# Television on the PC:
# An Assessment of the Video Market, Facts and Issues

*The PCI bus is the hub for many current and emerging broadband technologies*

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## Executive Summary

Analog video decoding as a function in the PC first emerged from a market need for dedicated tools and hardware supporting high-end PC-based video capture and editing applications. Since then, analog video decoder use in the PC has evolved into three distinct segments: video capture and editing solutions, video teleconferencing kits and PC television receiver cards. It is this latter category of television on the PC that has emerged as the primary and dominant segment.

Analog television receiver cards are beginning the transition from a niche retail category to the mainstream PC. Today's products have evolved in many ways including features, quality, performance and price, making them far more attractive than in the past.

The need for and availability of broadcast data in the PC is another primary reason analog television receiver cards are becoming more popular. The introduction of Windows 98™ with its WebTV for Windows™ feature, national broadcaster support of Vertical Blanking Interval (VBI) data and, in the future Digital Television (DTV) all contribute to addressing the need for a feature-rich broadcast data function in the PC.

The PCI bus is the hub for many of these current and emerging broadband technologies. PCI provides the PC access mechanism that:

- Most effectively supports the architectural partitioning of the various technologies in the PC, both today and tomorrow
- Best meets the requirements for a variety of current and emerging broadband applications

- Is the only solution that truly meets PC OEM build-to-order needs

Myths and misconceptions about the quality and feasibility of PCI video, somewhat common in the past, can no longer be substantiated. Technical evidence, PC OEM needs, the installed base of PCI-based solutions and the PC99 design guide requirements all validate PCI as a suitable and valuable architecture.

This paper will provide the following:

- An assessment of the television receiver card market and the market dynamics driving the move of PC television from a niche market to mainstream PC use.
- Information on the two basic video architectures and the advantages offered by PCI.
- A brief look at emerging PCI-based broadband technologies.
- An understanding of PCI video decoding facts and misconceptions.
- A primer on the basics of video and television (Appendix).

## Market Overview

### *Emerging Market Trends*

Historically, the typical PC television receiver card user was generally considered an early technology adopter, who procured the latest technology far ahead of the mainstream consumer. TV receiver products could only be found in the back row on the bottom shelf of the local computer store. The following factors have caused this to change:

- PC OEMs are looking for new ways to differentiate their products.
- TV card technology has become far less expensive and, with the introduction of PCI bus mastering devices like the Bt848, Bt848A, Bt878 and Bt879, new cost points can be achieved.
- The end user is becoming aware of the value proposition a television receiver card offers.
- There is greater availability of VBI and other data broadcast media beyond simple closed-captioning data.
- Microsoft's WebTV for Windows TV Viewer is an integrated part of the Windows 98 operating system.

## PC OEM Differentiation

Just a few years ago, PC OEMs had a variety of technologies they could use to differentiate their PC, such as audio, modem, CD-ROM and Ethernet. Recently, many of these technologies have become commodities as the PC industry enters an era of slower growth, particularly in the consumer space. As a result, PC OEMs are finding new ways to sustain market growth and market share objectives. Build-to-order is driving this new wave of differentiation for many OEMs. They are seeing television on the PC as a new product category with appeal based on developing market awareness of the TV function, TV applications and Microsoft's promotion of WebTV for Windows.

## Cost of Today's TV Receiver Card

Three or four years ago, the only solutions available supporting television on the PC were offered for $299-$399. The solution was attached to a Video Graphics Accelerator (VGA) and typically consisted of the VGA and an additional sandwich card that plugged on top of the VGA. With the introduction of the first PCI bus mastering video decoders, a new market segment, not tightly coupled to the VGA, was established in the retail space.
This architecture provided the benefit of giving only what the consumer needed—a TV card—no VGA, only TV. The first offerings were in the $149-$199 range, a substantial end-user savings. Technology has advanced, tuners are less expensive and the bill of materials of dedicated TV cards has been reduced significantly to provide board makers with a means to offer a $69-$129 retail product.

**VBI Content**

VBI is the portion of the video signal usually used to carry closed captioning or second language signals. There is a new wave of interest in VBI because it can be used to provide Web content and additional TV programming information to PCs that are equipped with compliant TV receiver cards.

Content developers create HTML content that broadcasters or cable companies insert into the VBI portion of the TV signal. The video signal that contains the Web content is then transmitted over the air or via cable to the PC for display alongside the on-screen TV window. Some popular applications that provide this capability include Intel's Intercast™, WavePhore's Wavetop™ and Microsoft's WebTV for Windows, which includes Intercast.

The value proposition of VBI is that viewers can receive Internet content directly over the airwaves, and more specifically, without being connected to the Internet via an Ethernet connection or POTS modem.

Users can also receive content faster. The fastest 56 Kbps modems rarely connect at speeds above 40 Kbps. During one second of broadcast video, there are 30 frames each with 42 lines of non-video information space. Up to 21 of these lines can be used for VBI content. While the details of the various approaches to implement VBI vary from manufacturer to manufacturer, some rough calculations demonstrate that a typical VBI interface transmitting 12 lines of content 30 times per second is the equivalent of transmitting data at 120 Kbps -- roughly 3 to 4 times the rate of today's modems. The other vital fact is that the Web content can be synchronized with the TV show content, thus enabling a richer TV viewing experience.

