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APPLICATION NOTE

Notebook Computing: Power and Performance Analysis

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1.0. EXECUTIVE SUMMARY

As the Motion Picture Experts Group (MPEG) movie playback is gaining popularity, the demand for better quality video and audio playback is increasing. The main factor associated with the quality of the video playback is the rate at which the video frames are processed. Systems that are capable of decoding 30 frames per second are desired. With today's technology, achieving higher frame rate video playback on a PC is possible, but, what is the best possible MPEG solution for a given PC?

For mobile computing, the system power consumption and battery life is an important issue that system designers face along with issues related to the size and cost. What is the best MPEG solution for a mobile PC? There are hardware MPEG solutions available but they are costly and take up board space. The software MPEG solutions have answers for the cost and board space but they highly utilize the CPU and raise the CPU power consumption. How then, can a system designer include the advantages of software MPEG solution along with lower CPU power consumption in a mobile PC? The answer is MMX™ technology.

MMX technology brings the best of two worlds together; high quality video and audio playback at lower system power consumption. It enables multimedia applications to be written so that they require less CPU utilization. Lower CPU utilization translates directly to lower CPU and system power consumption which in return results in longer battery life.

Intel has performed various tests and measurements on several different systems with various configuration to better understand the effects of MMX technology optimized MPEG-1 video playback on the system, and on CPU power and performance. Data was collected on MMX technology capable and scalar CPUs for comparison. Data was also collected on the system power and performance.

2.0. INTRODUCTION

For simplicity, in this report, the software MPEG-1 code capable of utilizing MMX technology is termed MMX optimized code for MPEG and the software MPEG-1 code not using MMX technology is termed scalar MPEG.

The purpose of this report is to analyze and compare the power and performance of the CPU and system during MMX optimized code for MPEG and scalar MPEG video playback. Data included in this report reflect the effects of the different MPEG-1 playback solutions on platforms with different configurations. Refer to Appendix A for configurations used.

Based on the previous analysis of MPEG-1 platforms and the measurements performed on MMX optimized code for MPEG there are three major components in a system that may inhibit the system from achieving full video quality at 30 fps. They are the CPU, video graphics controller, and MPEG player (decoder). Other than these three components, other system components such as chipset, memory and cache effect the system performance, therefore impacting the MPEG video playback. In a system using software decode it is desirable to use a chipset with a high degree of concurrency. During the Power and Performance Analysis (PPA) tests, the CPUs used for the power and performance measurements were the 150- and 166-MHz Pentium® processors. These CPUs are capable of handling MPEG decode at 30 fps. The graphics controllers used during these measurements are mobile and desktop graphics controllers which have full Direct Draw* support and are capable of video scaling. These graphics controllers are also capable of handling high video frame rate. As mentioned before, the MPEG decoder plays a major role in the MPEG playback. Both hardware and software decoders are used during the PPA tests. The hardware MPEG-1 player is a desktop version PCI card and the software MPEG-1 player is capable of detecting the MMX technology capable CPUs and execute the appropriate code. The same version of the software MPEG player is capable of executing the scalar MPEG code on the scalar CPUs.

To summarize the effect of MMX technology on systems, the multimedia extension instruction set allows faster execution of the software MPEG decoder on MMX technology capable CPUs, resulting in lower CPU utilization. This allows the Operating Systems (OS) to call Advanced Power Management's (APM) CPU Idle function during idle time and place the CPU into a low power state. The power saved on the system translates to longer battery life — a major concern in notebook environments.

3.0. BACKGROUND

In order to understand the data presented and to plan a system design suitable for playing MPEG-1 movies, a basic understanding of MPEG playback is needed.

MPEG data is normally stored in a secondary storage device, such as a CD ROM. The data stream from this source is read by the system and written to the main memory via a bus mastering IDE controller. The involvement of DMA is to eliminate the burden of data transfer from the CPU and leave the processor to do other system functions such as software decode. The CPU begins the audio and video decoding process by reading the data from main memory. Meanwhile, the data is cached by the cache controller. The processor begins the decompression process of the video and audio using supplied algorithms and other computations. The algorithms are integer intensive but can easily be handled by the Pentium processor. These algorithms constantly access the working set of information, for example a frame of video.

Typically, MPEG-1 video information is encoded in three different video frame types. This is done to eliminate redundant video information and capture and compress only the information that changes from frame to frame. index frame (I-frame) includes full frame information and are compressed using techniques such as Intraframe compression. predicted frame (P-frame) and bi-directional frame (B-frame) are the delta frames and are compressed using the Interframe compression technique. I-frames require more processing time but since there are fewer I-frames, they are processed less frequently than P- and B-frames.

