Graphics Controller '97 (GC'97)

Rev. 1.0

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WWW links of interest

http://www.intel.com/pc-supp/platform/agfxport/index.htm	Accelerated Graphics Port specification and other related information
http://www.intel.com/iaweb/intercast/index.htm	Intercast™ technology
http://www.intel.com/intel/july24/WHITPAPE.HTM	Whitepaper discussion on hybrid

applications

http://www.intel.com/pc-supp/platform/papers/mpeg2ovr.htm *Choosing a Platform Architecture for Cost Effective MPEG-2 Video Playback*

http://www.intel.com/pcoems/psvideo/devover.htm Intel Video Phone with ProShare™ technology

1. Executive Summary

GC'97 is a graphics controller design guide that is intended to serve as a guideline for the baseline capabilities that the graphics IHVs (Independent Hardware Vendors) need to implement in order to support emerging applications and usage models to be delivered by OEMs and ISVs in 1997, including:

- 3D Graphics
- Software MPEG-2 Playback
- Video Conferencing
- Intel Intercast™ Technology
- The Internet
- Family Room PC Capabilities

The 1997 PC platform will bring many new and exciting technologies and capabilities to the mainstream PC. First, the Accelerated Graphics Port (A.G.P.) will bring scalable, arcade quality 3D graphics to the mainstream PC. This will enable an unprecedented level of PC gaming, and also enable a new generation of 3D business-related applications. Second, the combination of DVD-ROMs and key features in a graphics controller will enable software MPEG-2 video playback on a mainstream PC while keeping implementation costs to a minimum. Finally, major OEMs will be shipping POTS video conferencing enabled systems, delivering on Intel's promise of a Communicating PC, while the driving forces of the Internet will make the Connected PC commonplace.

The intent of GC'97 is to establish a baseline set of features needed to support the applications discussed in more detail below for the high-volume, mainstream PC, although features and capabilities extending beyond those stated in this document are expected and encouraged. To achieve this goal one must partition feature support between hardware and software while keeping cost at a minimum. This document will make partition recommendations with the above goal in mind while striving to deliver the most value from the PC platform. Achieving this goal successfully will depend upon innovation from the graphics IHVs.

2. Target Audience

This document is targeted for distribution to graphics controller vendors and system OEMs. It is primarily for product managers/planners at IHVs who will be specifying the feature requirements for a 1997 family of graphics controllers, or for those product managers/planners at PC OEMs who will be specifying the requirements for a graphics subsystem. This document can also be used by ISVs to gain some insight into the mainstream graphics subsystem for PCs in 1997. Readers should use this document to develop an understanding of the partition recommendations that will help bring about a well balanced, high-performance graphics subsystem, at mainstream, volume price points.

3. Home PC and Business PC

As stated above, this document specifies the capabilities for baseline graphics controllers in the 1997 volume PC. It is well understood that specific segments of the market may require different needs. For example, an OEM may not require TV-out support for their corporate desktop platforms. Again, the intent is to establish a baseline set of features for high-volume PC sales.

The pull for new graphics controller features and performance is driven by both Home/Consumer PC users and Business PC users. The usage model between these two classes of users, however, varies. For example, a Home PC user might use software MPEG-2 playback capabilities to view films, or to play games with some MPEG-2 content, whereas a Business PC user might use the software MPEG-2 playback capabilities for interactive training of employees. Likewise, a Home PC user might use 3D graphics for a superior gaming experience, whereas a Business PC user might use a new generation of 3D business-related applications for data visualization.

An additional point of interest worth mentioning is that when one looks at 1996 OEM shipments, he/she will notice that the Business PC platforms were quick to adopt high-end graphics subsystems; this is one very important business reason why one should not assume that 3D graphics or MPEG-2 playback, for example, is only a target for the Home PC user. Finally, the expectation is that the baseline features for the 1997 mainstream PC will migrate to the entry level PC in 1998.

