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RAID level 4 - SWITCHED PARITY (Redundant Array of Independent / Inexpensive Disks)

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ABSTRACT

The ongoing evolution of latest kinds of computing systems have imposed a growing need in storage systems for high reliability, availability, security, and high-performance. One method of improving storage performance is through the utilization of special storage architectures. Redundant Arrays of Independent Disks (RAID) are often included in this type of architectures. RAID provides a useful way to increase storage performance and fault tolerance on a diversity of levels.
In this journal, a storage architecture is proposed which I have termed as "RAID level 4 – **Switched Parity**".
To achieve this innovative algorithm, a hardware called RAID controller card will be required. The schematic diagram and the working principle of this special RAID controller card designed by me is an important part of this journal which will overcome the problems/disadvantages of Network based RAID and Cloud based RAID.
Here we will be having two disks/storages for parity but it will be automatically switched as per situation. When local parity disk is connected and working fine then parity bits are stored in it. As soon as the local parity disk becomes inaccessible, the special RAID controller card will sense it. Then the parity bits will be automatically sent to the disk/storage connect to the network. This is because the architecture is designed to switch between 2 modes. The first mode when local parity disk is working, the architecture is delivering performance whereas the second mode when local parity disk fails, the parity is automatically sent to network attached parity disk resulting in fault tolerance. As the title of the journal states "Switched Parity", the parity data is automatically switched between local and network disk/storage as per the situation.
The proposed architecture holds many advantages over not only local RAID but also over Network based RAID and Cloud Based RAID.

Keywords

Computer Hardware; Computer Science; Mass Storage

I. Introduction

The mounting use of computer in all domains of life be it Corporates or Government organizations etc for storing and transferring of perilous information has augmented the prerequisite of having an advance level of storage system. Storing of large data physically can create space and security problems, the digital storage system is the need of the hour.
When it comes to huge data storage requirement, attaching hard disk with the computer discretely will not serve the purpose, instead a storage system (consisting of multiple Hard Disks) would be required. Below mentioned are some technologies / methods to achieve a storage system (with huge capacity)

- DAS (Direct Attached Storage)
- SAN (Storage Area Network)
- NAS (Network Attached Storage)
- RAID (Redundant Array of Inexpensive/Independent Disks)
- Cloud storage

From the above mentioned storage systems I will be focusing on RAID. There can be various types and levels of RAID from basic to advance. A brief overview of RAID is included in this Journal. Different RAID offer different advantages such as performance, security and fault tolerance. Before choosing and implementing one particular type/level of RAID we need to prioritize any one advantage.
The architecture proposed & designed will switch between 2 modes. The first mode when local parity disk is working, the architecture is delivering performance whereas the second mode when local parity disk fails, the parity is automatically sent to network attached parity disk resulting in fault tolerance. As the title of the journal states "Switched Parity", the parity data is automatically switched between local and network disk/storage as per the situation. A special RAID controller card designed by me will be required to achieve this.

II. RAID

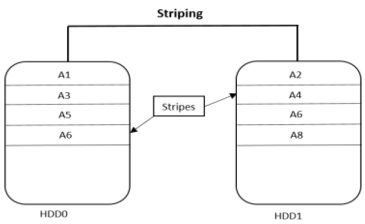
A disk array or RAID (Redundant Array of Independent Disks) may be a system that uses an array controller and multiple hard disk units to realize better performance and better reliability in compare to a single hard disk unit. The access to each hard disk is controlled by an array controller. RAID level is defined as per the different types of control methods used. By employing a redundant RAID level, system operation are often continued without data loss within the event that one or maybe two, for a few RAID levels, of the hard disk unit fail. In simpler language we can say that RAID is the technology by which smaller size hard disks are joined logically into array to give a combined large storage space. It involves presenting the single logical disk by arranging the physical disks into arrays. RAID provides the data reliability, security, better performance to all the people in need of online storage. Majorly it can be of two types:

- **Striping**
- **Mirroring**

2.1 STRIPING

Here we logically sequence the data by striping it into different fragments and stored into different physical devices. If we take two hard disks named HDD0 and HDD1 of 100 GB each and if we logically join it, we will get a combined capacity of 200 GB. Let's take an example to understand it. If we are saving a file of 8 MB in our computer then this file will be chopped down or stripped into 4 different pieces (for instance) and each piece will consist of approx. 2 MB. If each part/stripe is named as A1, A2, A3…..A8. Now stripe 1 will be stored in first Hard disk, stripe 2 in second Hard disk and so on alternatively. This is how 1 file is stripped into multiple parts and distributed equally in all the hard disks present in the array. Striping is shown in figure 1.

