



Xserve RAID

Technology Overview
February 2003



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Introduction

Exponential growth in the creation and distribution of digital content is driving demand for high-capacity storage solutions. Digital video footage, large databases, media-rich student documents, and immense scientific data sets require terabytes of storage—and protecting the integrity and accessibility of these digital assets has never been more critical. Apple addresses these needs with Xserve RAID, a breakthrough solution for high-performance protected storage.

Xserve RAID combines leading-edge storage technologies to deliver superior capacity, performance, and data protection in a 3U rack-optimized enclosure. The innovative Apple-engineered architecture features 14 ATA/100 drive channels, dual independent RAID controllers, and dual 2Gb Fibre Channel host interface. Together they provide up to 2.5TB of storage¹ with throughput of up to 400 megabytes per second.² For maximum reliability and availability, Xserve RAID also includes sophisticated environment management coprocessors and redundant hot-swap power supplies and cooling modules. In addition, a new file system journaling feature in Mac OS X Server protects file system integrity and facilitates rapid recovery in the event of an unplanned shutdown or system failure.

Designed to protect your digital assets as well as your organization's bottom line, Xserve RAID includes RAID Admin, a powerful remote management application that simplifies system administration and lowers deployment costs. RAID Admin offers fast, easy setup of protected storage volumes and also provides continuous monitoring of system hardware. If the monitoring system should ever detect a problem, it automatically sends out an event notification via email or pager—enabling you to swap out a failed part without interrupting service. For added peace of mind, the AppleCare Premium Service and Support Plan is available for Xserve RAID, providing up to three years of 24/7 telephone and email support, as well as rapid onsite repairs.³

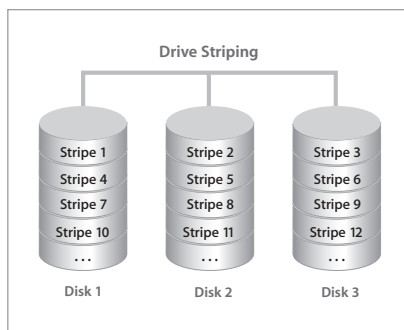
With Xserve RAID, Apple delivers a high-performance, high-availability storage system that is both affordable and easy to use. Designed for businesses, schools, and digital content creators, it is the ideal solution for managing and protecting critical data and digital assets.

Why RAID?

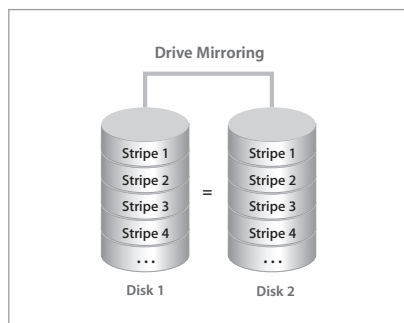
Who needs RAID?

A high-availability design and flexible deployment options make Xserve RAID ideal for a wide range of applications, including:

- Application and database serving
- Digital asset archiving
- Email and web serving
- Prepress operations
- Video production and editing
- Media streaming
- Advanced Photoshop operations
- CAD and 3D rendering
- Biotech and numerical clusters



Striping breaks a single file into data blocks and distributes it across two or more drives.



Mirrored drives contain identical sets of data for total redundancy.

Redundant array of independent disks, or RAID, is a grouping of multiple physical hard drives into an array, or RAID set, that appears to the host computer as a single logical storage unit. Use of RAID technology enables organizations to increase storage capacity while achieving levels of performance, reliability, and data protection not possible from a single hard drive. All drives in the array can operate simultaneously for dramatically faster overall throughput. RAID systems can also improve data availability and fault tolerance, because redundant data can be stored across multiple physical drives. Even in the event of a drive failure, the system can continue to operate without loss of data and with no interruption in service.

RAID Basics

RAID technology is based on three practices: *Striping* to improve storage performance, and *mirroring* and *parity* to provide redundancy for increased data protection. Most RAID configurations, or RAID levels, combine these techniques to provide a balance of data protection and performance.

Striping

Increased performance in a multidrive set is accomplished by data striping. As the name implies, striping divides a logical drive into data blocks, or stripes, that are distributed across the array of physical drives. Data is then laid down according to the stripe paths, so that each file is spread across multiple drives. Striping a set of disks greatly improves overall storage performance because each drive operates concurrently. While one drive is writing or reading a data block, another is seeking the next block in parallel. However, striping alone, known as RAID level 0, offers no data protection.

Mirroring

The simplest method of achieving data redundancy, mirroring involves writing identical copies of all data to a pair of physical drives. This results in very high data reliability: If one drive fails, the data is still available on the remaining disk drive. However, it also results in a storage efficiency of only 50 percent, because two physical drives are required to achieve a single drive's capacity. Mirroring alone is known as RAID level 1.

Parity

A more sophisticated method of creating redundancy, parity provides data protection for an array of drives without requiring complete duplication of the drive contents. Parity information can be used—along with the data on the surviving drives—to reconstruct the contents of a failed drive. The parity data can be stored on a dedicated drive, as in RAID 3, or distributed across an array of drives, as in RAID 5. In either case, parity provides much greater storage efficiency than mirroring—up to 85 percent for a set of seven drives. Since parity involves calculating complex algorithms, it requires a dedicated hardware RAID processor and cannot be implemented in software RAID.

Software versus Hardware RAID

RAID functionality can be implemented in hardware or software. Software RAID, included in Mac OS X and Mac OS X Server, enables you to stripe or mirror disk arrays for enhanced performance or greater data protection. However, software RAID is not practical for implementing RAID levels that use parity for higher availability and drive efficiency. Parity RAID levels, such as RAID 3 and 5, involve compute-intensive operations that can overtax the system processor, affecting overall performance. A hardware RAID controller prevents this bottleneck and delivers maximum throughput while providing the highest level of fault tolerance.

RAID Levels

Each RAID level offers a unique balance of I/O performance, data protection, and storage efficiency. Xserve RAID supports the most popular RAID levels, so you can select the best configuration for your application and your budget.

RAID 0: Striping

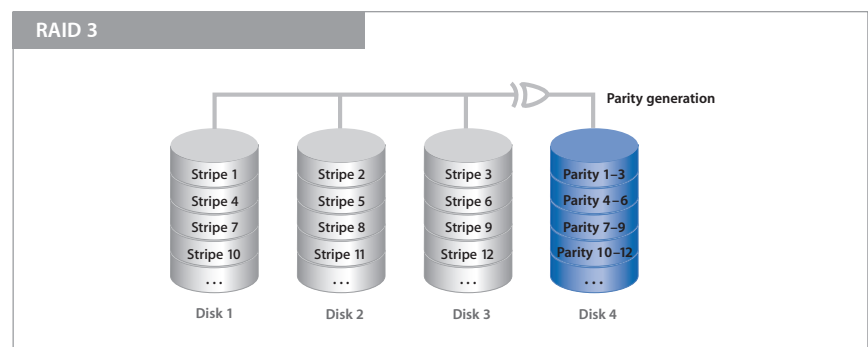
RAID 0 distributes data evenly in horizontal stripes across an array of drives. While RAID 0 offers substantial speed enhancements, it provides no data protection: If one drive fails, all of its data is lost and all drives must be reformatted. RAID 0 provides the most efficient use of drive capacity, because no storage space is dedicated to redundant data or parity information.

RAID 1: Mirroring

RAID 1 creates a pair of mirrored drives with exactly the same data. It provides a high level of data availability and, by using both drives simultaneously, offers fast read performance. Write speeds are lower, however, because all data is written twice—once to each drive. RAID 1 is also relatively expensive to deploy because it offers the poorest level of drive efficiency.

RAID 3: Striping with parity

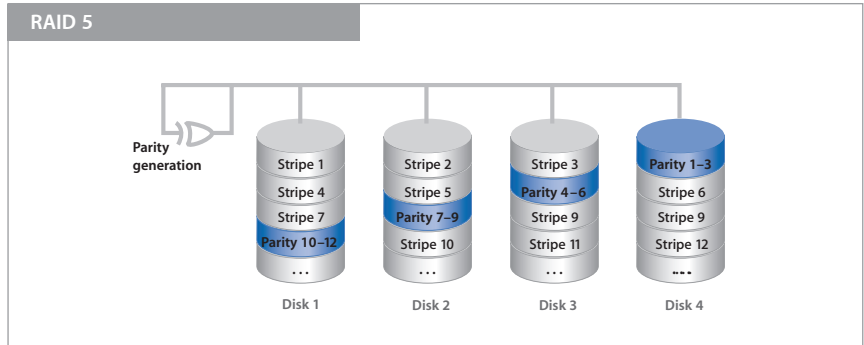
RAID 3 stripes data across two or more drives and stores parity data on a dedicated drive. In the event of a disk failure, the redundant parity bits can be used to reconstruct data on any drive. RAID 3 offers fast read rates and high data availability, with greater storage efficiency than RAID 1. Write performance in RAID 3 is faster than in RAID 1, but not as fast as in RAID 5, because it depends on the availability of a separate parity drive. RAID 3 requires a minimum of three drives; more drives result in faster performance and greater drive efficiency.



