Silicon Image

External Serial ATA

WHITE PAPER

September 2004

CONTENTS

INTRODUCTION

Digital content is pervasive in today's society, from digital music files and photographs to home movies, not to mention the multitude of financial, e-mail and household or business records a typical consumer keeps on their PC. Digital content is everywhere, and consumers want more of it. The explosion of all of this digital information is rapidly consuming available hard disk drive (HDD) space and creating a critical storage challenge. A recent study by UC Berkeley showed that 5 exabytes (or 5 billion gigabytes) of original information were created in 2002, and that this was twice the volume of information created just three years earlier. Over 90 percent of this information is stored on magnetic media, and numerous copies of this data are stored as well. With typical compression modes, a digital photograph requires about 2MB, a song can take 4MB, and an hour of standard definition video requires 2 GB of storage. Clearly, the need to add more storage capacity continues to explode, and a convenient solution has become more critical than ever before.

This proliferation of digital data that consumers want to keep, and in many cases, backup, is the driving force behind external storage. While it's generally possible to add another disk drive inside a PC, this can be a complicated process requiring installation of a new drive, the connection of new cables, and in some cases, the installation of a new controller card and the re-configuration of new software. A far easier approach is to plug in a disk drive specifically configured for external storage, one that can sit atop the desktop and does not require the end user to open the PC. Not only is this external drive simpler to install, but it also has the advantage of being portable, thus providing an easy means of transporting lots of data from one computer to another, whether it be family photographs or large work files. An external drive can also serve as a back-up copy that can be kept in a remote location in the event the original data is lost. Evidencing this demand, sales of external hard drives for PCs are doubling every year, outpacing sales of internal HDDs.

EXTERNAL STORAGE SOLUTIONS TODAY

Today, these external drives are typically connected with a USB or 1394 (FireWire) interface to most PCs. This is because the internal disk drives, designed with a parallel ATA interface (also known as an IDE interface) cannot be extended outside the PC for an external connection. The parallel ATA interface is not designed for external cables, cannot be hot-plugged (inserted or removed while the PC is powered and operating), and would require a cumbersome connector. In contrast, USB and 1394 provide a simple connector, have cables and connectors designed for external use, and allow devices to be added or removed while the computer is running.

The external drives that use USB or 1394, however, are really these same IDE drives with a conversion chip that serves as a translator from the ATA interface protocol used on the disk drive to the USB or 1394 protocol used for the connection. Inside the PC, a similar re-conversion takes place, allowing the computer to recognize and talk to the drive just like an internal one. The drives also require power to operate, which is typically supplied through an external AC adapter that plugs into the wall and connects to the drive housing.

WHY SERIAL ATA?

The disk drive industry is undergoing a significant technology transition, with Serial ATA replacing the parallel ATA interface that has served the last decade of PCs. Parallel interfaces, such as the older ATA disk interface, have difficulty in scaling to higher speeds needed in today's systems. Serial interfaces not only offer higher data rates, but also smaller cables and connectors, and lower voltage signals for internal storage. In addition, they provide an interface technology that can scale to accommodate system needs for increasing storage capacity and performance over the next decade. Additionally, the Serial ATA interface is well suited for external applications and provides a number of advantages over the USB and 1394 interfaces used today. According to John Monroe, Research Vice President, Gartner, "By the end of 2005, SATA will become the dominant standard HDD interface, and by the end of 2007, SATA should achieve 100 percent penetration in all desktop and notebook HDD markets."

Table 1 provides a comparison of the raw interface speeds and the data transfer rates over the three interfaces discussed—USB 2.0, 1394a, and Serial ATA. While there are plans for higher speed 1394, the most common disk drives shipped run at the 400 Mbps interface speed. Additionally, there are new specifications for Serial ATA that double the data rate to 3 Gbps, but most Serial ATA drives today run at the 1st generation speed of 1.5 Gbps.

