Designing A Low Cost, High Performance Platform For MPEG-1 Video Playback

Platform Architecture Labs/Desktop Product Group Technical Marketing
Intel Corporation

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Tim Mostad, Paul Buckley, Cameron Forouzandeh, Kevin Kennedy
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Introduction
Video playback on a personal computer places specific demands upon the underlying system hardware and software. In trying to meet these demands, OEMs and IHVs face a large number of implementation possibilities, each with cost/performance implications. The purpose of this paper is to examine the various options and then to recommend what we believe is the lowest cost, highest performance platform configuration for general purpose MPEG-1 video playback.

The following analysis examines each subsystem in isolation and quantitatively evaluates design tradeoffs in terms of impact on frame rate. A base system configuration was chosen that represents what is believed to be a $2,000 (U.S.) price point system for the first half of 1996. Market studies have shown that it represents the mid-point for high volume shipments and so it is an optimal target to gain the benefit for the broadest audience.

In summary, it was found software-only MPEG-1 playback can offer good performance and quality on volume price point PCs. These PCs require sufficient processor MIPs and well architected memory, cache, audio, graphics and I/O subsystems. Excellent system performance can be achieved with a 100 MHz (or faster) Pentium® processor in a well designed platform.

Section 1 - Video Playback Alternatives
PCs are seeing widespread adoption in the home, based upon their newly found abilities to offer rich multimedia entertainment. Playing full motion video on the PC is now seeing broad-based demand. As often happens in the PC industry, there are multiple solutions being offered that fill different performance, price, and capabilities considerations. The MPEG standards (1, 2, etc.) have their roots in the television industry and are well accepted for delivering movie and non-interactive video clips. Technologies, such as Indeo® Video Interactive, were designed specifically for desktop computer use and are focused on delivering the scalability and interactivity needed with games and edutainment applications. Each of these technologies is slightly different in focus and has unique aspects that suits it well for a given purpose. The rest of this paper focuses only on MPEG-1 technology though most of the learning can be applied to other compute intensive applications as well.

Note: From this point forward all references to MPEG will mean MPEG-1 unless otherwise noted.

MPEG is commonly used for non-interactive linear video playback, i.e., the user interacts with the computer which causes a video to play. When the video sequence ends, user interaction begins again. In this model it is not essential that the computer is capable of multitasking. The microprocessor can be used almost exclusively for the decompression process. Though the processing load is relatively high at current clock speeds, a faster microprocessor will handle this duty easily with the possibility of doing background processing as well. The most important attribute for linear MPEG playback is that the player launches quickly to ensure smooth application operation.

MPEG is also appearing in some “interactive” titles. However, the level of interactivity is generally low, such as the user choosing a path through a movie. Response latency is the key in this scenario as significant processor cycles are not needed. Again, it is acceptable in this scenario for decompression to heavily load the processor.

Section 2 - Hardware vs. Software MPEG-1 Playback
Assuming that MPEG is a required system capability, then two playback options exist. For dedicated applications, arguably, hardware-assisted MPEG playback provides the higher performance solution. MPEG decompression accelerators, either on an add-in card or on the system motherboard, are optimized to serve a single purpose. Depending upon the system architecture chosen, the data stream may use system I/O bus bandwidth but the load on the processor is typically quite low (less than 5% of the available processor

MIPs). See Appendix A for testing details. Digital video editing stations can benefit from processor availability by providing rapid response to mouse movement and/or other system activities. This is particularly important at lower processor clock speeds. The addition of dedicated hardware is justified by the higher system selling price in this case.

Other than the obvious, one key difference between hardware and software playback is the way audio is handled. Since studies have shown that audio quality has a bigger impact on perception than video, it is important for solutions to provide high quality audio. Hardware MPEG playback most often provides for audio decode on the same decoder chip as the video. This ensures audio/video synchronization and quality playback. CD-quality playback is achievable. In software-only playback implementations, the processor gives the audio channel the highest priority and drops video frames if insufficient processing time is available. Also software playback relies on using the system's audio CODEC, typically an add-in sound card, for audio playback. These cards are generally capable of 44.1 kHz, 16-bit stereo data rates. Processor utilization for audio at this data rate has been measured to be around 10%.

The main problem with dedicated hardware solutions is that the volume consumer market is much more price/cost sensitive and dedicated hardware that is not often used is difficult to justify. The extra processing capability added to the system does not help non-MPEG games or other applications run better. The cost of this hardware is often subtracted from other system components causing them to be downgraded to keep the overall system at a particular price point. Whether the system then has a slower processor, no cache, slower hard drive, or other lower cost feature, the user experiences slower system performance in almost all other applications.

