RAID Technology White Paper

As specialists in data storage, LaCie recognizes that almost all computer users will need a storage or backup solution and that people use and store data in different ways. Depending on their requirements, some people may prioritize performance and capacity, whereas others may be more interested in security and speed. In order to meet the storage needs of a wide range of users, LaCie's professional storage devices utilize RAID technology.

RAID (**Redundant Array of Independents Disks**) is a simple technology that improves the performance of external storage solutions. RAID allows you to choose the best way to use your device to fit your needs. Simply put, RAID technology either divides or duplicates the task of one hard disk between many (or as few as two) disks to improve performance, create data redundancy in case of a drive failure, or both.

This document describes the different RAID levels used in LaCie professional storage devices, and the characteristics used by each mode to optimize the speed, security or storage capacity of the hard drives in the RAID array.

Important:

No RAID configuration will protect data reliability from software or file system corruption. As a result, LaCie recommends that regular backups should always be performed to protect data.

RAID Terms

To better understand how RAID works, first familiarize yourself with the terms below:

- ✦ **Striping** is the splitting of data between multiple drives. Striped RAID arrays generally aim to merge maximum capacity into one single volume.

- ✦ **Mirroring** is the copying of data to more than one disk. Mirrored RAID arrays typically allow the failure of at least one disk in the array without any data loss, depending on the RAID level of the array.

- ✦ **Fault Tolerance** allows a RAID array to continue working (i.e. the data stored in the array is still available to the user) in the event of a disk failure. Not all mirrored RAID arrays are user friendly. For instance, some RAID devices must be shut down before a failed disk is replaced, whereas LaCie RAID devices feature "hot-swappaple" disk replacement that allows the device to remain on, and the data accessible, while the failed disk is replaced.

STANDARD RAID LEVELS

RAID 0

RAID 0 (also called FAST mode in some LaCie devices), is the fastest RAID mode. Requiring at least 2 drives, RAID 0 stripes data onto each disk. The available capacities of each disk are added together so that one logical volume mounts on the computer.

If one physical disk in the array fails, the data of all disks becomes inaccessible because parts of the data have been written to all disks.

Applications

RAID 0 is ideal for users who need maximum speed and capacity. Video editors working with very large files may use RAID 0 when editing multiple streams of video for optimal playback performance. A RAID 0 array is more suited for actively working with files (editing video, for example) and should not be used as a single storage backup solution or on mission-critical systems.

LaCie Products with RAID 0

- ✦ LaCie Rugged RAID
- ✦ LaCie 2big quadra USB 3.0
- ✦ LaCie 2big Thunderbolt™ 2
- ✦ LaCie 2big Dock Thunderbolt 3
- ✦ LaCie 5big Thunderbolt 2
- ✦ LaCie 6big Thunderbolt 3
- ✦ LaCie 8big Rack Thunderbolt 3
- ✦ LaCie 12big Thunderbolt 3

How RAID 0 Capacity Is Calculated

Each disk in a RAID 0 system should have the same capacity.

Storage capacity in a RAID level 0 configuration is calculated by multiplying the number of drives by the disk capacity, or $C = n*d$, where:
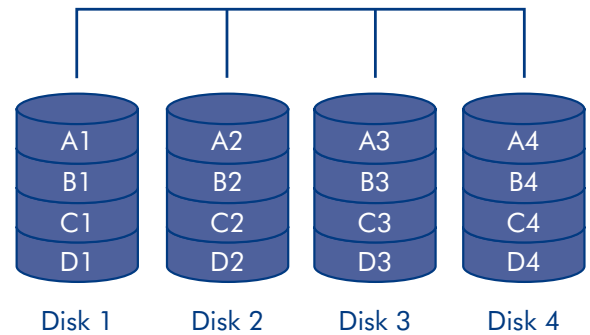
C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 0 array with four drives each with a capacity of 1000GB, the total capacity of the array would be 4000GB:

$C = (4*1000)$

RAID 0

Disk 1   Disk 2   Disk 3   Disk 4

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

RAID 1

RAID 1 (also called SAFE mode in some LaCie devices) is a secure RAID mode that requires at least 2 drives and works with pairs of drives. One logical volume mounts on the computer and the combined available capacity of both drives is limited to the capacity of the lowest-capacity disk. If one physical disk fails, the data is available immediately on the second disk. No data is lost if one disk fails.

