- **I/O device handler** processes the I/O interrupts, handles error conditions, and provides detailed scheduling algorithms, which are extremely device dependent.
- Each type of I/O device has own device handler algorithm.
  - first come first served (FCFS)
  - shortest seek time first (SSTF)
  - SCAN (including LOOK, N-Step SCAN, C-SCAN, and C-LOOK)
- Every scheduling algorithm should :
  - Minimize arm movement
  - Minimize mean response time
  - Minimize variance in response time

## RAID

- ✓ Redundant Array of Independent Disks
- ✓ Redundant Array of Inexpensive Disks
- ✓ A RAID system consists of two or more disks working in parallel.
- ✓ The software to perform the RAID-functionality and control the hard disks can either be located on a separate controller card (a hardware RAID controller) or it can simply be a driver.
- ✓ Sometimes disks in a RAID system are defined as JBOD, which stands for 'Just a Bunch Of Disks'. This means that those disks do not use a specific RAID level and are used as if

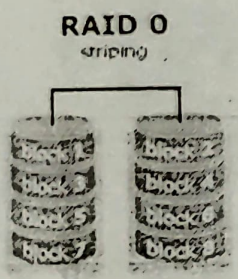
they were stand-alone disks. This is often done for disks that contain swap files or spooling data

✓ Goals:

- ❑ Increased reliability
- ❑ Increased performance

RAID 0 Striping

- In a RAID 0 system, data are split up in blocks that get written across all the drives in the array. By using multiple disks (at least 2) at the same time, RAID 0 offers superior I/O performance. This performance can be enhanced further by using multiple controllers, ideally one controller per disk




**Advantages**

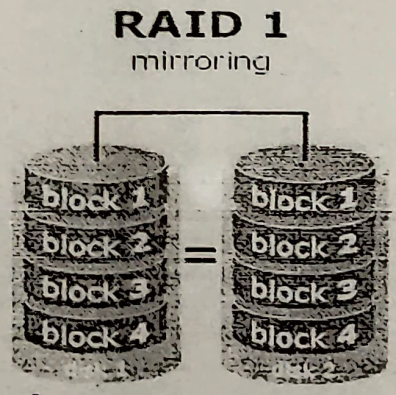
- RAID 0 offers great performance, both in read and write operations. There is no overhead caused by parity controls.
- All storage capacity can be used, there is no disk overhead.
- The technology is easy to implement.

**Disadvantages**

- RAID 0 is not fault-tolerant. If one disk fails, all data in the RAID 0 array are lost. It should not be used on mission-critical systems.
- Ideal use
- RAID 0 is ideal for non-critical storage of data that have to be read/written at a high speed, e.g. on a Photoshop image retouching station.

**RAID 1: Mirroring**

✓ Data are stored twice by writing them to both the data-disk (or set of data disks) and a mirror disk (or set of disks) . If a disk fails, the controller uses either the data drive or the mirror drive for data recovery and continues operation. You need at least 2 disks for a RAID 1 array.




RAID 1 systems are often combined with RAID 0 to improve performance. Such a system is sometimes referred to by the combined number: a RAID 10 system.

**Advantages**

- ✓ RAID 1 offers excellent read speed and a write-speed that is comparable to that of a single disk.
- ✓ In case a disk fails, data do not have to be rebuild, they just have to be copied to the replacement disk.
- ✓ RAID 1 is a very simple technology.

**Disadvantages**

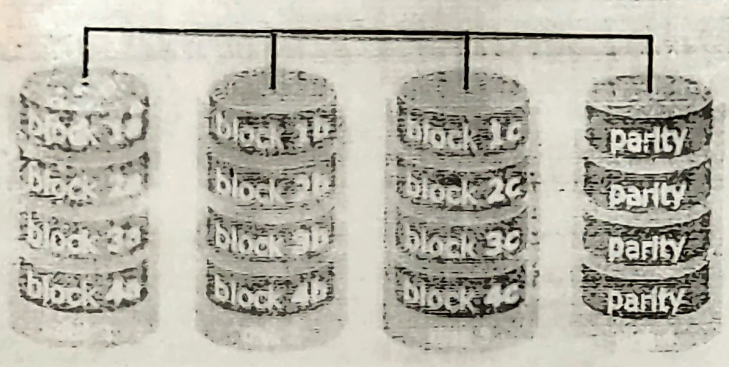
- ✓ The main disadvantage is that the effective storage capacity is only half of the total disk capacity because all data get written twice.
- ✓ Software RAID 1 solutions do not always allow a hot swap of a failed disk (meaning it cannot be replaced while the server keeps running). Ideally a hardware controller is used.
- ✓ Ideal use
- ✓ RAID-1 is ideal for mission critical storage, for instance for accounting systems. It is also suitable for small servers in which only two disks will be used.