Software MPEG playback on a platform optimized for this purpose provides the most flexible, lowest cost general purpose solution with video and audio quality nearly as good as platforms with hardware acceleration. The real benefit is that these optimizations enable such platforms to run most software better. This also includes other software video playback options including Indeo Video Interactive. The task then is to measure how much each system feature affects the frame rate and processor utilization.

Section 3 - Comparison of various software solutions

A number of software (or "soft") MPEG product playback options are available. The goal here is not to pick the soft MPEG "winner" but to suggest a solution that will provide good performance with good picture quality. This enables broad adoption of MPEG with little or no added cost to the PC platform. As happens early in this type of product cycle, performance of the initial soft MPEG products will improve significantly with each new release.

The criteria for selecting the best soft MPEG playback solution are both quantitative and qualitative. The quantitative benchmarks are established partly as a function of the medium (e.g. television or film) and partly in comparison to current hardware alternatives. The quality of playback is highly subjective and depends solely upon perception. Though both criteria combine to affect the end user experience, it is useful to consider them separately.

The quantitative target for MPEG playback is 30 frames per second (NTSC) or 25 frames per second (PAL). The usual software-only MPEG CODEC gracefully degrades the frame rate if it is unable to get enough processor MIPs to decode video after the audio decoding process gets its share. Whether or not this frame rate degradation is detectable is a function of the source material; the more the action, the more it is noticeable. The effects of dropping more than 15% to 20% of the total frames (which equates to frame rates below 25 fps for NTSC) becomes very visible and yields jerky, unsatisfactory images. For any MPEG player to be acceptable, it must not drop more than about 5% of the total frames. Again, for NTSC source material this means 28 to 29 frames per second (fps) at a minimum.

The perceived quality of an MPEG player depends on picture clarity, stability, and accuracy when compared to the original. It can never exceed the quality of the source material and it is further limited by the quality of the compression and the limitations inherent in the MPEG-1 standard. The best source material is film since it is “progressive”, i.e. it is not interlaced like television. All data needed for each frame is available sequentially instead of as sets of even and odd lines. The clips we chose were commercially prepared film source materials with extremely high quality compression and a relatively large amount of onscreen motion.

We looked for image artifacts typical with MPEG compression and playback. The following definitions are courtesy of Rick Doherty, Director, Envisioneering Group:

> **Blockiness (DCT blocks)**
> These are regular 8x8 or 16x16 pixel square patterns which are discernible in large regions of the screen. They are formed by the peculiar mathematics of the Discrete Cosine Transform, a set of mathematical formulae used to decimate and compress a field or frame of video into its most essential elements. When the corners and vertices of these blocks fall across naturally occurring edges and boundaries of an image, new artifacts appear but the root cause is the DCT block. For this reason, some new video codecs are exploring 4x4 and 2x2 blocks in an effort to reduce motion DCT artifacts.
>
> **Color Banding**
> These are patterns of color discernible after compression/decompression, usually caused by noise in the Analog to Digital and Digital to Analog circuitry of the editing system. To minimize these effects, some manufacturers are moving from eight to ten and twelve bit color encoding. However, these improvements can double and quadruple an editing system’s appetite for storage. Color banding is a particular problem where several cuts are made in an online session since any induced color artifacts often requires an operator to manually tweak color from one scene to another.
>
> **Frame Snapping**
> Smooth camera pans and action produce sudden left-right shifts in the image detail, as if one or more frames are missing. This usually occurs only at extremely high compression values, triggered by proprietary algorithms used to assemble a digital "frame" of video from two sequential fields. These can also be induced by editing systems which fail to locate the source of 3/2 pulldown artifact when film footage has been part of the source food chain in video tape production.
>
> **Busy Background**
> Normally stationary and static background regions (and some foreground elements) appear to be busy, as if there were small color regions roving about on their surface. Some call this the “sea of snakes” effect, from Indiana Jones, where the floor of the tomb seemed to be "alive." Others refer to this technically as quantization noise. Systems which use superior analog to digital converters, or more than eight bits of data for each color, tend to produce lower busy background artifacts.
>
> **Detail Color Noise**
> Like Color Banding, these effects are usually attributable to DCT artifacts and are minute patterns of color discernible after compression/decompression. These are usually created by noise in the A/D and D/A circuitry of the editing system’s electronic circuitry. Example: a field of grass will change from green to blue-green from frame to frame, a sweater may change color, a person's face will get redder and greener as frames advance, the sky may pick up purplish elements.

MPEG CODEC Comparison Results
We tested four different players from four separate suppliers, Xing, MediaMatics, CompCore, and NewLogic. We used identical platforms and had each vendor configure their system for optimal performance for their player. A group of trained and untrained observers viewed all systems side-by-side running identical high-quality MPEG clips.

