ABSTRACT
This paper contains general RAID configurations, with emphasis on RAID 0, 5, 6, and hybrid 1+0.

1. INTRODUCTION
Redundant Array of Inexpensive (or Independent) Disks, otherwise known as RAID, is an array of multiple drives, whether hard drives or solid state drives. This technology is sometimes used to increase performance, like with RAID 0. However, as its name suggests, its main use is to provide redundancy to help protect your data from drive failure.

2. SOFTWARE VS HARDWARE
RAID can be implemented with either a hardware RAID controller, or with OS software implementation. Either way has its pros and cons. Software does not require hardware, and is included in most operating systems, so it does not have additional cost. However, it has performance loss with any implementation other than RAID 0 or 1 due to CPU and RAM overhead. Hardware does not have the overhead of software, but is bound to the hardware controller, so you cannot take the drives out and use them in another computer.7

3. RAID PROFILES
3.1 RAID 0
RAID 0 (block-level striping without parity or mirroring) has each drive synchronized so that each sequential block of data is written to the next drive in the array. This provides increased performance, but has zero fault tolerance. The failure of a single drive destroys the array. The read/write performance is the data transfer speed of a single drive multiplied by the number of drives. Likewise, the storage size is the storage of a single drive multiplied by the number of drives. At least 2 drives are required.4

3.2 RAID 1
RAID 1 (mirroring without parity or striping) makes multiple copies of all data and creates mirrored “copies” on several drives. This profile has the performance and storage capability of a single drive. However, the fault tolerance is dependent on the number of drives in the array. As long as one drive in the array remains intact, all the data is present, providing a fault tolerance of the number of drives minus one. At least 2 drives are required.4
3.3 **RAID 2**
RAID 2 (bit-level striping with dedicated Hamming-code parity) is a theoretical profile, and was never placed into use.³

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[Figure 1. RAID 0.](#)

[Figure 2. RAID 1.](#)

[Figure 3. RAID 2.](#)
3.4 RAID 3
RAID 3 (byte-level striping with dedicated parity) has synchronized drives like RAID 0, however it is striped at the byte level, and one of the drives in the array is dedicated to parity for the remaining drives. This provides a fault tolerance of 1 drive, and performance and storage of the transfer rate of a single drive multiplied by one less than the number of drives. Requires 3 or more drives. This profile is seldomly used.\(^3\)\(^4\)

![RAID 3 Diagram](image)

Figure 4. RAID 3

3.5 RAID 4
RAID 4 (block-level striping with dedicated parity) is equivalent to RAID 1, only with an added parity drive. It has a fault tolerance of 1 drive, and performance and storage of the transfer rate of a single drive multiplied by one less than the number of drives. Requires 3 or more drives. This profile was only used for a short duration before being replaced by RAID 5.\(^3\)

![RAID 4 Diagram](image)

Figure 5. RAID 4.

3.6 RAID 5
RAID 5 (block-level striping with distributed parity) is identical to RAID 4 with the exception that the parity is distributed between the drives for sequential blocks. There are also 2 other variations to RAID 5, which include 5E and 5EE. RAID 5E includes a service spare drive that auto-populates if another drive in the array fails, while 5EE has 2 service spares.\(^3\)\(^4\)

![RAID 5 Diagram](image)

Figure 6. RAID 5.
3.7 RAID 6
RAID 6 (block-level striping with double distributed parity) is raid 5 with a second parity for each block level. This provides a 2 disk fault tolerance, and performance and storage of a single drive multiplied by 2 less than the number of drives. Requires a minimum of 4 drives. This profile is still used, but has decreased in popularity due to nested arrays. RAID 6E also exists, with a single service spare.\(^3\,^4\)

![RAID 6 Diagram]

Figure 7. RAID 6.

4. NESTED ARRAYS
Nested (Hybrid) arrays are made by making a RAID array with the individual components made out of other arrays. Nested arrays are usually designated by a 2 digit profile number, sometimes with a + between the digits. The digits designate the order of the array, with the lowest level first. For example, a RAID 10 profile is a striped set made out of multiple mirrored sets, while RAID 01 is a mirrored set made out of multiple striped sets. Commonly seen versions are made primarily out of RAID 0, 1, and 5, although you will sometimes see them include 3 or 6.\(^3\)

![RAID 10 Diagram]

Figure 8. RAID 10.

