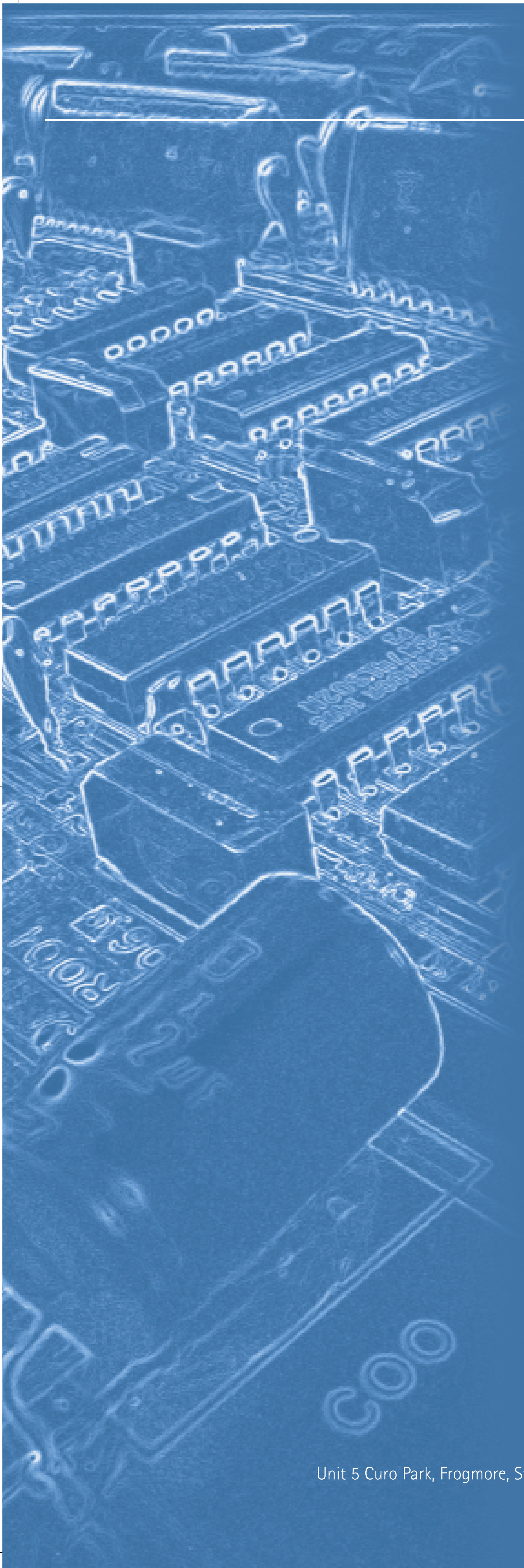

Technology Paper

Serial ATA

The new drive interface standard for the desktop and mobile PC

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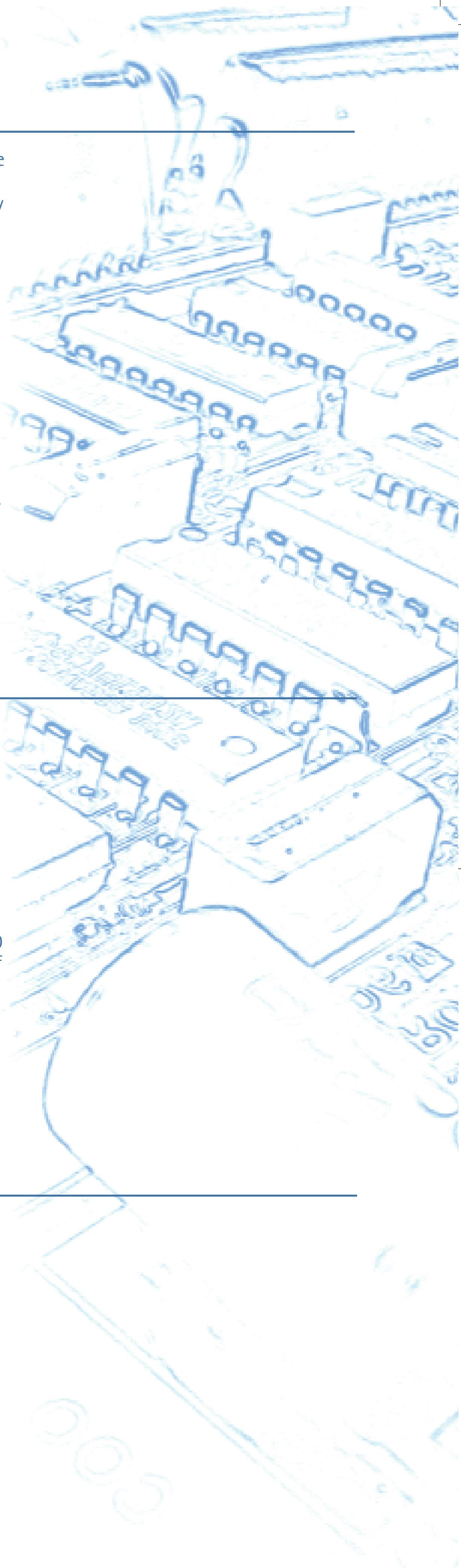