Conclusions
The results we derived were based on overall experience and are highly subjective. The general observation is that smoothness of motion is more important than image quality. Experiential data shows that watching a jerky player for an extended period of time (>15 min) causes physical discomfort such as a headache. Image artifacts on the other hand tend to disappear if viewing the display from greater than a few feet away. Thus more weight was placed on motion smoothness than image quality in creating the final rankings. For audio, the highest ranked 3 systems were all very close, nearly indistinguishable. The fourth ranked decoder was significantly worse in audio quality. One player, generally agreed to be the best overall, was chosen for the testing reported in the following sections.

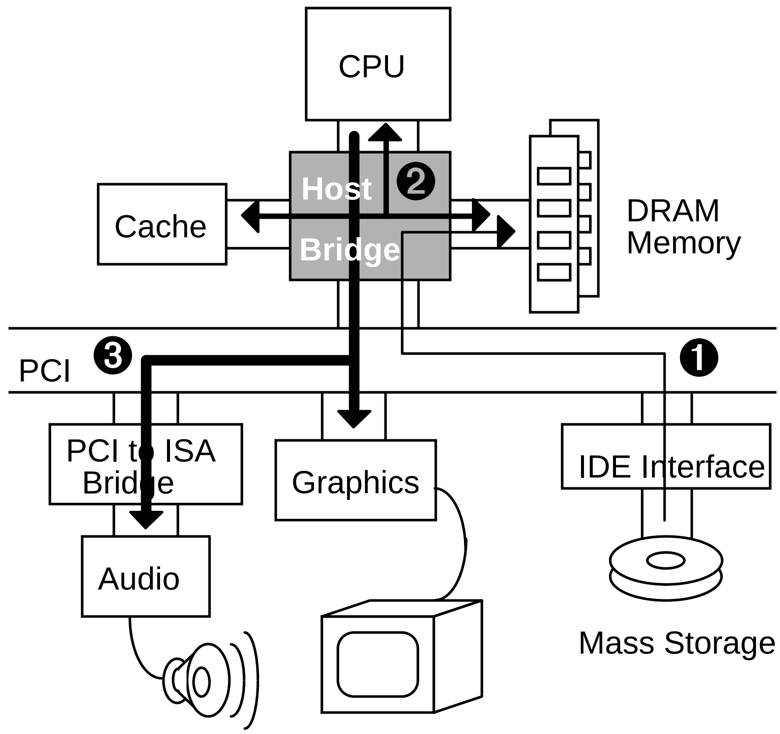
Section 4 - Platform elements and their effect upon video playback performance

For the purpose of the following discussion, picture quality and playback quantity (frame rate) will be considered together, that is picture quality is directly affected by frame rate. Most MPEG-1 decoders keep decode quality constant and drop frames if there is insufficient time to decode them. Assuming that the playback codec chosen can do an excellent job of decode, but will drop frames as needed to maintain quality, then the playback frame rate can be used as a benchmark for assessing the cost/benefits of the various system elements that affect the sustainable data rate.

With respect to video decompression performance, the system architecture can be considered as five subsystems:

1. Microprocessor/Memory
2. I/O interconnect
3. Mass storage
4. Graphics
5. Audio

To architect the lowest cost/highest performance system it is useful to understand the flow of data as it streams across the I/O bus from the mass storage subsystem, through decompression, and eventually ends up as pixels on a graphical display. Data flow is serial and pipelined. Each link in this chain can directly affect the quality of the playback by limiting total system throughput incrementally. Below is a diagram showing the data flow for an MPEG-1 playback system.



1. The first step involves primarily the mass storage and I/O interconnect subsystems if bus mastering is employed. Otherwise the microprocessor has to get involved taking time away from decompression. Data rates are relatively low (about 1.5 Mbits/second or 187 Kbytes/second) and the memory subsystem is not really burdened.
2. The second step involves mainly the Microprocessor/Memory subsystem. The microprocessor reads and writes to memory as it decompresses the images which is the compute intensive part of the process. It can involve either integer or floating point math.
3. After the microprocessor finishes the algorithms to decompress the video and sound, image and audio data is written to the appropriate devices. As you can see, the performance of the host bridge is critical to the capabilities of the system since it must efficiently manage data flow or it will easily be the system bottleneck.

The following analysis examines each subsystem in isolation and quantitatively evaluates design tradeoffs in terms of impact on frame rate. Around the $2K price range there are a number of system feature choices to be made and the objective is identify those that have the biggest impact on MPEG playback performance and to quantify as accurately as possible the performance benefit that each alone yields. It should then be a simple matter to make system feature choices and calculate the expected MPEG playback cost/performance (based on a given cost structure).