RAID 3 stripes data across two or more drives and stores parity data on a dedicated drive.

RAID 5: Striping with distributed parity

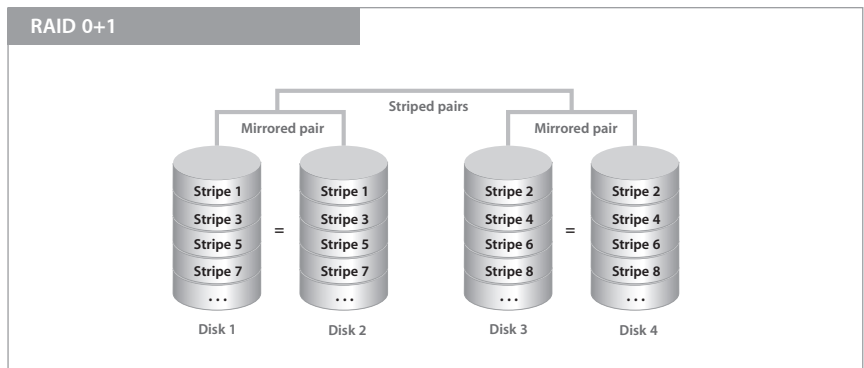
RAID 5 distributes both data and parity information across an array of drives one block at a time, with each drive operating independently. This enables maximum read performance when accessing large files and improves performance in a transaction-processing environment. Write performance is also improved because parity information is striped across the drives, removing the bottleneck of a single parity drive. RAID 5 is the most popular configuration for high-throughput protected storage. Like RAID 3, RAID 5 requires a minimum of three drives; more drives provide faster performance and higher storage efficiency.



RAID 5 distributes data and parity information across all the drives in an array.

RAID 0+1: Striping over mirroring

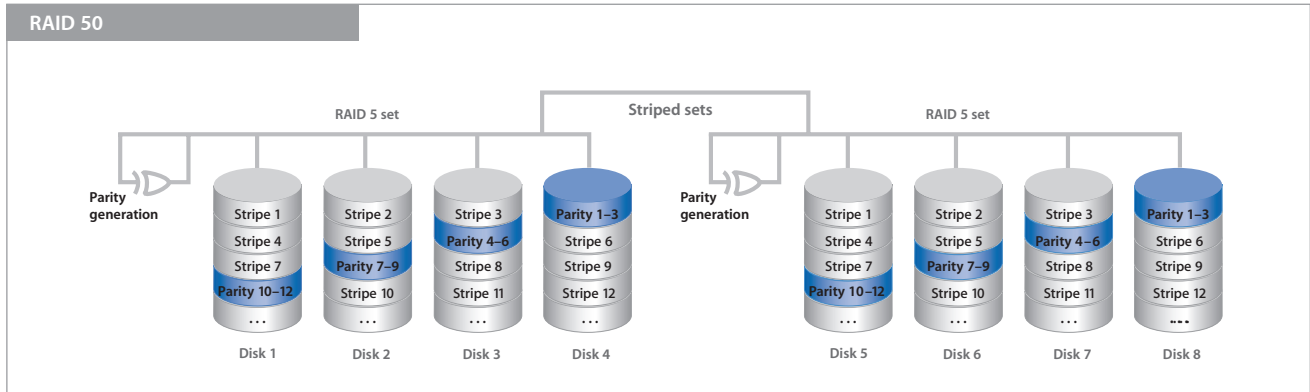
This hybrid RAID level is created by striping data across multiple pairs of mirrored drives. With Xserve RAID, both striping and mirroring are set up in hardware, which means the array can run independently of the server processor. RAID 0+1 provides higher throughput with less setup complexity than configurations that use software RAID for striping, such as RAID 10.



Xserve RAID offers a hardware RAID level 0+1, which mirrors drive pairs and then stripes data across the mirrored sets.

RAID 10, 30, and 50

Hybrid RAID levels 10, 30, and 50 use hardware RAID to create two or more sets in RAID 1, 3, or 5, and software RAID to stripe across the sets. This creates a single data volume with the best balance of performance and data protection. In the case of Xserve RAID, you can combine all 14 drives for high performance at maximum capacity.



This RAID 50 configuration uses software RAID to stripe data across two RAID 5 sets, which were created using hardware RAID.

Comparison of RAID levels

RAID level	Minimum number of drives required	Storage efficiency	Read performance	Write performance	Data redundancy
RAID 0	2	Highest	Very high	Highest	No
RAID 1	2	Low	High	Medium	Yes
RAID 3	3	High to very high	Medium	Medium	Yes
RAID 5	3	High to very high	High	High	Yes
RAID 0+1	4	Low	High	High	Yes
RAID 10	4	Low	High	High	Yes
RAID 30	6	High to very high	High	High	Yes
RAID 50	6	High to very high	Highest	Very high	Yes

Each RAID level offers a unique balance of performance, data protection, and drive efficiency. The efficiency of parity RAID levels increases with the number of drives in an array.

What to Look for in a RAID System

RAID is a cost-effective investment that can protect your business by increasing productivity and safeguarding critical data. When you choose a RAID configuration, you'll want to carefully consider your requirements concerning performance, data protection, data availability, and storage capacity. You'll also want a system that's easy to set up and easy to manage remotely. And in all cases, your RAID system should scale to meet the future needs of your organization and—at the same time—fit the budget you have today.

Performance

How fast do you need to read and write to disk? A storage system's bandwidth, measured in megabytes per second (MB/s), describes how quickly it can move large amounts of data. Bandwidth is crucial when transferring large files, as in prepress or video editing workflows.

Data protection

How safe does your data need to be? Because protection comes at a cost—in terms of both storage efficiency and performance—you need to carefully assess the risk of data loss. Data protection is typically paramount for maintaining mission-critical databases, storing student or customer records, and archiving digital assets.

Data availability

Does your data need to be available at all times without interruption? Data availability is critical for email, web, and database servers. In addition to choosing the appropriate RAID level, you'll want numerous fault-tolerance features, including redundant power and cooling components, a fast rebuild rate, and support for a hot spare that can instantly replace any drive in the RAID set.

Storage capacity

How much data do you need to store, now and in the future? Keep in mind that, with all RAID levels that offer data protection, some capacity will be used for storing redundant data, so your actual available storage will be less than the total capacity of the drives. Make sure you choose a system that can scale to meet your needs over time, whether you increase storage capacity or switch to a RAID level offering increased data protection in the future.

Product Overview



Xserve RAID combines leading-edge storage technologies to deliver superior capacity, performance, and data protection.



Xserve RAID works seamlessly with Xserve, Apple's highly acclaimed server solution. Equipped with single or dual 1.33GHz PowerPC G4 processors, Xserve packs phenomenal power and a rich feature set into an affordable 1U rack-optimized system.

Introducing Xserve RAID

Featuring massive capacity and a high-performance, high-availability architecture, Xserve RAID is a cost-effective answer to the growing storage requirements of businesses and educational institutions. And with best-of-class tools for remote setup and management, this powerful RAID solution delivers ease of use that could only come from Apple.

High-capacity storage. Xserve RAID holds up to 14 hot-swap Apple Drive Modules—a phenomenal 2.5TB of storage—in a rack-optimized 3U enclosure. Each 7200-rpm hard drive connects to a dedicated ATA/100 drive channel, eliminating a traditional source of bottlenecks and maximizing the 400MB/s Fibre Channel host connection. By adding more systems, you'll have virtually limitless expansion capabilities: A standard 42U rack can hold over 35TB of Xserve RAID storage.⁴

Fast data access. The advanced Xserve RAID architecture delivers fast access to storage without compromising data integrity. Dual independent RAID controllers provide protected storage with unprecedented performance. In fact, Xserve RAID boasts a throughput at RAID level 5 that's fast enough to support real-time high-definition (HD) 1080i video editing.

High-availability design. To ensure availability of your critical data, Xserve RAID is designed for nonstop operation. Redundant hot-swap power and cooling modules allow the system to keep functioning even if one module fails. All the active components are modular, making it easy to replace them in seconds—usually without any interruption of service.

Superior data protection. A high-availability architecture and dual independent RAID controllers support RAID levels 0, 1, 3, 5, and 0+1. In addition, Xserve RAID supports hybrid RAID levels 10, 30, and 50 when used in conjunction with host-based software RAID.

