

RAID-Systems

Everything you need to know.

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DER FORSCHUNG | DER LEHRE | DER BILDUNG

Table of contents

- 1 What is a RAID?
- 2 Requirements
- 3 Concepts of RAIDs
- 4 RAID Level
- 5 Hard- & Software-RAID
- 6 Usage

What is a RAID?

- **Redundant Array of Independent Disks**
 - ▶ Several connected hard drives
 - ▶ Building a logical unit
 - ▶ More functions and features
- Prevent data lost or to improve performance
- Reliability, availability, capacity

Requirements

- Several Hard drives (at least two; depending on RAID-Level)
- Special Controller or Software
- Enough Ports (SATA, IDE, ...; perhaps extra PCI card)

Table of contents

3 Concepts of RAIDs

- Striping
- Mirroring
- Parities
- Hot-Spare

6 / 58

Mirroring

- Same data on several disks
- Creates *redundancy*
- → Improves security

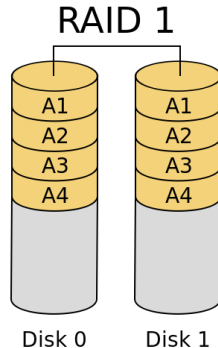


Figure 2 : [WCd]

Parities

- Creates parity data
- Saves parity data next to normal data
- → Restore data with parities

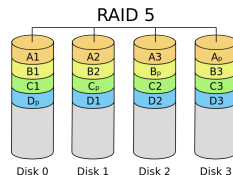


Figure 3 : [WCi]

Hot-Spare

- Free standby disk
- Used as replacement-disk
- Alternative to changing a broken disk

Table of contents

4 RAID Level

- RAID Level
- Level 0 - Striping Data
- Level 1 - Mirroring
- Level 2 - Bit-striping and Hamming-Code
- Level 3 - Byte-Striping and parity
- Level 4 - Striping and dedicated parity
- Level 5 - Striping and parity
- Level 6 - Double parity and striping
- Level 10 & 01
- Other levels

RAID Level

- *Level* = the type of RAID
- Standard level (e.g. RAID 0, 1, 2, ...)
- Combinations (e.g. RAID 10, 35, ...)

Level 0 - Striping Data

- Different data on different disks
- Visible as one logical disk
- Improves performance
 - ▶ Disk 1 reads, Disk 2 moves to next position
 - ▶ Disk 1 sends data, Disk 2 reads
 - ▶ Disk 1 moves, Disk 2 sends data

More information: [WCa]

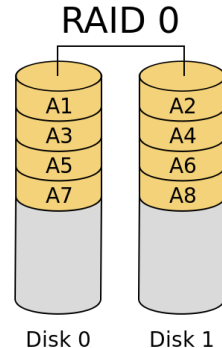


Figure 4 : [WCb]

Level 0 - Striping Data

- Minimum disks: 2 (also 3, 4, ...)
- Space efficiency: 1
 - ▶ 2 disks width 500GB → 1TB logical drive
- Failure rate: $1 - (1 - r)^n$
 - ▶ n := amount of disks
 - ▶ r := failure rate
- Fault tolerance: 0

More information: [WCa]

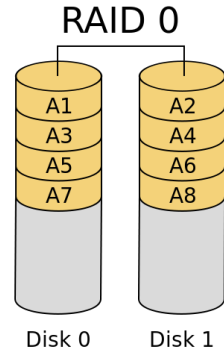


Figure 5 : [WCb]

14 / 58

Level 1 - Mirroring

- Minimum disks: 2 (also 3, 4, ...)
- Space efficiency: $\frac{1}{n}$
 - ▶ $2 \times 500\text{GB} = 1000\text{GB total}$
 $\rightarrow \frac{1000}{2} = 500\text{GB}$
- Failure rate: r^n
 - ▶ $n := \text{amount of disks}$
 - ▶ $r := \text{failure rate}$
- Fault tolerance: $n - 1$

More information: [WCa]

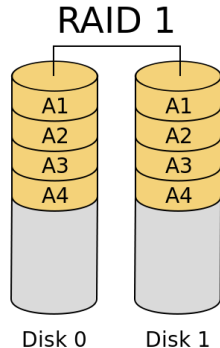


Figure 7 : [WCd]

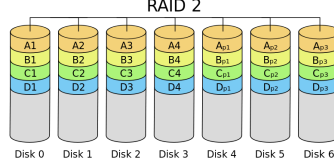


Figure 8 : [WCf]