From this frame of data, the processor decodes the pixel data. MPEG-1 video uses a YUV4:2:0 format which must be converted to the RGB format, at some point, for the graphics controller to use. The processor builds three planes of pixel data: a Y plane (luminance or lightness), and a U plane and V plane (chrominance or color). Using the CPU, software will occasionally expand the source format from YUV4:2:0 to the more popular YUV4:2:2 format. Conversion of the YUV4:2:0 to YUV4:2:2 and then to RGB format can be handled by some graphics controllers, allowing the CPU to utilize its time on other processes. This is commonly referred to as color space conversion.

Once the CPU has completed decoding a video frame, it writes the information to the frame buffer. A quality chipset plays a role at this point by buffering the data and then bursting them on the PCI bus and into the frame buffers. This chipset feature is called concurrency. The graphics controller uses the information in the video memory to refresh the screen. Interleaved with the video frame buffer writes are the writes to the audio codec to replay the audio portion of the program. Although, video playback takes the majority of the CPU bandwidth, sufficient CPU time is given to processing the audio. Because the ear is more sensitive to audio than the eye is to video, audio quality must not be sacrificed for higher video quality (frame rate). Audio codecs are capable of producing CD quality audio while requiring approximately 10 percent of the CPU MIPS (millions of instructions per second). Since the speaker quality in many mobile computer systems is not equal to desktop computer systems, dropping the audio quality to FM quality (from 44 KHz to 22 KHz) is acceptable in a mobile PC environment. This saves about 3 percent of the CPU bandwidth.

Once every measure is taken to leave the majority of the processor's time for processing the video frames, a processor, such as the Pentium processor, can easily achieve a high frame rate during MPEG-1 playback. The quality of the video playback is mainly measured by the frame rate (number of frames per second). The target frame rate for video playback on any system according to the National Television Systems Committee (NTSC) is 30 fps and 25 fps according to the Phase Alternate Line and Sequential Couleur A Memoire (PAL/SECAM). The software MPEG-1 decoder gives higher priority to audio decoding and will drop frames if the CPU is not capable of handling 30 fps. One should design a system with a fast CPU and take every opportunity to lower the processing load on a CPU in order to produce high quality MPEG-1 playback.

It is obvious that major system components for producing an MPEG-1 audio/video playback are the CPU, video graphics sub-system, software, chip set, and cache/memory configuration. The impact of each one of these major players on an MPEG-1 playback can be measured.

4.0. TEST METHODS

The following sections describe the software tools used for power and CPU utilization measurements, systems configurations, and basic test methodology.

4.1. Tools

Power Meter*: All system/CPU power measurements are performed with the aid of Power Meter Rev. 0.8 software. Power Meter programs the output voltage of the HP 6632A power supply via the GPIB connection and samples the power consumption of the load at the rate of 10 sample per second. The sampling period for all tests are about one minute. The average of these power samples (~600 samples) represent the load power consumption.

VTune*: CPU utilization is measured with the aid of VTune's Time-Based Sampling (TBS) tool. TBS is a general technique of interrupting the processor at a regular interval and collecting information about the state of the CPU. TBS traces the OS loads and unloads for all drivers and applications. The sampling rate and period are programmable. CPU utilization data presented in this document are sampled at the rate of 1000 sample per second for 20 seconds.

Frame Rate: There are several possible ways of measuring the frame rate of video playback. Most MPEG players supply a status report on a video playback that includes the frame rate. Some MPEG players runs a diagnostic/benchmark to analyze and rate the system components such as the CPU, the BUS, and the video controller. Based on this evaluation, these players report the frame rate that the system is capable of handling. These players do not use audio during this evaluation. Other MPEG players directly report the frame rate for the most recent MPEG clip played on the system. They include audio during measurement. Another method of measuring the frame rate is by using the Windows* media player and executing an MCI string command.

Intel Multimedia Benchmark (IMB): IMB measures the performance of the scalar and MMX technology-enabled processors. It was developed primarily to measure the performance of Pentium processors. It scores the CPU based on the weighted average of the video (55 percent), Audio (35 percent) and Image (10 percent).

4.2. System Power Measurements Method

Base Power: The total system base power is measured with audio/video drivers loaded and with Windows up and idle (no apps/audio/games running). The APM is enabled and both display and hard drive are powered up.

Active Power: System power is measured with the MPEG playback running and audio active. During the system power measurements (base or active), the power is supplied to the system through jumpers (evaluation board) or the battery terminals (notebooks) via HP power supply and the Power Meter software is used to measure the average power. Some of the system power data is presented as system power delta which is the idle power subtracted from active power.