From a broadcaster perspective, today's content producers include CNN, CNNHN, M2, HGTV, Lifetime, NBC, MSNBC, MTV and QVC for selected programs. Microsoft has suggested that up to 1,800 hours of content are now available weekly in the US alone.

**WebTV for Windows**

WebTV for Windows is the newest application to provide TV viewing capabilities and VBI content support. It is also part of a major broadcast initiative at Microsoft. Consumers who purchase Windows 98 and have compliant TV receiver cards can use the WebTV viewer that is included as part of the purchase of the operating system.

The WebTV for Windows feature of Windows 98 allows users to benefit from the integration of traditional television technologies and the personal computer. It let's users watch traditional

television broadcasts, as well as benefit from the ability to integrate broadcast and Internet data reception. WebTV for Windows offers the following capabilities:

- Find favorite television programs easily with a customized Electronic Program Guide (EPG). By entering their ZIP code and selecting their cable provider, users can find out what programs are scheduled, view episode or show details, search and set reminders for a particular show or instantly access any TV show they're interested in viewing.
- Watch any TV program on a PC monitor, even while using other software applications. Users can choose to watch TV in full-screen mode or in a resizable, movable window on the desktop. In addition, users can take advantage of the multi-monitor support in Windows 98 to have TV displayed on one monitor while continuing to use other Windows-based applications on another.
- View interactive TV programs that combine the broad-reach "push" capability of television with the personalized "pull" capability of the Web. These interactive programs combine standard television broadcast with additional HTML-based enhancements to create a new form of integrated television. WebTV for Windows provides both native support for these interactive programs along with support for Intel's Intercast-based programs.
- Receive Internet content without tying up the phone line. In the same way that data can be sent over the broadcast or cable system to enhance a TV program, Web content can also be sent separately and stored on the user's hard drive. This allows consumers to receive Web content in a "push" fashion without tying up the phone line. WavePhore Inc.'s WaveTop, included with Windows 98, is an example of a service that broadcasts specific content to subscribers built on this basic capability.

With the inclusion of the WebTV for Windows feature in Windows 98, consumers now have expanded access to information. Not only can they find shows more easily in an electronic programming guide and view traditional television programs, they can also receive data in the form of cached Web sites and enhancements to television.

**TAM Analysis**

Today, the underlying framework of PC television is the same traditional analog video that is used to broadcast television across the globe today. Broadcast TV standards have established the baseline definition for analog video formats, transmission and storage.
However, to be displayed on the PC, analog composite video must be converted to a digital format, hence the need for the analog video decoding function to accomplish this.

Figure 1 reflects the total available worldwide market (TAM) for the analog video decoding function in the PC space. Either a sideport or a PCI bus-mastering decoder can perform the analog decoding and digitizing function. The specifics of what these two architectures are will be described in a subsequent section. In Figure 1, the analog TV category represents the proportion of video decoders, which ship along with a television tuner (analog) as part of the solution.

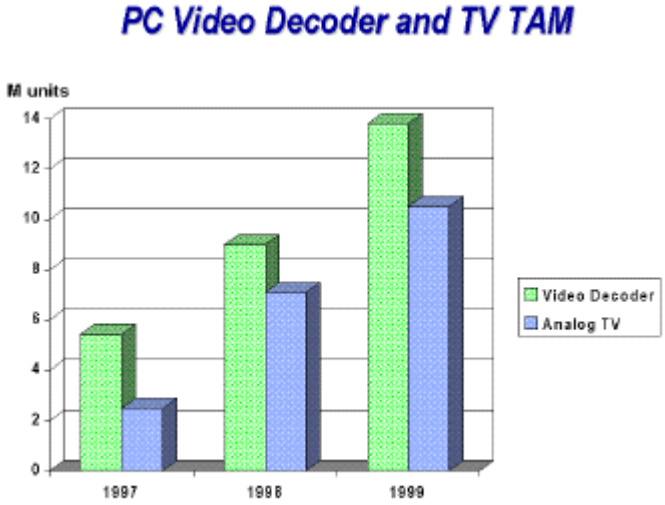


*Figure 1. TAM for Analog Video Decoders*

Sources: Instat, Dataquest, IDC, Forward Concepts, Internal

Several points are worth noting. The growth rate from 1997 to 1998 reflects an almost doubling of the market size and respective opportunity for the analog video decoding function. The attach rate of TV to the analog video decoder has moved from approximately 50% in 1997 to over 75% in 1998. The factors described in the previous section are the primary reasons this dramatic change has and will continue to occur.

**Hardware Architecture Alternatives**

Nearly 10 years ago, the first PC analog video technologies were developed. The first architecture is now termed videoport or sideport because it utilizes a digital data input port or "sideport" on the graphics controller to send video data and control information to the graphics controller.

In the past, video was seldom considered and today still remains an afterthought for many mainstream graphics controller manufacturers. Although many challenges remain, the emergence of VIP 2.0 (VESA video interface port specification 2.0) should continue to remove technical barriers and standardization issues. The standard used today is version 1.1 and it defines the method for connecting digital video devices to graphics controllers. It is a specification that defines the dedicated physical connection between the controller and one or more third party hardware devices.