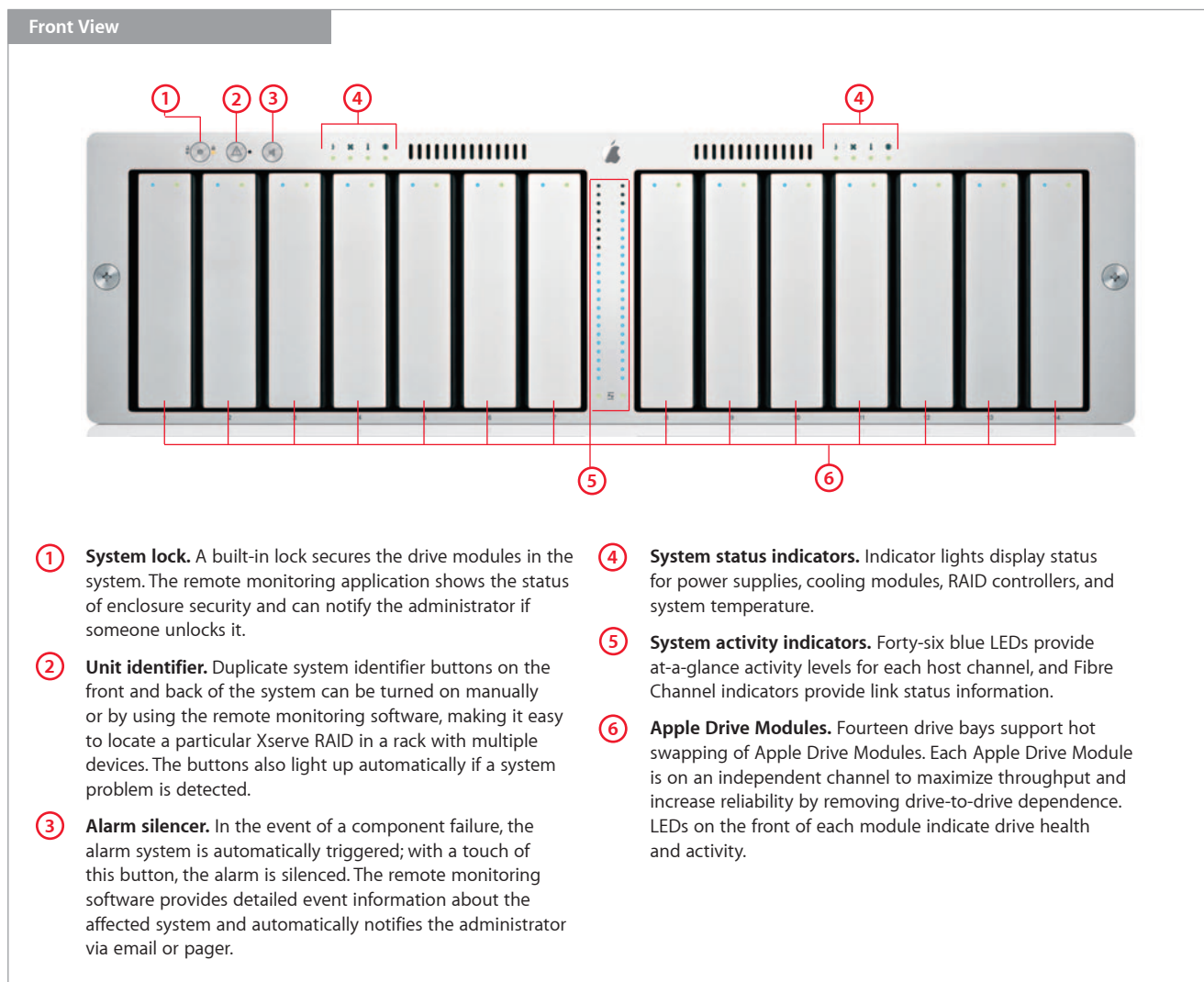
Advanced management tools. Sophisticated remote management capabilities dramatically simplify setup and maintenance of RAID storage. The Java-based RAID Admin application works with the environment management coprocessors to build RAID sets on the fly, allowing administrators to bring protected storage online instantly, without waiting for initialization. RAID Admin also provides real-time monitoring of hardware with automatic notifications via email or pager in the event of a component failure. The intuitive user interface and rapid event notification allow administrators to quickly identify problems and repair them without downtime or data loss.

Xserve RAID Components

The 3U Xserve RAID enclosure is built for superior reliability, availability, and serviceability. It features redundant, hot-swap components that enable the system to keep running even if a critical component fails. Independent drive channels and support for hot sparing allow a failed drive to be rebuilt without affecting the availability of the other drives.⁵ In addition, coprocessors built into the two RAID controllers constantly monitor the enclosure environment and system health. If a problem is detected, the remote monitoring software automatically notifies the administrator to ensure rapid resolution. And servicing Xserve RAID is as simple as removing the failed module and inserting a new one, with no tools required. Since Xserve RAID uses the same Apple Drive Modules as Xserve, Apple's 1U server, you can protect your storage investment by repurposing drives.

Front panel

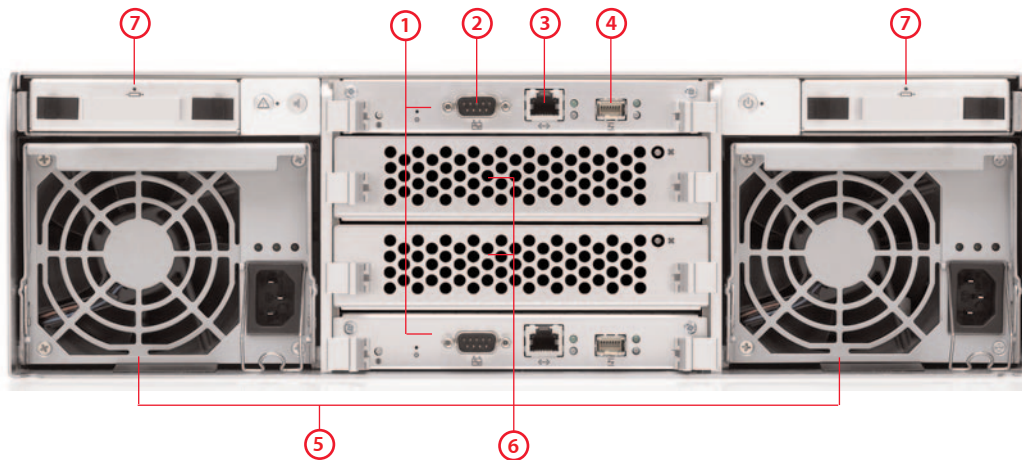
LEDs on the front panel provide continuous visual feedback on system status and activity levels for local monitoring of Xserve RAID systems.



Back panel

The back panel provides easy access to RAID controllers and field-replaceable power, cooling, and battery modules, as well as connectivity to one or more host computers and up to two uninterruptible power supply (UPS) devices.

Back View



- ① **RAID controller modules.** Two independent storage processor units manage RAID functions, data transfers, and failure protection for each set of seven drives. The environment management coprocessor in each controller simplifies configuration and management of RAID sets.
- ② **Serial ports.** Standard DB-9 serial ports provide connectivity to UPS units for protection from brownout or over-voltage conditions.
- ③ **Ethernet ports.** The 10/100BASE-T Ethernet ports enable administrative communications with the enclosure monitor for system configuration, monitoring, and diagnostics.
- ④ **Fibre Channel ports.** Each storage processor connects to the host system via a 2Gb Fibre Channel interface that provides bandwidth of up to 200MB/s per port.² Throughput is guaranteed, which means the bandwidth remains constant, even if more devices are added in a fabric configuration.
- ⑤ **Power supply modules.** Either of the redundant, load-sharing power supplies can power Xserve RAID alone should the other one fail. The power supplies are also hot-swappable: In the event of a failure, the component can be replaced in seconds without tools and without shutting down the system. A cord retainer on each power supply prevents accidental removal when cabling the system or replacing a failed component.
- ⑥ **Cooling modules.** Redundant, hot-swap cooling modules provide automatic front-to-rear cooling for rack environments. Designed to maintain an optimal ambient temperature, the cooling modules self-regulate their rotational speed based on the enclosure temperature.
- ⑦ **Optional batteries.** Xserve RAID offers optional Cache Backup Battery Modules that provide more than 72 hours of backup power to protect the integrity of data in the RAID controller cache during a power outage.

Xserve RAID Applications



Xserve RAID features industry-standard Fibre Channel connectivity and a rack-optimized enclosure, allowing it to blend seamlessly into existing data center infrastructures.

Xserve RAID is a revolutionary storage product that offers phenomenal performance and a feature set previously only available in vastly more expensive storage systems. Its massive capacity and advanced architecture give Xserve RAID unmatched application versatility. An ideal solution for consolidating and protecting digital assets in small or medium businesses and educational institutions, Xserve RAID also offers the performance and availability required by larger businesses, creative departments, and universities.