Applications

RAID 1 provides maximum data safety in the event of a single disk failure, but because data is written twice, performance is reduced slightly when writing. RAID 1 is a good choice when safety is more important than speed.

LaCie Products with RAID 1

- ✦ LaCie Rugged RAID
- ✦ LaCie 2big quadra USB 3.0
- ✦ LaCie 2big Thunderbolt™ 2
- ✦ LaCie 2big Dock Thunderbolt 3
- ✦ LaCie 5big Thunderbolt 2
- ✦ LaCie 6big Thunderbolt 3
- ✦ LaCie 8big Rack Thunderbolt 3
- ✦ LaCie 12big Thunderbolt 3

How RAID 1 Capacity Is Calculated

Each disk in a RAID 1 system should have the same capacity.

Storage capacity in a RAID level 1 configuration is calculated by multiplying the number of drives by the disk capacity and dividing by 2, or

$C = n*d/2$

where:
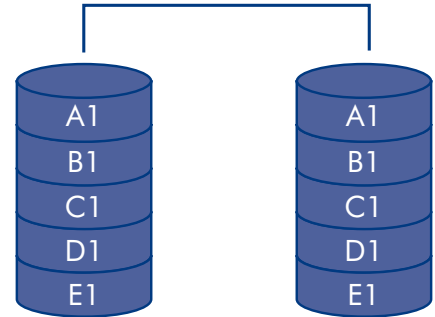
C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 1 array with two drives each with a capacity of 1000GB, the total capacity of the array would be 1000GB:

$C = (2*1000)/2$

RAID 1

A1	A1
B1	B1
C1	C1
D1	D1
E1	E1

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

RAID 3

RAID 3 uses byte-level striping with a dedicated parity disk (Disk 4 in the illustrations, right) so that one volume mounts on the computer. A RAID 3 array can tolerate a single disk failure without data loss. If one physical disk fails, the data from the failed disk can be rebuilt onto a replacement disk. If a second disk fails before data can be rebuilt to a replacement drive, all data in the array will be lost.

Applications

RAID 3 provides good data safety for environments where long, sequential files are being read, such as video files. Disk failure does not result in a service interruption because data is read from parity blocks. RAID 3 is useful for people who need performance and constant access to their data, like video editors. RAID 3 is not recommended for intensive use with nonsequential files because random read performance is hampered by the dedicated parity disk.

RAID 3

Disk 1	Disk 2	Disk 3	Disk 4
A1	A2	A3	Ap(1-3)
A4	A5	A6	Ap(4-6)
B1	B2	B3	Bp(1-3)
B4	B5	B6	Bp(4-6)
C1	C2	C3	Cp(1-3)
C4	C5	C6	Cp(4-6)

LaCie Products with RAID 3

✦ Currently, no LaCie products

How RAID 3 Capacity Is Calculated

Each disk in a RAID 3 system should have the same capacity.

Storage capacity in a RAID level 3 configuration is calculated by subtracting the number of drives by one and multiplying by the disk capacity, or
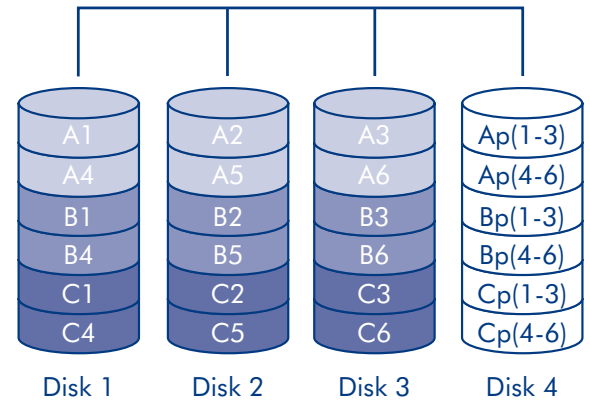
$C = (n-1)*d$

where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 3 array with four drives each with a capacity of 1000GB, the total capacity of the array would be 3000GB:

$C = (4-1)*1000$

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

RAID 3+Spare

In RAID 3+Spare, one disk in the array is left empty. If a drive in the array fails, the data from the failed disk is automatically rebuilt to the empty or "spare" disk.

Applications

In RAID 3+Spare disk failure does not require immediate attention because the system rebuilds itself using the hot spare, but the failed disk should be replaced as soon as possible.

LaCie Products with RAID 3+Spare

✦ Currently, no LaCie products

How RAID 3+Spare Capacity Is Calculated

Each disk in a RAID 3+Spare system should have the same capacity.