As a result of the technical challenges associated with sideport architectures, Brooktree (now Conexant Semiconductor Systems) concluded that video over the PCI bus was an alternate architecture that offered several distinct advantages:

- Video quality is not dependent on the graphics controller.
- Adding a TV card would be easier for the consumer because of reduced graphics card compatibility problems.
- One universal video-capture driver would work for all graphics controllers.
- A new product category that is independent of the graphics controller would be created.
- A new price point for the video/television function would be established.

As a result, the Bt848 was developed and introduced to the market as the first integrated video decoder and PCI bus-mastering device. This architecture has evolved and become one of the most successful video decoders available. Today, the run rate or shipments of the Bt848/A and Bt878/9 bus-mastering video decoders (the only integrated PCI video decoding product) are comparable to sideport in the PC space. This success has led to the evolution of many follow-on products, based on this PCI bus-mastering architecture.

Introduced in late 1997, Conexant's Fusion™ family of video decoders takes the core PCI video architecture one step further by combining feature-rich live video processing NTSC/PAL/SECAM video decoding and real time audio capture capability. Fusion also offers VBI data capture for data services offered by applications like Microsoft's WebTV for Windows, Wavephore's Wavetop, Intel's Intercast and teletext. The devices also support multiple composite and S-video inputs, multiple YCrCb and RGB pixel formats, complex clipping, superior video scaling and video resolutions up to 768 x 576.

The Fusion product family is comprised of two members, the Bt878 and the Bt879. The Bt878 is a low-cost video and mono television audio capture solution. The Bt879 provides FM stereo radio, BTSC stereo decoding and employs certified dbx-noise reduction techniques. The BTSC stereo decoding and dbx-noise reduction technology meets US FCC OET bulletin 60, revision A and is a requirement for stereo televisions shipped in the US.

Fusion, combined with Conexant drivers (for Win95 and Win98), provides dbx- noise reduction, FM radio and TV stereo audio over the PCI bus today. This technology directly translates into a bill-of-materials cost reduction that ranges from $ 7 to $ 15 depending on the features implemented. In addition, the audio is a digital technology that is Microsoft compatible.

Conexant is currently working closely with Microsoft on a driver solution that will address the market need for a low-cost television receiver solution that supports both WebTV for Windows and the audio capture functions the Bt878 and Bt879 hardware were originally designed to support.

The benefits of on-chip audio capture over the PCI bus, the issues associated with implementation and the Conexant/Microsoft solution will be the subject of a subsequent white paper available in early 1999.

**Market Segments**

Two distinct and viable market segments exist for PC video capture and television. These two categories are termed "sideport" and "PCI bus mastering".

Conexant supports, and will continue to offer, a variety of solutions tied to both architecture cores. It is not Conexant's intention, nor the position of this paper, to suggest that sideport solutions do not provide a compelling value proposition, particularly in the retail space. Each solution is used for different reasons and addresses needs of distinct and different market segments. It is however, Conexant's position that both are equivalent in terms of general features and market share and that misconceptions about the technical viability of PCI are unfounded. Furthermore, PCI is better suited for PC OEM build-to-order and lends itself well to future broadband technology architectures like cable modem and digital television.

Figure 2 provides a snapshot of the split between PCI and sideport architectures. The analysis shows an almost equal distribution of units between the two solutions.

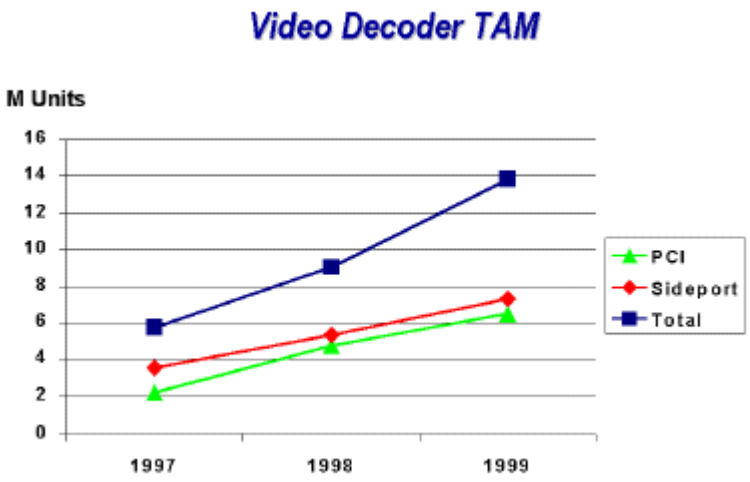


*Figure 2. PCI vs. Sideport Market Share in Millions*

Sources: Instat, Dataquest, IDC, Forward Concepts, Internal

The sideport architecture is dominated largely by ATI Technologies, who has been extremely successful in driving the number of television and video decoders present in the PC to significant volumes with the company's "All in Wonder™ " multimedia graphics and video accelerator product family.

According to ATI, the sideport architecture provides maximum video quality directly to their graphics chips, which are well architected for video applications. This solution allows the user to view TV/Video with no impact on system performance. At retail price points from $129 to $299, the All-in-Wonder products from ATI are enabling multimedia PCs by providing intelligent TV functionality, video capture, video editing, video output and DVD playback, together with a 2D/3D graphics upgrade from the industry leader. All-in-Wonder cards turn normal PCs into multimedia and entertainment powerhouses. In an environment where expansion slots are rare, an All-in-Wonder card provides a wealth of entertainment and information capabilities using just one slot. This eliminates integration difficulties, resulting in happier customers who are "up and running" immediately.