**RAID 3**

- ✓ On RAID 3 systems, datablocks are subdivided (striped) and written in parallel on two or more drives. An additional drive stores parity information. You need at least 3 disks for a RAID 3 array.

## RAID 3

parity on separate disk




- ✓ Since parity is used, a RAID 3 stripe set can withstand a single disk failure without losing data or access to data.

**Advantages**

- ✓ RAID-3 provides high throughput (both read and write) for large data transfers.
- ✓ Disk failures do not significantly slow down throughput.

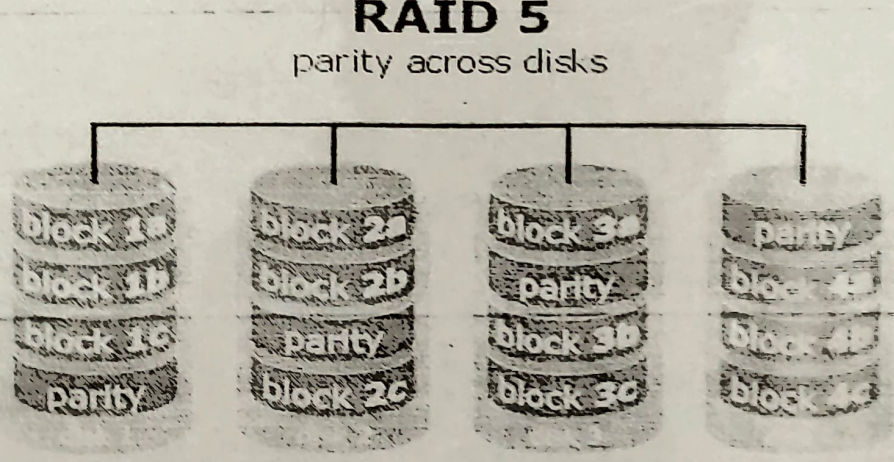
**Disadvantages**

- ✓ This technology is fairly complex and too resource intensive to be done in software.
- ✓ Performance is slower for random, small I/O operations.
- ✓ Ideal use
- ✓ RAID 3 is not that common in prepress.

**RAID 5**

- ✓ RAID 5 is the most common secure RAID level. It is similar to RAID-3 except that data are transferred to disks by independent read and write operations (not in parallel). The

data chunks that are written are also larger. Instead of a dedicated parity disk, parity information is spread across all the drives. You need at least 3 disks for a RAID 5 array. A RAID 5 array can withstand a single disk failure without losing data or access to data. Although RAID 5 can be achieved in software, a hardware controller is recommended. Often extra cache memory is used on these controllers to improve the write performance.




**Advantages**

- ✓ Read data transactions are very fast while write data transaction are somewhat slower (due to the parity that has to be calculated).