4. Graphics Subsystem Considerations

In 1997, OEMs will have two different ways to connect the graphics subsystem in a PC--either through A.G.P., or PCI. A.G.P. is expected to be supported by Intel chipsets designed for P6-family processor-based platforms, while PCI will be supported in both Pentium® processor and P6-family processor-based platforms. Since both Pentium processor and P6-family processor-based platforms will be selling in high volumes in 1997, all of the applications below need to be supported on both platforms. If any of the features/capabilities described below are platform dependent and thus have different requirements (e.g., bandwidth requirements for software MPEG-2 playback), it will be noted at the appropriate place.

3D Graphics

The transition from PCI to A.G.P. for graphics will be key in enabling high-performance 3D graphics for P6-family processor-based platforms; this will enable arcade quality graphics for the home, higher performance CAD at decreased price points for engineering applications, and a new set of business-related applications created to take advantage of 3D capabilities.

Video Capture

In 1997, there will a few different ways to capture video. One can use an analog capture solution that is then converted to a digital format, or one may use a digital USB camera.

Choosing the appropriate analog capture solution should enable video conferencing, still image capture, Intercast technology, and local video editing at full frame rate. Because of bandwidth limitations for USB, selecting a USB camera may preclude this capture device from being used for other applications beyond low frame rate video conferencing or the capture of a single image. For example, one might not be able to capture video from a source at 30 frames per second at a resolution of 640x480 in order to perform local video editing on a PC; furthermore, it might preclude the use of the Intercast application described below. In short, choosing an analog capture solution may enable more applications than a USB capture solution. In the near future, 1394 will be another high-bandwidth option for capturing video content.

Currently, analog capture capabilities are on a separate chip from the graphics controller. Depending on the demand from OEMs and consumers for video capture, it may make sense for cost reasons to integrate these capabilities directly into the graphics controller.

5. Balanced Partitioning

Balanced partitioning will bring about the highest performance system at any given price point. In concept, the idea is to allocate computing tasks throughout the entire system so that no one component is the limiting factor to achieving maximum performance. The graphics controller adds a great deal of value to the balanced partitioning concept. For example, support for color space conversion, and the combination of support for the YUV12 planar native MPEG-2 video format and bus mastering, are two examples where dedicated hardware adds more value than achieving the same result for software video playback on a PC. 3D graphics is another area where balanced partitioning is very important; here, maximum performance at mainstream prices is achieved by performing the geometry portion of the 3D pipeline on the processor, while implementing a hardware 3D setup engine and rasterization in the graphics controller.

6. Graphics Controller Feature Set

The remainder of this document contains three sections:

1) Application-Specific Requirements: This section highlights the graphics controller features required to support each of the target applications.

2) General Requirements: This section outlines standard features expected from a graphics controller in 1996 and 1997; most of these features are standard capabilities in today's graphics controllers.

3) Features/Capabilities Summary Chart: This section provides a cursory summary of the features/capabilities of a GC'97 graphics controller.

Application-Specific Requirements/Capabilities

3D Graphics

The primary usage for high-performance 3D on the Home PC will be 3D games, and one of Intel's objectives is to make the 2H'97 Home PC the premier home gaming platform. This requires 3D performance which equals or exceeds that of 1996/1997 arcade systems. Arcade quality games can be achieved through the use of rich texture mapping. A.G.P. was designed to offer the necessary bandwidth and latency to perform texture mapping directly from system memory, as opposed to copying all texture data to the local graphics controller frame buffer memory when needed; this new approach is called the "Execute model." The benefit of texturing from system memory is that it can offer high-performance that is scalable while keeping down the system cost; this price/performance benefit will enable arcade quality 3D graphics on the mainstream PC.

Optimally, the processor and the graphics controller work together to create a balanced 3D graphics pipeline. In general, geometry processing will be performed by the processor, while the rendering will be performed by the graphics controller; for balanced, high-performance systems, implementing a hardware 3D setup engine on the graphics controller will help prevent the 3D pipeline from being limited by the processor.

In addition to these general requirements for 3D, there are several other features and capabilities needed for enabling arcade quality 3D graphics on the 1997 mainstream PC.