Platform Implementation Options

(Note: For a description of the testing methodology used to obtain the following results see Appendix A)

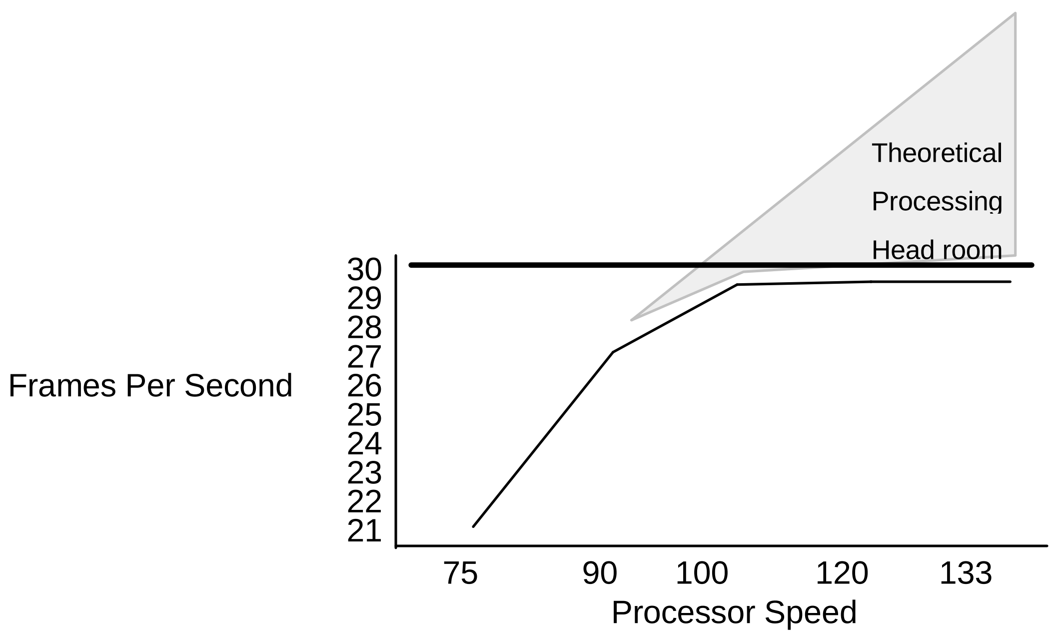
Pentium® Processor speed (75, 90, 100, 120, 133 MHz)
The Pentium processor was chosen as the baseline for several reasons, the most important being that it is the performance entry point for doing software-only MPEG-1 playback. Its integer and floating point performances are significantly improved over the 80486. Processor-specific software optimizations for the dual instruction pipes further separate it from its predecessors for doing native signal processing. Related studies on audio signal processing have shown the Pentium processor to be 2X to 6X faster than the 486 with the higher performance resulting from floating point improvements in the Pentium processor.

A range of processor speeds was chosen to help assess the effect of more MIPs being applied to the decompression part of the process. Also, depending upon the processor speed, the processor bus speed increases will affect the throughput of the data as it moves to and from main memory. The low end of the range, 75 MHz, is generally believed to be too slow to attain 30 fps MPEG-1 decode and playback but we wanted to test this assumption and establish the low end, or baseline, of the range. Above this baseline (i.e., the point at which 30 fps sustainable decode occurs), it is assumed that usable MIPs will be available for other processing such as responding to systems events and/or user interaction within games and applications.

System configuration: 8 Meg EDO DRAM, 256K Pipelined Burst cache, Bus Master IDE on, S3 Trio* 64V+ with 1M DRAM, CS4232 audio CODEC

Pentium Processor Speed	Average Frames/Second
75 MHz	21.1
90 MHz	27.1
100 MHz	29.5
120 MHz	29.6
133 MHz	29.7

Conclusions: These measurements show that, per the previous target of 28 to 29 fps, excellent MPEG playback is achievable with a 100 MHz processor. It also shows that the theoretical maximum of 29.97 fps was not achievable even with more computing power. We speculate that it may involve the system clock tick processing and/or interrupt handling of Windows* but more study is needed here. Lastly, and most importantly for the future, when interactive MPEG titles begin to become common later next year, the processor baseline will have advanced so that there is extra processor power to enable MPEG playback and multitasking with software-only MPEG players. The following graph illustrates this:



Second Level (L2) Cache
All systems, by virtue of having a Pentium processor, have a first level cache within the microprocessor. Many systems also include a second level cache. This second level cache can fill on-processor cache lines in the event of first level cache-line misses. For compute-intensive algorithms such as MPEG decode, the question is exactly how much the second level cache benefits the decoding. Second level (L2) cache adds cost and with the advent of EDO DRAM (see below), there is a growing belief that systems can perform well enough without L2 cache. This assumption was tested using cached and cache-less base level systems with Fast Page Mode (FPM) DRAM. The differences are shown below.

