further reduce the burden on limited network bandwidth. Businesses that deliver video to the desktop extend the

---

[7] Adobe Press Release, 1/27/97.

[8] Intel Architecture Laboratory measurements of the effects of MMX™ technology optimizations on underlying algorithms on a 200 MHz Pentium processor with MMX technology.

training, web-based computer help desks, and Internet communications. Video-enabled Intranet-based training with MMX technology eliminates the high production and distribution costs of hundreds of hours of videotape-based content to offices worldwide. This scheme permits central content management and ensures employees access only the most up-to-date information, and eliminates the need for experts to travel internationally to deliver live training at each site.

Videoconferencing naturally benefits from MMX technology's ability to accelerate communication, compression, and decompression of audio and video data streams. MMX technology enables professional quality videoconferencing by *doubling* frame rates previously achievable. The graph below illustrates the impact of MMX technology on Intel ProShare® conferencing frame rates for QCIF[9] image sizes over Plain Old Telephone Service (POTS) vs. ISDN.
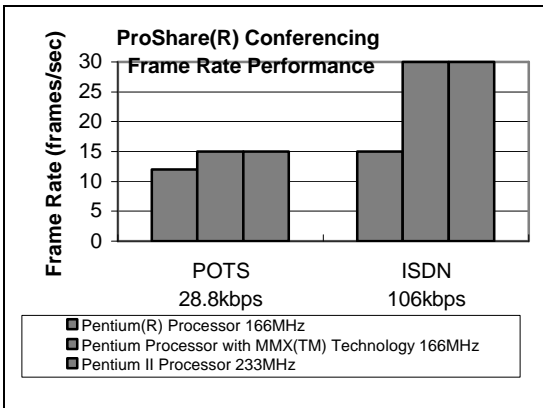
The improved frame rate due to MMX technology shown in the graph above is achieved concurrent with a reduction in processor utilization, increasing the available processor bandwidth for use by other applications or network activity.

Microsoft's collaboration and videoconferencing NetMeeting* software uses specialized codecs with MMX technology to provide enhanced performance for audio/video compression and decompression. These result in lower processor utilization and improved audio/video quality during a call.

---

[9] Quarter Common Interchange Format (QCIF) image size.

Web Browsers and MMX™ Technology

The Gartner[10] Group estimates that 80% of 'knowledge workers' will access the Internet from within PC applications *daily* to do their jobs in the next couple of years. The user's interface to the web via browsers and new plug-ins for viewing graphics and video/audio playback can be significantly improved with MMX technology. Static HTML web sites have already given way to dynamic multimedia interfaces that directly benefit from MMX technology. Microsoft will take advantage of MMX technology using Dynamic HTML's multimedia effects, which will be delivered in Microsoft Internet Explorer* 4.0. MMX technology-enhanced Direct3D* will also be included as an ActiveX* control in Internet Explorer to view 3D Internet content. The binary-to-ASCII text conversion in email and browser-based web interactions via *uuencoding* and *uudecoding* are basic functions which occur very frequently during normal web usage that are greatly sped up by MMX technology. Netscape is expected to include discussion and conferencing clients with audio streaming via plug-ins or Java applets. The Netscape Live3D* plug-in for Navigator* takes full advantage of Intel's MMX technology, giving users the ability to view more complex objects through increased texture and alpha blending, with increased performance.

Accelerating Database Applications with MMX™ Technology

Managing large databases of mixed media assets can be slow or inefficient with traditional databases because searches on complex data are based on textual file descriptions. MMX technology can improve the performance of hybrid object relational databases, which store more types of media data and perform faster complex queries. The Informix content management platform manages both complex and simple data types. Informix Universal Server and Illustra* Server* allow non-traditional data to be stored and manipulated by special MMX technology-optimized database modules called DataBlades*. These modules deliver efficient management of text, image, 2D/3D spatial,

---

[10] Gartner Group, Symposium/ITxpo 96.

2D/3D spatial, HTML, time-series, audio, video and other complex data types. 'Snap-in' DataBlades extend the core database server and client capabilities, permitting dynamic content management via custom indexing, pattern matching on complex data types, graphics, images, video, etc.

CONCLUSION

MMX technology will have a long-term beneficial effect on mainstream business applications and increases system, application and network performance while making innovative new applications viable for wide-scale deployment.