Hardware features that support arcade quality 3D graphics include:

- A.G.P. interface for P6-family processor-based platforms, and PCI interface for Pentium processor-based platforms

- Sustained fill rate of 30 Mpixels/s (bilinear filtered, Gouraud shading, perspective correct, ambient lit, Z-buffered), and increasing into 1998
- Hardware 3D setup engine capable of the following:
  - -Line slope differential (i.e., calculation of slope between vertices)
  - -Color differential (i.e., calculation of color change for pixels)
  - -Texture differential (i.e., mapping textures onto the (x,y) space)
  - -Intel is performing studies to show the geometry performance for various Pentium processor and P6-family processors in order to help a graphics IHV design a hardware 3D setup engine with sufficient performance to prevent 3D pipeline stalls. Data should be available this September.
- Support for both palletized and direct color texture mapping
- At a minimum support 640x480x16bpp
- High quality texture filtering (e.g., nearest point, bilinear, trilinear, etc.)
- Texture mapping perspective correct
- Bilinear (nearest level of detail) mip-mapping, or equivalent. For improved quality one might implement trilinear mip-mapping.
- Z-buffering (16-bit effective), or equivalent
- Alpha blending (8-bit effective)
- Fogging (8-bit effective)
- Scene/Edge antialiasing
- Support for meshed and unmeshed triangles
- Double-buffering
- Support for Write Combining (WC) on P6-family processor-based platforms; WC combines successive store operations to write an entire cache line at once, and may deliver about a 2-3x performance gain when compared to the Uncacheable mode of the P6-family processor
- Bus mastering for both Pentium processor and P6-family processor-based platform graphics controllers
- Support for high bandwidth frame buffer memories like that offered by synchronous DRAMs

Most important are the performance and quality targets necessary to enable arcade quality 3D graphics on the mainstream PC. Hardware implementation specifics are left to the IHVs, but some suggestions to hit these targets above include:

- For A.G.P. systems, implement pipelining; additional performance increases can be achieved by implementing sideband addressing
- For A.G.P. systems, implement the double-clocked 66MHz data transfer mode (i.e., “133” MHz)
- For A.G.P. systems, texture mapping directly from system memory (i.e., Execute model) is expected to offer the best price/performance level. The 3D accelerator performance hierarchy is as follows:

-Highest performance: Place all 3D data structures in the local graphics controller frame buffer memory, including textures, display buffer, render buffer, Z-buffer, etc; provide multiple high-bandwidth channels to the frame buffer (e.g., separate 64-bit channels for texture data, display surfaces, Z-buffer, etc.); and, an A.G.P. interface. This approach obviously requires a larger frame buffer memory to store high quality texture maps locally (e.g., 4MB or 8MB) when compared to executing texture maps directly from system memory. This will likely increase system cost beyond volume price points.

-**Best price/performance**: Execute texture mapping directly from system memory; place remaining 3D data structures in the local graphics controller frame buffer memory, including display buffer, render buffer, Z-buffer, etc; and, an A.G.P. interface. This would require the smallest local frame buffer memory, and would allow high quality texture maps to grow and scale with system memory.

-Lowest performance: Place all 3D data structures in the local graphics controller frame buffer memory, including textures, display buffer, render buffer, Z-buffer, etc; one high-bandwidth channel to the frame buffer; and, an A.G.P. interface. It should be noted that this model requires adequate bandwidth to support both the transfer of 3D data structures to the local frame buffer memory, while leaving enough bandwidth to support what is needed for rendering. This approach obviously requires a local frame buffer memory to store high quality texture maps locally (e.g., 1MB or 2MB). However, because of the smaller frame buffer size, there will be an increase in the amount of bandwidth needed to transfer textures; for high quality textures, this will decrease the amount of bandwidth available for rendering.

Software MPEG-2 Playback

The arrival of DVD-ROMs in the PC platform will enable playback of movie content encoded in the MPEG-2 format, as well as interactive games that may contain MPEG-2 content. Several major OEMs are expected to begin shipping PCs with DVD-ROM drives in 4Q'96 and early 1997. Intel is positioning the PC as a viable alternative to dedicated consumer players for DVD-Video playback. Therefore, playback quality must be as good as, or better than, the dedicated consumer players.