Xserve RAID also goes beyond the typical boundaries of affordable, high-capacity storage solutions by combining high data availability with ultrafast throughput. This makes it ideal for demanding video workflows. In fact, Xserve RAID delivers the fast, consistent throughput required for uncompressed and high-definition video postproduction.

Network-Shared Storage

Xserve RAID delivers optimal performance when paired with Xserve, Apple's highly acclaimed 1U server. Equipped with single or dual 1.33GHz PowerPC G4 processors, Xserve offers phenomenal computational power in a high-density rackmount enclosure. Its fast I/O subsystem features two full-length 64-bit, 66MHz PCI slots—with up to 533MB/s throughput—to take advantage of the advanced Xserve RAID architecture and 2Gb Fibre Channel interface. Dual independent Gigabit Ethernet ports ensure rapid delivery of stored data to client systems over today's high-speed networks.

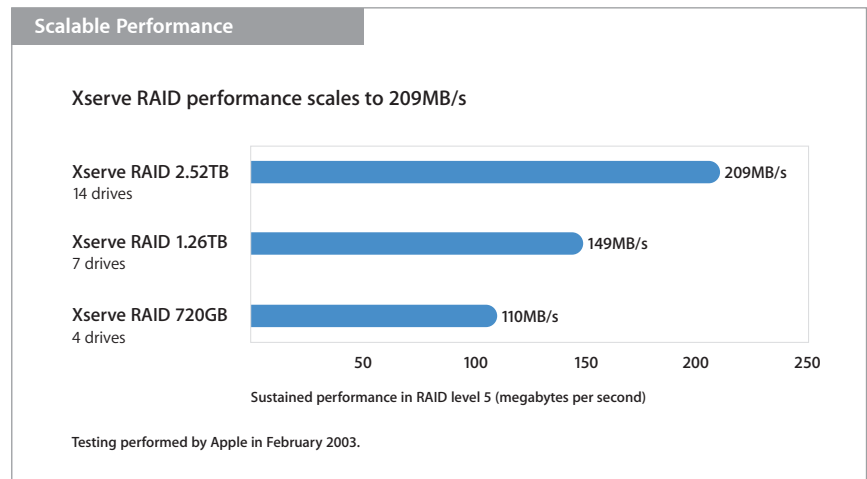
Together, Xserve and Xserve RAID create an ideal solution for sharing terabytes of data among Mac, Windows, and UNIX systems. Offering the compatibility of open standards and the ease of use of Macintosh, Xserve and Xserve RAID present an affordable alternative to traditional Network Attached Storage (NAS) devices. Mac OS X Server Unlimited-Client Edition is preinstalled on Xserve, allowing administrators to deploy comprehensive standards-based Internet services right out of the box. Its easy-to-configure file services use native protocols, including AFP, SMB/CIFS (Samba), and NFS, for seamless integration with existing network infrastructures and computing environments. And with no per-user licensing fees, Xserve with Xserve RAID delivers superior capacity and performance at a much lower price than that of comparably configured NAS appliances.

The hot-plug Apple Drive Modules work with both Xserve and Xserve RAID, providing investment protection as storage needs expand. Customers can start by purchasing a single Xserve with up to four drive modules and software RAID capabilities. As storage capacity and availability requirements grow, they can add an Xserve RAID and repurpose their original Xserve drive modules in a hardware RAID configuration.

Xserve solutions enable businesses and institutions to maximize uptime, minimize maintenance costs, and lower their total cost of ownership. Xserve and Xserve RAID rely on intuitive hardware monitoring and management tools for dramatically streamlined system administration. In addition, customers can purchase the AppleCare Premium Service and Support Plan for both products to ensure integrated support for their critical server and storage deployments.

Performance

With 14 independent drive channels and dual RAID controllers, the Xserve RAID architecture eliminates traditional bottlenecks, maximizing throughput and ensuring fast access to stored data. Support for simultaneous storage processing also allows the performance to scale as capacity increases.



Xserve RAID performance scales up to a phenomenal 209MB/s sustained throughput in RAID 5. Thanks to an advanced storage architecture, Xserve RAID can sustain storage performance at maximum levels across the entire array. The location or quantity of data on the array doesn't appreciably affect throughput, ensuring consistent, fast data delivery.

Value

Xserve RAID offers the lowest cost per gigabyte compared with leading products in the enterprise storage market. At the same time, it packs more gigabytes in less space—up to 2.52TB in a 3U enclosure.

Competitive enterprise storage solutions

Storage solution	Apple Xserve RAID	Dell EMC CX200	HP 7100	IBM ProFibre DF4000R	Sun StorEdge T3
Capacity	2.52TB	2.2TB	2.2TB	2.2TB	2.64TB
Size	3U	3U	Two 3U	Two 3U	Three 3.5U
Price*	\$10,999	\$30,000	\$109,968	\$43,974	\$144,300
Price per GB	\$4.36	\$13.63	\$50.21	\$20.08	\$54.66

* Based on suggested retail prices as published on resellers' websites on February 7, 2003.

Video Storage

With up to 2.5TB of online storage, Xserve RAID makes it easy to manage multiple video tasks. Even when used for editing in uncompressed HD 1080i, this robust storage system can hold nearly five hours of footage. What's more, Xserve RAID scales in both throughput and capacity: Users need only purchase the performance level and capacity they require today, with the assurance that their investment is protected as application and storage needs grow.

Performance

Xserve RAID offers video editors a breakthrough storage system that protects their crucial digital assets while ensuring the performance required to meet tight deadlines. Digital video editing places strenuous demands on storage systems to deliver high-bandwidth uninterrupted data streams. With a video-optimized architecture and dual independent 2Gb Fibre Channel interface, Xserve RAID offers industry-leading throughput for video postproduction—providing enough online bandwidth for working in high-definition (HD) video or supporting multiple streams of uncompressed standard-definition (SD) video with real-time effects.

High-speed storage for video editing

	Xserve RAID configuration		
Usable capacity—RAID 0	720GB	1.26TB	2.52TB
Usable capacity—RAID 5	540GB	1.08TB	2.16TB
	Video data rates supported		
DV	●	●	●
SD	●	●	●
SD dual stream		●	●
HD 24p			●
HD 1080i			●

Preliminary results of testing performed by Apple in February 2003.

Value

Thanks to its groundbreaking price and lowest cost per gigabyte, Xserve RAID is even more attractive to video professionals. With a high level of redundancy and scalable performance and capacity, it's the best value in protected storage for video editors working in nearly all video formats.

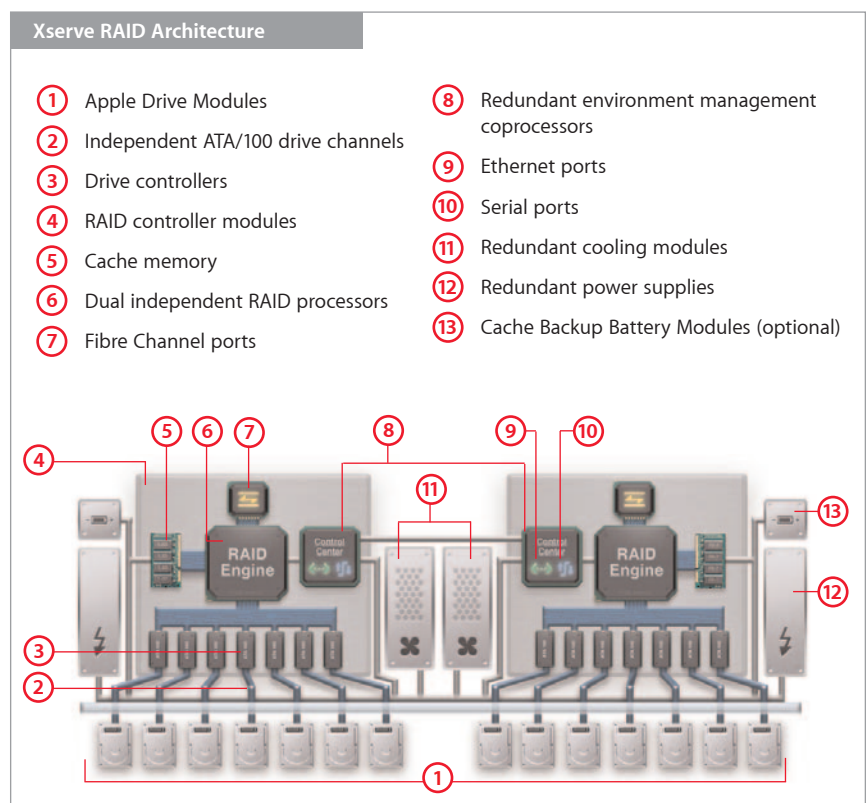
Competitive video storage solutions

Storage solution	Apple Xserve RAID	Rorke Galaxy-i	Medea VideoRAID FCRX	Avid LANshare 1000
Capacity	2.52TB	640GB	960GB	1TB
Size	3U	3U	3U	2U
Price*	\$10,999	\$9555	\$14,099	\$23,995
Price per GB	\$4.36	\$14.93	\$14.69	\$23.99

* Based on suggested retail prices as published on resellers' websites on February 7, 2003.