The All-in-Wonder product has answered the question so common in the earlier days of multimedia: "Why watch TV on your PC?" People do want to watch TV on their PC. "PC owners are a part of the TV generation and we can do two things at once as long as one of them is watching television," according to Blair Birmingham, Senior Product Manager, Multimedia Products for ATI Technologies Inc. "The successful sales and the awards won support this position," continued Birmingham.

ATI Technologies Inc. is now leveraging its success in the All-in-Wonder product line by offering a dedicated PCI bus-mastering product family with the new ATI-TV Wonder™. "With ATI's global reputation for quality and reliability at a reasonable price, OEMs have been asking us for PCI bus-mastering TV tuner cards and we have responded with the ATI-TV Wonder," says Toshi Okumura, Product Manager, Multimedia Products for ATI Technologies Inc.

"With the choice of an All-In-Wonder product, which also features the industry's best 2D and 3D graphics acceleration, or an ATI-TV Wonder that can attach to almost any graphics subsystem, ATI offers OEM and retail customers the most complete range of TV tuning solutions," said Cheryl Giblon, Group Product Manager, Multimedia Products, ATI Technologies Inc. "Our comprehensive product line is second to none in the industry, in terms of performance offered and awards won."

Hauppauge Computer Works, Inc., on the other hand, has established early on a leadership position in the dedicated PCI bus-mastering category with their WinTV™ Product line. At retail price points in the $79 to $129 range, these cable-ready television and broadcast data receivers work in any PC with a Pentium, an empty PCI bus slot and a VGA subsystem (PCI or AGP) with reasonably modern DirectDraw™ drivers. For the end-user, the television function can now outlive the current VGA board, preserving the investment in a television receiver even as new VGA cards offer compelling new graphics and gaming performance.

For the OEM, the television function is de-coupled from the choice of VGA implementation, allowing complete flexibility in a build-to-order environment, with all the attendant support and inventory cost benefits. And, with AGP graphics and local-bus disk drives, the PCI bus has several times the required bandwidth to handle the video transfer load.

According to Ken Plotkin, Vice President of Marketing at Hauppauge Computer Works, Inc., "With the rapidly growing popularity of the PCI-based WinTV as an add-on in the retail channel, it's only a matter of time before television reception, like CD-ROMs and modems, becomes a standard feature on PCs. It's a case of market demand and customer convenience."

**Architecture Drivers**

Cost for the video function and the market need for platforms that seamlessly combine video, TV and graphics in a single card solution often drive sideport usage. From the video function perspective (i.e., there is no additional cost for a dedicated PCI bridge), this architecture is considered most attractive from an integration and low bill-of-materials cost. This solution also does not require an additional PCI slot or additional PCB. Sideport architectures will continue to be attractive, particularly in the retail space, because of the seamless integration this architecture offers.

PCI solutions are selected today based on the architectural flexibility (i.e., works with any graphics card), universal software drivers (one driver fits all), build-to-order requirements of PC OEMs, video performance and the ability to support only a dedicated function. Tomorrow, PCI video solutions will be selected based on emerging broadband technology platforms that include satellite, DTV, cable modem and a variety of other architectures for which PCI is best suited. With this wide variety of Digital TV receiver modules, it will be essential to keep the TV receiver modules separate from the MPEG rendering side of things.

This evolution will make the analog video a check box function for a variety of broadband receiver products that include today's analog television receiver card and tomorrow's digital TV-receiver modules (cable, satellite and terrestrial).

## PCI Bus Mastering Advantages

The previous section touched upon some of the original advantages that a PCI bus mastering video decoder offered. These advantages still apply, particularly in the retail space. However, as the video capture/television receiver market evolves from a small niche retail segment to mainstream, new dynamics need to be considered in order to further establish the PCI bus as the video hub into the PC.

## PC OEM Considerations

The introduction of Windows 98 and WebTV for Windows has caused PC OEMs to take notice and consider adding television reception functionality to their offerings. Although a sideport solution can be very attractive to the OEM from a bill-of-materials perspective, it is more complicated to implement today.

## Graphics Adapter Selection

PC OEMs use a variety of graphics adapters from many different manufacturers across their low-end, mid-range and high-end products. Some of the graphics subsystems are on the motherboard, others on dedicated PCI or AGP cards. There is no strong indication of any further convergence in the PC graphics industry amongst the five or six top players, and furthermore, no indication that PC OEMs will select a single vendor for all product SKUs. If, for example, a PC OEM selects S3 for the low-end, ATI for the mid-range and Matrox for the high-end and chooses the same sideport video decoder, a minimum of three different solutions, each with unique hardware interfaces and software drivers, would be required.

Each graphics controller manufacturer approaches video differently and therefore implements a slightly different version of the video port hardware interface. This custom interface requires custom drivers not only between manufacturers, but often within a given manufacturer's product offering.

VIP 2.0, as graphics controller manufacturers come to support it, will help to improve things. However, it remains to be seen if this standard will be widely adopted, and if it will be fully implemented from both a hardware and software perspective.