SERIAL ATA PERFORMANCE LIMITED BY USB OR 1394 CONNECTIONS

In terms of raw interface speed, it is clear that Serial ATA can far outstrip the performance of USB or 1394 with a bandwidth that is more than three times larger. In transfer tests involving reading and writing data to a drive, the limiting factor is normally the drive itself, namely how fast the disk drive mechanism can read or write data from the spinning magnetic recording platters. With Serial ATA, the sustained read and write speeds are approximately 40-50 MB/sec currently, with the possibility of future increases. Write speeds can be a little higher, since the drive can use memory to cache some of the data to be written. Similar performance data would be obtained for the parallel ATA interface if the drive were connected internally. What is clear, however, is that the two external interfaces commonly used today, USB and 1394, actually slow down the data transfer,

with data rates only half as fast in some cases as the Serial ATA interface. This is due not only to the slower interface, but also to the need to translate the data from the drive language of ATA commands into a USB or 1394 protocol for transmission across that interface. The need to retranslate at the host PC side also has a penalty, for increased CPU cycles are needed to process the re-conversion at the PC.

This difference in raw interface speed is even more apparent when looking at the burst data rates. Burst transfer rates occur when data is read directly from the buffer memory on the disk drive, so the normal mechanical limitation of reading data off the platters is not present. In this case, the burst transfer rates from Serial ATA are nearly three times higher than that of USB or 1394, as would be expected given the raw interface speeds.

	USB 2.0	1394	Serial
Raw Interface speed	*480 Mbps*	*400 Mbps*	*1.5 Gbps (1500 Mbps)*
Benchmark comparison 64K read	*31.6 MB/sec*	*34.8 MB/sec*	*56.4 MB/sec*
Benchmark comparison 64K write	*26.5 MB/sec*	*26.7 MB/sec*	*54.2 MB/sec*
Burst Transfer Rate	*33.5 MB/sec*	*36.2 MB/sec*	*111.3 MB/sec*

Table 1: Comparison of interface speeds and data transfer rates for external disk drive interfaces

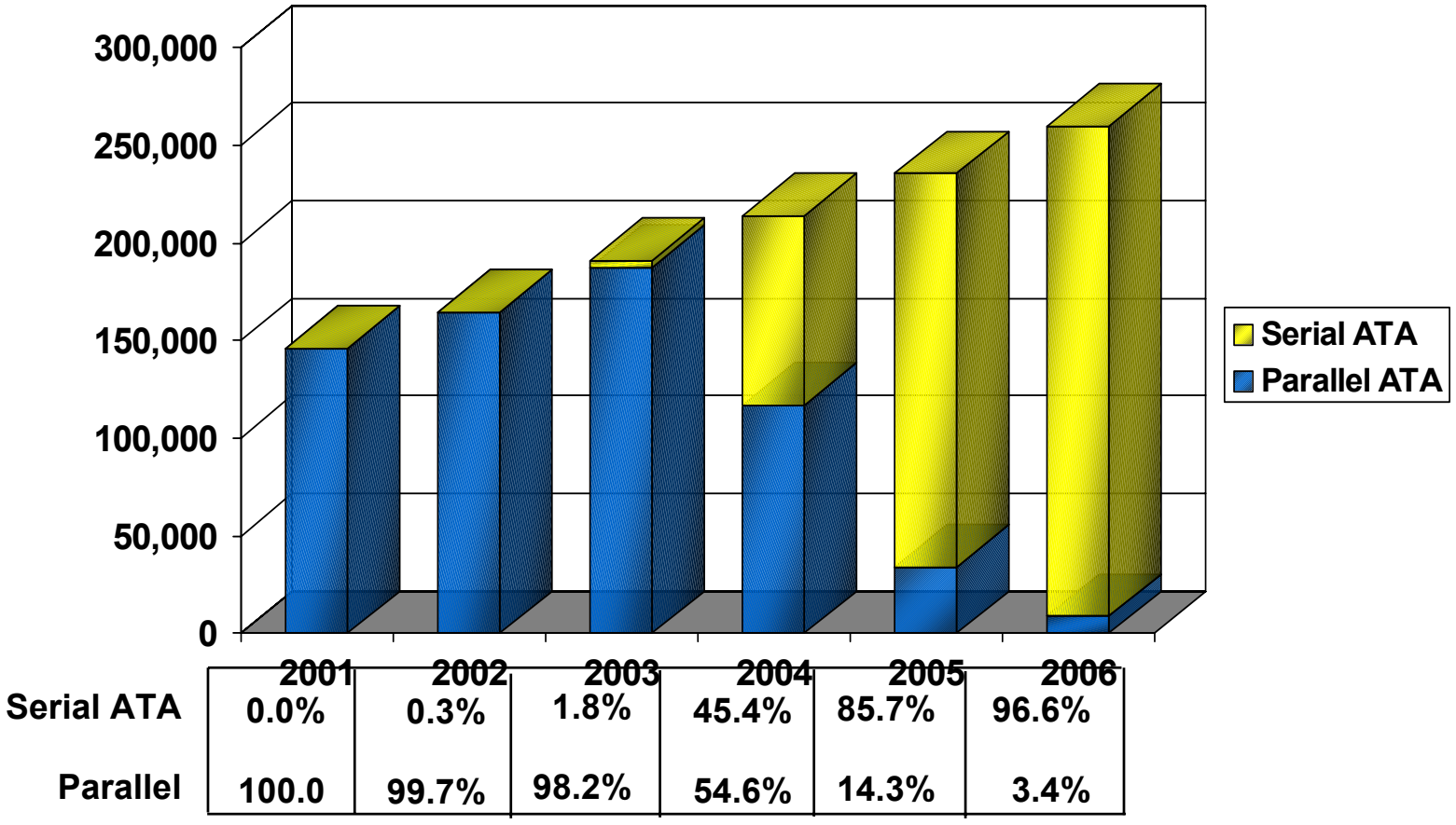
This performance discrepancy is important to the user who would frequently access data files on the external drive, or who would do extensive back-ups on a regular basis. As an example, transferring a 2 GB video file would take about 35 seconds over a Serial ATA connection at these rates, while more than one minute would be needed for a standard USB or 1394 drive.