System Architecture

Fast throughput and data availability are paramount for dedicated storage systems. That's why Xserve RAID combines leading-edge Fibre Channel, RAID, and ATA technologies in an innovative architecture designed for superior performance and reliability. Redundant, hot-swap components and a passive midplane data path protect your digital assets from single points of failure, while independent controllers and 14 drive channels provide high-speed throughput for delivering data quickly to the host system.



Drive Technology and Capacity

Instead of relying on expensive SCSI or Fibre Channel hard drives, Apple developed a high-throughput ATA to Fibre Channel storage architecture that delivers superior performance and reliability at a much lower cost. Xserve RAID achieves its massive 2.5TB capacity with 14 hot-swappable 180GB Apple Drive Modules. The high-capacity 7200-rpm ATA/100 drive modules provide affordable expansion and configuration flexibility as storage needs grow.

Fourteen independent drive channels

The multithreaded Xserve RAID system design provides a dedicated ATA/100 drive channel for each of the 14 drive bays. This maximizes throughput by preventing data bottlenecks. The elimination of interdrive dependencies also enhances availability. Because each hard drive is isolated on its own bus, a drive failure doesn't degrade the accessibility or performance of the surviving drives. In addition, independent drive channels reduce the complexity and cost of high-availability storage, since loop redundancy circuits and signal amplifiers aren't required, as in multidrive Fibre Channel and SCSI implementations.



Xserve RAID uses the same reliable, high-performance Apple Drive Modules as Xserve, Apple's 1U server solution.

Apple Drive Modules

Hot-plug Apple Drive Modules are compatible with both Xserve and Xserve RAID for greater flexibility in storage deployments. These ATA drives feature a unique handle design for fast, easy installation and a positive locking mechanism to hold them tightly in place after insertion. Sophisticated connectors called SCA II, or Single Connector Attachment II, protect the connecting pins from bending when a drive is inserted or removed. Carefully tested and qualified to ensure maximum performance and reliability, Apple Drive Modules work seamlessly with RAID Admin, Apple's innovative remote monitoring software for Xserve RAID.

Drive cache

Each Apple Drive Module is equipped with 8MB of cache memory for boosting throughput in performance-sensitive applications such as video editing. On-drive cache accelerates read and write speeds, but offers less protection in the event of a drive failure. For this reason, drive cache is turned off by default in protected RAID configurations, while video-optimized RAID sets and RAID 0 configurations activate drive cache by default.

The drive controller can access data stored in the drive cache much more quickly than it can read from or write to the actual hard drive platters. Activating drive cache enhances overall system read speeds by allowing the drive controllers to retrieve a block of data before it's required by the host system. The RAID controller provides instructions to each drive in an array, indicating what data block is required next and allowing the individual drive controllers to queue up the data for instant availability.

Similarly, the drive cache serves as a holding tank for data that is being written to the hard drive. When the RAID controller distributes write data to each drive, it can be stored in cache memory, allowing the drive controller to notify the RAID processor immediately that transmission was successful, also known as a "committed write." This frees up the storage pipeline for other needs while the data is being written to the drive platters at maximum speed. Using drive cache is inherently risky: If a drive were to fail during a write operation, the cached data could be lost. The performance needs of video editing and other high-throughput applications outweigh this risk in most situations, but activation of drive cache is not recommended where data protection is a critical requirement.

Hot-swap capabilities

The hardware RAID controllers and Apple-designed drive carrier enable true hot swapping of Xserve RAID drives. A failed drive can actually be removed and replaced without interruption in service or loss of data. The system will continue to operate while the contents of the failed drive are rebuilt on a replacement drive using redundant or parity information. (This feature is not applicable to a RAID 0 configuration, since it doesn't offer data protection.)

Monitoring of drive health

Xserve RAID hardware and remote monitoring software work together to provide industry-leading monitoring and alert capabilities. The RAID controller automatically reads Self-Monitoring, Analysis, and Reporting Technology (SMART) data from each hard drive. SMART data allows the drive to report its health and enables the operating system to warn the administrator of a prefailure condition—providing the opportunity to replace the hard drive before the failure occurs. Each drive module has two LEDs for local monitoring of drive activity and health.

Passive Midplane Data Path

The Xserve RAID architecture is designed to avoid vulnerability to a single point of failure. This means that the failure of any single component can't result in a systemwide failure and loss of data availability. With this in mind, Apple built Xserve RAID around a midplane that features a passive data path for highest reliability. The midplane is the central connector between the drives, RAID controllers, power supplies, and cooling modules. Most RAID systems depend on the midplane to relay data and instruction sets between drives, and a failure in the midplane can impair data availability. In Xserve RAID, all data passes through the independent drive channels, which are simply held in place by the midplane. This design improves system reliability and protects the availability of stored data.

RAID Controllers

Xserve RAID features two controllers that independently manage storage operations for a set of up to seven drives. Dual independent controllers allow for simultaneous storage processing, resulting in outstanding performance that scales as capacity increases. These controller modules offer advanced availability and manageability features, including the environment management coprocessor, which manages RAID functions and monitors status and activity of system components.

RAID Engine

Each Xserve RAID controller has a powerful RAID Engine processor that manages all the data transfers to and from the hard drives and host computer. It performs the complex parity calculations required for RAID levels 3 and 5, generating parity data on the fly while simultaneously managing write operations to each drive in the set. In the event of a drive failure, the RAID Engine uses redundant data to rebuild disk contents onto a spare drive.⁵ Xserve RAID supports RAID levels 0, 1, 3, 5, and 0+1 using the RAID processor, as well as hybrid RAID levels 10, 30, and 50 by combining hardware RAID capabilities with software RAID in Mac OS X.

The RAID Engine uses an innovative process to ensure that RAID sets are error-free and tuned for maximum throughput. When creating a RAID set, it verifies the integrity of the array using a multistep process to check every block on every disk for potential errors. If a bad block is discovered, RAID Engine simply chooses another block that's in close proximity to the original—eliminating unnecessary head movement that can result in lower performance.

To maintain optimal throughput on each RAID set, the RAID Engine uses a special technique that retrieves data on the first revolution of the RAID set. This avoids multiple retries, which can hamper performance on other RAID systems, and also allows Xserve RAID to maintain a nearly constant sustained throughput over the entire platter of a RAID set's hard drives. Outer and inner track performances are nearly identical, providing consistent, fast delivery of data to the host system. This is particularly critical in high-bandwidth applications such as HD video editing, which requires fast storage throughput for clean video capture and smooth playback.

Cache memory

Each RAID controller is equipped with 128MB or 512MB of cache memory. Cache memory in the controller enhances read and write performance, improving overall storage throughput. Streaming data can be queued into the cache to dramatically accelerate read performance. Sophisticated algorithms measure data patterns and usage, dynamically re-allocating read cache to achieve optimal performance.

Write-back cache. For performance-critical applications, the cache memory can be used to accelerate write speeds with a configuration called write-back cache. In this mode, data is considered committed, or successfully received, as soon as the RAID controller writes back to the host that the information has been received in cache memory. However, like on-drive cache, write-back cache affects recoverability in the event of disaster. Cached data is stored in SDRAM, which requires a continuous supply of power. A power outage or major system failure could result in the loss of cached data, since it hasn't yet been written to the hard drive. This risk can be minimized by connecting a UPS system or by using the optional Cache Backup Battery Modules. Battery modules provide a minimum of 72 hours of power to preserve the contents of the cache until system power is restored.

Write-through cache. When write-through cache is enabled, the RAID controller writes data straight through the cache—directly to the disks—before informing the host that the write was committed. Enabling write-through cache does not affect read cache settings. Write-through cache impacts overall throughput to varying degrees, depending on the amount and type of data delivered by the host. The use of write-through cache is not recommended for high-bandwidth applications or when multiple servers are attached to Xserve RAID.

Write-through is the recommended setting for protected RAID without a battery or UPS device. For RAID 0 configurations or applications that require the fastest performance possible, write-back cache is recommended. If a power outage occurs while using write-back cache with a UPS system, Xserve RAID automatically reverts to write-through cache to protect the data in case of a UPS failure.

Environment management coprocessors

Each Xserve RAID controller module contains a specialized coprocessor that monitors the enclosure environment and manages configuration of the main processor's RAID functions. This innovative feature simplifies management and boosts reliability by ensuring continuous feedback on the status and activity levels of system components.

The environment management coprocessor integrates seamlessly with RAID Admin software to provide advanced capabilities such as RAID Now for background initialization during RAID creation. Each coprocessor operates on an independent PCI bus and communicates with the host system via Ethernet. All the management and monitoring processes are handled "out of band," which means Fibre Channel bandwidth is not specified for management chores.