System configuration: 100 MHz Pentium chip, 8 Meg DRAM, 256K cache, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

Memory Configuration	Average Frames/Second
Cache-less with FPM	22.9
Async cache with FPM	26.3
Cache-less with EDO	26.2

Conclusions: Fast page mode systems require cache to begin to approach the performance required for software-only MPEG playback, but better memory technology is needed to achieve the required performance on 100 MHz systems. EDO DRAM, which will be discussed later, even without a secondary cache, offers performance equal to Fast Page Mode DRAM plus asynchronous cache when doing MPEG playback.

PBSRAM/Asynchronous SRAM
As a corollary to the need for second level cache, the type of cache employed comes in question. Asynchronous second level cache has been the mainstay for cache architecture since its inclusion in personal computers. Recently, advanced cache architectures have become available. Synchronous burst, also know as Pipeline Burst SRAM, or PBSRAM, is becoming more common, particularly in performance critical applications.

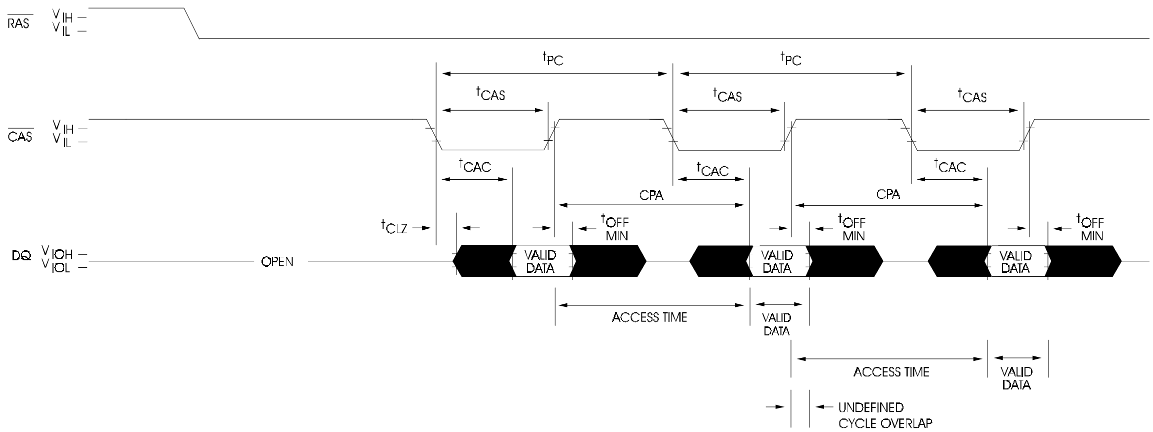
PBSRAMs offer significant performance improvements which can theoretically yield gains such as 3-1-1-1 memory read and 2-1-1-1 memory write cycles using 10 ns PBSRAM on a 100 MHz processor. This reduces wait states by nearly 50% compared to asynchronous implementations. Whether these wait states equal improved application performance is highly dependent upon the application. How this affects the frame rate of MPEG playback for the chosen CODEC is shown below.

System configuration: 100 MHz processor, 8 Meg FPM DRAM, 256K cache, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

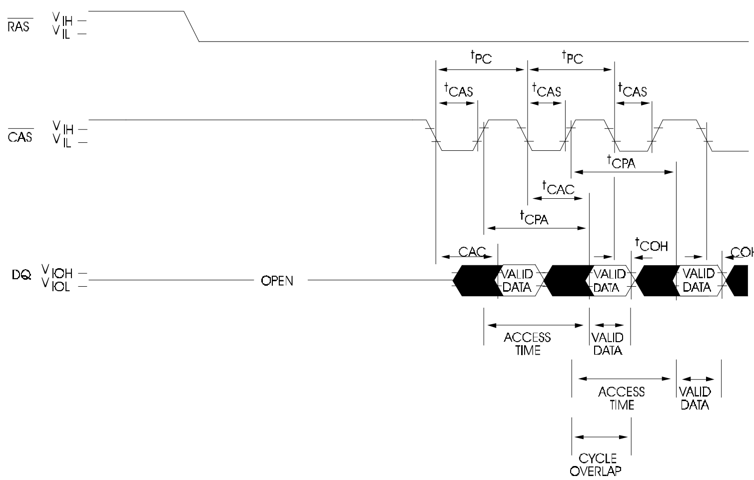
Memory Configuration	Average Frames/Second
Async SRAM	26.3
PBSRAM	29.4

Conclusions: PBSRAM is required to get into an acceptable range for MPEG playback.

EDO DRAM/Fast Page Mode DRAM
Extended Data Out (EDO) DRAM is a recent development in memory technology that can result in the doubling of main memory bandwidth for sequential memory reads but does not affect write performance.