Level 3 - Byte-Striping and parity

- Striping on byte-level
- Separate parity disk
- High performance for large files (e.g. uncompressed videos)
- Replaced by RAID 5

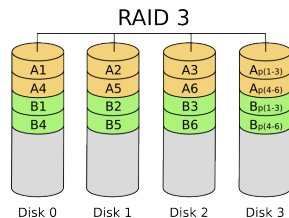


Figure 9 : [WCg]

Level 4 - Striping and dedicated parity

- Striped data
- Parity data on separate disk
- Always read parity data
→ bottleneck

More information: [Kum08, p.4, 3.4.]

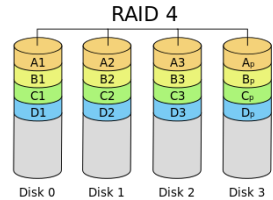


Figure 10 : [WCh]

Level 5 - Striping and parity

- Striping data
- Parity data using XOR
- Read performance like RAID 0

More information: [Leu]

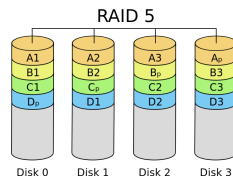


Figure 11 : [WCi]

Level 5 - Striping and parity

What is XOR?

- $\text{XOR}(1, 0) = 1 = \text{XOR}(0, 1)$
- $\text{XOR}(1, 1) = 0 = \text{XOR}(0, 0)$
- $\text{XOR}(0, 1, 1)$
 $= \text{XOR}(\text{XOR}(0, 1), 1)$
 $= \text{XOR}(1, 1)$
 $= 0$

Level 5 - Striping and parity

Saving data

Saving the data $A = (100011101)$ on a RAID 5 with 4 disks.

- $A_1 = (100), A_2 = (011), A_3 = (101)$

- Calculate parity data A_p :

- ▶ $\text{XOR}(1, 0, 1) = 0$

- ▶ $\text{XOR}(0, 1, 0) = 1$

- ▶ $\text{XOR}(0, 1, 1) = 0$

- ▶ $A_p = \text{XOR}(100, 011, 101) = (010)$

- Full data: $(100, 011, 101, 010)$

Level 5 - Striping and parity

Recover data

Full data set: (100, 011, 101, 010)

Lost some data: (100, ~~011~~, 101, 010)

- $\text{XOR}(1, 1, 0) = 0$
- $\text{XOR}(0, 0, 1) = 1$
- $\text{XOR}(0, 1, 0) = 1$
- $\text{XOR}(100, 101, 010) = (011) = A_2$

Level 5 - Striping and parity

- Minimum disks: 3 (also 4, 5, ...)

- Space efficiency: $1 - \frac{1}{n}$

- Failure rate:

$$1 - (1 - r)^n - n \cdot r \cdot (1 - r)^{n-1}$$

▶ n := amount of disks

▶ r := failure rate

- Fault tolerance: 1

More information: [WCa]

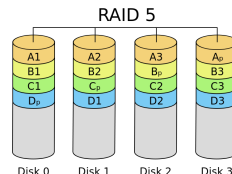


Figure 12 : [WCi]

Level 6 - Double parity and striping

- Like RAID 5 with more parity
- Fast reading
- Slow writing (calculating parities)
- Fault tolerance: 2

More information: [Kum08, p.5, 3.6.]

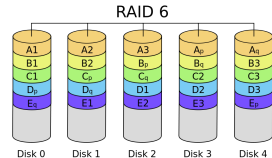


Figure 13 : [WCj]

Level 10 & 01

- Combination of RAID 0 and RAID 1
- Fast reading/writing
- Pretty secure (mirrored data)

Differences

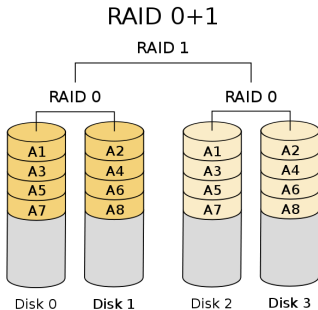


Figure 14 : [WCc]

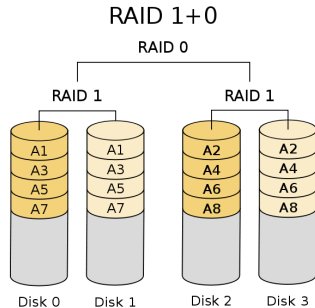


Figure 15 : [WCe]

Other levels

Lots of combinations possible:

- Mirrored: 02, 03, 05, ...
- Striped: 15, 1E, 51, ...
- Other: 45, 55, 5EE, 53, ...