## Worldwide Television Support

If a PC OEM plans to address global needs, essentially four different tuner products would be required to achieve this, making a grand total of 12 different offerings using a sideport decoder. All this uniqueness costs OEMs money in supporting an unrealistic variety of products rather than just one or two. It could be suggested that the savings from eliminating the extra cost of the PCI bridge is more than offset by maintaining a large number of board-level SKUs.

Now if that same OEM considers a dedicated PCI card based on the Bt878 or Bt879, then the OEM only needs to qualify a single piece of hardware (assuming interchangeable tuners for NTSC, PAL and SECAM) with a single software driver.

## TV Viewer Application

Today, every television solution for the PC comes with a unique TV viewer application. A given card manufacturer will provide a single TV application for all markets and customers.
This TV application will look, feel and run the same on any graphics controller and can ship with any PC.

The TV viewer for a sideport solution is unique to the graphics controller it is bundled with. The features and functions vary and are dependent on the graphics controller video support. For example, if a given controller supports both overlay and primary surface, the user interface for the TV viewer would likely reflect that feature.

The result of using sideport for the PC OEM is not only unique hardware per graphics controller, but potentially unique drivers and even a unique look and feel to the TV viewer application. This will depend on the graphics adapter used and the sideport decoder selection. If however, the OEM used the Bt829 with a WDM driver and DirectShow™ application, some of the variability on the software side can be eliminated.

## Flexibility

PCI bus-mastering television receiver solutions offer the most flexibility for both the retail board maker and the PC OEM. The solution consists of only a single hardware board and a single driver that can be added to any PC system at will.

## Graphics Controller Limitations

The graphics controller it is attached to can limit the quality of the video sideport.
For example, the video decoder may offer very sophisticated scaling capability. However, if the graphics controller does not also support that same level of functionality, the feature cannot be properly used.

## Future Technologies

The Fusion family of single-chip broadcast media capture products is just one example of how Conexant Semiconductor Systems (formerly Brooktree) is utilizing the PCI bus as the hub to provide PC solutions with variety of uses and applications. Next-generation solutions could include PC-based satellite and/or digital television receiver cards, teleconferencing solutions and other broadband communications solutions. Figure 3 shows some of the types of solutions that can be architected from Conexant’s core video technology and the PCI hub.

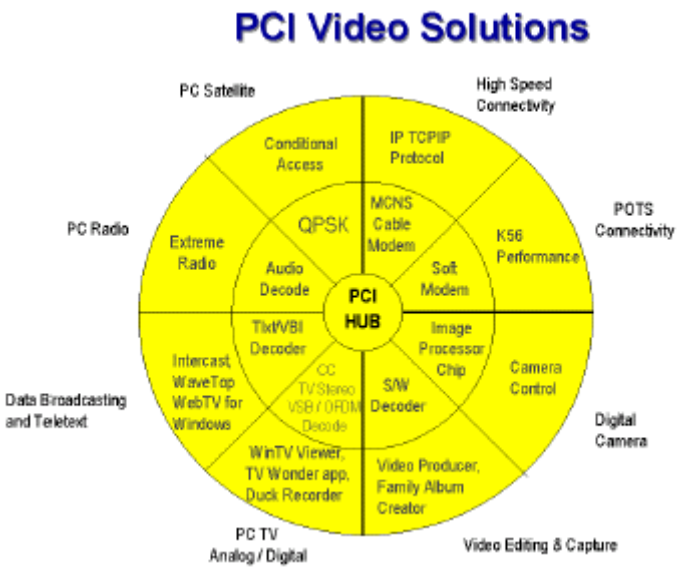


*Figure 3. Solutions based on Conexant's Core Video Technology & PCI Hub*

### Facts and Misconceptions about PCI Video Solutions Bus Bandwidth

The most common misconceptions and concerns expressed about PCI video are about maximum bus bandwidth requirements.

### Video De-interlacing and Bandwidth Considerations

Standard television and computer monitor displays use fundamentally different methods for displaying moving images over time. Assuming a standard NTSC rate of 60 fields at 640x480 pixels per frame (actually 29.97 frames/second), a standard television will display the odd numbered lines during the first sixtieth of a second, followed by the even numbered lines the following sixtieth of a second. This technique, called interlacing, combined with the high persistence phosphors used on television picture tubes, gives an acceptable illusion of continuous motion.

Computer monitor displays, on the other hand, are typically non-interlaced, displaying every line each time the display is refreshed. Displaying standard television signals on a non-interlaced display requires that some kind of *de-interlacing* algorithm be performed.

The total bandwidth required to display a typical full-resolution (640x480) NTSC video signal is approximately 18 megabytes per second based on the following calculation:

640 pixels * 480 lines * 2 YCrCb bytes/pixel * 29.97 fields/sec = 18,413,568 bytes/second

There are primarily three methods for de-interlacing television signals on a computer monitor display:

- Single Field Display
- Weave Mode
- Bob Mode

In all cases of watching live video, the signal is written directly into the graphics card's frame buffer, with no additional PCI bandwidth required for additional buffer copies. In *no* case does the total PCI bandwidth requirement exceed the maximum NTSC requirements described above.