In order to accelerate the integration of DVD video playback capabilities into the high-volume platform, decode should be done by software. Hardware MPEG-2 video solutions generally require 2-4MB of memory and a DSP, and are likely to be cost prohibitive for the mainstream PC. The cost of this hardware may be saved if decode of the MPEG-2 stream is handled by Intel processors with MMX™ Technology. Currently, for systems with Pentium processors with MMX Technology the partition for MPEG-2 playback is such that video decode is done by the processor, and audio decode is done by dedicated hardware. With the arrival of P6-family processors with MMX Technology in the home, audio decode will be done by software as well, and allow an even greater cost savings.

Detailed information regarding software MPEG-2 playback, and the performance advantages and disadvantages of different graphics subsystems, can be found in the following Intel document: (1) ***Choosing a Platform Architecture for Cost Effective MPEG-2 Video Playback***. This document can be found at the Intel web site listed on the Table of Contents page at the front of this document.

Hardware features in a graphics controller that support software MPEG-2 playback include:

- A.G.P. interface capable of a transfer rate >200MB/s, or a PCI interface capable of a transfer rate >100MB/s; the capability to absorb bursts of data in excess of these transfer rates is the **most crucial factor** identified today for full frame rate playback. In short, the graphics controller should be able to support zero wait-state write performance to the local graphics frame buffer memory.
- Color space conversion
- YUV4:2:2 packed video format support
- Double-buffering
- X-Y interpolation for video image upscaling
- 2MB local frame buffer

For graphics controllers that can support the combination of bus mastering as well as support for the YUV4:2:0 (YUV12) planar video format (i.e., native MPEG-2 video format), the performance increase in frame rate has been measured at 13%. Also, support for YUV12 planar reduces the uncompressed video stream write bandwidth to the local graphics frame buffer by 25% when compared to the YUV4:2:2 video format.

The copy protection method chosen for MPEG-2 content may impact graphics controllers, and if appropriate, this document will be updated when details become available.

Video Conferencing

Major OEMs will be begin shipping POTS video conferencing enabled systems in the second-half of 1996; it is another new application that will drive sales of Home PCs. Standards-based H.324 and H.320 video conferencing applications will permit broad deployment of easy to use systems and make the Communicating PC a reality.

Some requirements needed to support video conferencing may be dependent on which vendor's video conferencing software is chosen. Intel Video Phone with ProShare™ technology is one example of a low-cost video conferencing product that communicates over standard telephone lines. The application conforms to H.324 standards, thus ensuring interoperability with other products conforming to the H.324 standards marketed by other vendors. Engineered for OEM platform integration, Intel Video Phone with ProShare technology delivers video compression, audio compression and full duplex speakerphone via the Intel Pentium processor thereby reducing hardware costs for manufacturers. For further product information please see http://www.intel.com/pcoems/psvideo/devover.htm.

Hardware features that support video conferencing include:

- Ability to capture YUV4:2:2 packed video data at a resolution up to 320x240 for video conferencing. (Higher resolutions for video capture will need to be supported for still image capture, and for those desiring to do local video editing, e.g., up to 640x480.)
- Ability to write the YUV12 planar video format to system memory (Note that this is the format used in Intel's Video Phone with ProShare technology conferencing software; other vendors' video conferencing software might have different requirements.) The ability to write the YUV12 planar video may also more easily enable MPEG-1 video encode in the future.
- High quality downscaling (e.g., interpolated/filtered down scaling; decimation is not acceptable)
- X-Y interpolation for video image upscaling

A desirable feature for video conferencing is support for two hardware accelerated windows with independent scaling.

Intel Intercast Technology

Intel has championed Intercast technology, a new industry technology that enables TV broadcasters to transmit data within the Vertical Blanking Interval (VBI) of a standard television signal. This technology allows content providers to broadcast program-related information like sports statistics, recipes, biographies, or web pages along with the television program itself. This program-related information may be stored and accessed locally on the hard disk of a PC. In addition, there also may be URLs (i.e., Internet web page addresses) embedded in the program-related information sent by the broadcasters; this will allow TV content providers to point Intercast viewers to web pages on the Internet that can be accessed via their modem. In short, Intercast combines the content-rich medium of broadcast television along with the power of a PC to bring about a new usage model for TV--interactive television.