The mass move to Internet/Intranet technologies with rich content will continue, perhaps affecting the workplace as profoundly as word processing and desktop publishing. MMX technology will help remove the complexity and cost associated with sophisticated applications by reducing the need for custom hardware solutions. The industry acknowledges the benefits of MMX technology, demonstrated by the appearance of new and optimized software applications, tools and MMX technology-based systems.

The Pentium II processor extends the performance of the Pentium Pro processor and adds the capabilities of MMX technology. Pentium II processor-based systems will arrive in the second quarter of 1997 as the high-performance business systems of choice. Intel will promote the continued success of MMX technology by continuing to provide extensive developer support, and by incorporating MMX technology in all future microprocessor offerings. Collectively, these activities will proliferate higher quality applications and platforms to business users worldwide, enabling enhanced communications and higher productivity for employees who take advantage of MMX technology. By mid-1998, **all** Intel Architecture microprocessors will incorporate MMX technology. To take maximum advantage of this direction, and to prepare the installed base and provide the most headroom for high-performance applications, ensure that new systems contain microprocessors with Intel MMX technology.

# APPENDIX A: QUANTIFYING THE PERFORMANCE BENEFITS OF MMX™ TECHNOLOGY

Users are accustomed to periodic software upgrades that deliver performance benefits without modifications to underlying hardware. Such improvements are often achieved by specialized compilers or improved coding techniques. However, the significant performance acceleration via routines optimized for MMX technology will only be apparent on platforms with microprocessors that incorporate MMX technology. MMX technology-optimized software performs 'processorID' checks to verify Intel Architecture MMX technology instruction set support by the underlying microprocessor, allowing the execution of higher performance optimized routines. Otherwise, older, non-optimized routines must be executed. **Users cannot realize the performance benefits of MMX technology from software upgrades alone:** the client PC **must** be MMX technology-enabled to take advantage of the optimizations. The following benchmarks help quantify the benefits of executing MMX technology-optimized software on PCs with Intel MMX technology microprocessors.

The Norton Multimedia* Benchmark[11] compares a system's multimedia capabilities against the basic Multimedia PC (MPC) Level 2 specification.
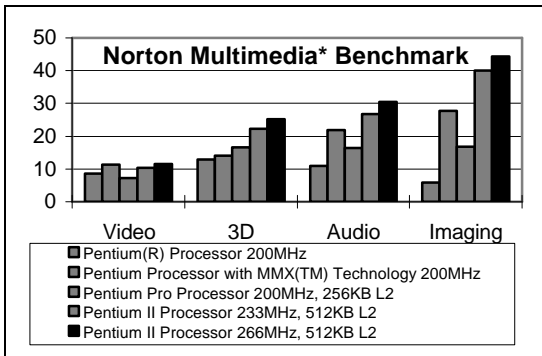
The benchmark reports performance in four multimedia areas: Video (video performance, MPEG* video decompression, AVI video frame rates); 3D (rendering capabilities); Audio (audio mixing and MPEG audio performance); and Imaging (image processing manipulations).

The Intel Media Benchmark[12] is an Intel-developed benchmark which measures multimedia performance. It incorporates audio and video playback, image processing, wave sample rate conversion and 3D geometry. The chart below compares processor performance on Windows* 95.

---
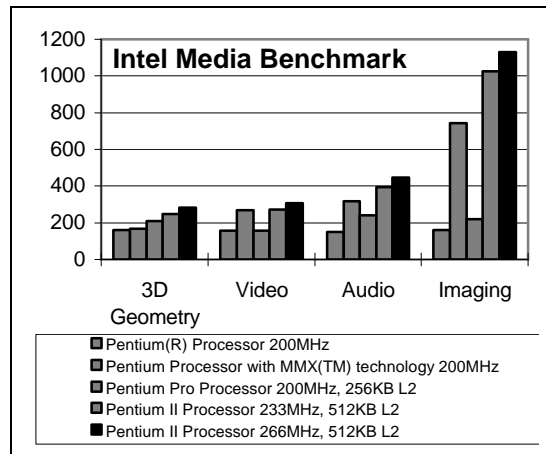
[11] See Appendix D for selected individual component scores and system configurations.

[12] See Appendix D for selected individual component scores and system configurations.