This setup is used to measure the system and CPU power. The Power Meter software running on the desktop PC programs the HP power supply via. GPIB connection and then records the current and voltage output of the HP power supply, 10 times per second. The HP power supply is connected to the battery terminals of the system under test and it supplies power to the system with a constant voltage.

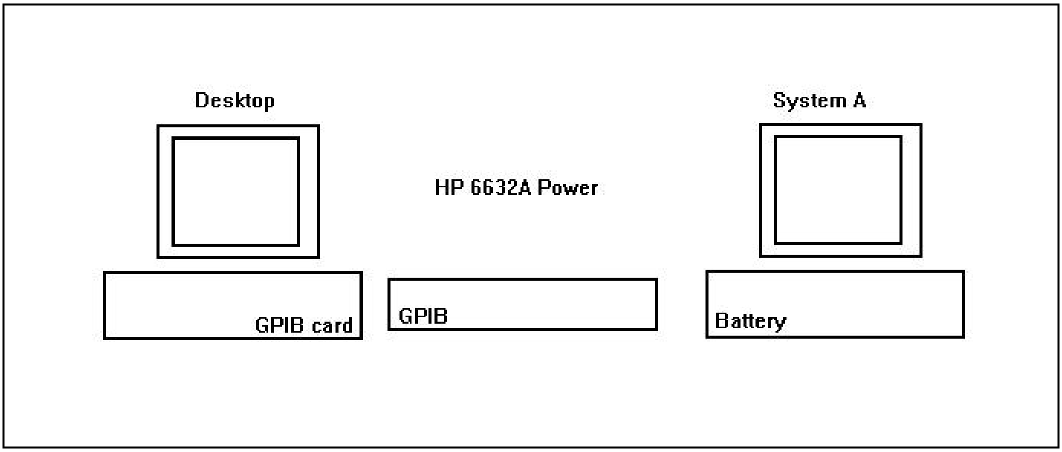

Figure 1. Power Measurement Setup

4.3. CPU Power Measurement Method

Base Power: In order to measure the CPU power usage, the CPU power plane is isolated (open evaluation boards) and the Power Meter is used to measure the average power. The base CPU power measurement methodology is the same as the base system power measurement methodology.

Active Power: The CPU power usage due to running applications is measured while running an MPEG or VideoCD file with audio active. The measurement is performed with the CPU power plane isolated and power to CPU supplied via HP power supply.

4.4. CPU Utilization Measurements Method

Base Utilization: VTune is used to measure the CPU utilization. VTune calculates the average CPU utilization of each individual task and saves the data in a table. In order to calculate the CPU utilization of each application, the base CPU utilization must be measured first. The base CPU utilization is measured with audio/video drivers loaded and Windows up and idle (no application running). The results of the base CPU utilization are used to calculate the active CPU utilization.

Active Utilization: With an MPEG file running, VTune is used to measure the CPU utilization of each individual task. The results are then compared to the base CPU utilization and the difference between the two results are used to calculate the actual CPU utilization due to running an application. The interrupt timer is set to RTC and the sampling rate is set to 1 ms. The sampling period is set to 20 seconds.

4.5. Picture Quality Measurements Method

Frame Rate: Picture quality of the MPEG playback is highly subjective and highly depends on perception. Frame rate is one element of the picture quality and it can be measured while other elements of the picture quality such as picture clarity or stability are not measurable and can only be visually perceived. Frame rate close to the ideal target frame rate of 30 fps (NTSC) produce a smooth (not jerky) picture. Some of the software MPEG players provide tools for measuring the frame rate on a given system (see Section 4.1). Whenever one of these tools is used to measure the frame rate, several measurements are taken and averaged to produce the correct frame rate. Another method used to measure the frame rate is via MCI commands. In this case, the Windows media player box is opened along with the MCI string command dialog box. Through these boxes any portion of an MPEG clip can be played and the number of "skipped" frames is measured.

5.0. TESTS AND DATA

Table 1 lists the data collected on the MMX optimized code for MPEG, scalar MPEG, and hardware MPEG platforms.

5.1. CPUs

The following data describes the effects of the MMX optimized code for MPEG playback on different CPUs with different speeds.

The frame rates indicated in Table 1 are measured via MCI control commands and the MPEG player tools. The source MPEG file is encoded at 30 fps with CD quality audio. The video setting for these measurements are 800x600 (full screen) at 256 colors. All measurements are taken during full screen video playback. The unsynchronized frame rates are measured without audio and are not synchronized to the MPEG source file. This means that the MPEG playback can surpass the encoded source frame rate. The unsynchronized frame rate shows the processor's computing power at 100 percent CPU utilization and mainly is used for comparison to other processors, running at different speed (with and without MMX technology capability). The results indicate that the MMX technology capable systems perform more than 40 percent better than the systems without the MMX technology capability.