Hardware RAID

Table of contents

5 Hard- & Software-RAID

■ Hardware RAID

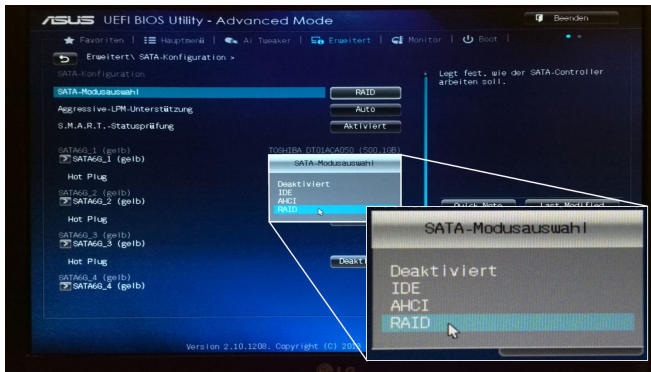
■ Software RAID - Windows

■ Software RAID - Linux (Ubuntu)

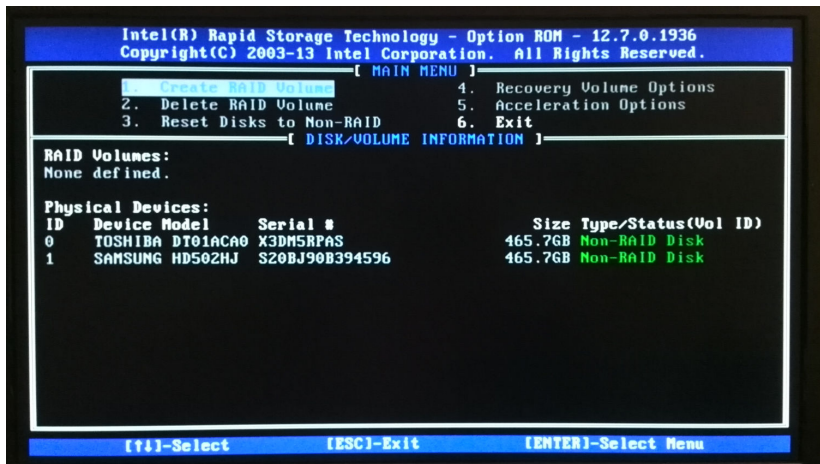
■ Comparison

Hardware RAID

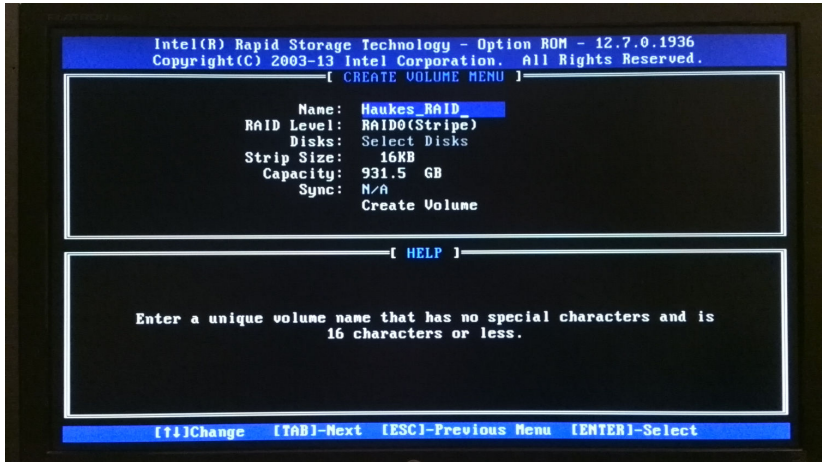
- Based on Hardware (controller)
- Most mainboards can handle RAID
- Available RAID level depending on controller



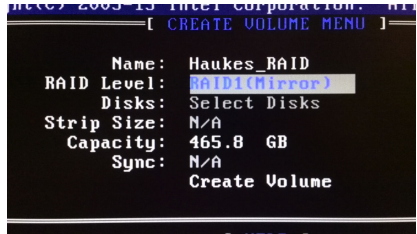
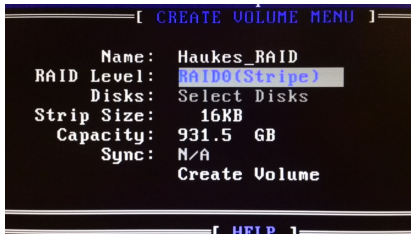
Hardware RAID