Background

The parallel ATA (AT Attachment) specification has defined the common standard storage interface for PCs since the protocol was introduced back in the 1980's. Parallel ATA has maintained its success for many years for three primary reasons: 1) Low Cost, 2) virtually universal operating system support, and 3) the ability to evolve to higher speeds and performance whilst maintaining backwards compatibility with older parallel ATA devices.

From its original interface speed of just 3MB/s, parallel ATA has moved up to burst transfer rates of 66MB/s and 100MB/s and beyond. The latest generation of the parallel ATA interface, Ultra ATA-133, goes even further with a burst transfer rate of up to 133MB/s.

While parallel ATA has enjoyed an illustrious track record, the specification is now showing its age. Parallel ATA imposes some serious design issues on today's developers, including a 5 volt signaling requirement, high pin count, major cabling headaches and, perhaps most significantly, limited performance headroom.

The serial ATA architecture has been created to overcome many of the design limitations of parallel ATA, whilst enabling the storage interface to scale with the growing demands of modern PC and workstation platforms. Serial ATA is designed to be a software-transparent "drop-in" replacement for parallel ATA that maintains compatibility with existing operating systems and drivers whilst adding performance headroom for up to a decade to come.

The end of Parallel ATA

Parallel ATA has served the IT industry well but as with all good things, it must come to an end. The following are the main reasons for parallel ATA running out of evolutionary potential:

• **High pin count** – Parallel ATA requires 26-pins per channel. Multiply that per channel and that's a total of 52 pins plus grounding plus power.

• **High voltage** – Parallel ATA requires 5V transceivers, which pose major integration problems with new silicon processes.

• **Cabling problems** – Since the introduction of Ultra ATA-66, the data cable requires 80 conductors. This makes the data cable large and cumbersome with a maximum length of 18 inches. Not only can these cables be difficult to route inside a computer system, they can cause air-flow problems and can lead to thermal issues.

• **Performance issues** – Parallel ATA has essentially reached its upper performance limit with a burst transfer rate of 133MB/s. To increase this performance level further, the parallel ATA interface would need to be modified to incorporate other technologies such as LVD (Low Voltage Differential) signaling.