The CPU power consumption results in Figures 2 and 3 indicate about 37 percent lower power consumption when MMX optimized code for MPEG playback is compared to scalar MPEG playback. On the system power consumption side, the same conclusion can also be drawn. The system base power consumption is measured while Windows is up but not running any applications. This base power is measured to be about 12.5 watts and it does not include the power consumed by the hard drive, CD and CRT. The system base power varies from system to system. The

system active power consumption is measured while the MPEG is running. The delta between the active and base power is the power consumed by the system due to the MPEG playback. The MMX optimized code for MPEG vs. scalar MPEG system power delta indicates about 37 percent power savings on the MMX technology capable systems.

In order to better understand the source of power saving on the MMX technology capable systems, the following CPU power traces has been captured from the Power Meter.

Table 1. MMX™ Optimzed MPEG Code vs. Scalar MPEG (CPU and System Power and Performance)

	MMX™ Optimized Code for MPEG 150-MHz Pentium® Processor[1]	Scalar MPEG 150-MHz Pentium Processor[1]	MMX Optimized Code for MPEG 166-MHz Pentium Processor[1]	Scalar MPEG 166-MHz Pentium Processor[1]
Sync. Frame Rate	30	28.3	30	29.8
Unsync. Frame Rate	55	38	63	42
CPU Utilization	64%	98%	59%	98%
CPU Base Power[2]	1.0 W	1.0 W	1.0 W	1.0 W
CPU Active Power [3]	3.6 W	5.6 W	3.8 W	6.2 W
Relative System Power Increase[3]	5.6 W	8.9 W	5.8 W	9.5 W

NOTES:

1. Configuration: Titus board, 16M DRAM, 256K L2 cache, mobile graphics controller, Windows 95*, MMX™ technology capable player, 30 fps with CD audio MPEG file
2. Base power = Windows up and idle
3. Active Power = MPEG playing

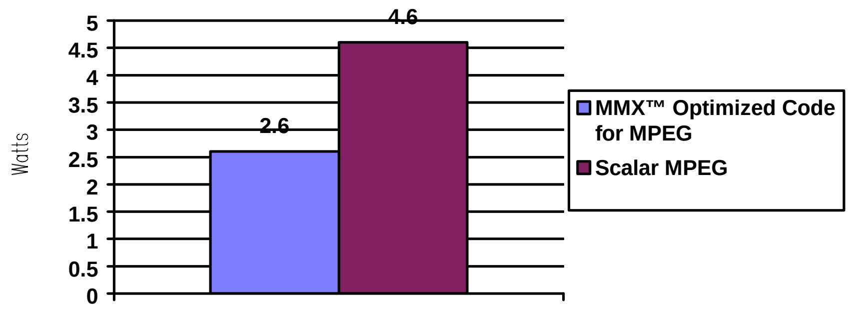

Figure 2. CPU Power Increase During MPEG-1 Playback

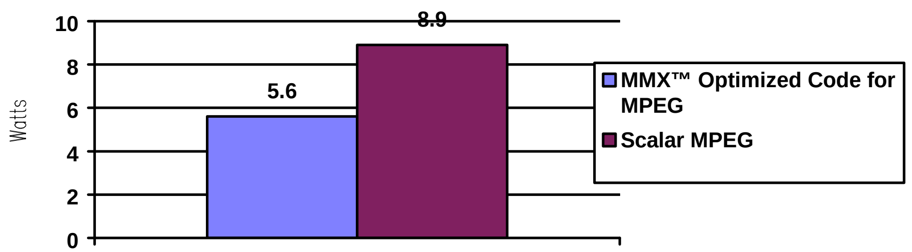

Figure 3. System Power Increase During MPEG-1 Playback

As the waveforms in Figures 4, 5 and 6 show, the CPU power savings are due to activation of APM BIOS. Lower CPU utilization by MMX optimized code for MPEG allows the operating system to be idle about 36 percent of the time. The operating system takes advantage of this idle time and triggers the APM CPU idle function. This APM routine requests the chipset to signal the CPU to enter the Stop Grant state and shut down it's internal clocks. During the CPU stop clock, the CPU power consumption drops dramatically. During the MMX optimized code for MPEG playback, the MPEG code returns control back to the OS at a rate of 30 times per second so the OS can initiate the idle call.