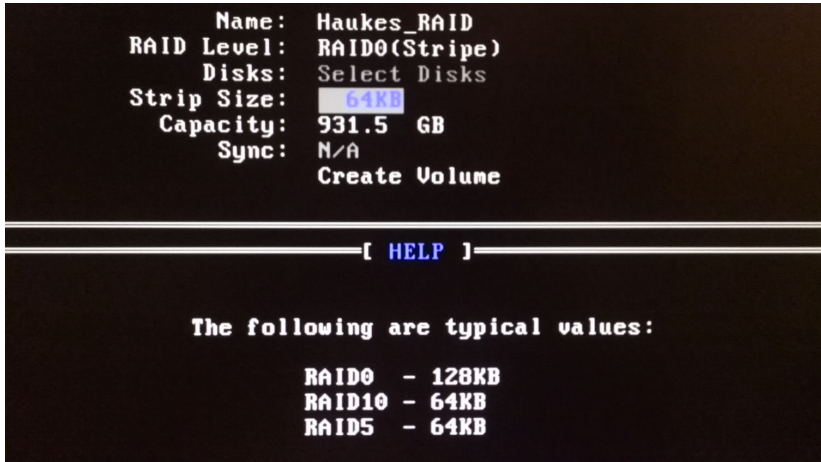
Hardware RAID



Hardware RAID



Hardware RAID



Software RAID - Windows

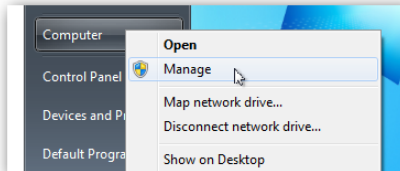
Table of contents

- 5** Hard- & Software-RAID
 - Hardware RAID
 - **Software RAID - Windows**
 - Software RAID - Linux (Ubuntu)
 - Comparison

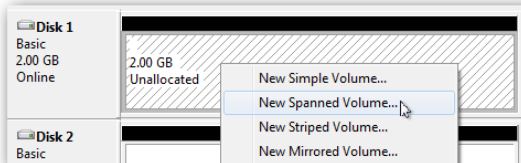
Software RAID - Windows

1. Go to the disk manager

shortcut: win+R→diskmgmt.msc

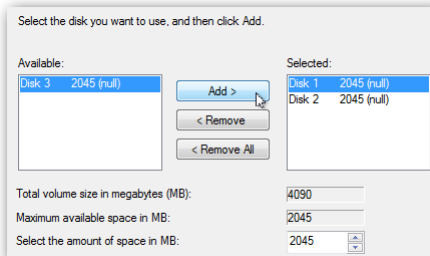


2. Choose an empty hard drive and the RAID type

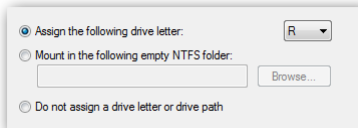


Software RAID - Windows

3. Add more disks

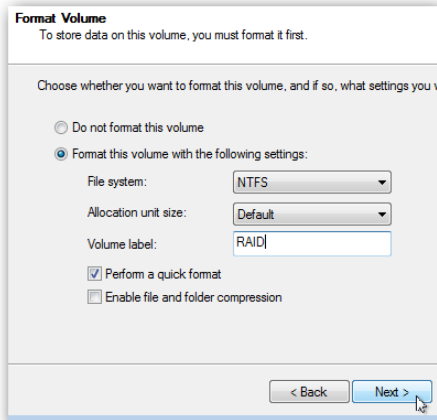


4. Choose a drive letter



Software RAID - Windows

5. Decide on some options



Software RAID - Windows

5. RAID will appear as one drive



Images and more information: [Gar]

Software RAID - Linux (Ubuntu)

Table of contents

- 5** Hard- & Software-RAID
 - Hardware RAID
 - Software RAID - Windows
 - Software RAID - Linux (Ubuntu)**
 - Comparison

Software RAID - Linux (Ubuntu)