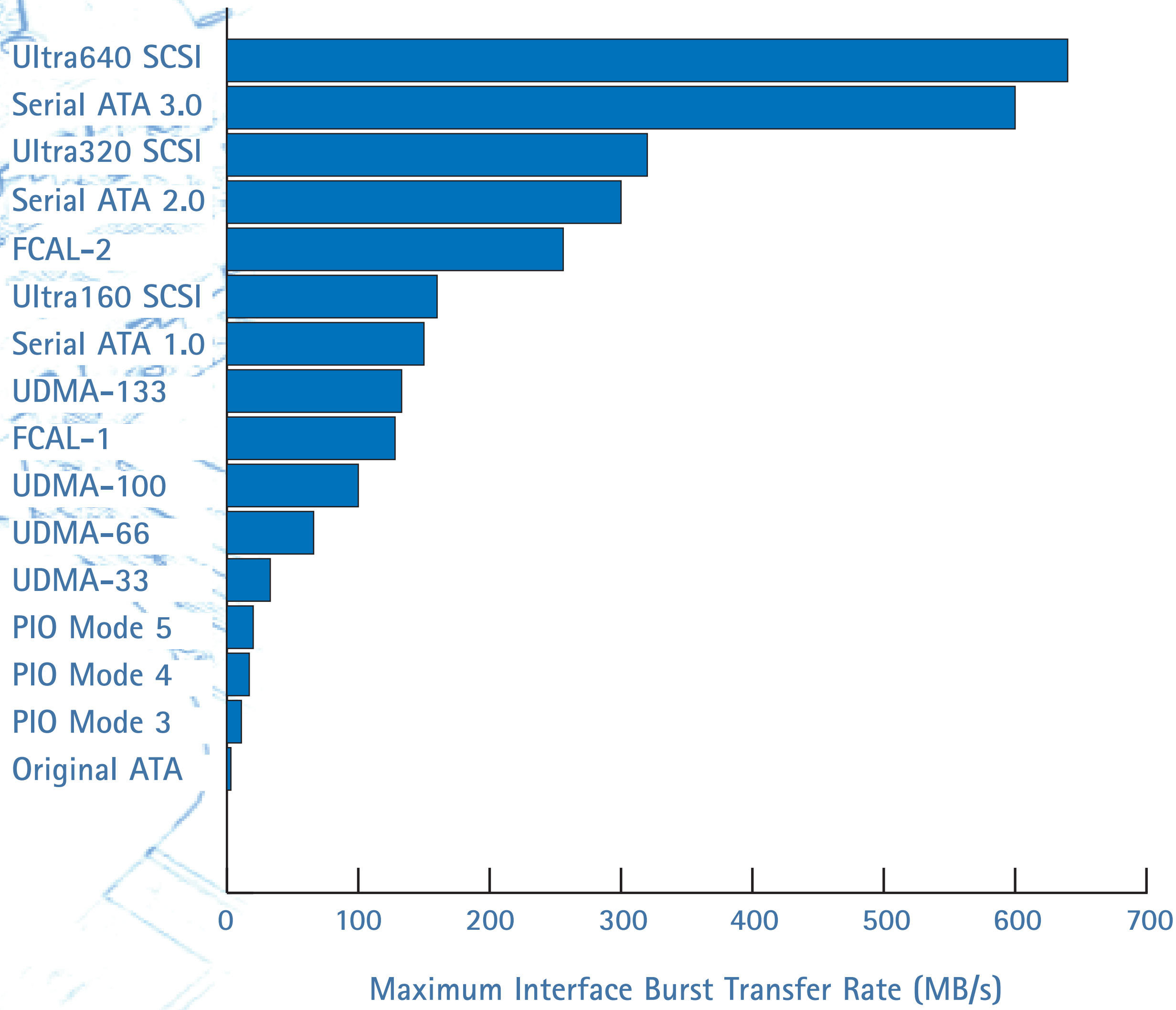
The Successor to Parallel ATA

With a limited time before parallel ATA becomes insufficient for modern PC and workstation systems, it is necessary for parallel ATA to evolve into a new standard that can continue to support the price/performance requirements of future workstation, desktop and mobile PC platforms. The software transparency and backwards compatibility of Serial ATA makes it the logical choice to supercede parallel ATA.

Comparative Performance

Probably the most significant benefit of Serial ATA over parallel ATA is the performance increase offered and the opportunity for future performance increases. Current parallel ATA interfaces have evolved from, initially, 3MB/s through to 33MB/s, to 66MB/s, to 100MB/s and finally to the latest 133MB/s burst transfer rate, but this is about the maximum the parallel ATA interface can achieve.