Another important factor in favor of the Serial ATA disk drive solution is cost. As Serial ATA becomes the dominant internal disk drive interface, the cost for these drives will be equivalent to, and ultimately lower than, the parallel ATA drives they replace. These drives can essentially be used “as is” in an external application, without the need for an expensive protocol translation chip. The typical cost for a 1394-to-ATA or USB-to-ATA chip can range from $5 to $10, which must be

factored into the final cost of the external disk drive solution. If an ATA drive can be used "as is", or with a simple buffer chip that only amplifies signal levels, the cost of the solution can be far less.

SERIAL ATA TRANSITION

The transition from parallel ATA to Serial ATA began in 2002 with the availability of PCI-based Serial ATA host controllers and Serial ATA disk drives. In 2003, the first PC chipsets incorporating Serial ATA were shipped, and over the coming year, Serial ATA will continue to replace parallel ATA ports on chipsets until both hard drives and optical drives have completely converted to Serial ATA. Analyst data (shown in composite form in Figure 1) shows roughly a 5 percent market share for Serial ATA disk drives in 2003, with a forecast of roughly 50 percent market share by late 2004. In 2005, Serial ATA will account for nearly 85 percent of the drives shipped, and parallel ATA will essentially disappear in 2006.



	2001	2002	2003	2004	2005	2006
Serial ATA	0.0%	0.3%	1.8%	45.4%	85.7%	96.6%
Parallel	100.0	99.7%	98.2%	54.6%	14.3%	3.4%

Figure 1: Conversion rate of desktop disk drives from Parallel ATA to Serial ATA.

In large part, the chipset roadmaps from vendors such as Intel, VIA, SIS, ATI and NVIDIA are driving this transition. Parallel ATA interfaces on the chipsets consume a significant number of pins, need 5V tolerance and require a great deal of board space to route. With Serial ATA, the signal voltage (nominally 500-600 mV) is more compatible with today's process technologies, only four signal pins are needed per channel, and the connector, cabling and board space needed are all much smaller than with parallel ATA. Other Serial ATA benefits include the dedicated host to drive connection, future speed increases and added performance benefits through features such as native command queuing. The second-generation SATA speed of 3 Gb/s has been introduced, and 3 Gb/s host controllers are already available.