Preparation

1. Install mdadm and gparted with
`sudo apt-get install mdadm gparted`
2. Find hard drives in `/dev/sd<a-z><0-9>`
(e.g. `/dev/sdb1`)

Software RAID - Linux (Ubuntu)

Partitioning

3. Create empty partition:

```
sudo parted /dev/sd... mklabel gpt
```

4. Mark partition as RAID-partition:

```
sudo parted /dev/sd... set 1 raid on
```

Software RAID - Linux (Ubuntu)

Create RAID

5. Use mdadm to create a RAID:

```
sudo mdadm  
    --create /dev/mdx  
    --auto md  
    --level=xy  
    --raid-devices=n  
    /dev/sd<a-z><0-9>
```

Software RAID - Linux (Ubuntu)

Create filesystem and mount it

6. Create new filesystem on RAID (`-b` and `-E` for RAID 0, 5, 6, 10, ...)

```
sudo mkfs.ext4  
    -b 4096  
    -E stride=s, stripe-width=t  
    /dev/mdx
```

7. Mount the new drive with mount:

```
sudo mount /dev/mdx /media/...
```

Software RAID - Linux (Ubuntu)

- Example: Create RAID 10 with 4 disks:

```
sudo mdadm  
  --create /dev/md0  
  --auto md  
  --level=10  
  --raid-devices=4  
    /dev/sdb1  
    /dev/sdc1  
    /dev/sdd1  
    /dev/sde1
```

More information [ubu, 3.x Anlegen eines RAID]

Comparison

Features	Software RAID	Hardware RAID Controller
Independent	No	Yes
RAID performance	Depending on Server(load)	High: Independent of server(load)
Functionally vulnerable to malware	Yes	No
Ability to migrate to other OS	Limited	Yes
Costs	low costs	high costs
Typical RAID levels	RAID 0, 1	RAID 5, 6

Figure 16 : Redrawn to [ada06, p.4]

Table of contents

6 Usage

- Private
- Commercial

Private

- Gaming PCs use RAIDs for better performance
- Storage systems (e.g. NAS) use RAID as well

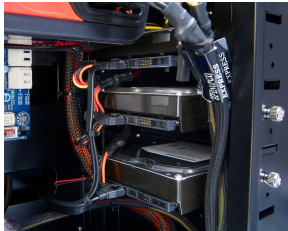


Figure 17 : Gaming PC with RAID [bt]



Figure 18 : NAS server with 4 disks for RAID 10 or similar [MLN]

Commercial

- Small to mid-size companies/data center
- Huge data center (e.g. Facebook, Google, ...) have own systems

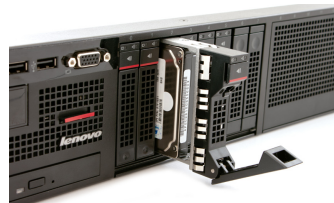


Figure 19 : [Len]

Thanks :)

[ada06] adaptec.

Hardware raid vs. software raid: Which implementation is best for my application?

https://www.adaptec.com/nr/rdonlyres/14b2fd84-f7a0-4ac5-a07a-214123ea3dd6/0/4423_sw_hwraid_10.pdf, 2006.

Last accessed: 18.04.2015.

[bt] bit tech.

Gladiator titan prometheus gaming pc.

http://images.bit-tech.net/content_images/2010/06/gladiator-titan-prometheus-gaming-pc-review/aria-titan-prometheus-4-1280x1024.jpg.

Last accessed: 17.04.2015.

[Gar] Justin Garrison.

How to Create a Software RAID Array in Windows 7?

www.howtogeek.com/howto/36504/

[how-to-create-a-software-raid-array-in-windows-7](#)

Last accessed: 17.04.2015.

[Kum08] Arvind Kumar.

Redundant array of inexpensive disks (raid) - technical paper.

[http://www.finitysend.com:](http://www.finitysend.com:34999/get/pdf/93)

[34999/get/pdf/93](#), 2008.

Last accessed: 18.04.2015.

[Len] Lenovo.

Storagereview lenovo thinkserver rd630 drive bays.

<http://www.storagereview.com/images/>

[StorageReview-Lenovo-ThinkServer-RD630-DriveBays.jpg](#)

Last accessed: 17.04.2015.

[Leu]

Laurens Leurs.

Raid.

<http://www.prepressure.com/library/technology/raid>.

Last accessed: 17.04.2015.

[MLN]

MLN.

Qnap ts-419p ii all-in-one 4-bay nas server for home & soho.

