The Path from 3Gb/s to SATA 6Gb/s: How to Migrate Current Designs to the SATA Revision 3.0 Specification

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Abstract:

The new Serial ATA Revision 3.0 specification doubles the throughput of SATA-based interconnects to 6Gb/s for a wide range of applications and eliminates storage as a system bottleneck. While the spec's increased data rate seems to capture most of the limelight, the SATA Revision 3.0 specification introduces several new features and capabilities that improve the performance, power efficiency, and cost-effectiveness of SATA technology in a way that enables developers to leverage much of their existing IP. This whitepaper will explore the key differences between SATA Revisions 2.6 and 3.0 and what impact they will have on new designs. Another whitepaper, "Fast Just Got Faster: SATA 6Gb/s," provides an overview of the benefits and applications enabled by SATA 6Gb/s technology. An FAQ document also is available.

In the race for faster throughput, there rarely seems to be a time when interconnect standards remain the same long enough to allow the industry to feel as if it can catch its breath. Every few years, interfaces are expected to at least double their data rates to keep pace with increasing bandwidth demand. With the penetration of digital audio and the continuing momentum of digital video, storage interfaces are being pressed to their limits.

Doubling an interface data rate typically requires a redesign of many of the interface's internal components and may introduce new signal integrity issues which in turn can prompt modifications in connector pin count, cabling, equalization and pre-emphasis, protocol, training, or many other factors. Each change can introduce complexity, cost, and confusion. Sometimes these changes can also be significant enough to effectively create an entirely new interface in everything but name, requiring ASIC redesign, new board layout, rewritten drivers, and so on.

When the Serial ATA International Organization (SATA-IO) began design of the SATA Revision 3.0 specification, the designers wanted to double the interface data rate while enhancing support for multimedia applications − without introducing major changes that could adversely affect cost, increase design complexity, or reduce the quality and performance of the SATA interface. Key to meeting this goal is maintaining backward compatibility with SATA 3Gb/s connectors and cabling. In addition to operating at 6Gb/s, SATA Revision 3.0 offers advanced Native Command Queuing (NCQ) streaming, enhanced power management, new form factor connectors for compact embedded applications, and simplified testing.

Moving to SATA 6Gb/s

The primary challenge designers face when moving from 3 to 6Gb/s is that losses in signal amplitude over boards and cables increase as data rates rise. Higher frequency signals have increased sensitivity to attenuation and jitter. When attenuation and jitter become too pronounced, signal quality degrades and throughput drops significantly because of an increasing number of resends. Attenuation is also affected by cable length.

The key factor driving the SATA Revision 3.0 specification is backward compatibility. While there are advanced technologies available for managing attenuation and jitter, such modifications to a specification can require non-trivial redesign across the development and supply chain – ASICs, PHYs, cabling, connectors, drivers, and applications. By allowing SATA 6Gb/s systems the ability to utilize the same connectors and cables as SATA 3Gb/s systems, most of the modifications required to achieve 6Gb/s are confined to the PHY layer. Except for doubling the data rate, the PHY is no more complex than that defined by the SATA Revision 2.6 specification. Changes to the protocol itself are minor, and the physical connectors and cables remain unchanged.

By avoiding the introduction of training or advanced signal quality technology, SATA 6Gb/s requires no heroics, so to speak, to implement, enabling designers at all levels to leverage most of their existing IP. This approach accelerates time-to-market because designers do not need to completely redesign their systems.

More Than Just Faster Transfer Speeds

SATA Revision 3.0 offers designers more than just higher data rates. While support for 6Gb/s is clearly the highlight of this third-generation SATA technology, the designers of SATA Revision 3.0 sought to add capabilities while maintaining SATA's low cost structure. Important enhancements to the SATA Revision 3.0 specification include new compact connectors, enhanced NCQ streaming and management, advanced power management features, and simplified testing. These new features also function at 1.5Gb/s and 3Gb/s.

Connector Options

SATA Revision 3.0 introduces two connectors to bring SATA technology to smaller devices. In addition to reducing overall connector size, these new connectors meet the strict design requirements specific to applications where device profile is a primary design consideration. The new 7mm optical disk drive (ODD) connector enables

designers to create slimmer and lighter consumer electronic devices such as notebooks, netbooks, and DVD players.

The new smaller Low Insertion Force (LIF) connector provides a more compact form factor to accommodate even shorter- and thinner-profiled 1.8-inch storage devices. The LIF connector characteristics are particularly well suited for embedded storage applications, which can best utilize the streamlined footprints of these new LIF-SATA storage devices.