The environment management coprocessors offer redundancy for increased fault tolerance. Each coprocessor communicates with both RAID controllers and all of the hard drives. If one of the RAID environment managers fails, the other takes over and continues the monitoring and managing functions for the system to avoid any interruption in service. Of course, it also immediately notifies the administrator of the component failure.

Because the RAID environment managers connect to the host computer over Ethernet using standard Internet protocols, it's easy to connect to and monitor Xserve RAID systems from any computer on the Internet. (See the "Management and Monitoring Software" section for more information on these solutions.) In addition to an Ethernet port, both RAID environment managers have a serial port for connecting an optional UPS device, providing an extra measure of protection against power surges or electrical outages.



Apple Fibre Channel PCI Card

Xserve RAID connects to an Xserve or Power Mac G4 host system using the dual-port 2Gb Apple Fibre Channel PCI Card (sold separately).

Fibre Channel Interconnect

Xserve RAID features two independent 2Gb Fibre Channel ports for ultrafast data transport between the storage system and the host computer. Previously available only in high-end RAID systems, this industry-standard interconnect technology provides superior bandwidth, availability, and deployment flexibility over SCSI interconnect technology. To ensure interoperability, Xserve RAID uses the latest industry-standard SCSI 3 protocol for data transfer.

400MB/s throughput

Each 2Gb Fibre Channel port offers 200MB/s bandwidth for a total throughput of up to 400MB/s.² Fibre Channel is the only storage connectivity technology that provides guaranteed bandwidth, so the host computer receives data at the same high speed as the RAID system sends it out.

Superior scalability

Unlike with Gigabit Ethernet or SCSI technologies, adding storage units to a Fibre Channel network won't lead to congestive data loss or reduced overall bandwidth. The highly scalable Fibre Channel technology can address up to 126 devices per loop, with each device receiving a full 200MB/s throughput. SCSI technology allows for a maximum of only 15 devices per channel, which means that large SCSI arrays involve added expense and complexity.

Flexible deployment capabilities

The Fibre Channel interface supports multiple topologies and transport protocols, providing flexible deployment options to suit different applications. While SCSI supports only dedicated point-to-point connections, Fibre Channel can be configured using point-to-point, loop, and switched fabric topologies.

Point-to-point. The simplest storage topology, point-to-point employs a direct connection between the disk array and the host computer. With two Fibre Channel ports, Xserve RAID offers point-to-point connectivity for up to two host systems. Each host has independent access to a RAID set of up to seven drives.

Loop. This topology employs a Fibre Channel hub to connect multiple servers and storage devices. The 2Gb/s Fibre Channel bandwidth is shared among all devices connected to the hub, and only two systems can communicate with one another at the same time.

Switched fabric. Similar to an Ethernet infrastructure, this storage topology uses Fibre Channel switches to connect multiple disk arrays and devices. A switched fabric is the most flexible topology, because it allows all the connected servers and storage devices to communicate with one another simultaneously—without sharing bandwidth.

Long-distance connectivity

Xserve RAID connects to a 2Gb Fibre Channel PCI Card in the host computer via a thin, flexible copper or fiber-optic cable. The Fibre Channel interface also provides support for much longer distances between the storage and the host system than is possible over SCSI cables. The Apple Fibre Channel PCI Card accepts optical transceivers allowing it to use fiber-optic cables that can extend 500 meters. This is particularly useful for organizations using Xserve RAID to back up or archive critical data. Long-distance connectivity provides the added protection of physical separation in the event of a major disaster.

High-Availability Design

The modular design and use of redundant components make Xserve RAID ideal for operations where data availability is crucial. Its enclosure is designed for easy serviceability. All active components are field replaceable and most are hot-swappable. LEDs on the front and rear indicate the health of each component: green means OK, yellow indicates warning, and red means fail. In the event of a part failure, the remote monitoring system notifies the administrator, and repairs can be accomplished in seconds—usually without shutting down the system.

Redundant components

The environment management coprocessor monitors the Xserve RAID enclosure and status of system components. If one of the power supplies fails, the other one can simply take over and power the system alone until the failed module is replaced. If the enclosure gets too hot or a cooling module fails, the environment manager dynamically adjusts the speed of the remaining cooling module to maintain optimum system temperature. The coprocessors themselves are redundant: Both monitor the entire enclosure and record status information on all components, enabling automatic adjustments and remote notifications as needed. If a coprocessor fails, the other one can take over monitoring of the system.

Power backup

A single Xserve RAID power supply can sustain the system in the event of a power outage or electrical surge. Each RAID controller has its own DB-9 serial port, allowing Xserve RAID to connect to and monitor up to two UPS sources. When the system detects input power has been switched to a UPS source, it automatically changes the cache mode from high-throughput write-back to safer write-through cache—protecting data transactions should the UPS fail.

If the UPS system is capable of reporting a low power level, Xserve RAID can alert the administrator of the condition, permitting a manual shutdown prior to the power running out. However, shutdown may not be necessary: With optional Cache Backup Battery Modules in Xserve RAID, data transactions in the RAID controller cache are protected for more than 72 hours after an input power failure. Once power is restored, Xserve RAID will write the transactions and begin recharging the batteries. If battery power is low, the system will remain in write-through cache mode until the battery charge is over 50 percent, when it will return to write-back mode.

Hot sparing

Xserve RAID can be configured with a global hot spare on each RAID controller. If a drive fails, the RAID controller can automatically rebuild its data on the spare drive without requiring intervention by the administrator. The rebuild operation occurs in the background while the controller processes normal host reads and writes, so that service continues uninterrupted.⁵ Rebuild rate automatically varies with the amount of traffic, or fabric load, on the RAID controller to promote the best mix of performance and rebuild speed. As soon as the administrator replaces the failed drive, Xserve automatically configures it as a new hot spare for the array.

Easy serviceability

Automatic notifications facilitate quick problem resolution, and hot-swap components make Xserve RAID easy to service. Optional AppleCare Service Parts Kits provide replacement modules for all active components. Power supplies, cooling modules, RAID controller modules, and hard drives can be removed and replaced in seconds without tools. And these components are all hot-swappable, which means they can be replaced without interrupting data availability. Xserve RAID has a scheduled shutdown feature that allows for planned maintenance without running down the cache backup batteries. This feature can also be beneficial if Xserve RAID is stored for long periods of time.

Journaling

Xserve RAID benefits from a robust new file system journaling feature in Mac OS X Server that enhances the availability and fault resilience of servers and server-attached storage devices. Journaling protects the integrity of the Mac OS Extended (HFS+) file system in the event of an unplanned shutdown or power failure. It also helps to maximize the uptime of servers and storage devices by dramatically expediting repairs to the affected volumes when the system restarts.

When journaling is enabled on a storage volume, the server automatically tracks file system operations and maintains a continuous record of these transactions in a separate file, called a journal. The operating system can use the journal to return the file system to a known, consistent state after a failure. This eliminates the need to perform a consistency check on the entire file system during startup—a process that can take hours on a multi-terabyte volume. Instead, when the server is restarted, Mac OS X Server simply replays recent transactions in the journal, bringing the system up to date and resuming operations that were interrupted during the failure. With a journaled file system, server restart takes just seconds—regardless of the number of files or volume size of internal or external storage.

Management and Monitoring Software



The Java-based RAID Admin application makes it easy to set up, manage, and monitor Xserve RAID systems from virtually anywhere on the Internet.

Xserve RAID comes with RAID Admin, powerful remote management software that dramatically simplifies setup and monitoring of multiple Xserve RAID systems. The robust self-monitoring technology maximizes storage availability while minimizing the pressure on system administrators. In the event of a hardware failure, RAID Admin can automatically notify the administrators via email, pagers, or email-capable cell phones—allowing them to stay in touch with storage deployments and resolve issues whether they're on the other side of campus or across the country.

The RAID Admin application works with the environment management coprocessor in each RAID controller to continuously monitor system activity and the status of all key subsystems. The coprocessors connect to the host system via Ethernet, providing dedicated, out-of-band system management capabilities. This ensures optimum system performance and reliability, because administrative and monitoring activities don't hamper the throughput of the RAID processors or the Fibre Channel interface.