Storage capacity in a RAID 3+Spare configuration is calculated by subtracting the number of drives by two and multiplying by the disk capacity, or
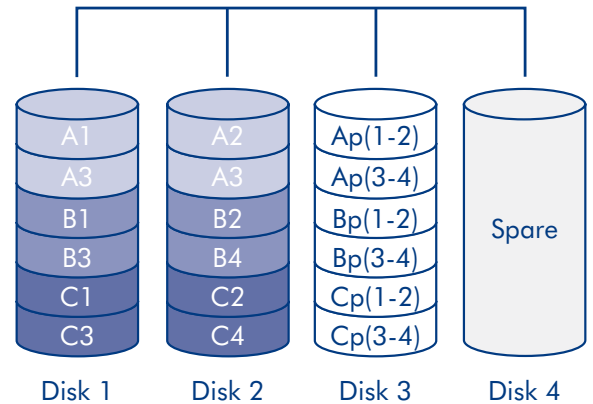
$C = (n-2)*d$

where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 3+Spare array with four drives each with a capacity of 1000GB, the total capacity of the array would be 2000GB:

$C = (4-2)*1000$

RAID 3+Spare

Disk 1	Disk 2	Disk 3	Disk 4
A1	A2	Ap(1-2)	
A3	A3	Ap(3-4)	
B1	B2	Bp(1-2)	Spare
B3	B4	Bp(3-4)	
C1	C2	Cp(1-2)	
C3	C4	Cp(3-4)	

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

RAID 5

RAID 5 combines the striping of RAID 0 with data redundancy in an array with a minimum of three disks.

The difference between RAID 3 and RAID 5 is that a RAID 3 configuration will offer better performance at the expense of slightly less overall capacity. Data is striped across all disks and a parity block (P) for each data block is written on the same stripe. If one physical disk fails, the data from the failed disk can be rebuilt onto a replacement disk. No data is lost in the case of a single disk failure, but if a second disk fails before data can be rebuilt to a replacement drive, all data in the array will be lost.

Applications

RAID 5 combines data safety with efficient use of disk space. Disk failure does not result in a service interruption because data is read from parity blocks. RAID 5 is useful for archiving and for people who need performance and constant access to their data, like video editors.

LaCie Products with RAID 5

✦ LaCie 5big Thunderbolt 2

✦ LaCie 6big Thunderbolt 3

✦ LaCie 8big Rack Thunderbolt 2

✦ LaCie 12big Thunderbolt 3

How RAID 5 Capacity Is Calculated

Each disk in a RAID 5 system should have the same capacity.

Storage capacity in a RAID level 5 configuration is calculated by subtracting the number of drives by one and multiplying by the disk capacity, or

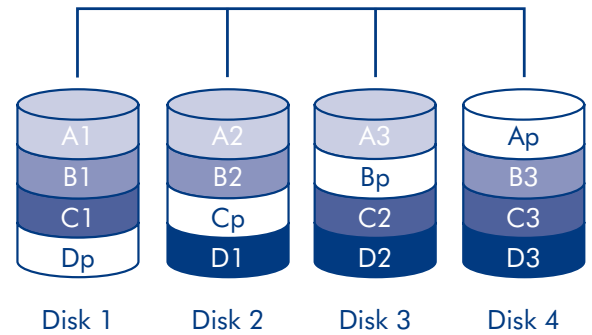$C = (n-1)*d$

where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 5 array with four drives each with a capacity of 1000GB, the total capacity of the array would be 3000GB:

$C = (4-1)*1000$

RAID 5

Disk 1   Disk 2   Disk 3   Disk 4

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

RAID 5+Spare

RAID 5+Spare, is a RAID 5 array in which one disk is used as a spare to rebuild the system as soon as a disk fails. At least four disks are required.

If one physical disk fails, the data remains available because it is read from the parity blocks. Data from a failed disk is rebuilt onto the hot spare disk. When a failed disk is replaced, the replacement becomes the new hot spare. No data is lost in the case of a single disk failure, but if a second disk fails before the system can rebuild data to the hot spare, all data in the array will be lost.

Applications

The main advantage of RAID 5+Spare is that users can continue to access data even while the data is rebuilt to the spare drive. RAID 5+Spare has good data safety but disk space is limited by the presence of the hot spare which is not used until one of the other disks fails. Disk failure does not require immediate attention because the system rebuilds itself using the hot spare, but the failed disk should be replaced as soon as possible.