<http://www.mln.com.au/img/files/3823/qnap-419pii-t.jpg>.

Last accessed: 17.04.2015.

[ubu]

ubuntuusers.

Software-Raid.

[http:](http://wiki.ubuntuusers.de/Software-RAID)

[//wiki.ubuntuusers.de/Software-RAID](http://wiki.ubuntuusers.de/Software-RAID) Last
accessed: 17.04.2015.

[WCa]

Wikimedia-Commons.

Comparison.

[http://en.wikipedia.org/wiki/Standard_](http://en.wikipedia.org/wiki/Standard_RAID_levels#Comparison)
[RAID_levels#Comparison.](http://en.wikipedia.org/wiki/Standard_RAID_levels#Comparison)

Last accessed: 17.04.2015.

[WCb]

Wikimedia-Commons.

Raid 0 with two disks (disk 0 and disk 1) over one logical
volume a with odd blocks on disk 0 and even blocks on
disk 1.

[http://upload.wikimedia.org/wikipedia/](http://upload.wikimedia.org/wikipedia/commons/thumb/9/9b/RAID_0.svg/325px-RAID_0.svg.png)
[commons/thumb/9/9b/RAID_0.svg/](http://upload.wikimedia.org/wikipedia/commons/thumb/9/9b/RAID_0.svg/325px-RAID_0.svg.png)

[325px-RAID_0.svg.png.](http://upload.wikimedia.org/wikipedia/commons/thumb/9/9b/RAID_0.svg/325px-RAID_0.svg.png)

Last accessed: 15.04.2015.

[WCc] Wikimedia-Commons.

Raid 0+1: striped sets in a mirrored set.

http://upload.wikimedia.org/wikipedia/commons/thumb/a/ad/RAID_01.svg/600px-RAID_01.svg.png.

Last accessed: 17.04.2015.

[WCd] Wikimedia-Commons.

Raid 1 with two disks (disk 0 and disk 1) over one logical volume a with all blocks replicated/mirrored from drive 0 to drive 1.

http://upload.wikimedia.org/wikipedia/commons/thumb/b/b7/RAID_1.svg/325px-RAID_1.svg.png.

Last accessed: 15.04.2015.

[WCe] Wikimedia-Commons.

Raid 1+0: mirrored sets in a striped set.

http://upload.wikimedia.org/wikipedia/commons/thumb/b/bb/RAID_10.svg/600px-RAID_10.svg.png.

Last accessed: 17.04.2015.

[WCf] Wikimedia-Commons.

Raid 2 with seven disks and each group of bits (orange, yellow, green, and blue) on disks 0-3 have three parity bits on disks 4-6.

http://upload.wikimedia.org/wikipedia/commons/thumb/b/b5/RAID2_arch.svg/800px-RAID2_arch.svg.png.

Last accessed: 17.04.2015.

[WCg] Wikimedia-Commons.

Raid 3 with four drives (disk 0, 1, 2, and 3) two 6-byte blocks, a & b, shown with their two bytes of parity on disk 3.

http://upload.wikimedia.org/wikipedia/commons/archive/f/f9/20091206154152!RAID_3.svg.

Last accessed: 17.04.2015, .png-creation with Inkscape.

[WCh] Wikimedia-Commons.

Raid 4 with four disks (disk 0, 1, 2, and 3) and each group of blocks (orange, yellow, green, and blue) have a parity block on disk 3 (which is the dedicated parity block).

http://upload.wikimedia.org/wikipedia/commons/thumb/a/ad/RAID_4.svg/320px-RAID_4.svg.png.

Last accessed: 15.04.2015.

[WCi]

Wikimedia-Commons.

Raid 5 with these four disks (disk 0, 1, 2, and 3) and each group of blocks (orange, yellow, green, and blue) have a distributed parity block that is distributed across the four disks.

http://upload.wikimedia.org/wikipedia/commons/thumb/6/64/RAID_5.svg/675px-RAID_5.svg.png.

Last accessed: 15.04.2015.

[WCj]

Wikimedia-Commons.

Raid 6 with five disks (disk 0, 1, 2, 3, and 4) and each group of blocks (orange, yellow, green, blue, and purple) has two distributed parity blocks that are distributed across the five disks.

http://upload.wikimedia.org/wikipedia/commons/thumb/7/70/RAID_6.svg/800px-RAID_6.svg.png.
Last accessed: 17.04.2015.