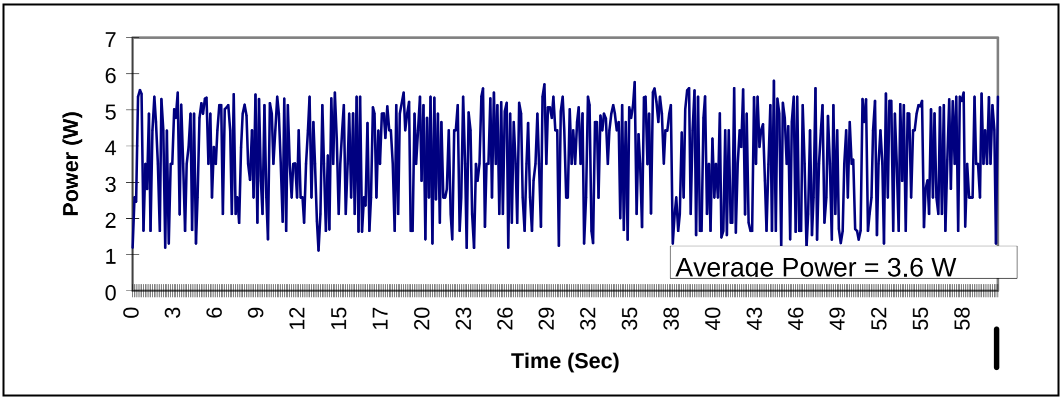

Figure 4. CPU Power Consumption MMX™ Optimized Code for MPEG (APM Enabled)

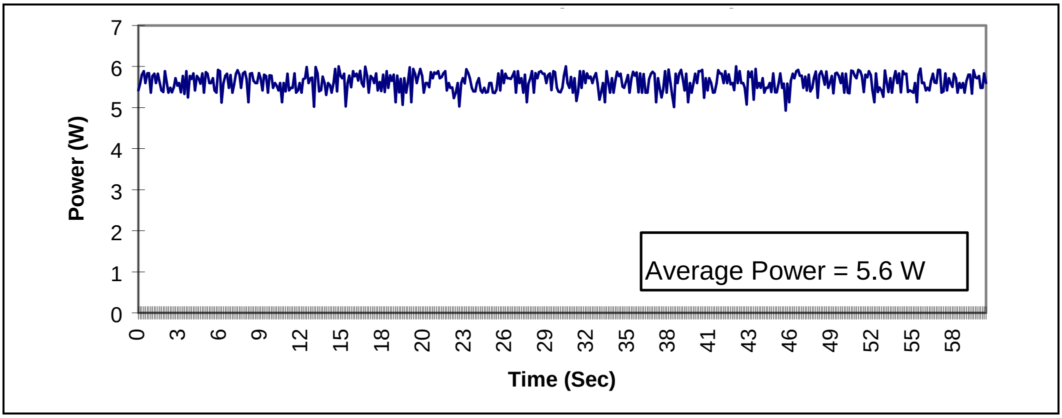

Figure 5. CPU Power Consumption Scalar MPEG (APM Enabled)

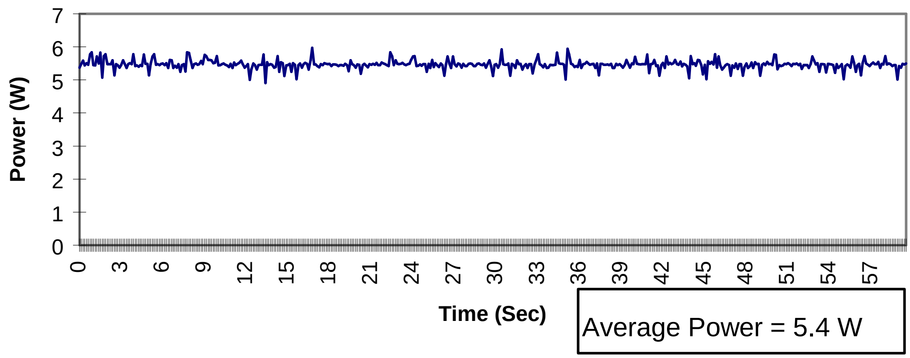

Figure 6. CPU Power Consumption MMX™ Optimized Code for MPEG (APM Disabled)

Table 2 shows the power savings due to MMX technology and APM. Scalar MPEG decoders utilize the CPU continuously, therefore the OS does not find the opportunity to call APM in order to stop the CPU internal clocks. This has the same effect as turning off the CPU power saving features by disabling the APM. In both cases, the CPU is utilized by application and OS at all time which results in higher average power consumed by the CPU. The system active power (delta) also indicates that the OS can take advantage of the CPU idle time and request Stop Clock to save power.

During the MPEG power and performance measurement, the Windows sound system was configured to be the source of driving the audio. With this configuration, test results show that MMX optimized code for MPEG audio utilizes the CPU 10 to 12 percent of the time while the scalar MPEG audio uses up to 15 percent of the CPU time.