A low cost implementation model for Intercast can best be described as follows. Through the use of a TV tuner and a video capture chip that is connected to the local side bus of a graphics controller, the television signal is: captured, digitized at the appropriate oversampling rate, and split into its VBI and video streams; then the VBI data is bus mastered into system memory where the processor will decode the information and prepare it for display, while the video stream is scaled/filtered and sent to the display to be viewed. A higher cost implementation supports all of the previously mentioned functionality, but is a stand-alone PCI bus mastering add-in card. Today the audio signal is prepared by a separate chip (typically analog) that is connected to the composite output of the TV tuner.

Once again, it should be noted that currently these capture capabilities are on a separate chip from the graphics controller, and that depending on the demand from OEMs and consumers for video capture, it may make sense for cost reasons to integrate these capabilities directly into the graphics controller. The integration cost savings will extend beyond Intercast technology, and into video conferencing and local video editing.

A partial list (see comment below regarding detailed hardware design requirements) of hardware features that support Intercast technology include:

- Capture and digitize TV broadcast signals at appropriate oversampling rates
- Separate VBI and video portion of signal, especially before any filtering is done
- Bus mastering the VBI data into system memory is recommended, although it is not necessary; it is also possible to read data from the video frame buffer using the processor at vertical interrupt time. However, note that Intercast is only one of several applications mentioned in this document that can realize performance benefits from bus mastering.
- For side-port architectures, there must be hardware cooperative support between the video decoder and the graphics controller frame buffer for a separate VBI DMA channel in order to deposit the VBI data into a different location within the frame buffer, and in order to support a different (faster) sample rate for the raw VBI data versus the decoded video data
- Support for a TV overlay surface in a variety of color modes (e.g., 8-bit, 16-bit, 24-bit, etc.)
- Scale and filter video image for display
- I^2C support is necessary for supporting TV tuners and video decoders

Detailed hardware design requirements needed to support Intercast can be found in Intel's ***VBI Hardware Design Guide***, which should be available on Intel's web site this September.

The Internet

The Internet has certainly become one of the driving forces in PC computing today. As we move into 1997, additional capabilities and applications will continue to be added to the Internet. From a graphics standpoint, the most significant of these will include VRML-based Internet applications and interactive web gaming. At this point there are no Internet specific features needed in graphics controller hardware. However, a fast rendering engine will be an advantage in those instances where a web game stores information locally on a user's machine, such as texture map information, as opposed to transferring it over the much slower Internet; this is one example of a "hybrid application," which is an application designed to take advantage of both local and on-line computing resources. This will allow compute intensive tasks to be performed locally, while environmental variables, such as a change in a game player's position during an interactive gaming experience, could be sent over the Internet. For business-related Internet applications, a fast rendering engine will more easily permit one to smoothly navigate complex VRML scenes generated by business data visualization applications.

Information on Intel's Internet Media Symposium, where hybrid applications were discussed in detail, can be found at the Intel web site listed on the Table of Contents page at the front of this document.

Family Room PC Capabilities

In addition to the applications that will drive graphics requirements in 1997, new usage models for the PC must also be understood. The most significant new usage model is the Family Room PC; one such example is the Destination Big Screen PC from Gateway2000. Multimedia initiated the convergence of the PC and consumer electronics, and this trend will continue with the addition of richer media such as MPEG-2 video and AC-3 audio. The traditional PC usage model in time is being extended to new rooms, new uses, and new users.

A major enabler for Family Room PC computing applications, like interactive 3D WWW games, MPEG-2 movie viewing, and Intercast technology, is a large VGA monitor or a TV. In 1997, it is unlikely that it will be economically feasible to bundle large screen (i.e., 25"+) VGA monitors with the volume platform, although this would eliminate the requirements below while delivering better image quality; for economic reasons, it is assumed that the volume platform Family Room PC display will be on a large screen TV.