LaCie Products with RAID 5+Spare

✦ LaCie 5big Thunderbolt 2

✦ LaCie 8big Rack Thunderbolt 2

How RAID 5+Spare Capacity Is Calculated

Each disk in a RAID 5+Spare system should have the same capacity.

Storage capacity in a RAID 5+Spare configuration is calculated by subtracting the number of drives by two and multiplying by the disk capacity, or

$C = (n-2)*d$
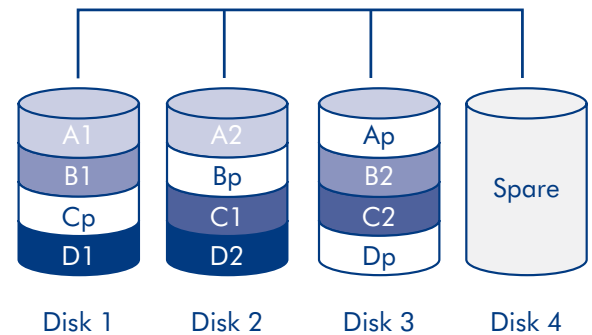
where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 5+Spare array with four drives each with a capacity of 1000GB, the total capacity of the array would be 2000GB:

$C = (4-2)*1000$

RAID 5+Spare

Disk 1   Disk 2   Disk 3   Disk 4

RAID 6

In RAID 6, data is striped across all disks (minimum of four) and two parity blocks for each data block (p and q in the diagram at right) are written on the same stripe. If one physical disk fails, the data from the failed disk can be rebuilt onto a replacement disk. This Raid mode can support up to two disk failures with no data loss. RAID 6 provides for faster rebuilding of data from a failed disk.

Applications

RAID 6 provides data reliability with the addition of efficient rebuilding in the case of a failed drive. RAID 6 is therefore useful for people who need serious security with less of an emphasis on performance.

LaCie Products with RAID 6

✦ LaCie 5big Thunderbolt 2

✦ LaCie 6big Thunderbolt 3

✦ LaCie 8big Rack Thunderbolt 2

✦ LaCie 12big Thunderbolt 3

RAID 6

Disk 1	Disk 2	Disk 3	Disk 4	Disk 5
A1	A2	A3	Ap	Aq
B1	B2	Bp	Bq	B3
C1	Cp	Cq	C3	C3
Dp	Dq	D2	D3	D3

How RAID 6 Capacity Is Calculated

Each disk in a RAID 6 system should have the same capacity.

Storage capacity in a RAID 6 configuration is calculated by subtracting the number of drives by two and multiplying by the disk capacity, or

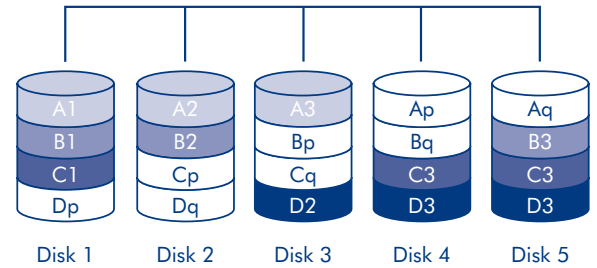$C = (n-2)*d$

where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 6 array with five drives each with a capacity of 1000GB, the total capacity of the array would be 3000GB:

$C = (5-2)*1000$

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

NESTED RAID LEVELS

RAID 0+1

RAID 0+1 is a secure RAID mode that is composed of a mirror of striped sets. RAID 0+1 arrays should have disks in multiples of four. For LaCie products with five disks, in a RAID 0+1 array, the fifth disk will either be a spare or will be unused. In the diagram, at right, array B is a mirror of array A.

Up to two disks can fail in a RAID 0+1 array without loss of data, as long as the failed disks are not part of different RAID 0 pairs. In reference to the diagram, disk 1 and disk 2 could fail and the data would be preserved on disks 3 and 4.

Applications

RAID 0+1 provides good speeds because of RAID 0 striping, but cuts the available capacity of a device in half (assume all disks in the array have the same capacity).

LaCie Products with RAID 0+1

✦ Currently, no LaCie products

How RAID 0+1 Capacity Is Calculated

Each disk in a RAID 0+1 system should have the same capacity.