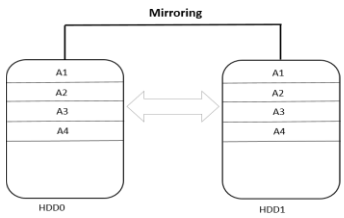
Figure 1. Striping



2.2 MIRRORING

In this we duplicate our data by using two hard disks. Like if we are working on hard disk 0 then the same data will be copied in hard disk 1 in the background and serve as a backup later on. If any 1 of the Hard disk gets damaged then the system (Computer) works without any interruption as the same data including the Operating System is present on both the disks. Mirroring is shown in figure 2.

Figure 2. Mirroring



III. RAID levels

Table 1 shows the names of standard RAID levels.

Levels	Description
RAID 0	Block-level striping without parity or mirroring
RAID 1	Mirroring without parity or striping
RAID 2	Bit-level striping with Hamming code for error correction
RAID 3	Byte-level striping with dedicated parity
RAID 4	***Block-level striping with dedicated parity***
RAID 5	Block-level striping with distributed parity
RAID 6	Block-level striping with double distributed parity

Table 1. Different RAID levels

3.1 RAID 4 (Block-level striping with dedicated parity)

This is much like RAID 3, where data was striped into bytes and in RAID 4 it utilizes a dedicated parity disk and data is striped on the level of blocks *(default block size = 512 Bytes)*. Since a dedicated parity disk is required the write performance suffers as write in parity disk becomes a hindrance like RAID 3 but here the data is striped on block levels thus effectuating the aforementioned hindrance. Regular parity calculations declines the writing performance but RAID 4 offers good reliability. RAID 4 is shown in figure 3.

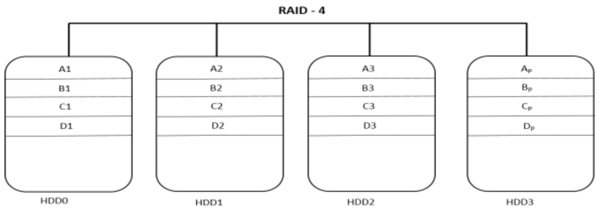


Figure 3. **RAID – 4**

3.2 Network based RAID

After exploring various RAID levels as well as Nested RAID levels, Researchers have thought of few more technologies and incorporated these technologies to augment RAID levels. One of it is termed as Network based RAID level as displayed in figure 4. Here the array of the disks which is used in RAID configuration is not only local disk as well as it is also having network disk which is called NAS (Network Attached Storage). For Example, we can have two disks locally clubbed together using stripping technology and we can do mirroring of this local disks to a NAS. Subsequently the data is not only present in local disks but also somewhere outside the physical area of the system essentially connected with the network. This network can be either wired or Wi-Fi.

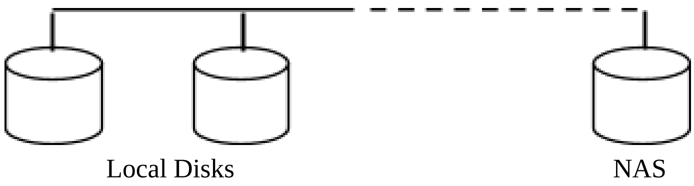


Figure 4. Network based RAID

Disadvantages of Network Based RAID

- As the data is stored in a network attached storage system so the writing speed will become very slow because the data is written to the local disk as well as it is sent to a storage system which is at distant place from the system resulting in slower performance
- As it is connected to the network and not the internet so the users outside the LAN cannot access this Data further enhancement of network RAID was thought of and hence a new concept came up as mentioned below.