At this point in time quality is more important than the level of integration, although depending on the attach rate by OEMs it may make sense to begin integrating TV-out functionality. One possible implementation today is to have an analog RGB output signal from the graphics controller that would connect to a chip containing all TV-out functionality (e.g., overscan compensation, flicker filter, etc.); one benefit of this solution is that it can be independent of the graphics controller, that is, universal in nature. A second possible implementation, and somewhat similar to the previous approach, is to have a companion chip tightly coupled to a private bus of the graphics controller; this would be more of a proprietary design because of the proprietary bus requirements, but one benefit is that the graphics controller could then provide a digital RGB output signal to the TV-out companion chip, and deliver higher quality by eliminating the need for the digital to analog conversion and at the same time provide some cost savings. Finally, a third possible implementation is to integrate some of the TV-out functionality (e.g., overscan compensation, flicker filter, etc.), and use a separate chip for the analog encoding. Today's TV-out implementation strategy is left to the innovation of the graphics IHV, but as stated above, the attach rate by OEMs and possible cost savings in the future may drive this functionality to move into the graphics controller.

Hardware features that support TV-out include:

- Support for both NTSC and PAL standards. The choice between NTSC and PAL must be programmable/selectable.
- Flicker filter so that horizontal lines do not blink on interlaced screens; the minimum acceptable implementation is a 3-line flicker filter. The choice to turn the flicker filter on or off needs to be programmable/selectable.
- Overscan compensation so that an entire PC image will fit within the viewing area of a TV screen. Vertical scaling must be filtered/interpolated, decimation will not deliver an acceptable quality. The choice to turn the overscan compensation on or off needs to be programmable/selectable.
- CCIR-601 requirements regarding fundamental television parameters (e.g., color burst frequency, synchronization amplitude, etc.)

Some other issues that should be considered:

- Unfortunately, there are no objective measurements for defining an acceptable quality TV-out implementation; however, a TV-out implementation should permit the viewing of a 10-point font within a normal viewing distance within the family room. Furthermore, it should be noted that quality is affected not only by the TV-out implementation, but also by the quality of the TV display.
- Simultaneous display support for VGA and TV-out. Taking this one step further, ideally the VGA output would be independent of the TV-out display; this would allow, for example, an individual working on local video editing to perform the editing work on the VGA display while watching results on the TV display (i.e., different images on each of the two displays).
- Support for both S-video and composite video output connectors

General Requirements for 1996 and 1997 Graphics Controllers

Other necessary graphics controller features include:

Compatibility

- Full VGA support
- Windows GUI acceleration at 40-50 Winmarks

Hardware Protocol Compliance

- PCI 2.1 compliance for Pentium processor-based platforms
- A.G.P. compliance for P6-family processor-based platforms

Software Compliance

- Support Microsoft DirectX* (DirectDraw*, Direct3D*, etc.)
- Support Microsoft ActiveX*
- Write Combining (WC) support for P6-family processor-based platforms

Power Consumption

- This document does not address this issue in any detail. All reasonable steps should be taken to minimize power dissipation.

7. Features/Capabilities Summary Chart

This is a cursory summary of the features/capabilities discussed above. For a complete and accurate listing of the features/capabilities please reference the material above.

3D Graphics	S/W MPEG-2 Playback	Video Conferencing	Intercast Technology	Family Room PC Capabilities	GC'97 Graphics
A.G.P. or PCI interface 30Mpix/s fill rate H/W 3D setup engine High-quality texture filtering Mip-mapping Z-buffering Alpha blending Fogging Antialiasing Meshed/Unmeshed triangle support Double-buffering Write Combining Bus mastering					A.G.P. or PCI interface 30Mpix/s fill rate H/W 3D setup engine High-quality texture filtering Mip-mapping Z-buffering Alpha blending Fogging Antialiasing Meshed/Unmeshed triangle support Double-buffering Write Combining Bus mastering
	A.G.P. > 200MB/s PCI > 100MB/s Color space conversion YUV4:2:2 support Double-buffering X-Y interpolation 2MB local frame buffer				A.G.P. > 200MB/s PCI > 100MB/s Color space conversion YUV4:2:2 support X-Y interpolation 2MB local frame buffer
		Capture YUV4:2:2 up to 320x240 Write YUV12 planar data to system memory High-quality downscaling X-Y interpolation			Capture YUV4:2:2 up to 320x240 Write YUV12 planar data to system memory High-quality downscaling
			Capture and digitize TV signal Separate VBI and video Support for a TV overlay surface I^2C support		Capture and digitize TV signal Separate VBI and video Support for a TV overlay surface I^2C support
				NTSC and PAL support Flicker filter Overscan compensation	NTSC and PAL support Flicker filter Overscan compensation