Storage capacity in a RAID 0+1 configuration is calculated by multiplying the number of drives by the disk capacity and dividing by 2, or
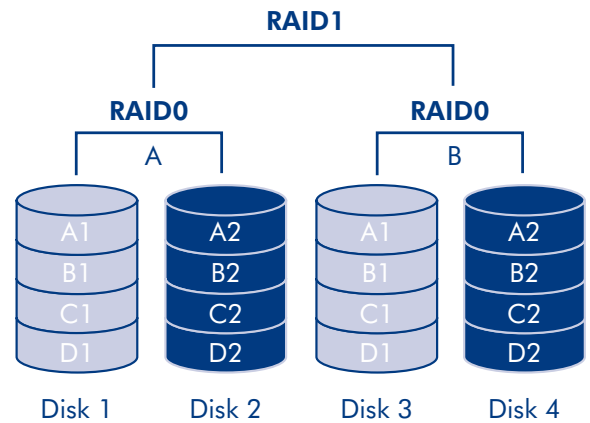
$C = n*d/2$

where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 0+1 array with four drives each with a capacity of 1000GB, the total capacity of the array would be 2000GB:

$C = (4*1000)/2$

RAID 0+1

RAID1

RAID0   RAID0

A   B

Disk 1	Disk 2	Disk 3	Disk 4
A1	A2	A1	A2
B1	B2	B1	B2
C1	C2	C1	C2
D1	D2	D1	D2

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

RAID 10

RAID 10 (also called RAID 1+0) is another RAID level that combines the attributes of other levels, specifically RAID 1 and RAID 0. It is a "stripe of mirrored sets," meaning that data is striped across two mirrored arrays. The striping occurs between arrays and the mirroring occurs within the same array, which makes the rebuilding very fast. RAID 10 arrays should have disks in multiples of four. For LaCie products with five disks, in a RAID 10 array, the fifth disk will either be a spare or will be unused. See the diagram at right.

In a RAID 10 array, one disk from each mirrored pair can fail with no data loss. However, the working disk in an array with a failed disk becomes a weak point for the entire array. If the second disk in a mirrored pair fails, the entire array is lost.

Applications

RAID 10 provides good speeds because of RAID 0 striping, but cuts the available capacity of a device in half (assuming all disks in the array have the same capacity).

LaCie Products with RAID 10

✦ LaCie 5big Thunderbolt 2

✦ LaCie 6big Thunderbolt 3

✦ LaCie 8big Rack Thunderbolt 2

✦ LaCie 12big Thunderbolt 3

How RAID 10 Capacity Is Calculated

Each disk in a RAID 10 system should have the same capacity.

Storage capacity in a RAID 10 configuration is calculated by multiplying the number of drives by the disk capacity and dividing by 2, or

$C = n*d/2$

where:
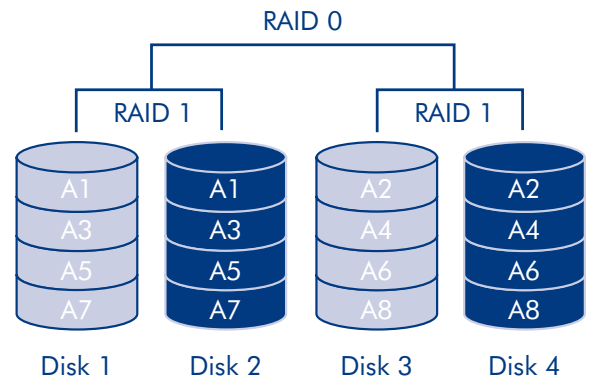
C = available capacity

n = number of disks

d = disk capacity

For example, in a RAID 10 array with four drives each with a capacity of 1000GB, the total capacity of the array would be 2000GB:

$C = (4*1000)/2$

RAID 10

RAID 0

RAID 1 — RAID 1

Disk 1	Disk 2	Disk 3	Disk 4
A1	A1	A2	A2
A3	A3	A4	A4
A5	A5	A6	A6
A7	A7	A8	A8

RAID 50

RAID 50 combines both RAID 5 and RAID 0 features. Data is striped across disks as in RAID 0, and it uses distributed parity as in RAID 5. RAID 50 provides data reliability, good overall performance and supports larger volume sizes. RAID 50 also provides high reliability because data is still available even if multiple disk drives fail (one in each axle). The greater the number of axles is, the greater the number of disk drives that can fail without the RAID 50 array going offline. RAID 50 arrays consist of six or more physical drives.