The first implementation of Serial ATA (Serial ATA 1.0) arrives with a burst transfer rate 1.5Gb/s which equates to approximately 150MB/s. The second generation of Serial ATA (Serial ATA 2.0), arriving around 2004, is expected to be introduced with a burst transfer rate of around 3Gb/s or 300MB/s. Similar performance increases can be expected approximately every two years for the next decade or so.

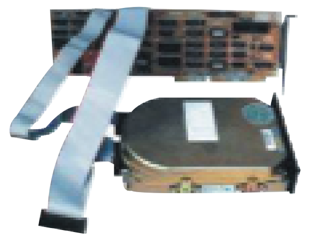


The Parallel ATA Interface

• IDE / ATA

IDE (Integrated Drive Electronics) describes a class of hard disk subsystem which was designed for AT-compatible PCs to overcome the performance limitations of earlier subsystem standards such as ST506 and ESDI. The IDE standard was introduced in the mid to late-1980s.

The IDE standard stipulated that the logic that controls the operation of the hard disk actually be integrated onto the drive itself. This approach allowed individual drive manufacturers to optimize disk I/O performance without the limitation of being fixed to a specific controller standard. Instead, a simple interface was defined through which the drive electronics would interchange data with the host computer and receive and respond to various commands.



ST506 Control Card & Drive

The IDE concept was originally proposed in 1986 by Western Digital and Compaq. While the term IDE in itself does not necessarily represent a standard, their proposals were incorporated into an industry agreed interface known as AT Attachment (ATA). This defined a command and register set for the interface through which the drive unit communicates with the host PC.

ATA Drive with Intergrated Logic

• Enhanced IDE (E-IDE)

As drive manufacturers began to develop their products in response to the opportunity offered by the adoption of the ATA standard, it became evident that the drive performance (3MB/s) and capacity (528MB) would ultimately reach a level at which the interface would cease to be a facilitator and become a bottleneck.

The next logical step was to develop an enhanced version of the ATA interface which would support those key features lacking in the original IDE specification. In 1993, Western Digital proposed E-IDE as an enhanced but compatible extension to the existing ATA standard and incorporated E-IDE features into their own range of Caviar drives.

Because the new E-IDE standard added to the existing ATA standard, E-IDE drives were fully backwards compatible with earlier ATA drives. The major drive manufacturers, therefore, included support for E-IDE in their "standard" ATA compatible drives rather than offer two separate product ranges.

The final step was the release of E-IDE adapter cards which allowed system builders to incorporate the technology into PCs build with off-the-shelf motherboards and take advantage of the E-IDE drives they had already bought. Inevitably, E-IDE controllers were integrated onto motherboards and, nowadays, 99.9% of all motherboards incorporate an E-IDE controller in some fashion.

Throughout the 1990s and into the new millennium, the E-IDE standard evolved incorporating newer technologies extending its capabilities and performance levels. Later versions of the PIO (Programmed Input/Output) standard were incorporated allowing higher transfer rates up to 33MB/s.

Eventually, DMA (Direct Memory Access) transfers, an alternative to PIO, were incorporated to increase performance even further; the current DMA standard (UDMA/133) allows burst transfer rates of up to 133MB/s.

The Serial ATA Interface

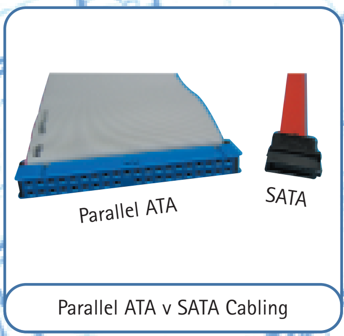
The familiar parallel ATA interface has been the primary storage interface in PCs for the past 10 years. For a variety of reasons, many of which have been detailed already, a new solution is required to keep pace with the growing demands of desktop and mobile PCs.

The leading manufacturers in the IT industry have developed a new interface specification designed as a drop-in replacement for the parallel ATA interface. Known as Serial ATA, this new serial interface is designed to overcome the limitations of parallel ATA whilst launching a roadmap that could drive more 10 years of storage interface performance evolution.