Optical drives will follow the lead of hard drives in transitioning to the Serial ATA interface. A few optical drives are now available with a Serial ATA interface, and more will be converting in the next year or two as the parallel ATA support from chipsets is removed. In general terms, the optical drive transition will be about one year behind the Serial ATA adoption curve in the hard drive market.

With the transition from parallel to Serial ATA occurring in force, the opportunity for employing native Serial ATA hard drives and optical drives as external solutions is clear. The Serial ATA interface provides not only higher performance than the USB or 1394 interface, but also a cost savings since the protocol translation chip is no longer required.

THE NEED FOR NEW CONNECTORS AND CABLES

In the initial specification, Serial ATA is used primarily as a replacement for an internal hard drive within a PC chassis. The original cable specification described a 1 meter cable designed for internal use that does not have any specific features for EMI, ESD or other attributes required by an external interconnect. As the desire for external Serial ATA drives became apparent, the Serial ATA II Work Group investigated the requirements for a new cable and connector more suited for an external drive and developed a new specification to satisfy these requirements. The specifications for the cable and connector are included in the new specification – Serial ATA II Specification: Cables and Connectors, Volume 2. The detailed electrical signaling requirements are included in the Serial ATA II Specification: Physical layer.

In order to address the requirements for a reliable and consumer-friendly external interconnect, several factors required consideration. For a typical external storage device using USB or 1394 interfaces, a cable needs to be long enough to reach from a PC sitting on the floor to a drive that would sit on a desktop. To accommodate this likely scenario, the cable length was increased from 1 meter to a nominal value of 2 meters. To help prevent accidental cable removal, the cable was also designed with some retention features requiring a little greater force to insert or dislodge. A

rendering of the cable and connector shown in Figure 2 highlights these features that have been added, including spring clips in the receptacle that would be found in the drive or PC, and detents in the cable-end connectors where the spring clips will grip.

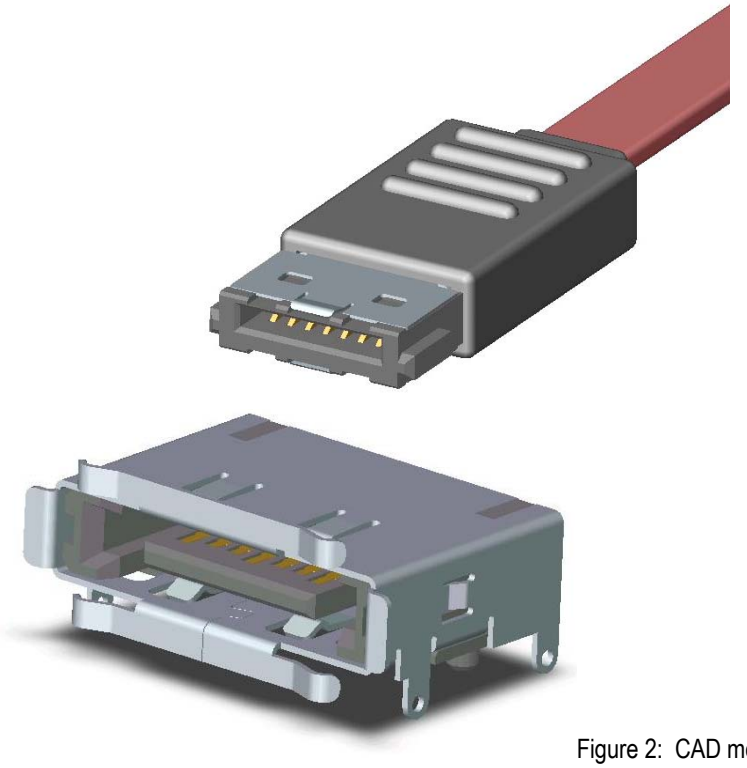


Figure 2: CAD models of the new cable end connector and PCB receptacle for the external consumer SATA cable.