5. CODE
The code written tests the time taken to copy 3 separate 1 GB files, then averages the time required. This number is then used to calculate the data transfer speed. This is then adjusted if your system is running a RAID profile. The adjusted number is then used to calculate the transfer speed for various RAID profiles. The calculations used are listed below. \(N\) is the number of disks, and \(x\) is the storage space or transfer speed. All calculations are based using the HP SmartArray P411. Output displayed uses the time values of 4.6s, 4.71s, and 7.81s for an average of 5.71s.\(^1\)
5.1 **RAID 0**
For storage space for any number of drives, and for transfer speed up to 8 drives, the calculation is xN. For up to 10 drives, transfer speed is (x-10)N. Calculations not made after 10 because transfer speed decreases.\(^1\)

```
RAID 0:
Two drives: 717.757 MB/S
Four drives: 1435.51 MB/S
Six drives: 2153.27 MB/S
Eight drives: 2871.03 MB/S
Ten drives: 3488.79 MB/S
Performance decreases after 10 drives
All RAID stats are based on the HP SmartArray P410 RAID controller.
```

Figure 9. RAID 0 output.

5.2 **RAID 5/6**
Transfer speed and storage size for RAID 5 is x(N-1), while RAID 6 is x(N-2). The max transfer speed for both of these profiles is 800 MB/S.\(^1\)

```
RAID 5:
Data transfer rate maxes at 800 MB/S
3 drives: 717.757 MB/S
4 drives: 800 MB/S
All RAID stats are based on the HP SmartArray P410 RAID controller.
```

Figure 10. RAID 5 output.

```
RAID 6:
Data transfer rate maxes at 800 MB/S
4 drives: 717.757 MB/S
5 drives: 800 MB/S
All RAID stats are based on the HP SmartArray P410 RAID controller.
```

Figure 11. RAID 6 output.

5.3 **RAID 10**
Because this is just two RAID 0 arrays that have been mirrored, this profile follows the rules for RAID 0 with half as many drives.

```
RAID 1+0:
Four drives: 717.757 MB/S
Eight drives: 1435.51 MB/S
Twelve drives: 2153.27 MB/S
Sixteen drives: 2871.03 MB/S
Twenty drives: 3488.79 MB/S
Performance decreases after 20 drives
All RAID stats are based on the HP SmartArray P410 RAID controller.
```

Figure 12. RAID 10 output.

5.4 **GENERAL INFO**
The general info output uses the above calculations and adds some other information as well.
Your data transfer rate in RAID 0 for 2 to 8 drives would be 358.879 MB/S multiplied by the number of drives. For example, 4 drives would give you 1435.51 MB/S. Ten drives would give you 3488.79 MB/S, due to slight performance loss. After 10 drives, transfer rate decreases. **High performance, no redundancy.

Your data transfer rate for RAID 5 is 358.879 MB/S multiplied by the number of drives minus 1, to a maximum transfer of 800 MB/S. For example, 4 drives would give you 800 MB/S. **Good performance, can rebuild after single drive failure.

Your data transfer rate for RAID 6 is 358.879 MB/S multiplied by the number of drives minus 2, to a maximum transfer of 800 MB/S. For example, 5 drives would give you 800 MB/S, the same speed as a RAID 5 array of 4 disks. **Decent performance, can rebuild after failure of 2 drives.

RAID 1+0 follows the same pattern as a RAID 0 array of half as many disks. For example, 8 drives give you 1435.51 MB/S, the same as 4 in a RAID 0. **Better performance than single disk, can repair after multiple drive failures as long as it is not matching drives.

All RAID stats are based on the HP SmartArray P411 RAID controller.

### Figure 13. General information output.

6. **Results**

Results are shown in table and graph format.

<table>
<thead>
<tr>
<th>RAID version</th>
<th>Performance</th>
<th>Storage</th>
<th>Fault Tolerance</th>
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<td>BEST</td>
<td>NONE</td>
</tr>
<tr>
<td>1</td>
<td>AVERAGE</td>
<td>AVERAGE</td>
<td>BEST</td>
</tr>
<tr>
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<td>VERY GOOD</td>
<td>SINGLE</td>
</tr>
<tr>
<td>6</td>
<td>GOOD</td>
<td>GOOD</td>
<td>SINGLE</td>
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<tr>
<td>10</td>
<td>HIGH</td>
<td>HIGH</td>
<td>UP TO HALF</td>
</tr>
</tbody>
</table>

### Figure 14. Performance statistics, based on 150 MB/S drives.
7. REFERENCES