Thanks to its combination of software transparency, low cost, scalability and design flexibility, Serial ATA has attracted widespread industry support and is set to become the replacement for the current parallel ATA standard.

Features of Serial ATA

Serial ATA was designed as the natural successor to parallel ATA by providing for future expansion and performance headroom, but set out to solve many of the limitations of current parallel ATA technology. The Serial ATA interface incorporates, amongst others, six major improvements over parallel ATA.



Parallel ATA v SATA Cabling

• Lower Voltage Signaling

Parallel ATA is based on TTL signaling, which requires integrated circuits to tolerate input signals as high as 5V. In the near future, integrated circuits manufactured on the leading manufacturing processes will not be able to efficiently support 5V signaling voltages. With the upcoming fine lithographies, it will not be feasible to continue supporting 5V signaling tolerance. Serial ATA addresses these integration issues by reducing the signaling voltages to approximately 250mV (500mV peak-to-peak).

• Improved Cable and Connector plant

The current parallel ATA cable and connector plant is a bulky cable nest made up of unwieldy 80 conductor ribbon cables and 40 pin connectors. These are not only unsightly, but can cause problems with cable management and can lead to thermal issues as air-flow problems arise.

Serial ATA utilizes a small, flexible 4 conductor cable with lengths of up to 1m allowing cables to be routed much more efficiently.

• Pin efficiency

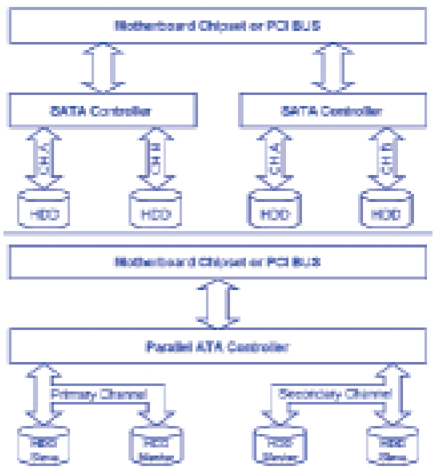
Currently, the parallel ATA interface has 26 signal pins going into the interface chip. Serial ATA uses only 4 signal pins, increasing the pin efficiency and accommodating a highly integrated chip implementation. The low pin count allows reduces the cost of the interface in manufacturing whilst providing greater reliability.

• Master-Slave Interaction

With today's parallel ATA implementation, pairs of devices share a common cable in a master-slave relationship. This interaction between devices results in the available bandwidth being shared between the devices. Additionally, since some devices on the cable interact, these must be jointly qualified, resulting in the substantial expansion of system integrators' qualification matrixes in order to comprehend all possible combinations of devices.

By contrast, Serial ATA is a point-to-point interface where each device is directly connected to the host via a dedicated link. Each device, therefore, has the entire interface bandwidth dedicated to it, and there is no interaction between devices. This means software can be streamlined, eliminating the overhead associated with coordinating accesses between the master and slave device sharing the same cable.

The absence of the master-slave interaction means there is no arbitration on the bus resulting in lower latencies. To the user, this translates to increased performance and added ease of use and installation, as there are no configuration jumpers



• Hot-Plug Opportunity

An additional benefit of Serial ATA is the opportunity for devices to be hot-plugged and inserted directly into standardized drive bays, an approach not directly supported by parallel ATA. Serial ATA includes all the mechanical and electrical features necessary to allow devices to be directly inserted into "SCA" (Single Connector Attachment) style environment while the system is powered and the protocol ensures that the device discovery and initialization is handled. This is true for 2.5inch drives also as both 3.5inch and 2.5inch drives share a common physical interface allowing for far greater density of drives in specific configurations.


Supermicro 5-bay SATA Hot-Swap Backplane

• Data Robustness

Data robustness has been a long-standing issue with parallel ATA. No form of data checking was designed into the parallel ATA interface during its early development. However, when the first UDMA mode was introduced, a degree of data protection was introduced in the form of CRC (Cyclic Redundancy Checking), which enabled the verification of interface data for the first time. Unfortunately, ATA command data is not checked in parallel ATA systems and remains a potential source for errors.