3.3 Cloud Based RAID

It is enhancement of Network based RAID. In the Cloud based RAID as in figure 5, the array of RAID hard disks were also connected with the Cloud storage instead of network storage. Which means the storage system was placed somewhere very far-flung from the actual system, Cloud storage and the actual system were attached through internet. Hence a virtual array of disks was made to form RAID in which few disk were locally connected to the system whereas few disks or storage system were far away from the local system in a different area and network essentially connected with internet connection.

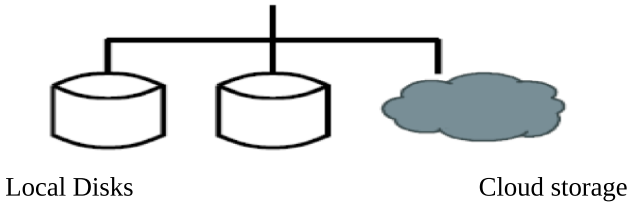


Figure 5. Cloud based RAID

<u>Advantages of Cloud based storage system</u>

- Storage capacity could be expanded
- We can join or stripe many cloud storage in different part of the world, hence practically it will give unlimited storage space.
- As the storage was connected to internet, a user from anywhere in the world connected with internet could access the data of this RAID array

<u>Disadvantages or gap of Cloud based storage system</u>

- Internet connectivity is required which brings an additional OPEX cost.
- As the data is stored in a distant place and the data is sent to that storage system via internet, so the system will slow down and the performance of the RAID array will deteriorate.
- The data is sent through shared medium such as Internet, hence hackers can corrupt or steal the data

IV. RAID LEVEL 4–SP (Switched Parity)

I am proposing a special architecture of RAID level which I have named as “RAID LEVEL 4–SP (Switched Parity)”. To implement RAID LEVEL 4–SP (Switched Parity), a specially designed RAID controller card will be required, which will overcome the problems/disadvantages of Network based RAID and Cloud based RAID.

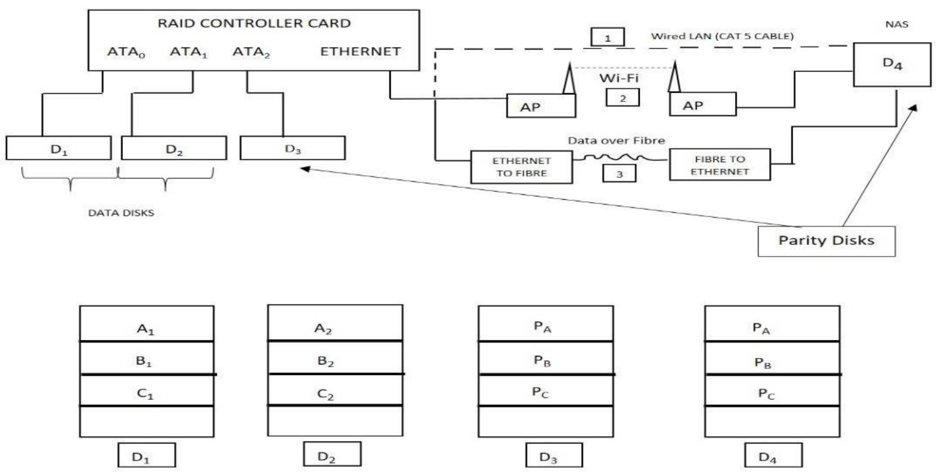


Figure 6. Connection diagram of the RAID controller card

Generally RAID level 4 is block level stripping with dedicated parity, previously the researchers have also implemented RAID level 4 with DP(Double Parity) where they had kept one parity disk in the array of the local disk and the other parity was in the storage device away from the system, connected either with LAN or internet. The parity data was simultaneously stored at two places, first one in Parity disk locally present and the second one on the disk attached to Network or Internet (cloud).