Power Management

The earlier SATA Revision 2.6 specification introduced two power modes – Partial and Slumber – on the interface that operate independently of power management schemes integrated in storage devices. To conserve power – especially in battery-operated applications – devices can power off SATA portions of the interface circuitry when the interface is not in use, such as when a hard drive is in seek mode. For SATA Revision 2.6 devices, the shift from Partial to Slumber mode required the host to first change modes from Partial to Active before entering Slumber mode. In addition, SATA Revision 2.6-enabled peripherals have to wait for permission from the host to remove power supplied to the interface.

SATA Revision 3.0 introduces an Automatic Partial to Slumber mode transition which 1) eliminates the need to first enter Active mode and 2) enables either hosts or devices to initiate Slumber without asking permission from the other side of the link. These two improvements increase the length of time SATA interfaces can be powered down, enabling the power efficiency of SATA 6Gb/s PHYs to approximate SATA 3Gb/s PHYs, depending upon the implementation. While 6Gb/s PHY designs are expected to have a higher active power, the total active time/duty cycle to transfer equivalent data will be approximately half that of 3Gb/s devices.

Multimedia Support through Native Command Queuing

Another new SATA Revision 3.0 feature is Native Command Queuing (NCQ) streaming, which shifts management of time-limited commands from devices to hosts. NCQ streaming was designed to enable isochronous data transfers between applications with high bandwidth requirements, such as audio and video, while also improving the performance of lower priority transfers.

When using ATA power management commands, the host sends a time limit with a command. If a device cannot complete the command in the designated time, the

device will abort the command and either returns an undefined response or truncated data.

When NCQ streaming is employed, the host sets as well as manages the time limit for the command. The time limit is still passed to devices with the intention the time limit will be used to prioritize requests. However, because the host is managing the timer, the host has control of all pending commands. This allows the host to determine whether a command which has exceeded the time limit will be aborted or kept active.

One of the benefits of NCQ is that it provides a mechanism for optimizing data access. The NCQ protocol enables multiple commands to be staged for processing by a hard drive, thus allowing the drive to decide the most efficient way the group of commands is to be executed. For example, a disk drive may change the order in which the commands are processed to reflect the relative location of where the requested data is stored compared to the current position of the read/write head over the media platters. NCQ streaming balances priority and efficiency by allowing the host to pass protocol information to the drive, thereby guaranteeing reliable media playback while simultaneously permitting the drive to improve the performance and throughput of other, lower priority system tasks that may otherwise have been adversely impacted.

Related NCQ improvements include queue management features that give hosts direct control of outstanding NCQ commands as well as the ability to manage the processing of NCQ commands to optimize performance. New features include an Abort subcommand and the ability to read SMART logs using the Direct Memory Access (DMA) protocol.

With the Abort subcommand, when the host timer expires for a particular command, the host is given the option of aborting a particular tag number, aborting all streaming commands, or aborting all commands currently in the queue.

The ability to read SMART logs directly to DMA is a feature which improves host efficiency by beginning the phase out of certain programmed input/output (PIO) protocols. When PIO is used to read SMART logs, the host must read each individual two-byte register it wants to examine. DMA-based commands eliminate the need for host involvement during log reading. Hosts only need initiate the SMART log read and then are free to perform other tasks until the DMA notifies the host that the entire read operation is complete.

Clarifications

The SATA Revision 3.0 specification also brings a variety of important but lower profile additions, corrections, and clarifications to the SATA specification. Most of these changes do not alter how the SATA interface operates but aid in clarifying the specified requirement. For example, SATA Revision 3.0 states that the frequency and signal type to be used for the out-of-band (OOB) signaling which two devices use to negotiate transfer rate is the same as that used in Revision 2.6. This clearly indicates that SATA-based ASIC designs will not have to change their OOB circuitry to operate with new SATA Revision 3.0-enabled devices.

Data validity clarifications are another example of lower profile clarifications included in the SATA Revision 3.0 specification. Previously when a host-issued read command was unexpectedly terminated, there was ambiguity as to which part of the received data was valid. Problems arose when applications began using data as it arrived; some vendor implementations truncated data in the middle of a FIS while others ended at the next 8K data set. SATA Revision 3.0 specifies that the host should not assume data is valid until a data completion is received.

Another important clarification involves the Identify Device command. Earlier versions of the specification did not clearly address dependencies between some of the bits returned from the Identify Device command and when such data was valid. This can specifically be seen in words 76-79, which are owned by SATA-IO. Overall, the SATA Revision 3.0 specification also better aligns SATA with the INCITS ATA8-ACS standard. A complete list of changes is provided in the Revision History section contained in the SATA Revision 3.0 specification.

SATA-IO is currently working to update the external SATA (eSATA) specification to support 6Gb/s speeds. Because of their exposed nature, external interconnects must be more rugged and support longer cable lengths than internal interconnects. So as not to delay the release of the internal SATA 6Gb/s specification, accommodations for eSATA were not included in the SATA Revision 3.0 specification. The eSATA 6Gb/s specification is targeted for release in the near future.