Serial ATA offers more thorough error checking and error correction capabilities than are currently available with parallel ATA. The end-to-end integrity of transferred commands and data can be guaranteed across the Serial ATA bus.

Implementing Serial ATA

Serial ATA was designed with ease of use and integration in mind giving the potential for a very smooth transition from parallel ATA to Serial ATA. These considerations were aimed not only towards the user, but towards system integrators and system designers also, which stands to make the Serial ATA interface very easy to adopt.

• Software Implications

Serial ATA has been designed as a drop-in replacement for parallel ATA offering what is effectively a software transparent transition from parallel ATA to Serial ATA. The implications of this are that there should be no software modifications required to obtain basic functionality.

Generally, operating systems with existing IDE support should be able to support Serial ATA, albeit in a limited form. As is to be expected, driver support for the specific Serial ATA controller will be required to take full advantage of the features and performance benefits of Serial ATA, but this should not pose a major problem as this is common to virtually every new device on the market.

• Serial ATA Hard Drives

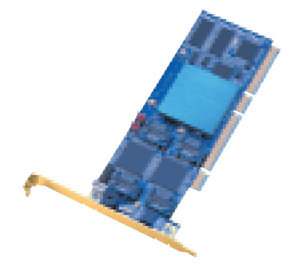
All major hard drive manufacturers including, Fujitsu, Hitachi, Seagate, Maxtor and Western Digital, are offering Serial ATA drives. Faster Serial ATA drivers, boasting Serial ATA 2.0 features and performance, are expected in 2004.

• Parallel ATA drives and ATAPI Devices

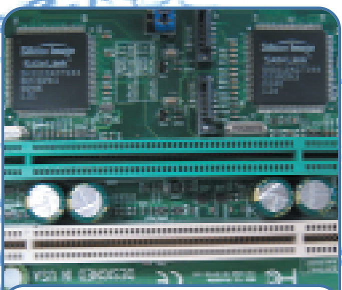
Current parallel ATA and ATAPI devices will still be available for some time. As with the evolution of parallel ATA, Serial ATA is designed with backwards compatibility in mind. It will be possible to connect standard parallel ATA devices to a Serial ATA system by way of a "dongle" or adapter.

Similarly, it will be possible to use a different dongle/adapter to run Serial ATA drives on parallel ATA systems allowing system integrators to use Serial ATA drives in current systems providing customer's with a performance upgrade in the future.


ICP Parallel ATA to SATA Converter



ICP GDT8546RZ SATA RAID Controller



Silicon Image SATA Controller on Supermicro X5DAL-TG2

Supermicro 5-Bay SATA drive enclosure

• System Hardware Implications

Serial ATA can be incorporated into systems in one of three ways:

1. Integration of a Serial ATA controller directly onto the motherboard
2. Integration of a Serial ATA controller within a motherboard chipset
3. The addition of a PCI based Serial ATA controller card.

It can be expected that add-in PCI cards will be introduced to add Serial ATA functionality to systems. This type of implementation also allows users of older systems to enjoy the benefits of Serial ATA without the need for a major upgrade to the system hardware.

As the transition from parallel to Serial ATA progresses, it is inevitable that Serial ATA controllers will be incorporated into motherboard manufacturers' designs. Initially, this can be expected in the form of a specific Serial ATA controller being added to the PCB design. As Serial ATA becomes more mainstream, it can be expected that Serial ATA functionality be incorporated into motherboard chipsets, in the way parallel ATA is today.

The use of Serial ATA over parallel ATA is actually looked upon as a bonus by motherboard designers as Serial ATA requires only 4 data/ground lines per channel as opposed ten times that for parallel ATA. Routing 40 data and grounding lines on a motherboard is not only tricky, but requires a great deal of space on the PCB.

• RAID Systems

Whereas parallel ATA was not well suited to RAID environments (for several reasons), these issues have been resolved by Serial ATA which make it a very tempting alternative for RAID systems. Serial ATA is not expected to replace SCSI as the primary technology for RAID; instead Serial ATA is expected to complement SCSI and offer a lower cost alternative.