Applications

RAID 50 improves upon the performance of RAID 5 particularly during writes, and provides better fault tolerance than a single RAID level does. This RAID level is recommended for applications that require high fault tolerance, capacity, and random access performance.

LaCie Products with RAID 50

✦ LaCie 6big Thunderbolt 3

✦ LaCie 12big Thunderbolt 3

RAID 50
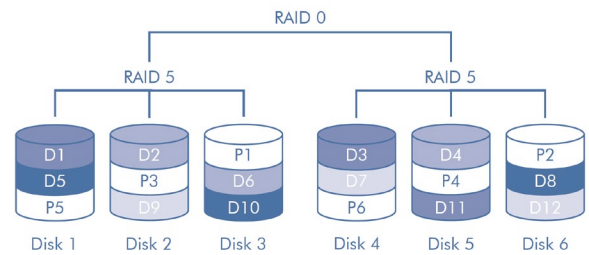
How RAID 50 Capacity Is Calculated

When you create a RAID 50, you must specify the number of axels. An axle refers to a single RAID 5 array that is striped with other RAID 5 arrays to make RAID 50. An axle can have three or more physical drives, depending on the number of physical drives in the array.

Storage capacity in a RAID 50 configuration is calculated by multiplying the number of RAID 5 arrays (axles) capacity, or

$C = ((n/a)-1)*d*a$

where:

C = available capacity

n = number of disks

d = disk capacity

a = number of RAID 5 arrays

For example, in a RAID 50 array with six drives each with a capacity of 1000GB, the total capacity of the array would be 4000GB:

$C = ((6/2)-1)*1000*2$

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

RAID 60

RAID 60 combines both RAID 6 and RAID 0 features. Data is striped across disks as in RAID 0, and it uses distributed parity as in RAID 6. RAID 60 provides data reliability, good overall performance, and supports larger volume sizes. RAID 60 also provides high reliability because data is still available even if multiple disk drives fail (two in each axle). The greater the number of axles is, the greater the number of disk drives that can fail without the RAID 60 array going offline. RAID 60 arrays consist of eight or more physical drives.

Applications

Two sets of parity data provide enhanced data protection, and striping improves performance. RAID 60 arrays also provide high data transfer speeds. Although high in cost and complexity, performance and efficiency and fault tolerance are superior to RAID 6.

LaCie Products with RAID 60

✦ LaCie 12big Thunderbolt 3

RAID 60
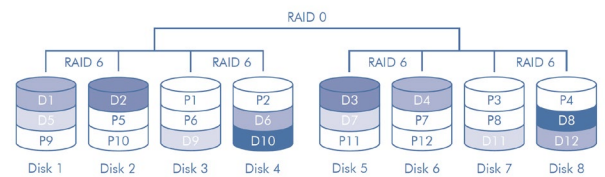
How RAID 60 Capacity Is Calculated

When you create a RAID 60, you must specify the number of axels. An axle refers to a single RAID 6 array that is striped with other RAID 6 arrays to make RAID 60. An axle can have four or more physical drives, depending on the number of physical drives in the array.

Storage capacity in a RAID 60 configuration is calculated by multiplying the number of RAID 6 arrays (axles) capacity, or

$C = ((n/a)-2)*d*a$

where:

C = available capacity

n = number of disks

d = disk capacity

a = number of RAID 6 arrays

For example, in a RAID 60 array with eight drives each with a capacity of 1000GB, the total capacity of the array would be 4000GB:

$C = ((8/2)-2)*1000*2$

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

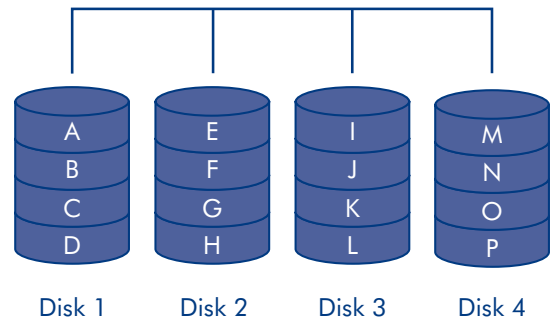# OTHER CONFIGURATIONS

Concatenation

When disks are concatenated, their capacities are combined and data is written to the primary disk in the array until it is full and then to successive disks. Concatenation provides no performance advantage or added measure of data safety. It is simply a method of combining two physical disks into one volume for greater overall capacity.