### Single Field Display

In this method, no de-interlacing takes place. Only one field of the two is displayed, and the other is simply discarded. The displayed field is typically digitized at either 320x240 pixels or 640x240 pixels for increased horizontal resolution. This method is quite acceptable for small window sizes, and may even be used for full-screen-overlay scaled operation with a somewhat "soft" appearance to the image.

The total bandwidth required for this method is:

320 pixels * 240 lines * 2 YCrCb bytes/pixel * 29.97 fields/sec = 4,603,392 bytes/second

640 pixels * 240 lines * 2 YCrCb bytes/pixel * 29.97 fields/sec = 9,206,784 bytes/second

### Weave Mode

In this method, sequential frames are digitized directly into a memory buffer that represents the full 640x480 frame. The first field is digitized into the odd lines, the second field into the even lines. The two fields are in essence "weaved" together, then displayed at 30 frames per second. This method may result in "combing" motion artifacts on the edges of objects with horizontal motion, but provides superior quality to the single-field display, particularly if used intelligently with subject matter originally digitized from motion picture source.

The total bandwidth required for weave-mode operation is exactly that required for the full NTSC resolution case described above:

640 pixels * 480 lines * 2 YCrCb bytes/pixel * 29.97 fields/sec = 18,413,568 bytes/second

### Bob Mode

Bob mode takes advantage of the overlay hardware available in most modern graphics controllers to simulate the spatial and temporal characteristics of the original video signal.

Both the odd and even fields are digitized at 640x240 resolution into a separate overlay buffer in the off-screen portion of the graphics adapter frame buffer. The odd field is then displayed at 640x480 resolution using the interpolated scaling hardware on the graphics controller overlay. This results in each line of the video field being displayed using two lines on the graphics display, with every other line interpolated from the surrounding lines. The even field is then displayed at 640x480 resolution, but is shifted down on the graphics display one line relative to the odd field. Thus, the fields are correct both in time and space. If the display refresh is locked to the source video rate of 29.97 hertz, an excellent simulation of an interlaced television display can be achieved.

The total bandwidth required for bob-mode operation is exactly that required for the full NTSC resolution case described above:

640 pixels * 240 lines * 2 YCrCb bytes/pixel * 2 fields * 29.97 fields/sec = 18,413,568 bytes/second

**VBI Bandwidth Requirements**

It has been suggested that use of VBI data will double the PCI bus bandwidth required for video. Some have expressed a concern that for each video frame there is an equivalent VBI frame required (i.e., all the lines of data are processed over the PCI bus). Others have expressed concern that if the user is just doing VBI capture that the entire video window is sent over the PCI bus.

Both suggestions are simply *not* valid. Although VBI content is in addition to the video image data being passed over the PCI bus, it is limited to only the lines of data that are active in the vertical blanking interval. Additionally, if only VBI data is active, then that is the only data being transferred over the PCI bus.

VBI-digitizing PCI bandwidth is a linear function of the number of VBI lines being digitized and whether the current operation mode is NTSC or PAL.

For NTSC operation, up to 12 lines with 1536 8-bit luminance samples may be produced for each field. The maximum total bandwidth is calculated by:

1536 bytes/VBI lines * 12 lines maximum * 60 fields/second = 1,105,920 bytes/second.

For PAL operation, up to 18 lines with 1920 8-bit luminance samples may be produced for each field.

Maximum total bandwidth is calculated by:

1920 bytes/VBI lines * 18 lines maximum * 50 fields/second = 1,728,000 bytes/second.

Note that in typical operation, the total number of VBI lines being digitized will probably be much less than the maximum allowed.

**Graceful Degradation**

The Bt878 and Bt879 provide a means to handle bandwidth bottlenecks caused by slow targets and long bus access latencies of old systems.

The Bt878/9 PCI video decoders have internal DMA FIFOs that are used to buffer transfers from the video digitizer to system memory to allow for some PCI bus access latency. When digitizing live video, the video *must* always be delivered to the display buffer in essentially real time. The Bt878/9 on-board FIFOs provide the required data buffering and the PCI bus specification 2.1 compliance.

Normally, devices on the PCI bus share the total bandwidth under the control of the PCI master controller. If the Bt878 is not able to obtain access to the PCI bus due to another device

failing to release ownership of the bus (violation of the 2.1 specification), the Bt878 may not be able to transfer the digitized video over the PCI bus before its internal FIFO overflows. Since the Bt878 uses the PCI bus to fetch its own DMA program, there may also be rare cases where the part must be able to "catch up" after being denied access to the bus for a extended period of time.

If a PCI DMA FIFO overflow condition occurs, the Bt878 will first start dropping individual digitized video pixels if only video data is affected by the overflow condition. If the Bt878/9 is also unable to fetch its own DMA program, whole scan lines may be dropped.

The look of the resulting display will depend on the actual design of the application displaying the video. In many cases, if the video is being digitized into a pair of buffers, one for each field, then stale data from a previous field will be displayed in the place of the dropped pixels or scan lines. If the buffers are cleared by the application before the fields are transferred, then the dropped pixels or scan lines may be replaced by solid black or other colored pixels, depending on the color space used for the digitizing operation.

In all cases, the Bt878/9 will re-synchronize with the live video display once PCI bandwidth becomes available. It also should be noted that degradation environments are rare and that most common occurrences are associated with other non-PCI 2.1 compliant devices.