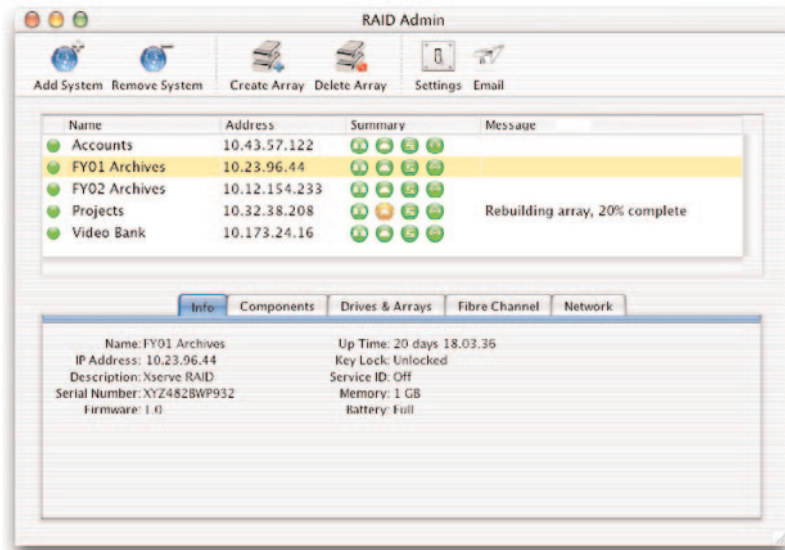
Setting Up and Monitoring Storage

The new RAID Admin is a Java-based application that provides an intuitive interface for creating protected storage volumes, managing preferences, and monitoring storage hardware. Because it works over TCP/IP, you can configure and monitor protected storage from anywhere on the Internet. In addition, it uses robust password authentication to protect your storage systems from unauthorized access.

RAID Admin makes it easy to monitor all Xserve RAID systems on the network. Next to each system name and IP address, icons display in green, yellow, or red to indicate the health of each subsystem, while the tabs below provide detailed information about operating conditions and performance. If operating conditions for any subsystem exceed predefined thresholds, RAID Admin sends email notifications to the administrator for fast problem resolution without downtime or data loss.



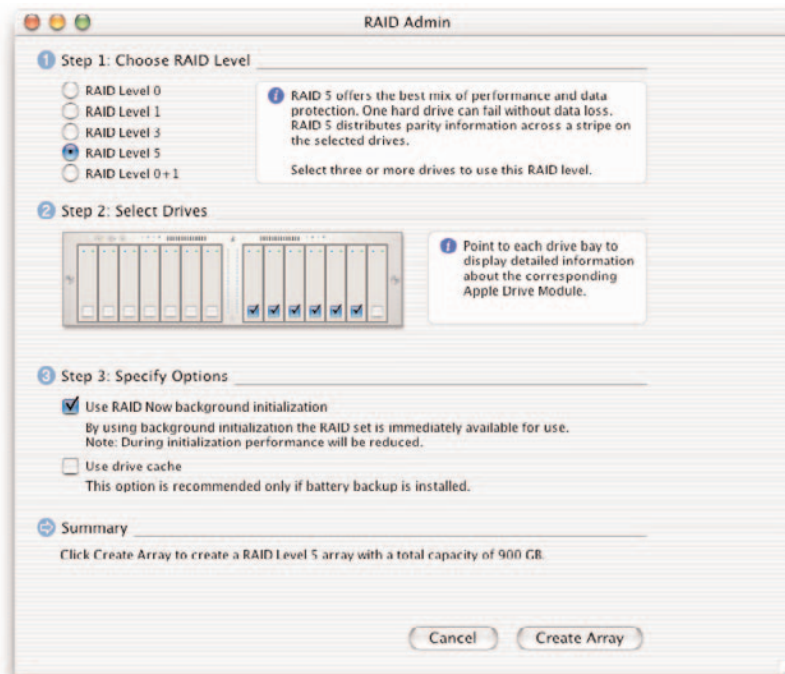
Using Apple's Rendezvous technology, RAID Admin automatically discovers Xserve RAID systems on your network for easy addition to the display.



RAID Admin software displays summary health and activity information for multiple Xserve RAID systems.

Creating RAID Arrays

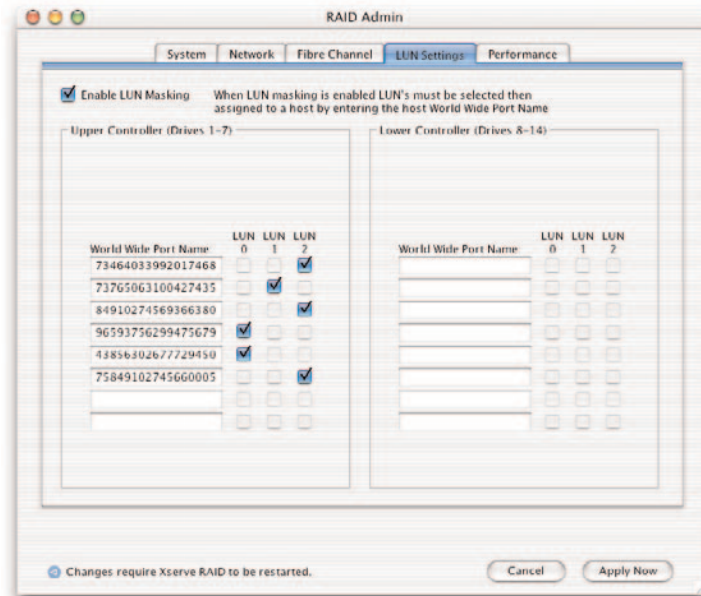
RAID Admin provides an easy-to-use interface for creating RAID sets on the fly. Choose a RAID level and you get information about the benefits and limitations of that level. Next, click the drives you want to assign to the RAID set. RAID Admin even gives you information about each of the drives in your Xserve RAID system, so there's no guesswork. Any remaining drives are automatically assigned as global hot spares for each controller. Last, choose background initialization to make the newly created RAID set available immediately.



RAID Admin lets you create disk arrays in three easy steps.

Advanced Networking Features

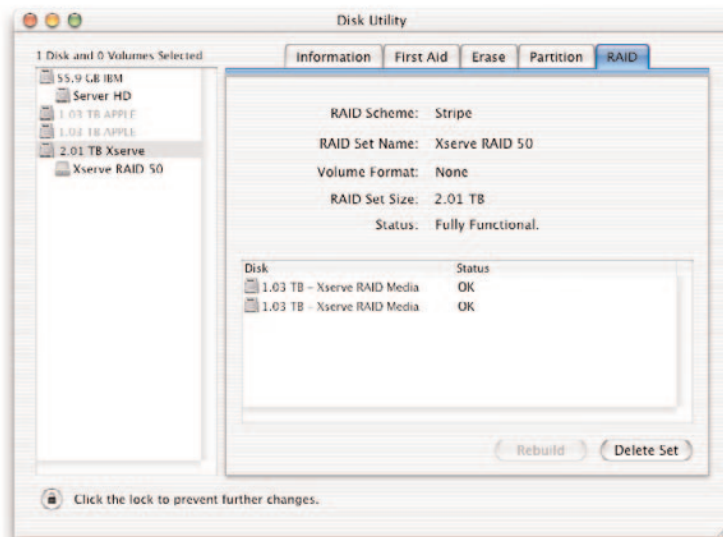
RAID Admin offers advanced Fibre Channel networking features such as LUN mapping, which enables you to make storage volumes accessible to specific host systems while masking them from others on the Fibre Channel network.



An intuitive interface makes it easy to set LUN mapping and Fibre Channel preferences.

Managing Storage Volumes

Administrators can manage storage volumes using Disk Utility from any Mac OS X or Mac OS X Server system. Disk Utility enables you to initialize arrays in Mac OS Extended or UNIX File System formats; turn on file system journaling; and set up software RAID arrays.



Disk Utility makes it easy to use software RAID to create hybrid RAID levels 10, 30, and 50.

Service and Support

Today's businesses and institutions rely on digital assets to keep their operations running smoothly. Downtime is not an option. To ensure rapid issue resolution for critical data storage systems, Apple offers a comprehensive range of service and support products.

AppleCare Premium Service and Support Plan

The same server-class support product that Apple introduced with the new Xserve systems in May 2002 is now available for Xserve RAID. The AppleCare Premium Service and Support Plan provides up to three years of expert telephone and email support and onsite hardware service. Apple technical support experts are available 24 hours a day to help customers determine whether they're experiencing a hardware failure or a RAID configuration issue. In either case, Apple support staff will work to get the storage back online as quickly as possible. And because Xserve RAID hardware and software come from the same company, there's no frustrating fingerpointing. One Apple phone number handles the problem.

The AppleCare Premium Service and Support Plan covers hardware repairs with four-hour onsite response during business hours and next-day onsite response after business hours (terms apply).³ For added peace of mind, Apple-authorized technicians perform repairs using genuine Apple parts.

Training and support resources available on the AppleCare support website can also help keep Xserve RAID systems running smoothly. This easy-to-use website publishes in-depth product information, training on hardware and software installation and configuration, and technical resources, including the AppleCare Knowledge Base, discussions, and downloadable software on Apple's Featured Software site.

Xserve RAID customers can purchase the AppleCare Premium Service and Support Plan at any time while the hardware is still under its original one-year warranty. However, since coverage ends three years after the hardware purchase date, customers will get maximum advantage when they make both purchases at the same time.