APPENDIX B: ADDITIONAL MMX™ TECHNOLOGY DETAILS

As mentioned in the 'Intel Architecture MMX Technology Overview' above, a wide array of applications were analyzed to determine how new instructions could enhance the performance of the most basic, compute intensive functions. The key attributes of these applications were:

- Small integer data types (for example: 8-bit graphics pixels, 16-bit audio samples)
- Small, highly repetitive loops
- Frequent multiplies and accumulates
- Compute-intensive algorithms
- Highly parallel operations

MMX technology was designed as a set of basic, general purpose integer instructions that can be easily applied to the needs of most multimedia and communications applications. MMX technology is the most significant enhancement to the Intel Architecture since the Intel386™ was introduced in 1985. The highlights of this new technology are:

- Single Instruction, Multiple Data (SIMD) technique
- Fifty-seven new instructions
- Eight 64-bit wide MMX registers overlayed on existing registers
- Four new data types

SIMD Techniques

The Single Instruction Multiple Data (SIMD) technique vastly speeds up software performance by using a single instruction to process multiple data elements in parallel. This parallelism greatly increases performance. The MMX technology supports parallel operations on byte (8-bit), word (16-bit), and double-word (32-bit) data elements, and also the new quad-word (64-bit) integer data type. SIMD is analogous to using a central power switch to turn on 64 lights in an office complex instead of turning on each bank of 8 lights one by one.

For example, the `pmaddwd` instruction allows a 'packed `multiply` and `add` of 4 words into 2 double-words' as visually represented below. Four multiplications and 2 summations are performed in parallel with one instruction:

1 word = 16 bits

a	c	e	g
*	*	*	*
b	d	f	h

a*b + c*d	e*f + g*h
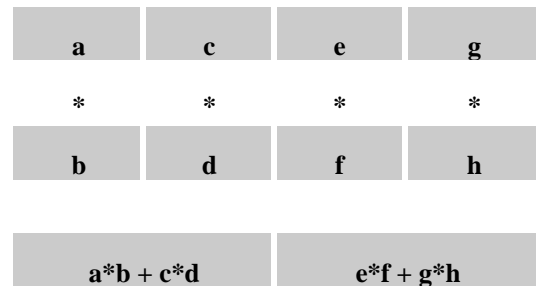
2 double-words = 64 bits wide

APPENDIX C: TOOLS FOR BUILDING AND TESTING NEW MMX™ TECHNOLOGY APPLICATIONS

Since March 1996, when Intel publicly released the details of MMX technology, ISVs have participated in Intel Developer Support Programs, implemented coding enhancements, and used examples, libraries and software performance analysis tools provided by Intel. As a result, tool vendors are prepared with optimized offerings now.

Compiler and debugger support for MMX technology are available in: Microsoft's Visual C++*, Powersoft's Watcom C++ and NuMega

Technologies' SoftICE*. Microsoft also takes advantage of MMX technology in the Direct3D addition to the DirectX* family of interactive media APIs. Direct3D, currently shipping with Windows 95 and planned to ship with Windows NT, offers a highly optimized software-only rendering engine with transparent, high-performance, device-independent services. Superscape's implementation of Direct3D with it's own rendering technology offers new features to application and content developers using Superscape real time 3D authoring tools. Use of the new features (smooth shading, lighting, Z-buffering and transparency) are all greatly accelerated by MMX technology up to 8x over Pentium processor systems without MMX technology.

MMX technology-enhanced authoring tools are available from Macromedia, Inc. Director*, provides timing and interactivity for media elements such as 2D and 3D graphics, animation, sound, and digital video from a wide variety of sources and can create stand-alone runtime applications. Macromedia expects animation and multimedia playback performance to increase by up to 50% and MMX technology provides a speed-up of up to 40% in 256 color mode using ink bitmap images and animations.

The Intel Signal Processing Library with MMX technology code allows signal processing functions previously requiring DSPs (Digital Signal Processors) to be performed natively on a host Intel Architecture processor with MMX technology. The Intel Recognition Primitive Library provides developers of speech and character-recognition software a set of generic MMX technology-enhanced functions. Intel's web site shows several coding examples of common data manipulation functions accelerated by MMX technology. VTune*, a unique visual performance analysis and software tuning tool for the Intel Architecture locates trouble spots, and offers advice and suggestions on how to maximize code performance using MMX technology.