In addition to the mechanical aspects of the cable and connector, several electrical issues were addressed to ensure that the external connected drive meets regulatory requirements for electrostatic discharge (ESD) and electromagnetic interference (EMI) emissions and susceptibility. Figure 3 also shows that the connector is shielded with a metal enclosure on all four sides of the signal conductor, and that flanges on the end of the connector are provided to ensure a good ground path is provided to the chassis for the drive and PC. The cable-end connector is also shielded with metal on all four sides, ensuring that a good ground between the cable and connector is provided.

Compared with the standard internal connector, the signal contacts in the receptacle are recessed further into the housing, which helps prevent any ESD discharge from reaching the high-speed signal contacts. Use of the metal enclosure provides a good ground return path, which dissipates any ESD discharge during cable insertion or removal.

The ground paths provided will help to minimize any EMI emissions from the external drive, but additional steps were taken to modify the cable by adding an extra layer of shielding surrounding

both of the differential signal pairs in the cable. In a standard internal cable, each pair is shielded individually. This shielding remains in the external cable, but an additional over wrap is also provided.

As demonstrated by the changes summarized above, there are substantial differences between the cable and connector construction for internal and external Serial ATA applications, as appropriate for the particular usage requirements. Because of these differences, the connectors are keyed to prevent the inadvertent use of an unshielded internal cable in an external application where it would be inappropriate. To accomplish this, the internal signal connector in the receptacle was made wider, and the total width of the cable end connector narrower, so that an internal cable cannot be plugged into an external connector. Another easy way to distinguish between the two connectors is that the internal cable has an L-shaped tongue to provide an easy blind mate key. For the external connector, the blind mating orientation is accomplished by shifting the signal contacts off center within the connector.

One final difference worth noting is that an internal cable is not intended to be removed from its connections very often, and thus is built only to withstand 50 insertion and removal cycles. For an externally attached hard drive, this number could be much higher, so the cables and connectors are designed to support 5000 insertion and removal cycles.

EARLY EXTERNAL SERIAL ATA OFFERINGS

The market desire for an external Serial ATA interface connection is demonstrated by the fact that some products providing this functionality have already come to market in advance of the final external Serial ATA specification. Many of these early products, however, were developed using an internal SATA connection, which does not provide all the required attributes described above that are designed into the new external cable and connector. As a result, it is expected they will quickly move to the new, approved designs. Even more undesirable are some of the early external Serial ATA products that used other connector technology, such as 1394 or DB9 (standard monitor interconnect) cable and connectors. These were not designed to accommodate high-speed Serial ATA signals, and can cause much confusion with consumers who may assume that a different type of signal is output on the connector. Imagine the problems that would occur when connecting an expensive digital camcorder to a 1394 connector that is actually driven by a Serial ATA controller. With the release of the new specification, this confusion will be cleared up, and compliant, consumer-friendly external Serial ATA devices can proliferate.

ELECTRICAL SIGNALING REQUIREMENTS

One of the features identified above is the ability to have a longer cable, up to 2 meters, for an external application. Since the original Serial ATA specification was designed for the internal 1-meter cable, there was not sufficient design margin in the spec to drive the longer cable. The Serial ATA specification sets minimum and maximum transmit voltages that must be sent from a Serial ATA host or device, and also a minimum voltage that a receiver must be able to decode properly. For the internal cable at a speed of 1.5 Gbps, the transmission voltage that must be sent from the host to the drive, or vice versa, ranges from 400 to 600 mV. The receiver must be able to decode voltages between 325 and 600 mV to account for some loss in signal though the cables and connectors.

With the 2-meter cable, in order to account for any additional losses over the cable, the minimum voltage transmitted is raised from 400 to 500 mV, and the minimum receiver sensitivity is further decreased to 240 mV. These changes accommodate any additional degradation within the longer cable or additional connectors in the signal path. It should be noted that the signal levels vary slightly for the 3 Gbps signaling rate, and that the compliance points where these signals need to be verified are at the point where the external cable is plugged in, not at the silicon device.