In conclusion, faster executing MMX optimized code for MPEG code utilizes the CPU less often than the scalar code and allows the OS to call APM BIOS. Through APM routine, the CPU internal clocks are turned off, causing a lower CPU power consumption. The CPU power consumption can be reduced further by programming the chipset to stop the external host (CPU) clock during the Stop Clock state.

5.2. Hardware vs. Software MPEG-1

The following data explains the differences between the CPU/system power and performance on platforms with hardware accelerated MPEG player or software MMX optimized code for MPEG or scalar MPEG player.

Table 2. CPU and System Power and Performance with APM Enabled or Disabled

	MMX™ Optimized Code for MPEG APM Enabled	MMX Optimized Code for MPEG APM Disabled	Scalar MPEG APM Enabled
Sync. Frame Rate	30	30	28.3
CPU Utilization	64%	58%	98%
CPU Base Power	1.0 W	5.5 W	1.0 W
CPU Active Power	3.6 W	5.4 W	5.6 W
Relative System Power Increase	5.6 W	9.0 W	8.9 W

NOTES:

- Configuration: Titus board, 150-MHz Pentium® processor, 16M DRAM, 256K L2 cache, mobile graphics controller, Windows 95, MMX technology capable player, 30 fps with CD audio MPEG file
- Base power = Windows up and idle
- Active Power = MPEG playing

Table 3. Hardware vs. Software MPEG Players

	Hardware MPEG	Software MMX™ Optimized MPEG Code	Software Scalar MPEG
Frame Rate (Box/Full Screen)	30/30	30/30	29/28.3
CPU Utilization	13%	65%	97%
CPU Base Power	1 W	1 W	1 W
CPU Active Power	1.95 W	3.6 W	5.6 W
Relative System Power Increase	8.5 W	5.6 W	8.9 W

NOTES:

- Configuration: Titus board, 150-MHz Pentium® processor, 16M DRAM, 256K L2 Cache, mobile graphics controller MMX optimized code for MPEG/scalar MPEG player
- Base power = Windows up and idle
- Active Power = MPEG playing

As shown in Table 4, it is evident that the hardware MPEG decoder utilizes the CPU less often than the software MPEG decoder. This low CPU utilization translates to lower CPU power consumption, but the hardware (DSP) itself consumes power. Therefore, the total system power consumption of hardware MPEG platform is higher than the platform with software MMX optimized code for MPEG capability. Also, hardware MPEG consumes power when Windows is setting idle and MPEG is not running. Software MPEG does not waste power when MPEG is not running.

In conclusion, hardware accelerated MPEG playback uses more power than the software MMX optimized code for MPEG playback when system is active or idle. As a result, hardware MPEG drains the system battery faster (about 15 percent faster if the system is idle 80 percent of the time and active 20 percent of the time).

5.3. Memory/Cache

Data presented in the following table shows the effects of the system memory and cache on the CPU/system power and performance during MMX optimized code for MPEG playback.

The data in Table 4 indicates that the size of the system memory has a slight effect on the system performance during MMX optimized code for MPEG playback while the L2 cache improves the CPU performance by about 7 percent and lowers the CPU and system power consumption. The L2 SRAM module used here, consumes about 0.9 Watts of power but overall reduces the total system power consumption by about 0.1 Watt.

In conclusion, second level cache reduces the CPU utilization during MMX optimized code for MPEG playback, therefore it reduces the CPU power consumption.

5.4. Video Source/Format

Table 5 lists data collected on MMX optimized code for MPEG platform, during MPEG playback, while using different video sources and format.

A quad-speed CD drive was used for the purpose of the above tests. A 30 fps video clip (.mpg format) and a 24 fps movie clip (.dat or VideoCD format) was played from both sources (CD and hard drive). The difference between the MPEG and VideoCD frame rate causes differences between the system power and performance. In fact, if both MPEG clip and VideoCD movie were encoded at the same frame rate, the CPU utilization and power consumption during MPEG or VideoCD playback would be identical.

In conclusion, video source or format does not effect the system power and performance. Only the video quality (frame rate, audio type, etc.) effects the system power and performance.

Table 4. Effects of the Memory and L2 Cache

	8M -Cache	8M +Cache	16M -Cache	16M +Cache	24M -Cache	24M +Cache
Frame Rate	29.8	30	29.9	30	29.9	30
CPU Utilization	70%	66%	70%	65%	70%	64%
CPU active power	3.9 W	3.7 W	3.9 W	3.6 W	3.9 W	3.5 W
Relative System Power Increase	5.6 W	5.6 W	5.7 W	5.6 W	5.8 W	5.6 W

NOTES:

- Configuration: Titus board, 150-MHz Pentium® processor, 8/16/24 M EDO DRAM, 0/256K synchronous cache, MMX™ optimized code for MPEG player, 30 fps with CD audio MPEG clip
- +Cache = L2 cache enabled (256K)
- -Cache = L2 cache disabled
- Base power = Windows up and idle
- Active Power = MPEG playing