ADDITIONAL INFORMATION

For more information on MMX technology, please consult the following sources, or your system or software vendor.

- World Wide Web:
  http://www.intel.com
  http://mmx.com
  http://developer.intel.com/drg/mmx

- Intel Literature Center: 1-800-879-4683

- Intel Customer Support: 1-800-628-8686

APPENDIX D: BENCHMARK SCORES AND SYSTEM CONFIGURATION

Table 1: Individual Component Scores

Processor Benchmarks	Pentium® Processor 200 MHz	Pentium Processor with MMX™ Technology 200 MHz	Pentium Pro Processor 200 MHz 256 kB L2	Pentium II Processor 233 MHz 512 kB L2	Pentium II Processor 266 MHz 512 kB L2
Intel Media Benchmark/ Windows* 95	**156.00**	**255.43**	**194.38**	**310.40**	**350.77**
Video	155.52	268.70	158.34	271.98	307.24
Image Processing	159.03	743.92	220.75	1026.55	1129.01
3D Geometry	161.52	166.44	209.24	247.68	281.61
Audio	149.80	318.90	240.82	395.79	446.72
Norton Media Benchmark	**9.6**	**13.8**	**11.6**	**17.2**	**19.4**
Video	8.5	11.4	7.2	10.4	11.6
3D Graphics	12.8	14.0	16.6	22.2	25.2
Audio	10.9	21.9	16.4	26.7	30.4
CD-ROM	4.1	4.1	4.1	4.1	4.1
Imaging	5.8	27.7	16.8	40.0	44.3

intel.

Table 2: Benchmark System Configurations

Processor:	Pentium® and Pentium Processor with MMX™ Technology – 200 MHz	Pentium Pro Processor 200 MHz – 256 kB L2	Pentium II Processor 233 MHz and 266 MHz – 512 kB L2
System	Intel 82430 VX PCIset based motherboard	Intel 82440 FX PCIset based motherboard	Intel 82440 FX PCIset based motherboard (Portland PD440FX)
FPU	Integrated		
Primary Cache	Pentium Processor – 16 kB (8 kB I + 8 kB D) Pentium Processor with MMX Technology – 32 kB (16 kB I + 16 kB D)	16 kB (8 kB I + 8 kB D)	32 kB (16 kB I + 16 kB D)
Secondary Cache	512 kB WB Burst	256 kB WB Burst	512 kB WB Burst
Memory Size/Speed	Windows* 95 – 32 MB SDRAM		
Hard Disk Controller/Bus	Adaptec 2940UW* SCSI/PCI		
Hard Disk	Seagate ST32550W		
Video Controller/Bus	Matrox Millennium*/PCI		
Video Memory Size/Type	2 MB WRAM		
Operating System	Windows 95		
Video Driver Revision	Matrox 3.22 with Microsoft DirectX* 3.0a		
Graphics	1024x768 Resolution, 16-bit color		
CD-ROM Drive	Pioneer SCSI DR-433		
Sound Card	Creative Labs Sound Blaster* 16		

intel.

UNITED STATES, Intel Corporation
2200 Mission College Blvd., P.O. Box 58119, Santa Clara, CA 95052-8119
Tel: +1 408 765-8080

JAPAN, Intel Japan K.K.
5-6 Tokodai, Tsukuba-shi, Ibaraki-ken 300-26
Tel: + 81-29847-8522

FRANCE, Intel Corporation S.A.R.L.
1, Quai de Grenelle, 75015 Paris
Tel: +33 1-45717171

UNITED KINGDOM, Intel Corporation (U.K.) Ltd.
Pipers Way, Swindon, Wiltshire, England SN3 1RJ
Tel: +44 1-793-641440

GERMANY, Intel GmbH
Dornacher Strasse 1
85622 Feldkirchen/ Muenchen
Tel: +49 89/99143-0

HONG KONG, Intel Semiconductor Ltd.
32/F Two Pacific Place, 88 Queensway, Central
Tel: +852 2844-4555

CANADA, Intel Semiconductor of Canada, Ltd.
190 Attwell Drive, Suite 500
Rexdale, Ontario M9W 6H8
Tel: +416 675-2438