**PCI Bus Streaming Limitations**

As with any technology architecture, equal time must be provided to review, record and assess any applicable limitations. Over time, subsequent generations of Conexant PC decoders have addressed system-level performance issues from both a hardware and software perspective.

Although data buffering and latency issues have in large part been addressed with the Fusion family of PCI decoders, system-level limitations may occasionally be uncovered as new video applications and codecs emerge. For instance, large-resolution applications with maximum color depth combined with PCI bus devices that hold the PCI bus (burst mode operations) for extended periods of time (often not PCI bus compliant) can under certain conditions cause noticeable degradation of video on older systems.

Solutions range from creative software driver architectures and the use of efficient video codecs to running the application in a smaller video window with less color depth.
The real-time nature of video in the PC is unique in that there is a limit to the amount of data buffering that can be economically provided within the PCI decoder device for large image sizes and full color resolution.

Conexant believes that any further improvements to handle poor PCI bus partners that access and hold the PCI bus too long are best addressed by improvements to system chipset architectures and through more stringent requirements to the PCI bus specification.

Conexant is committed to enhancing its PCI decoder and communications technology and will continue to work with Intel and other partners to address these residual concerns for future generations of PC systems.

## PCI Bus Longevity

Although some have claimed that the PCI bus was soon to part from the PC system in favor of 1394, it is now the case that the PCI bus will continue to be important and available well into the next century.

Conexant believes there is still a great deal of life in PCI and furthermore understands that Intel will continue to drive improvements with successive generations of the PCI specification and respective chipsets offered. PC technologies like audio, modem, Ethernet and video will continue to be best suited on the PCI bus well into the year 2002. Conexant will continue to work with Intel on future broadband architectures and PCI bus specification requirements for the next generation products.

## Typical End User Use

Most video capture and PC television cards come bundled with a variety of applications from video conferencing to video email and video editing for very sophisticated TV viewers. Most of these applications are developed based around a CIF viewing window (320 x 240). As a result, most consumers will typically use the applications in this viewing window size.
Therefore, on average, assuming maximum color depth (32 bit), the data rate over the PCI bus is approximately 8 megabytes per second.

## Retail Customer Feedback

The Bt848/A PCI video decoder is one of the market's most successful video solutions. If bandwidth or other issues were prevalent, many complaints would have been received by Bt848/A vendors over time, particularly considering the wide variety of target systems on which PCI video capture/PC television cards have been installed.

According to retailers, the most common complaint is with incompatibilities associated with the graphics card. Specifically, older graphics products and those from fourth-tier card manufacturers are well known for not being compliant with PCI bus specification 2.1 and/or not offering DirectDraw compliant drivers. In either case, the solution often lies with the graphics card manufacturer.

## Graphics Move to Accelerated Graphics Port (AGP)

Today, the PC market is in the process of moving away from older PCI-based graphics controllers to new AGP solutions. By the end of this year, most new high-end, mid-range and some low-end PC system boxes will provide AGP graphics as standard fare. PC graphics has, in the past, been the primary user of PCI bus bandwidth and the primary source of PCI 2.1 specification non-compliance. With this transition, only rather low-bandwidth devices (audio, modem etc.) will remain attached to the PCI bus. This extra bandwidth further ensures PCI bus-mastered PC television cards will operate flawlessly in today's PC systems.

## PC99 Design Guide Requirements

PC99 is intended to provide video guidelines for 1999 and 2000. The specification itself is video-architecture-agnostic, providing criteria for both sideport and PCI bus-mastering architectures.

It is interesting that PC98 was actually more restrictive with respect to PCI video than PC99. Over the course of the last year or so, the market (retail, PC OEM, end-users) have begun to recognize the flexibility, video quality and ease of implementation that PCI bus mastering provides. The market has come to appreciate that the perceptions and technical concerns thought to limit the proliferation of PCI video are in fact not issues at all.

"The PC99 design guide reflects the changing market and advances in technology, without relaxing it's fundamental aim of ensuring video quality on the PC keeps getting better every year," said Dave Marsh, the technical evangelist for TV and Video at Microsoft. "Microsoft's WebTV development team and Conexant have been working together on operating system support for the Bt829 sideport decoder and the Bt848A/878/879 PCI video decoder for quite a while," continued Marsh. "This effort has resulted in two Conexant hardware solutions, that support WebTV for Windows. We are finding the PCI video architecture is often preferred by PC OEMs particularly because of the flexibility a stand-alone card can provide. This interest on the part of OEMs has influenced a recent decision to include PCI video support as a primary video architecture in the first release of Windows 2000 (previously known as NT 5.0)."

"With the wide variety of Digital TV delivery methods, it is even more important to keep the TV receiver modules separate from the video rendering side of things. PCI-based ATSC receiver modules will bus master a transport stream to host memory for de-muxing in DirectShow software on the host. Many of these cards will also be able to receive analog NTSC broadcasts and they will bus master the raw digitized standard definition video over the PCI bus."

## General Information

The primary recommendation of the PC99 System Design Guide to developers regarding the use of the PCI bus for live video decoding is to avoid "oversubscription" of the bus. The worst-case total bandwidth requirements for full-resolution (640x480x30fps @ 24-RGB bits/pixel) NTSC video decoding will never exceed 28 megabytes per second. In fact, the most common form of operation (320x240x30fps @ 16-YUV or RGB bits/pixel) requires less than 5 Megabytes per second, hardly stressing the capabilities of the PCI bus.