Here a special type of RAID level has been proposed by me, I have named it RAID level 4 SP (Switched Parity). Although we will be having two storages for parity but not at the same time. Means it will be switched as and when required. Only one parity disk will be active at a time.
Let us take an example, we will use 3 disks in local array system and 1 disk (or storage system) will be connected to the network or internet.
Now, in local array Disk 1 and Disk 2 will be data disk and will be configured as per stripping technology. Hence the capacity of D_1 and D_2 will be added together.
Let us assume that both the disk will be of 100 GB each, therefore the total capacity will be of 200 GB.
Meanwhile D_3 which is also connected to the local disks array, is a parity disk of 100 GB. Because parity data will be exactly half of the actual data.
In other words parity of data present in D_1 and D_2 will be generated and then that parity will be saved in D_3 taking half the space.
RAID controller card which I have proposed will have 4 ports, 3 ports for local hard disks (ATA, SCSI etc.) and the 4^{th} port will be Ethernet port.
Obviously this Ethernet port would be mapped as ATA port by this RAID controller card.
Which means the MAC address will be mapped to IDE port address **(e.g. 00:0a:95:9d:68:16 → 0168-016F)**
This Ethernet port can be connected to a network hard disk or NAS through either of the below mentioned 3 methods.
Network cable (e.g. cat 5 cable) / Wi-Fi (using Access Points) / Fibre (using Ethernet to Fibre converters).

As per “Fig. 6” let’s say that the storage unit which is away from the system is connected through network or internet is called D4. This D4 is also parity disk but any one of the disk will work at a time either D3 or D4, they will be automatically switched as per the algorithm illustrated below (Fig 7) with the help of flow chart.

4.1 Explanation of working logic

Below displayed flow chart illustrates the working logic of the proposed architecture.

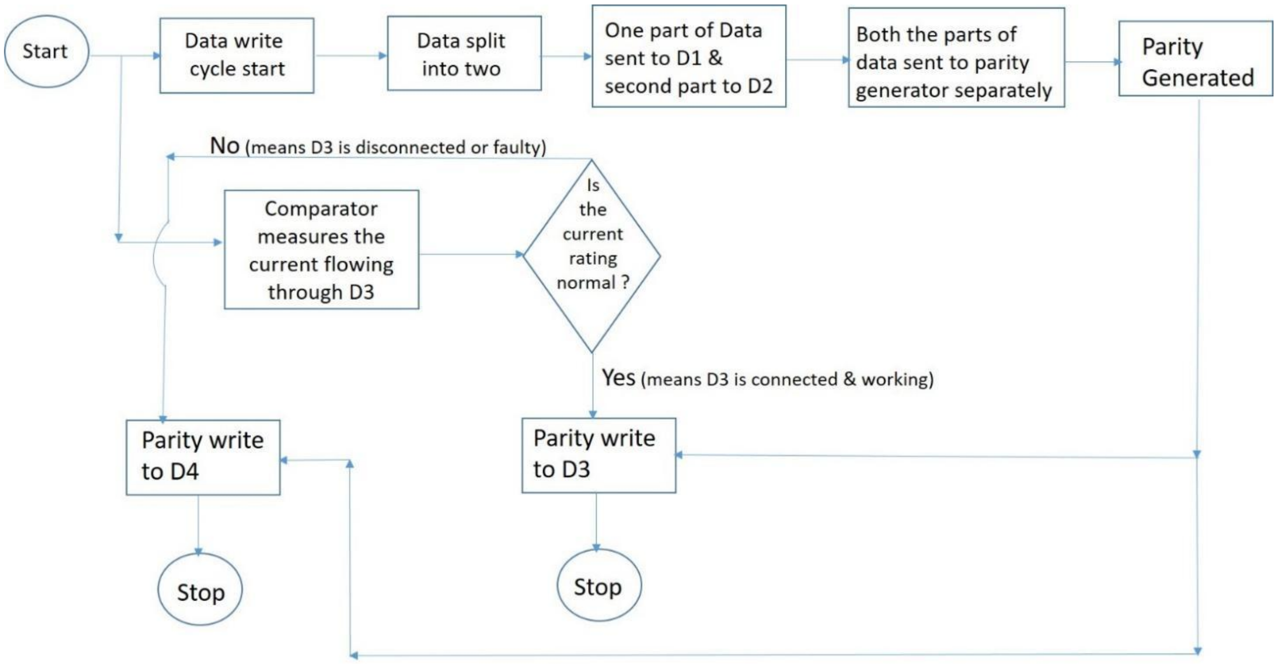


Figure 7. **Flow Chart**

Let’s write data to this RAID system and understand the working logic illustrated in figure 7.