Since many of the existing disk drives and Serial ATA chipsets were originally designed with only the internal signal levels in mind, they may not be able to meet the more rigorous requirements of the external interconnect levels. For this reason, the spec allows a buffer chip to be used in either the device or host system to provide the increased signaling levels or receiver sensitivity where necessary.

SERIAL ATA HOST CONNECTIONS

While it is easy to imagine a custom external disk drive being designed to support a Serial ATA interface, the question of how to enable an external Serial ATA connection on the host is more open-ended. As noted above, many of the initial chipsets and discrete controllers were designed without the ability to directly support an external drive attachment, although second generation designs are likely to add these capabilities. Thus, the use of a separate controller, typically PCI based, would be needed for an external interconnect.

With a PCI card-based solution, an external interconnect can be provided on the PCI bracket, as shown in Figure 3. This provides an easy and reliable way to equip a PC with an external connection, either built to order with such a card installed, or through customer installation of an after-market PCI card.

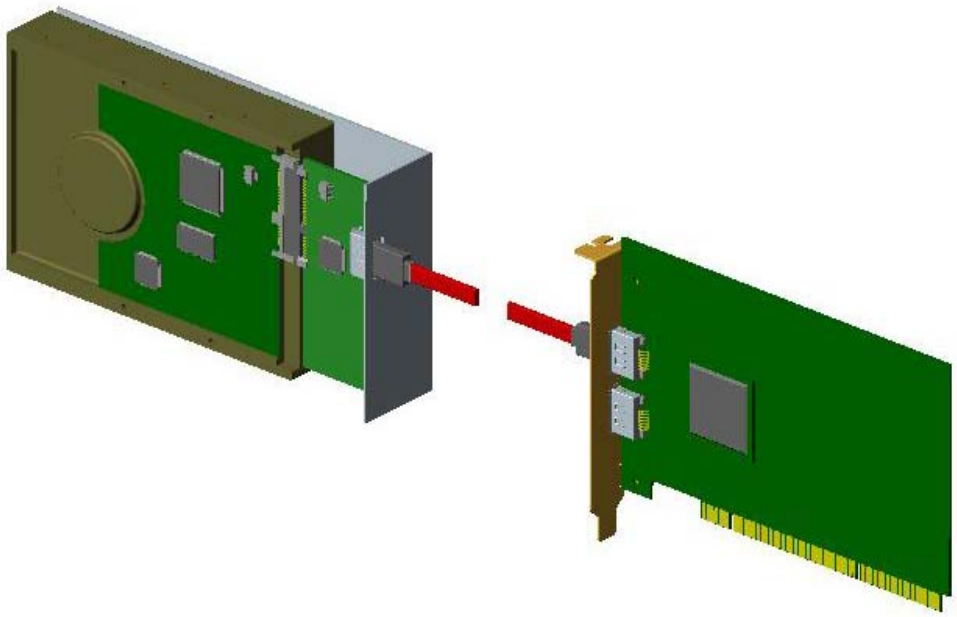


Figure 3: An external Serial ATA connection from a PCI card to an external drive chassis.

For motherboards that use a controller designed to support external Serial ATA connectivity, either in the chipset or through an added PCI based controller, the connection choices are either to mount an external Serial ATA connector on the motherboard, or to use a cable from an internal connector up to a receptacle on a PCI bracket, as shown in Figure 4. In this case, it should be noted that the internal cable to the bracket should only be connected to a Serial ATA device that can meet the electrical compliance requirements outlined above.