## Digital Broadcast TV PCI Bandwidth Requirements

Digital Broadcast TV solutions based on Conexant's PCI bus-mastering technology will not use the PCI bus for transport of the decoded video streams; rather, the PCI bus will only be used for the transport of demodulated MPEG-2 compressed transport streams. In the worst-case scenario for digital terrestrial and digital cable, a 20 and 40 Megabit-per-second transport stream will need to be sent over the PCI bus to memory buffers for software de-multiplexing. The MPEG-2 decode will be closely associated with the graphics card and therefore the uncompressed high definition video never has to travel over the PCI bus. In digital TV cases, the total PCI bandwidth required would never exceed about 5 Megabytes-per-second, which is well below the requirements of raw digitized analog TV signals.

## Summary

PC television is a new market opportunity with a tremendous amount of potential. Several additional conclusions can be drawn based on the discussion here in:

- The video decoding market is just beginning the transition from a niche market to the mainstream PC. Primarily PC television applications, VBI content and Microsoft's WebTV for Windows initiative are driving this transition.
- PCI analog video decoding has been established as a robust and viable architecture in the PC space, not only by board makers like ATI and Hauppauge, but also by PC OEMs that have recently introduced PCI-based solutions.
- The PCI bus is the foundation and hub for current and emerging broadband technologies.
- PCI video is fully endorsed and supported by both Microsoft and Intel.
- Technical concerns about PCI bus-mastering video are not based on fact, but simply on previous misconceptions that cannot be substantiated.
- The Bt878/879 video decoders meet PC99 requirements.

## Appendix - Video and Television Technology Overview

*NTSC, PAL and SECAM*

Baseband video is a simple analog signal that contains video analog data and video synchronization data, and is used to display the picture properly at the receiving end. The details of the signal depend on the video standard used —NTSC (National Television Standards Committee), PAL (Phase Alternate Line) or SECAM (Systeme Electronique Couleur Avec Memoire). This white paper focuses primarily on NTSC because it is the primary standard used in North America and Japan as well as the primary standard for source material used to create video.

When the broadcast TV industry began, the powers-that-be in the United States selected 525 lines per frame as the standard. Worldwide however, there are about a dozen different standards in use, making TV sets (tuners specifically) incompatible across many geographic boundaries. This incompatibility is the same in the PC space. In terms of resolution, there are only two approaches: 625 lines per frame at 50 Hz and 525 lines per frame at 60 Hz. The latter is consistent with the North American standard known as NTSC.

In normal operation, a video signal is generated by a video source, which could be a camera, VCR or a TV tuner. To transmit the picture, the source first generates a vertical synchronization signal (VSYNC). This signal resets the receiver (PC monitor) so that it begins picture display at the top of the screen. After the VSYNC signal is sent, the video source then scans the first line of the image. Once the scan line is complete, the camera generates a horizontal synchronization signal, which resets the receiver so that it will display the next line starting at the left-hand edge of the display. For each line of the image – there are 525 lines defined by the NTSC standard – a scan line and a horizontal synchronization pulse are sent.

The NTSC standard also dictates that 30 complete pictures (frames) are to be sent by the video source each second. If complete images were sent at this rate, there would be a great deal of flicker, which would result in a poor user experience. To reduce flicker, each frame is

divided into two fields of 262.5 lines and grouped as even or odd. This results in 60 fields or halves of the image being sent each second. The image is thus spread between two fields reducing flicker because a new part of the image is being drawn every 1/60th of a second instead of every 1/30th.

**RGB Color Space**

The method of coding color information is known as color space. In it's simplest terms, the color space of any color can be defined by a fixed number of variables.

One type of color space is RGB or red, green, blue. In RGB color space, the three variables are the intensity of the red, green and blue colors. The RGB color space is a natural choice for recording and displaying color images. However, it lacks compatibility with black and white video systems, a requirement for imposed by the FCC at the time color television was designed. As a result, RGB is generally translated to YUV color space to maintain compatibility and then translated back to RGB for the display of the color image on the PC monitor.

**YUV or YCrCb Color Space**

YUV is a method of color encoding for transmitting color video images while maintaining compatibility with black and white television. It also offers the advantage of using less bandwidth than the three separate video signals of an RGB video transmission.

YUV data consists of two main components: Luminance (Y), which corresponds to the brightness of the pixel and chrominance (UV or CrCb), which corresponds to the color of the pixel.

Luminance is created from an RGB input by adding together specific proportions of the RGB signal.

Chrominance defines two aspects or components of the color, the hue or tint of the color and the saturation or intensity of the color. One component (Cr) consists of the difference between the red portion of the RGB input and the luminance value of the RGB signal. The other component (Cb) consists of the difference between the blue portion of an RGB input and the luminance value of the RGB signal.

**Composite and S-Video**

NTSC color video is defined as a basic black and white video signal with the inclusion of a color burst after each horizontal synchronization pulse and a chrominance signal that is combined with a luminance signal. This signal is known as Composite Video, since it combines the two signals.

S-Video is a higher quality video interface, which allows interconnection between the PC television card and a home VCR for example.

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