4.1.1 Firstly the data will be divided into two parts. Where the first half will be written in D_1 and the other part will be written in D_2. Subsequently these two part of data will go to a parity generator circuit where parity data is generated. Parity data will go to a De-multiplexer (Not shown in flow chart to keep it simple). It is a 1:2 De-multiplexer.

4.1.2 One output of the DEMUX will be connected to the port where D_3 is connected (D_3 is local parity disk). Another output of the DEMUX will be connected to the Ethernet port present on the specially designed RAID Controller Card. Here D_4 is connected which is a cloud storage or NAS.

4.1.3 Whatever data comes to the input of this DEMUX, it will be sent to any one of the output depending upon status (Active/Inactive) of D_3. There will be a special comparator circuit present in this RAID Controller Card which will detect or compare the current flowing to the local parity disk called D_3. If D_3 is disconnected, current will become 0. If there is any fault in this hard disk, like short circuit then the current will be too high. Whenever Comparator detects the current flowing to D_3 is not in normal range, either very low (if the hard disk is disconnected) or very high (if there is a short circuit in the hard disk), at that moment the comparator will send a signal to the DEMUX to change the output port.

4.1.4 The input of the DEMUX that was getting the parity data and which was normally coming to D_3, will now go to Ethernet port and will be ultimately saved in D_4 which is our cloud storage or NAS and is actually connected to this Ethernet port. Only now the parity will be written to that NAS or Cloud storage instead of local parity disk D_3.

4.2 Architectural design of proposed RAID Controller Card

Below figure 8 is the schematic circuit diagram of proposed RAID Controller Card whose working principle is already explained above.