(a) Conventional FPM



(b) EDO

UNDEFINED

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Use of EDO DRAM can push memory read bandwidth up to 250 MB/s. This should yield an obvious benefit for MPEG decode in which the processor works on a continuous stream of sequential read data from main memory. Since EDO does not speed up write performance, the variable is the ratio of reads to writes. If the ratio is high (i.e., many reads occur for each write), then the value of EDO will be apparent and the relative price/performance of EDO will be low. However, if the inverse is true, many writes for each read, then the extra cost incurred for incorporating EDO may not be worthwhile. This is what the following test attempts to reveal. While the exact results are dependent upon the specific decoder implementation, the MPEG decoding process, from a “black box” perspective, is expected to be fairly consistent across implementations.

System configuration: 100 MHz processor, 8 Meg DRAM, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

Memory Configuration	Average Frames/Second
Async cache/FPM	26.3
Async cache/EDO	27.1
PBSRAM/FPM	29.4
PBSRAM/EDO	29.5

Conclusions: EDO DRAM offers a slight performance increase but the process is inherently memory bandwidth bound which is why the cache offers a significant improvement. From the processor speed results we can see the processor is very nearly compute bound which will mask some of the benefits of faster memory performance.

System memory size
The system memory size needed is largely dependent upon the operating system employed. Windows 95 can run in as little as 4 MB but it is generally accepted that 8 MB is needed to do anything useful. The question to be answered here is whether a memory size greater than 8 MB, such as 16 or 32 MB, will result in improved performance. Of course this is somewhat dependent upon the software architecture of the MPEG player being used and what else may be running in the system. For the purpose of this paper, which seeks to establish a baseline, only Windows 95 and the MPEG player were resident in memory as the system memory size was varied. The results are shown below.

System configuration: 100 MHz processor, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

Memory Configuration	Average Frames/Second	
	8 MB	**16 MB**
Async cache/FPM	26.3	25.6
Async cache/EDO	27.1	26.7
PBSRAM/FPM	29.4	29.0
PBSRAM/EDO	29.5	29.6

Conclusions: Though it might appear that the 16 Meg system was slower for most cases, the tests were within 0.75 fps which is considered the margin of error for this testing. There is therefore no appreciable difference for MPEG-only video playback. This does not take into account the potential advantage that extra memory may bring for what may be future interactive MPEG titles and for the operation of Windows 95 itself. The good news is that only 8 MB is needed to hit the performance target.

Bus Master IDE/IDE
The second aspect to mass storage subsystem performance is the amount of processor overhead incurred by servicing the I/O device. Polled I/O (such as the various PIO modes in the PC) requires that the processor be involved in regularly reading status from the I/O device and setting up the DMA channel to move the data. This can inflict up to 40% overhead on the processor which directly steals time that can be used for better purposes, such as MPEG decode.

A better approach is to employ bus mastering by the I/O controller (sometimes referred to as IDE DMA). In this scheme, the I/O controller directly writes into the appropriate buffer in the main system memory array without intervention by the processor (other than initially setting up the device and then doing small amount of maintenance). Overhead is extremely low, typically around 1% of processor bandwidth. Given that MPEG-1 playback consumes a large portion of the available processor MIPs, bus mastering can yield significant benefits. Bus mastering has long been available through the use of SCSI but now that bus mastering IDE is available on PCI, a larger audience is accessible through the lower cost of IDE.

The question to be answered here is the I/O overhead sufficiently large for MPEG to make the use of bus mastering apparent? The following chart shows the measured results for each.

System configuration: 100 MHz processor, 8 Meg EDO DRAM, 256K PBSRAM cache, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

Bus Master IDE	Average Frames/Second
Off	28.2
On	29.5

Conclusions: The use of Bus Master IDE moves the MPEG performance from the low end of what we defined as acceptable to what is nearly the maximum possible. The advantage of bus mastering is not as obvious in this configuration as we have measured for other applications. We believe the answer may lie in the processor graph above. The curve starts to flatten before 100 MHz therefore there is already some headroom for the processor to be doing some other things. Servicing the IDE interface may almost completely fit in this space though this is not completely understood. We ran a test the following test which seems to support our conclusion.

System configuration: 75 MHz processor, 16 Meg EDO DRAM, 256K PBSRAM cache, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

Bus Master IDE	Average Frames/Second
Off	24.2
On	26.7

Conclusions: The result was larger, 2.5 fps vs. 1.5 fps increase. Still more work could be done to better understand bus mastering in an MPEG playback system. Nevertheless, since Bus Master IDE is virtually free from a product point of view and the drivers are included in Windows 95, there is little reason not to include it as a feature in the platform. Also, you can take advantage of bus mastering for both the hard drive and CDROM if they connect them to separate IDE channels. The cost to do this is one IDE cable and the proper selection of a CDROM drive capable of bus mastering.