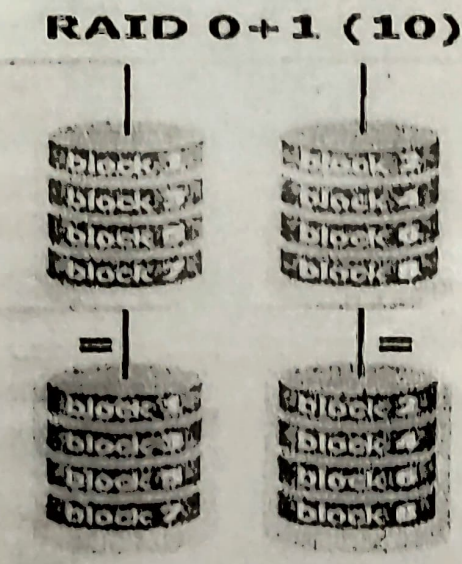
**Disadvantages**

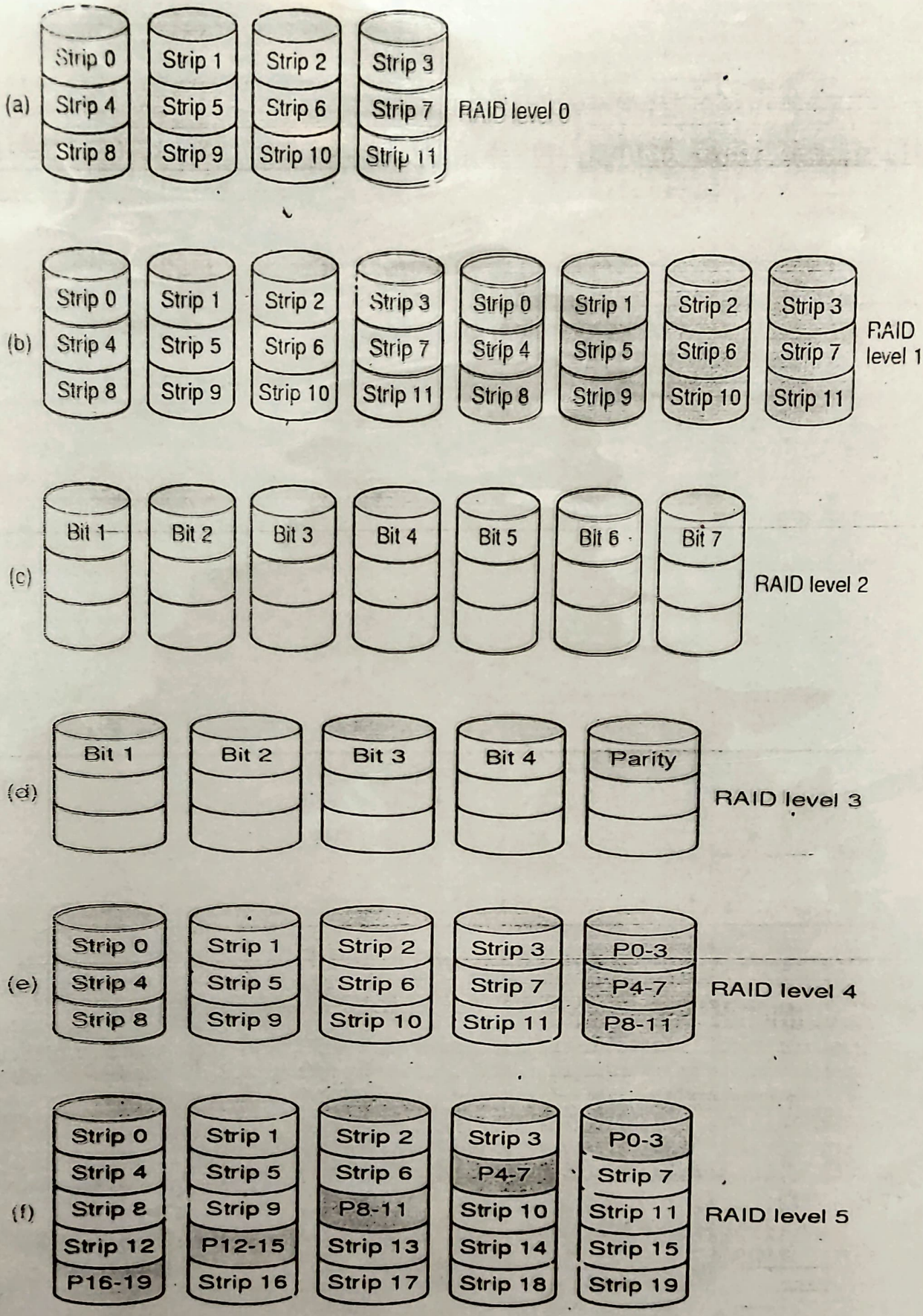
- ✓ Disk failures have an effect on throughput, although this is still acceptable.
- ✓ Like RAID 3, this is complex technology.

- ✓ Ideal use
- ✓ RAID 5 is a good all-round system that combines efficient storage with excellent security and decent performance. It is ideal for file and application servers.

**RAID 10: a mix of RAID 0 & RAID 1**

RAID 10 combines the advantages (and disadvantages) of RAID 0 and RAID 1 in a single system. It provides security by mirroring all data on a secondary set of disks (disk 3 and 4 in the drawing below) while using striping across each set of disks to speed up data transfers.




(a)
Strip 0
Strip 4
Strip 8
Strip 1
Strip 5
Strip 9
Strip 2
Strip 6
Strip 10
Strip 3
Strip 7
Strip 11
RAID level 0
(b)
Strip 0
Strip 4
Strip 8
Strip 1
Strip 5
Strip 9
Strip 2
Strip 6
Strip 10
Strip 3
Strip 7
Strip 11
Strip 0
Strip 4
Strip 8
Strip 1
Strip 5
Strip 9
Strip 2
Strip 6
Strip 10
Strip 3
Strip 7
Strip 11
RAID level 1
(c)
Bit 1
Bit 2
Bit 3
Bit 4
Bit 5
Bit 6
Bit 7
RAID level 2
(d)
Bit 1
Bit 2
Bit 3
Bit 4
Parity
RAID level 3
(e)
Strip 0
Strip 4
Strip 8
Strip 1
Strip 5
Strip 9
Strip 2
Strip 6
Strip 10
Strip 3
Strip 7
Strip 11
P0-3
P4-7
P8-11
RAID level 4
(f)
Strip 0
Strip 4
Strip 8
Strip 12
P16-19
Strip 1
Strip 5
Strip 9
P12-15
Strip 16
Strip 2
Strip 6
P8-11
Strip 13
Strip 17
Strip 3
P4-7
Strip 10
Strip 14
Strip 18
P0-3
Strip 7
Strip 11
Strip 15
Strip 19
RAID level 5