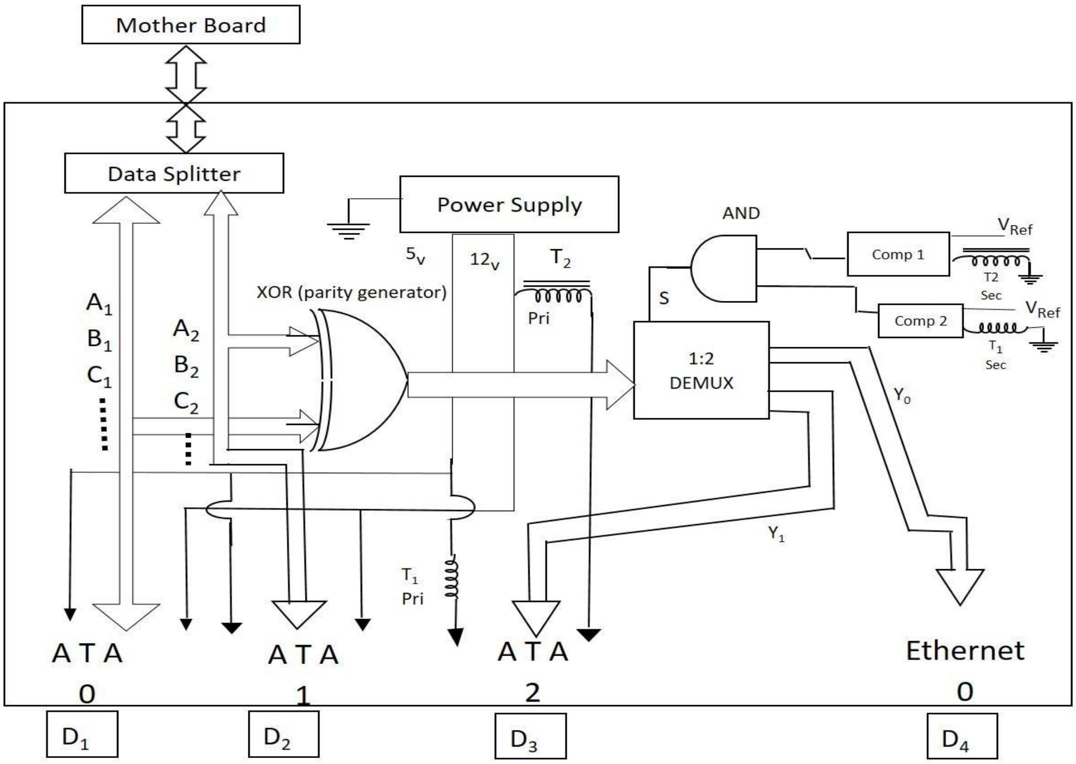


Figure 8. **Schematic diagram**

Below table 2 is the list of full forms of the abbreviations used in the above schematic diagram.

Sl. No.	Abbreviation	Full form
1	**RAID**	Redundant Array of Inexpensive/Independent Disks
2	**ATA**	Advanced Technology Attachment
3	**DeMux**	Demultiplexer
4	**XOR**	Exclusive OR
5	**T_1**	Transformer 1
6	**T_2**	Transformer 2
7	**Comp1**	Comparator 1
8	**Comp2**	Comparator 2
9	**AP**	Access Point
10	**NAS**	Network Attached Storage
11	**Pri**	Primary winding of transformer
12	**Sec**	Secondary winding of transformer
13	**V**	volts
14	**V_{ref}**	Reference Voltage
15	**AND**	AND gates

Table 2. Abbreviations used in the above diagram

4.3 Schematic circuit diagram

The below mentioned Schematic circuit diagram of the RAID controller card for Switched Parity is drawn with the help of EasyEDA simulator. As the circuit is large and complex, due to the limitation of simulator engine, while running simulation the circuit was divided into 2 parts.

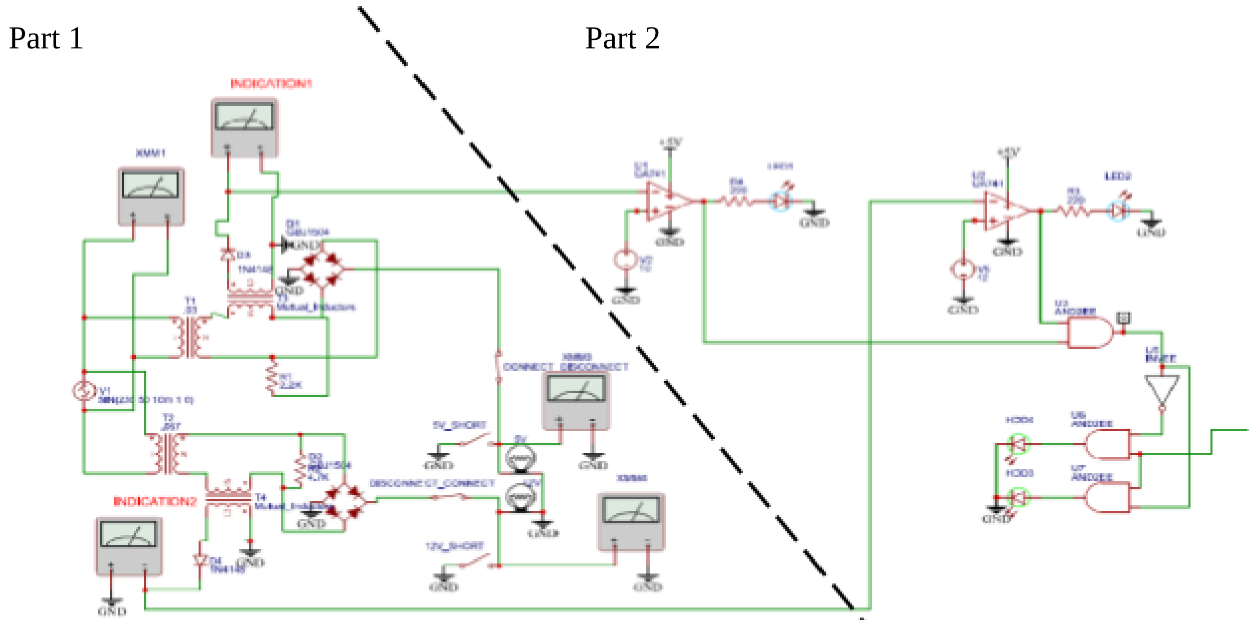


Figure 9. **Circuit diagram**

Below is table 3 showing scenario wise different output voltages with respect to part 1 circuit shown in figure 9.