Chipset

The chipset is at the heart of the system. Of all system features, it can have the most profound affect on system performance. Most chipsets not only manage the second level cache, but also serve as the controller to main memory and the system's I/O bus, PCI in this case. So complex are the interactions of these various parts that it is really only possible to analyze the chipset from a "black box" approach.

Instead of trying to benchmark the constituent pieces of chipset performance, such as memory bus bandwidth and PCI bus access to main memory, the approach is to judge the additive affects of these performance characteristics on MPEG playback for another chipset. We tested a previous generation chipset to the current 82430FX, the 82430NX. We changed the motherboard in our system while keeping all things equal, such as clock speed, memory size, video controller, etc. We had to compare to async cache and FPM DRAM since the 82430NX chipset is not capable of working with the newer memory technologies. Below are the results of the testing.

System configuration: 100 MHz processor, 8 Meg FPM DRAM, 256K Async cache, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

Chipset	Average Frames/Second
82430NX	22.4
82430FX	26.3

Conclusions: The choice of chipset definitely affects the performance of MPEG-1 playback. The one chosen comparison is not necessarily representative of the entire market but it does point out the performance improvements provided by the 82430FX and the need to pay attention to chipset selection.

Video memory size

Related to the choice of graphics controller but somewhat independent is the question of how much video memory offers optimal playback quality. This is more of a function of the way the MPEG playback software was written. Inefficient use of video memory, especially in the off-screen drawing process could lead to higher performance with more memory. We ran this on only the chosen playback software with the results shown below. In the future we may choose to test this across multiple MPEG implementations to better compare implementations.

System configuration: 100 MHz processor, 8 Meg FPM DRAM, 256K cache, Bus Master IDE on, S3 Trio 64V+, CS4232 audio CODEC

Video Memory Size	Average Frames/Second
1 MB	29.5
2 MB	29.5

Conclusions: Though we have noted performance differences related to memory size on other lower performance MPEG players, the chosen player seems to make very efficient use of the memory provided and there is no difference for memory size in the tests we ran.

Video add-in/video down

The last aspect of video design that might affect video playback performance is the chosen implementation of the graphics subsystem. Some efficiency might be gained by putting the graphics on the motherboard, or as it is commonly known "down", over putting it on an add-in card. Again, keeping all things equal, we tested the same graphics device that is on our reference platform on an add-in card. The results are shown below.

System configuration: 100 MHz processor, 8 Meg FPM DRAM, 256K cache, Bus Master IDE on, S3 Trio 64V+ with 1M DRAM, CS4232 audio CODEC

Video Location	Average Frames/Second
Add-in	29.4
Down on Motherboard	29.5

Conclusions: In the chosen design, as with all other well designed platforms, there is no difference in MPEG play back for add-in graphics solutions when compared to devices on the motherboard. This is a feature of the PCI bus and will be true for all compliant peripheral devices capable of also residing on add-in cards. As one last data point, we tested refresh rate of the graphics card and found it has no measurable effect for the chosen controller. It must be doing a good job of synchronizing memory access and screen updates.

Section 5 - Configuring the best low cost MPEG-1 playback platform
From our study, we discovered the following system configuration to yield the best cost/performance for software-only MPEG playback while meeting the criteria set for acceptable video quality. Of course the results for any particular vendor may be dependent upon their particular cost structure.

- 100 MHz (or higher) Pentium processor
- 82430FX chipset
- 256 KB PBSRAM
- 8 MB EDO DRAM
- Bus Mastering IDE
- Type F DMA enabled
- A video enabled graphics device (either add-in or on motherboard) such as the S3 64V+ from S3 with 1 MB of DRAM

Conclusion
In the course of this study we reaffirmed much of what we already believed: quality MPEG-1 playback is indeed possible on a volume $2K PC platform, and new system technologies such as PBSRAM, EDO DRAM, bus mastering, etc. yield tangible benefits by enabling new system capabilities.

We also learned a few things that lead us to want to know more. When you look at a system feature in isolation, it is easy to demonstrate specific cost and/or performance benefits, but when running applications, many benefits get obscured by system interactions. This is not too surprising but it points to the fact that even though software MPEG playback performance is a good test of system capability, it is not perfect. More study is required in the area of multitasking to measure the benefits of some of the system attributes, particularly as the processor speeds up which, in turn, may enable the simultaneous use of other applications. The key is to ensure that a faster processor means better application performance. Since new processor generations help drive the market, other results may stall the growth of the PC market and the industry may miss the opportunity to bring new uses and users to the desktop.