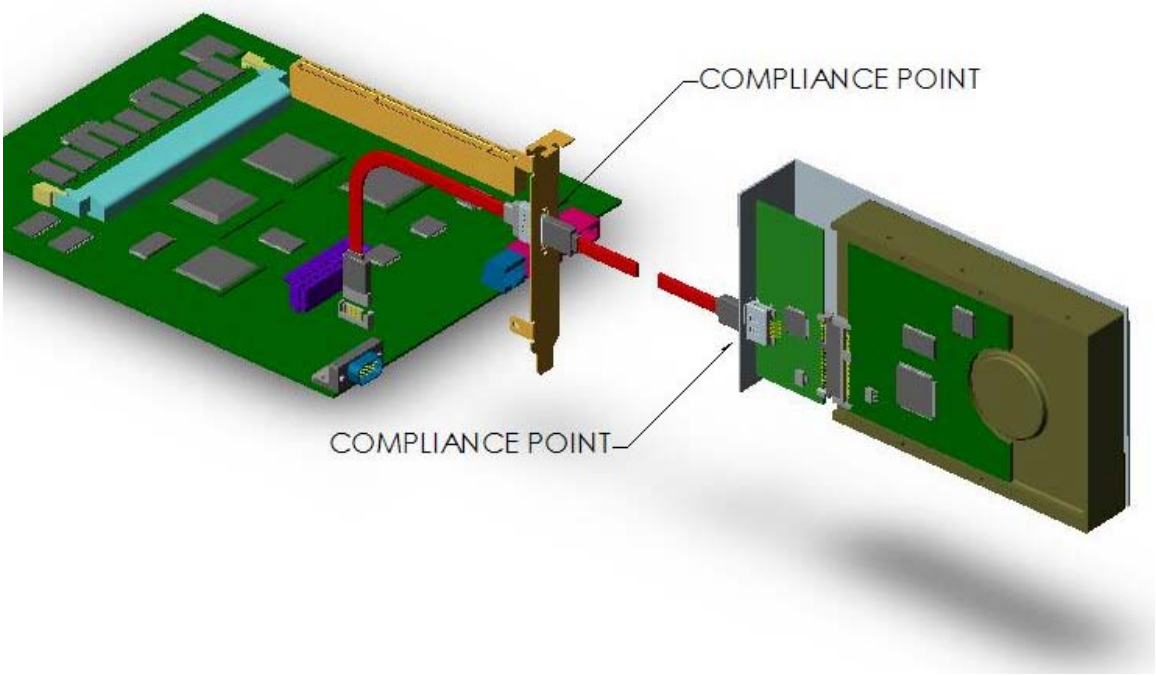


Figure 4: An external Serial ATA host connection enabled with a bracket that is cabled to a motherboard Serial ATA connector. The compliance points for the external specification are at the contact points for the external cable.

Many motherboards use a fairly well defined connector footprint to fit into standard PC chassis. Within this connector envelope, an external Serial ATA connector would be needed, and would likely need to displace an existing connector—either a legacy connector which is no longer highly utilized, or perhaps a USB or 1394 connector that would be better served by an external Serial ATA connector. Other PC designs are more flexible in their connector requirements, ranging from server platforms to XPC form factors, and we can expect to see more of these devices using external Serial ATA connectors in the near future.

In notebook applications, an easy way to enable external Serial ATA connectivity is through the use of a PCMCIA based controller. Since PCI-based controllers can be readily designed to use this interface, some of these products have already been introduced, albeit with the internal connector as noted earlier. An example of this type of interconnect is shown in Figure 5. These products will be refreshed soon with the proper connector designed for external Serial ATA applications. With the introduction of PCI-Express into the next generation of notebook designs, the PCMCIA card can be replaced with a PCI-Express card, which will offer even higher performance on par with the internally connected drives.

Figure 5: Examples of a PCMCIA adapter card that supports an external SATA interface for added disk storage in a notebook.

Power is supplied to the external storage device via a separate means, which is outside the scope of this specification. This separate means is expected to be similar to power delivery for USB or 1394 external drives, which typically use a wall mounted AC power transformer. For 2.5" disk drives (or smaller), which require only 5V connections, some solutions have used other peripheral connections such as USB or the PS-2 connectors to supply power to a Serial ATA drive, as shown in Figure 6.

Figure 6: A power connector for 2.5" external drives that draw power from a USB port.