Table 5. Hard Drive vs. CD and MPEG vs. VideoCD

Tests	Frame Rate	CPU Utilization	CPU Power	System Power delta
MPEG from Hard Drive	30	64%	3.6	5.6
MPEG from CD	30	64%	3.6	5.6
VideoCD from Hard Drive	24	61%	3.4	5.5
VideoCD from CD	24	61%	3.4	5.5

NOTE:

- Configuration: Titus board, 150-MHz Pentium® processor, 16M DRAM, 256K L2 Cache, mobile graphics controller MMX™ optimized code for MPEG player

5.5. Intel Multimedia Benchmark (IMB)

The Intel Multimedia Benchmark (IMB) Rev. 1.0 was developed by Intel to measure the performance of scalar CPUs running algorithms found in multimedia uses. It incorporates video playback, image processing and audio sample rate conversion.

IMB is used to benchmark the system performance of several different platforms with different CPU/bus speed. The benchmark score was collected on both MMX technology capable CPUs (150-MHz Pentium processor and 166-MHz Pentium processor) and scalar CPUs (100-MHz Pentium processor and 133-MHz Pentium processor).

Comparing the IMB scores of the two 150-MHz processors (Table 6), there is a 78 percent system performance improvement for MPEG video playback which is due to the differences in the CPUs (cache size, etc.) and MMX technology. From Table 7, one can calculate the performance improvement due to the differences in the CPUs (without MMX technology) to be about 12 percent. This means, during MPEG playback, more than 66 percent of the system performance boost is due to the MMX technology.

In conclusion, MMX technology boosts the system performance by more than 66 percent during MPEG playback. It also improves the system performance when other multimedia applications are used.

Table 6. IMB Scores

Pentium® Processor	Overall	Video	Image Proc.	3DG	Audio
100 MHz	87	84	84	85	94
133 MHz	111	109	109	108	122
150 MHz	116	115	119	116	118
150 MHz (MMX™ Technology)	191	205	488	119	246
166 MHz (MMX Technology)	211	227	545	134	270

NOTES:

- Configuration: Titus board, 16M EDO DRAM, 256K L2 Cache, mobile graphics controller, Windows 95*
- MMX™ technology CPUs (MPEG player recognizes the MMX technology capability and runs the appropriate code)

Table 7. CPU Performance Without MMX™ Technology

	150-MHz Pentium® Processor (without MMX™ Technology capability)	150-MHz Pentium Processor (MMX Technology turned off)
Sync. Frame Rate	25.1	28.3
Unsync. Frame Rate	34	38
CPU Utilization	98%	98%

NOTE:

- Configuration: Titus board, 16M EDO, 256K L2 cache, mobile graphics controller, Windows 95*, MMX™ optimized code for MPEG/scalar MPEG player, 30 fps with CD audio MPEG file

5.6. Mobile PC Analysis

The following data (Tables 9, 10, 11 and 12) was collected from two different mobile PCs. Both of these notebooks were modified slightly by removing 133-MHz Pentium processor CPUs and installing 150-MHz Pentium processor and 166-MHz Pentium processor in order to test the MMX technology. CPU speed measurement indicate that the Notebook-1 is running at 133 MHz and the Notebook-2 is running at 166 MHz.

Both notebooks have low base performance. For this reason the performance boost that MMX technology brings to these mobile PCs may not be evident at first glance of the data. If we consider the Notebook-2 for example, MMX optimized code for MPEG playback utilizes the CPU 75 percent of the time, indicating 23 percent performance boost (as compare to expected 40 percent performance boost). But looking at the frame rate, 30 fps for MMX optimized code for MPEG and 22 fps for scalar MPEG, one can see that the performance boost caused by MMX technology is much larger than what the CPU utilization indicates.

The same argument can be used when the system power consumption is considered. The base system power consumption is high so the percentage of the system power saving caused by the MMX technology seems low. Also, if the system was capable of playing the scalar MPEG at a higher rate (close to 30 fps), then the difference between the power consumption due to MMX optimized code for MPEG or scalar MPEG playback would have been larger.

In a mobile environment, the CPU and/or system power consumption must always translate to battery life in order to have better meaning. As the data in Table 10 indicates, MMX technology has extended the battery life by 10 percent due to the CPU and system power savings without decreasing the video quality.

In conclusion, MMX technology can improve the system performance and extend the battery life up to 40 percent during MPEG playback. The amount of performance improvement and power savings varies from notebook to notebook and it depends on their "base" performance and power consumption.