Scenario	5 volt line (logic board of HDD)	12 volt line (Motor of HDD)	Indication 1 (will go to I/P of Comparator 2)	Indication 2 (will go to I/P of Comparator 1)	Remarks
1	CLOSE	CLOSE	14.1 V	23.4V	D3 is connected and working
2	OPEN	OPEN	7.7 uV	2.5uV	D3 is disconnected.D3 not working
3	SHORT	SHORT	66.2uV	23uV	Logic board & motor driver board of D3 are short circuited.D3 not working
4	OPEN	CLOSE	13.5nV	14uV	5 volt supply or logic board not working.D3 not working
5	CLOSE	OPEN	1.4mV	2.5uV	12 volt supply or motor driver board not working.D3 not working
6	CLOSE	SHORT	1.6uV	40.2uV	Logic board section OK but motor driver section short.D3 not working
7	SHORT	CLOSE	8.6mV	1.9mV	Logic board section short but motor driver section OK.D3 not working

Table 3. Scenario wise different o/p voltages of part 1 circuit

Below is table 4 showing scenario wise digital logics with respect to part 2 circuit shown in figure 9.

Scenario	Comparator 1 (12 volt circuit of HDD)	Comparator 2 (5 volt circuit of HDD)	AND gate Inputs	AND gate Output / Select line Input of DEMUX	Remarks
1	HIGH	HIGH	HIGH,HIGH	HIGH	Parity data is sent/written to D3
2	LOW	HIGH	LOW,HIGH	LOW	Parity data is sent/written to D4
3	HIGH	LOW	HIGH,LOW	LOW	Parity data is sent/written to D4
4	LOW	LOW	LOW,LOW	LOW	Parity data is sent/written to D4

Table 4. Scenario wise different logics of part 2 circuit

V. Results

When local parity disk (D3) is connected and working fine then the DEMULTIPLEXER is steering the parity bits to D3 and it is stored there. As soon as power (5volt & 12 volt) of D3 is cut off due to disconnection of the HDD or its current consumption is going beyond permissible range, the DEMULTIPLEXER diverts the parity bits to D4 assuming that there is a fault in D3. The RAID controller card designed by me is working as expected which is proved by EasyEDA simulator.

VI. Conclusion

The achievements of this research work can be concluded into the below mentioned bullet point.

- **Internet connection isn't required always**, it will only be required when the local parity disk fails and the auxiliary parity disk D4 is a cloud storage. In this situation parity bits will be sent to the cloud parity disk.
- As the parity is not written to both the disk (D3 & D4) simultaneously, hence **performance reduction will not be there when local disk D_3 is working fine**. Only in the case of fault when D_3 is not working then the parity will be written to the cloud or NAS. At that particular time only, performance will be compromised but not always.
- Since we are not mirroring the data to the network drive or internet (cloud), only parity is mirrored so, there will be **no risk on data privacy**. Even if the hacker hacks the parity it will be of no use as data can't be retrieved from only parity.
- **Efficiency of storage capacity** would be **50 %** and **fault tolerance** which it can handle would be of **2 disks** [one from the data disks (D1/D2) and another one from the parity disks (D3/D4).

VII.Limitations and Future Studies

A specially designed RAID controller card will be required and to make it operational a program needs to be written which will be used as the driver software of this card. Moreover 1 extra disk (D4) would be required to be kept active as a standby which will come into action immediately as soon as local parity disk (D3) fails. A driver software needs to be written to represent Ethernet port as virtual SATA port. More research has to be done to improve efficiency and fault tolerance.

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