Appendix A - Test Methodology For Measuring MPEG-1 Soft Playback Frame Rate

Purpose

The purpose of this test was to measure the number of frames per seconds outputted to display frame buffer while playing a single MPEG-1 clip using different type processor speeds, cache, DRAM, and bus mastering IDE.

Reference Platform Configuration

Hardware Configuration

Component	Reference	Comments
Motherboard	Advanced/MC LPX	
BIOS	1.00.01.CH0	Latest
Processor	Pentium processor, 100 MHz	
Cache	256KB PBSRAM (15 ns)	CELP module
DRAM	8M EDO (60ns)	2x4M SIMM (2x8M SIMM for 16 M)
HDD	WD Caviar* 2850 (850 MB)	
CD-ROM	Sony CDU-76 (4x IDE)	MS IDE-DMA enabled
Audio	Crystal CS4232 audio codec	
Graphics	S3 Trio 64V+ w/ 1 MB 70 ns DRAM	

Software Configuration

Component	Reference	Comments
OS	Windows 95	Upgrade (Intel version)
Video mode	640x480, 8 bit color	
Drivers:	S3 Trio 64V+ (DD support)	Beta from S3
	Microsoft DirectDraw* run time	From Games SDK

System Hardware Description

Testing was performed on two Pentium processor systems using the Advanced/MC motherboard. One system was configured with 16 MB and the other with 8 MB of memory. The actual speed of the Pentium processor used in these systems was 100 MHz. With the flexibility of the mother board used in these systems, we were able to downgrade the system speed to 90 and 75 MHz by relocating the appropriate jumpers. Upgrading the system speed to 120 and 133 MHz was also possible by using a 133 MHz processor. The Advanced/MC baseboard is also capable of L2 cache upgrades, accepting 256 KB using standard asynchronous or Pipeline Burst SRAM. The memory subsystem is designed to support up to 128 MB of EDO or standard Fast Page DRAM in standard 72-pin SIMM sockets. The Advanced/MC baseboard also utilizes Intel's 82430FX PCI Chipset which enabled us to use PCI Bus Mastering IDE which was used for bus mastering the 4X CD-ROM off of the second IDE channel. As for multimedia capabilities, Advanced/MC baseboard contains a Crystal CS4232 audio CODEC which is integrated onto the baseboard. The CS4232 provides 16-bit stereo, SoundBlaster* Pro compatible audio with full-duplex capabilities.

MPEG-1 Clip Characteristics
The MPEG-1 clip used for the purpose of this measurement was encoded with the following characteristics:

Video Characteristics

Type:	System Stream
Size:	352X240
Picture Rate:	30 fps
Bit Rate:	1,151,600 bps
Parameters:	Constrained
VBV Buffer:	40 Kbyte
Coding Pattern:	sgBBIBBPBBPBBPBBPSGBBIBBPBBPBBPBBPSGB......

Audio Characteristics

Audio Layer:	II
Header CRC:	Off
Bitrate:	224 Kbps
Sampling Freq.	44.1 KHz
Mode:	Stereo
Copyright:	Yes
Originate:	Yes
Emphasis:	Off

Testing Procedure
We invoked the MPEG playback software and opened an MPEG file. (This is the MPEG-1video clip which was encoded based on the parameters stated above). To ensure minimum processor interrupts during playback, the start on the video player was invoked via a keystroke (F6) in place of using the mouse. While the mouse pointer was set on the top of the active video window, the left mouse button was double clicked to convert the player window into a full screen. After the completion of the video, the frames per second information was recorded by looking at the reported information out of the Help Menu on MPEG playback control panel. This process was repeated 5 times to obtain an average number on the fps. This process was repeated for all configurations.

Appendix B - Miscellaneous: pointers to useful web sites, vendor phone numbers, specifications, etc.

Software MPEG playback vendor contacts:

CompCore: George Haber (408) 773-8310
MediaMatics: Prem Nath (408) 496-6360
NewLogic: Peter MacCormack (360) 896-8321
Xing: Sean O'Toole (805) 473-0145

MPEG API standards effort:

OM-1 Consortium
Open MPEG Consortium
849 Independence Avenue, Suite B
Mountain View, CA. 94043
(415) 903-8320
FAX: (415) 967-0995

info@om-1.com
http://www.om-1.org

Reference material:

How People Will Buy MPEG and What That Means For Publishers, Jan Ozer, CD-ROM Professional, November 1995.

To purchase MPEG-1 and ISO 9660 (CD-ROM format) specifications, contact:

International Organization for Standardization (ISO)
WWW at http://www.iso.ch/

Other sources:

Software Publisher's Association:
http://www.spa.org/

MPC Working Group (and MPC-3 spec)
http://www.spa.org/mpc/