The IMB scores listed in Table 11 indicate a performance increase of 40 to 60 percent when compared to the scores listed in the Table 6 (133- and 150-MHz Pentium processor). This performance increase is due to MMX technology. But if the IMB scores for the notebooks are compared to the scores measured on the 150-MHz Pentium processor platforms (Table 6), the MMX technology performance boost is not as high as expected. The reason for this varies from system to system and requires further investigation on each individual system.

Table 8. Mobile PCs System Performance

MPEG-1	Frame Rate (Box/Full Screen)	CPU Utilization
Notebook-1 (MMX™ Technology)	30/29.9	80%
Notebook-1 (Without MMX Technology)	22/19	98%
Notebook-2 (MMX Technology)	30/29.8	75%
Notebook-2 (Without MMX Technology)	24/21	98%

NOTES:

- See Section 4.2 for configuration

Table 9. Mobile PCs Total System Power

Mobile PCs	MMX™ Optimized Code for MPEG Playback	Scalar MPEG Playback	Win Idle Hard Drive & Screen On	Win Idle Hard Drive Off Screen On	Win Idle Hard Drive Off Screen Off
Notebook-1	25 W	27 W	15.8 W	15.3 W	10.5 W
Notebook-2	28.5 W	32.2 W	19 W	18.5 W	16.2 W

NOTES:

- See Section 4.2 for configuration

Table 10. Mobile PCs Battery Rundown Tests

Mobile PCs	MMX™ Optimized Code for MPEG Playback	Scalar MPEG Playback	Win Idle Hard Drive & Screen On
Notebook-1	110 Min.	99 Min.	194 Min.
Notebook-2	77 Min.	68 Min.	115 Min.

NOTES:

- See Section 4.2 for configuration

Table 11. Mobile PCs IMB Scores

Mobile PCs	Overall	Video	Image Proc.	3DG	Audio
Notebook-1	158	150	414	107	218
Notebook-2	187	213	457	128	202

NOTES:

- See Section 4.2 for configuration

APPENDIX A
CONFIGURATIONS

	Open Test Platforms	Notebook-1	Notebook-2
Platform:	Rev-B open evaluation board		
CPUs:	100-, 133- and 150-MHz Pentium® processors (2.9 volts), 150-MHz Pentium processor with MMX™ technology (2.5 volts), 166-MHz Pentium processor with MMX technology (2.5 volts)	166-MHz Pentium processor (running at 133 MHz and 2.9 volts)	Pentium processor (running at 166 MHz and 2.9 volts)
Bus Speed:	60, 66 MHz	66 MHz	66 MHz
Chipset:	Intel 430MX	In-house	In-house
Graphics Cards:	Several “mobile” and desktop graphics controller on add-in PCI evaluation card		
Displays:	CRT Monitor with up to 1024x768 resolution	TFT 800x600 LCD - 256 color	TFT 800x600 LCD - 256 color
Hard Drives:	0.5Gbytes EIDE	1.3G IDE	1.3 G IDE
CD ROM Drives:	4X IDE (DMA mode)	4X	6X
DRAM Sizes:	8,16, 24M EDO	32M	16M
L2 Cache Sizes:	256K Synchronous SRAM (when caching is enabled)	256K SRAM	256K SRAM
Audio Codec:	Melody evaluation card		
Battery:		Li-ion (10.8 V, 5.6 Ah)	Li-ion (14.4 V, 2.6 Ah)
Operating System:	Windows 95*		
System BIOS:	AMI 1/96	AMI	AMI
APM:	Enabled (disabled during some of the tests)		
VTune:	Revision 1		
Power Meter:	Revision 0.8		
IMB:	Intel Multimedia Benchmark Revision 1.0		

	Open Test Platforms	Notebook-1	Notebook-2
SW MPEG:	With a switch to turn the MMX technology on/off		
HW MPEG:	Video/graphics/MPEG/audio card all in one		
MPEG Clips:	Gloria (MPEG); 44 KHz stereo audio, 30 fps video		
VideoCD:	Clear and Present Danger (VideoCD); 44 KHz audio, 24 fps video Terminator 2 (VideoCD); 44 KHz stereo audio, 24 fps video Rock (VideoCD); 44 KHz stereo audio, 30 fps video	Clear and Present Danger (VideoCD); 44 KHz audio, 24 fps video	Clear and Present Danger (VideoCD); 44 KHz audio, 24 fps video
MPEG File Size:	On average about 10 MB per minute of video and audio		
MPEG Sources:	Hard drive or CD ROM drive		
Video Sizes:	Standard box (SIF, 352x240), full screen (800x600)		
BIOS Setting:		Full CPU power, APM enabled, other power savings disabled	Full CPU power, APM enabled, other power saving disabled