DIGITAL VIDEO RECORDERS: AN EMERGING APPLICATION FOR EXTERNAL STORAGE:

One of the growing areas for hard drive consumption is in consumer electronic devices—in particular, digital video recorders (DVRs) such as TiVo and similar devices. An increasing number of cable set top boxes and satellite receiver systems are being designed with hard drives to allow consumers to record video programming. A hard drive has significant benefits over earlier magnetic tape approaches used in a VCR, not only in the ability to record or playback multiple streams of data simultaneously, but also in the capacity to record hundreds of hours of programming on a single disk. Additional user enhancements such as intuitive programming guides and viewer preference-based customizable recording make these systems an integral part of their owners' TV experience.

Many DVR users underestimate the storage capacity they will require, particularly with the growing availability of high-definition (HD) content. To hold an equivalent amount of HD programming content, storage requirements will need to increase almost tenfold above that required for standard definition content. Early HD PVR systems contain 250 to 500 GB of disk capacity, which is often achieved with multiple drives. To increase the capacity of their DVRs, consumers currently have the option of either adding an additional internal drive or replacing the original drive with a larger one. However, both of these solutions require the user to open the system and add a new drive. Not only can this be a complex process, it usually voids the warranty as well.

In contrast, using an external Serial ATA connector on these devices can provide an easy way to add capacity, One set-top box (STB) vendor, Scientific Atlanta, has already embraced this concept and is promoting a next-generation STB that will have an external Serial ATA connection.

External Serial ATA also enables STB manufacturers to employ a new business model. With video recording devices, the disk drive is typically the most expensive component in the system. As a result, it can represent a barrier to more widespread adoption of these devices. The ability to use an external Serial ATA connection could allow a cable provider, for example, to ship a box that is "PVR ready," but leaves the choice, and the cost, of what drive size a user needs up to the end customer.

Optical drives are seeing increased usage as external devices as well. Whether it's the desire to add a recordable drive to a system that was not originally configured with one, or just the need for a higher speed device, external optical drives are actually outselling external hard disk drives today. There is also an increasing demand for DVD recorders in the PVR market, where a user records programs to the disk drive for normal use and playback, but can archive them to a DVD for permanent storage.

HOME NETWORKS : ANOTHER EMERGING APPLICATION

External Serial ATA also has applications in home networks, which are growing in popularity due to consumers' desire to share storage capacity and content with multiple PCs and users in a home. New Serial ATA features such as a port multiplier, which allows a single host connection to access multiple disk drives, can provide an easy way to add terabytes of storage capacity to a host system with an external Serial ATA connection. This capacity can be shared by multiple users, partitioned into different configurations and used to provide automatic backups of other devices on the network, for example. An example of such a device is shown in Figure 7:

Figure 7: An example of an external storage appliance that uses five standard desktop drives, connected through a port multiplier to a single SATA host connection.

With the increasing growth for digital content, one external drive may not always be enough to add, and a port multiplier based device can allow users to continue adding storage easily as their needs expand. This new usage model is enabled by Serial ATA, and is another benefit from the transition to this new interface technology.

CONCLUSION

The completion of the external Serial ATA specification paves the way for the proliferation of high-performance, cost-effective, portable external storage devices. Serial ATA offers higher data rates than USB or 1394, which will be most apparent to users who frequently access data on their external drive. In addition, external Serial ATA drives have the potential to be much lower in cost than USB or 1394 drives, which must include a conversion chip that adds cost to the drive.

In the near term, the market for external Serial ATA will primarily be driven by consumers transitioning from the more expensive and lower performance external USB and 1394 devices to external Serial ATA as a means of adding more storage capacity to an existing PC. The growing availability of HD content is also driving applications for external Serial ATA in the home entertainment realm, where external Serial ATA drives can easily provide additional storage capacity for PVRs and STBs. External Serial ATA will also be deployed in home networks, where Serial ATA's ability to access multiple drives from a single host connection will prove beneficial.

Silicon Image, Inc.
1060 E. Arques Avenue
Sunnyvale, CA 94085
T 408.616.4000 F 408.830.9530
www.siliconimage.com