SATA 6Gb/s Cabling

In the transition to SATA 6Gb/s, it will be important to use high-quality cabling. Problems may be related to the use of cables made from marginal materials that perform at the edges of SATA 3Gb/s tolerances, which could become a failure point at

the faster 6Gb/s signal rates. SATA-IO therefore recommends that only high quality cables and connectors be utilized for SATA 6Gb/s.

Cable manufacturers and all suppliers of SATA products are encouraged to register their products on the SATA-IO Integrators list. This list is available to the public as a resource for determining reliable products that meet the SATA interface specification.

High-speed Signal Testing

An important goal for SATA-IO during the development of the SATA Revision 3.0 specification was to provide simplified testing of SATA-based equipment to speed product development and troubleshooting. By inviting testing tool vendors to participate as early contributors to SATA Revision 3.0, the new 1.4 Unified Test Definition Specification (UTD) for SATA 6Gb/s was designed to take full advantage of the advanced capabilities of existing testing tools. In addition to clarifying various ambiguities in the 1.3 Unified Test Definition Specification (UTD), several testing parameters have also been removed, which further simplifies the creation and automation of test benches.

By embracing that the tolerances required at 6Gb/s are much tighter than at 3Gb/s, developers and end-users can avoid expending resources and time troubleshooting problems that do not actually exist. Added cable length and connectors used to attach test equipment can introduce jitter and attenuation onto the link. The presence of testing tools can mask or introduce signal integrity issues. Test setups that performed at the margin of SATA 3Gb/s may need to be updated to meet Revision 3.0 specs for SATA 6Gb/s to avoid setup-induced problems appearing as issues with devices under test.

Attenuation and jitter can be minimized by using the shortest possible cable lengths and collocating testing tools with devices under test as well as eliminating unnecessary discontinuities in connectors, splices, and adaptors. To further protect signals from interference, the use of high-quality shielded cables that guard the entire cable should be employed. Users should also make themselves familiar with the various connection methods available and how each reduces or compensates for added jitter and attenuation. A comprehensive discussion on how to avoid SATA 6Gb/s cabling issues is provided in the white paper entitled “Successful SATA 6Gb/s Equipment Design and Development,” which is available on the SATA-IO Web site.

Maximizing Bandwidth Utilization

Doubling the data rate of the SATA interface brings many performance advantages to end-users. Higher performance benefits a wide range of applications, including enterprise storage, RAID as well as faster data processing in desktop and notebook PCs. In order to fully utilize SATA capabilities, however, developers may need to employ other technologies to match data access to interface throughput.

Readiness to function at the 6Gb/s speed will vary by device type. Solid state drives (SSDs) have none of the mechanical access latencies associated with hard disk drives and already utilize all of the available 270 MB/s bandwidth of SATA 3Gb/s. Some of the next-generation SSDs are expected to need the SATA 6Gb/s potential transfer speed of over 580 MB/s.

The SATA port multiplier feature can be used to aggregate up to 15 drives onto a single SATA port to increase bandwidth utilization. Port multipliers were part of the SATA specification since version 1.0 and require host links to support Frame Information Structure-based (FIS) switching. This allows the host to communicate with one drive after another without having to wait for various transactions to complete. These are prevalent in entry-level server applications and are becoming increasingly important for high-bandwidth applications such as HD video post-production systems.

Naming Conventions

In order to avoid confusion between different SATA specifications, the SATA-IO has outlined some basic naming conventions that are geared to eliminate ambiguity. Manufacturers should avoid using the terms “SATA III” and “SATA 3.0,” as it is unclear whether “SATA 3.0” refers to the SATA Revision 3.0 specification, SATA 6Gb/s as defined by the SATA Revision 3.0 specification, or the SATA 3Gb/s transfer rate.

The terms “SATA II”, “SATA 2.6”, and “Gen 2” should be avoided as well. While the terms “Gen 3”, “Gen 2”, and “Gen 1” are used within the SATA Revision 3.0 specification, they refer to technical specification items and should not be used for marketing or product naming purposes.

The formal name for the new specification is the “Serial ATA Revision 3.0 specification.” The technology can be referred to as “SATA 6Gb/s” and products should be called “SATA 6Gb/s <product name>.” By following these naming conventions, the storage industry can avoid undesirable confusion that could stall adoption in the market place.

Conclusion

There are many reasons why SATA is the dominant internal storage interface worldwide. With the SATA Revision 3.0 specification, storage can better support real-time multimedia transfers and other high-bandwidth applications. By maintaining backward compatibility, SATA-IO enabled the ability to double data transfer rates without requiring a complete redesign of equipment or compromising the quality, reliability, and performance for which SATA is well-known.