The AppleCare Service Parts Kit has an Apple Drive Module, power supply module, cooling module, and RAID controller module.

AppleCare Service Parts Kit

Customers can also purchase AppleCare Service Parts Kits for their Xserve RAID systems. These kits contain a RAID controller module, a cooling module, a power supply module, and a 180GB Apple Drive Module. Xserve RAID is designed for quick and easy swapping of crucial parts; no tools or training certifications are needed. AppleCare Service Parts Kits let system administrators keep key components handy to address the most common hardware failures. When customers combine the AppleCare Premium Service and Support Plan with an AppleCare Service Parts Kit, Apple experts can often help them troubleshoot and fix their system right over the phone—day or night—without having to wait for a technician.

Visit www.apple.com/support/products or call 800-275-2273 (in the United States and Canada) for more information about AppleCare service and support products.

Additional Service and Support Products

Complex applications and network installations may require expert long-term technical support. Apple offers additional support options to keep Xserve and Xserve RAID systems up and running.

Mac OS X Server Software Support. This cost-effective, flexible support product delivers comprehensive phone and email consulting. Apple technical experts help with advanced networking issues, including integrating Mac OS X Server into heterogeneous environments, configuring and managing network services, and developing open source components for Mac OS X Server. Pricing is based on the number of incidents and the level of support required. For more information, visit www.apple.com/support/products or call 800-275-2273 in the United States and Canada.

Apple Professional Services. Designed for medium-size and large organizations looking to integrate Xserve, Xserve RAID, and Mac OS X Server with other enterprise systems—such as Windows, UNIX, and LDAP—Apple Professional Services offers customized consulting beyond the scope of traditional technical support. Services include project planning, platform migration, and development of custom applications.

Mac OS X Server Training and Certification. Apple also offers comprehensive training and certification programs for system administrators and developers using Mac OS X Server. These classes offer the fastest and most cost-effective path to understanding Mac OS X and Mac OS X Server in depth. Training classes are taught in Apple Authorized Training Centers or onsite at customer locations by a team of veteran instructors with real-world experience. These programs are a great way to develop technical skills and also to market those skills to IT management. Certification testing centers are available in most major U.S. metropolitan areas.

For more information about Apple Professional Services or Mac OS X Server Training and Certification, visit www.apple.com/services.

Technical Specifications

Storage

- Fourteen internal drive bays on independent 100MB/s channels for up to 2.5TB of internal storage¹
- Four, seven, or fourteen 180GB 7200-rpm ATA/100 Apple Drive Modules with 8MB disk cache (standard configurations); empty drive bays contain blank modules
- Support for reading SMART data from Apple Drive Modules for prefailure notification

RAID controllers and cache memory

- Dual independent controllers, each with environment management coprocessor for out-of-band remote management and monitoring
- 128MB of cache per controller (256MB total); support for up to 512MB per controller (1GB total)
- Cache Backup Battery Modules (sold separately) for over 72 hours of memory protection

RAID operation

- Support for RAID levels 0, 1, 3, 5, 0+1, 10, 30, 50 (10, 30, and 50 require host-based software RAID)
- Support for multiple RAID sets, multiple hosts, and LUN masking
- Background RAID set creation; automatic variable background rebuilding;⁵ global drive hot sparing (per RAID controller)

Fibre Channel storage-to-host connection

- Dual 2Gb Fibre Channel ports (HSSDC2), 200MB/s throughput per channel with guaranteed bandwidth (400MB/s full duplex)²
- Host connectivity using 2Gb Apple Fibre Channel PCI Card (sold separately) or compatible third-party PCI card
- Support for point-to-point, loop, and switched fabric topologies
- Dual 10/100BASE-T Ethernet for remote management

Apple Fibre Channel PCI Card (sold separately)

- 64-bit, 66MHz card with two SFP 2Gb Fibre Channel ports; compatible with 32-bit, 66MHz slots
- Two 2.9-meter Fibre Channel copper cables (SFP transceiver to HSSDC2); compatible with SFP fiber-optic cables and transceivers

Cooling

- Redundant hot-swap cooling modules with self-regulating speeds and front-to-back cooling
- Environmental monitoring system for automatically maintaining optimal ambient temperature

Electrical requirements

- Redundant load-sharing hot-swap power supplies (450W); universal input (90V to 264V AC), power factor corrected
- Maximum input current: 7.1A (90V to 132V) or 3.5A (180V to 264V)
- Power usage: 300W typical continuous power, 400W maximum continuous power
- Dual DB-9 serial ports for UPS systems
- Frequency: 47Hz to 63Hz, single phase

Environmental requirements

- Operating temperature: 50° to 95° F (10° to 35° C)
- Storage temperature: -40° to 116° F (-40° to 47° C)
- Relative humidity: 5% to 95% noncondensing
- Maximum thermal output: 1365 BTUs per hour
- Maximum altitude: 10,000 feet
- FCC Class A approved

Size and weight

- Height: 5.25 inches (13.3 cm)
- Width: 17 inches (43.2 cm)
- Depth: 18.4 inches (46.7 cm)
- Fits EIA-310-D-compliant, industry-standard 19-inch-wide four-post racks from 24 to 36 inches deep; deeper racks require third-party extender
- 60 to 110 pounds (27 to 45 kg), depending on configuration

Purchasing Information

The following standard Xserve RAID configurations are available. You can also order custom-configured systems with additional Apple Drive Modules and more cache memory.

Order number	M8668LL/A	M8669LL/A	M8670LL/A
Total available storage ¹ —RAID 0	720GB	1.26TB	2.52TB
Usable storage ¹ —RAID 1	360GB	540GB	1.08TB
Usable storage ¹ —RAID 3 and 5	540GB	1.08TB	2.16TB
ATA/100 Apple Drive Modules (7200 rpm)	Four 180GB drives	Seven 180GB drives	Fourteen 180GB drives
On-drive cache	8MB per drive	8MB per drive	8MB per drive
Expansion	Fourteen drive bays with independent 100MB/s ATA channels for up to 2.5TB of storage		
Also included	Mounting screws with M5, M6, and 10/32-inch threads; caged nuts; two agency-approved 12-foot power cables		
Service and support	90 days of free telephone support and one-year limited warranty; optional extended service and support products		
System requirements	Xserve or Power Mac G4 (800MHz or faster) with Mac OS X v10.2.4 or Mac OS X Server v10.2.4 (or later) and compatible Fibre Channel PCI card		

Other Products

These products are available to enhance your Xserve RAID system.

- Apple Fibre Channel PCI Card, order number M8940G/A
- Xserve (single-processor server), order number M8888LL/A
- Xserve (dual processor server), order number M8889LL/A
- 180GB Apple Drive Module, order number M8939G/A
- Cache Backup Battery Modules (2), order number M8941G/A
- AppleCare Premium Service and Support Plan, order number M8927LL/A
- AppleCare Service Parts Kit, order number M8929G/A

Service and Support Details

Xserve RAID includes 90 days of free telephone support and a one-year limited warranty. In addition, Apple offers world-class support options for your Xserve server and storage systems. For more information on service and support options, visit www.apple.com/support/products or call 800-275-2273 in the United States or Canada.

- **AppleCare Premium Service and Support Plan.** Covers hardware repairs with four-hour onsite response during business hours and next-day onsite response after business hours (terms apply). Up-and-running support and basic troubleshooting are also available by phone or email 24 hours a day.³
- **AppleCare Service Parts Kit.** Provides crucial Xserve RAID parts—a RAID controller module, power supply module, cooling module, and 180GB Apple Drive Module—for rapid onsite replacement and resolution of the most common hardware failures.
- **Mac OS X Server Software Support.** Provides consultative phone and email support for advanced Mac OS X Server integration and migration issues.
- **Apple Professional Services.** Offers comprehensive consulting for enterprise-oriented deployments. Services include installation and integration, planning and migration, application development, and project consulting. See www.apple.com/services or call 800-848-6398 in the United States or Canada.

For More Information

For more information about Xserve technologies, including Xserve, Xserve RAID, and Mac OS X Server, visit www.apple.com/xserve.

¹For hard drive capacity measurements, 1GB = 1 billion bytes and 1TB = 1 trillion bytes; actual formatted capacity less. Maximum capacity of 2.5TB achieved through use of fourteen 180GB Apple Drive Modules. Usable capacity depends on drive configuration and RAID level. ²Actual rates will vary depending on drive configuration and RAID level. ³A separate AppleCare Premium Service and Support Plan must be purchased for each Xserve RAID system to be covered. To qualify, systems must be within the one-year hardware warranty. Coverage ends three years after date of Xserve RAID purchase. Actual onsite response time and availability of onsite service depend on location; see www.apple.com/support/products/premium for details. Local telephone fees may apply; telephone numbers may vary and are subject to change. ⁴Host operating system limitations apply. ⁵Automatic rebuild requires a designated hot spare; not available for RAID level 0.