Due to the physical interface of Serial ATA and the software protocols implemented, Serial ATA is particularly well suited to hot-plug environments in a very similar way to 80-pin SCA SCSI devices. Serial ATA "SCA", aka HRC (Host Receptacle Connector), backplanes are already emerging in low and mid-range server systems from leading manufacturers.

Currently, the majority of available SATA backplanes are without any form of management (often referred to as "Dumb backplanes"), but future evolutions will include management reporting technologies similar to SAF-TE and SES as currently found in SCSI and FibreChannel systems.

Due to the design of SATA, RAID support will be more comparable with SCSI rather than Parallel ATA. Current Parallel ATA RAID systems typically support only RAID 0 or RAID 1 primarily because the technology is ill suited to operating in a RAID environment. Most SATA RAID systems, like the majority of SCSI systems, support RAID levels 0, 1 and 5 with the provision for less common configurations such as RAID 10.

Other principles, common to SCSI, are available in SATA RAID systems such as ZCR – Zero Channel RAID. This is essentially a low-cost PCI card, which can be installed into a compatible motherboard, and works in conjunction with the standard SATA controller already integrated on the motherboard and offers full hardware RAID support directly off the motherboard.

New specifications, released on the 29th of April 2003, detail a new Serial ATA Port Multiplier, which allows for up to 15 devices to be connected to a single host port. This technology is of particular significance in RAID environments where drive numbers can be high. Where previously every drive in a Serial ATA drive enclosure would require it's own cable and host port, up to 15 drives can be connected to just one port reducing costs even further by reducing the need for multi-port RAID controllers.

Where does Serial ATA fit in the market place?

Naturally, parallel ATA and Serial ATA will operate in tandem during the transition period. As parallel ATA is phased out over the coming months, Serial ATA will become the replacement interface for the parallel ATA market. This should not be considered a cause for concern as the features of Serial ATA are certainly to the advantage of everyone and pricing for Serial ATA controllers and drives should be on a par with current, equivalent parallel ATA products.

As a direct replacement for parallel ATA, the use of Serial ATA will continue where parallel ATA left off, as the primary interface standard in most desktop PCs, low-end/mid-range workstations and most systems where storage at a low cost is required. Future versions of SCSI (e.g. Ultra 640) and FibreChannel (at speeds of up to 10Gb/s) will remain the preferred choice for performance and high-end systems.

However, markets typically recognized for their use of both SCSI and FibreChannel, such as SAN (Storage Area Networks) are expected to take on Serial ATA with the release of the new iSCSI standard.

What is iSCSI and why is Serial ATA so well suited?

iSCSI is an emerging technology expected to be a massive success in the SAN market place. iSCSI is a new interface which essentially combines the SCSI protocol with the IP protocol allowing storage subsystems to communicate and transfer data over standard Ethernet implementations.

Allowing storage systems to operate together is by no means a new idea, but iSCSI allows the use of standard (and typically ready installed) network architecture using ordinary CAT5 cabling and standard Ethernet switches, whereas typical SAN solutions require high cost interconnects (which are often FibreChannel). Additionally, iSCSI is not dependant on any particular drive interface standard. These factors allow a SAN solution to be implemented at very low costs.

Typical SAN solutions are not only costly because of the interconnects used, but because of the drive technologies often implemented. Usually, SAN systems run either SCSI or, more typically, FibreChannel drives primarily because of their performance and features. Parallel ATA was simply not an option because of the speed limitations and general technical unsuitability to this mode of operation.

Serial ATA removes many of these limitations and actually makes the prospect of iSCSI even more appealing. Where, previously, parallel ATA was inadequate and SCSI/FibreChannel too expensive, Serial ATA fits neatly between the two ends of the scale. While SAN configurations based on future evolutions of SCSI and FibreChannel will remain the preferred choice for high-end and enterprise level solutions, Serial ATA and iSCSI offer suitability and performance at a very low cost, putting this inexpensive and exciting new technology within reach of a new customer base.