Concatenation allows full use of the capacity of all disks in the array and most data can survive a disk failure. Only data on the failed disk and data that is partially written on the failed disk and an operative disk is lost.

LaCie Products with Concatenation Mode

✦ LaCie 2big quadra

Concatenation

A	E	I	M
B	F	J	N
C	G	K	O
D	H	L	P
Disk 1	Disk 2	Disk 3	Disk 4

How Concatenation Capacity Is Calculated

Storage capacity in a concatenation configuration is calculated by multiplying the number of drives by the disk capacity, or $C = n*d$

where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a concatenation array with four drives each with a capacity of 1000GB, the total capacity of the array would be 4000GB:

$C = (4*1000)$

JBOD

JBOD stands for Just a Bunch of Disks. Each disk in the array, whether part of separate devices or the same device, mounts on the computer as a separate disk.

LaCie Products with JBOD Mode

- ✦ LaCie 2big Thunderbolt 2
- ✦ LaCie 2big Thunderbolt 2
- ✦ LaCie 2big Dock Thunderbolt 3
- ✦ LaCie 5big Thunderbolt 2
- ✦ LaCie 6big Thunderbolt 3
- ✦ LaCie 8big Rack Thunderbolt 2
- ✦ LaCie 12big Thunderbolt 3

JBOD

Disk 1   Disk 2   Disk 3   Disk 4
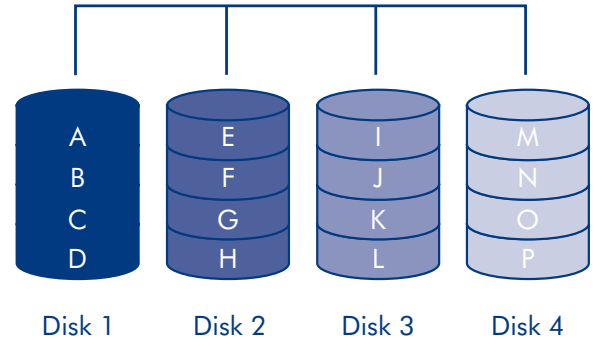
How JBOD Capacity Is Calculated

The total capacity of a JBOD array is the sum of the capacities of each of its disks, or

C = n*d

where:

C = available capacity

n = number of disks

d = disk capacity

For example, in a JBOD array with four drives each with a capacity of 1000GB, the total capacity of the array would be 4000GB:

C = (4*1000)

RAID 0

RAID 1

RAID 3

RAID 3+Spare

RAID 5

RAID 5+Spare

RAID 6

RAID 0+1

RAID 10

RAID 50

RAID 60

Concatenation

JBOD

RAID Selection

LaCie RAID Technology White Paper

RAID	LaCie Rugged RAID	LaCie 2big quadra	LaCie 2big Thunderbolt 2	LaCie 5big Thunderbolt 2	LaCie 6big Thunderbolt 3	LaCie 8big Rack Thunderbolt 2	LaCie 12big Thunderbolt 3
RAID 0	✓	✓	✓	✓	✓	✓	✓
RAID 1	✓	✓	✓	✓	✓	✓	✓
RAID 3							
RAID 3+Spare							
RAID 5				✓	✓	✓	✓
RAID 5+Spare				✓	✓	✓	✓
RAID 6				✓	✓	✓	✓
RAID 0+1							
RAID 10				✓	✓	✓	✓
RAID 50						✓	✓
RAID 60							
Concatenation	H	H		✓			✓
JBOD	✓	✓		✓	✓	✓	✓

ABOUT LACIE

Through a combination of cutting-edge engineering and a rich history of unique design aesthetics, LaCie has earned an excellent reputation for producing products that are the perfect synthesis of form and function. Our hard disks, network and RAID solutions, optical drives, displays, and accessories are created to enhance and expand your computing environment, no matter its platform or configuration.

Featuring the exclusive styles of world-renowned designers such as Neil Poulton, Ora-Ïto, Karim Rashid, and Sam Hecht, LaCie's award-winning products look stunning and perform with unparalleled reliability and versatility. LaCie is a global leader in manufacturing top-of-the-line tools that are often first to market, constantly raising the bar and reestablishing industry standards.

Please visit our website: www.lacie.com, for up-to-date product specifications—available in multiple languages for worldwide accessibility. Use it to purchase items online, contact our excellent technical support or locate the sales office or reseller nearest you.

LaCie

www.lacie.com