Greatest Performance Hard Drive (G-Drive)

The Greatest Performance Hard Drive (**G-Drive**) is invented to provide the greatest performance for storage hard drives in real life systems with **RDMA** (**R**otation **D**ivision **M**ultiple **A**ccess) technology. The **Cloud-OS** was invented with the **RDMA technology** to allow each user has a chance to access their data on every rotation of the hard drive disk. This invention will introduce the new Hard Drive with new Geometry Disk Layout, dual CPUs, and dual Actuators with additional Writer Port to provide the Hard Drive with greatest write and read performance. The G-Drive will have three controllers; the main controller will communicate with the host and control the other two actuator controllers. The main controller will pass the host read and modify commands to Actuator-1 controller, and pass the host write commands to Actuator-2 controller. The Actuator-1 controller will handle the read/modify commands from host. The Actuator-2 controller will handle host write commands data to the outer SMR temporary zones (25% outer LBAs), then both controllers will manage and organize the data to their target locations when they have a chance. This will improve the random operations performance close to the sequential operations. Each actuator controller has its own CPU to control its Actuator for Servo heads and arms moments. The G-Drive will have additional LED flashing at a fix position with a Photo Sensor to track and count every rotation of the disk. This LED feature will help the Servo Controller to seek to a specific location, Sector, Track or Zone faster and more accurate. The G-Drive disk will be divided into **36 clove Rotational Zones**, and the data disk space will be divided into **16 Radius Zones** within the Data Radius with the same space from each other. This 16 Radius Zones create **16 Circular Tracks**; these tracks will be the **Radius Sector Info Tracks**. With this Geometry Disk Layout and the LED at 0° degree of the disk, the G-Drive will perform greatest seeking to any location, sector or LBA faster and more accurate than the current hard drive technology. The G-Drive will write data LBA outward direction opposite with the current hard drive technology. The LBA outward direction orientation will provide the OS easier to organize the system files, system data and the user data.

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Existing Hard Drive Layout and Issues

Figure-1 below shows the current hard drive with 64 clove zones and with the common ID, MD and OD zones. The current hard drive has boot sectors at inner cylinders and start LBA zero is at the outer most cylinders. The LBA is written inward direction which is harder for the OS to manage the system files, system data and the user data. The current hard drive with a single CPU cannot achieve the busy system and low performance on random operations. In reality, most systems do read and write data randomly at any location on the disk.

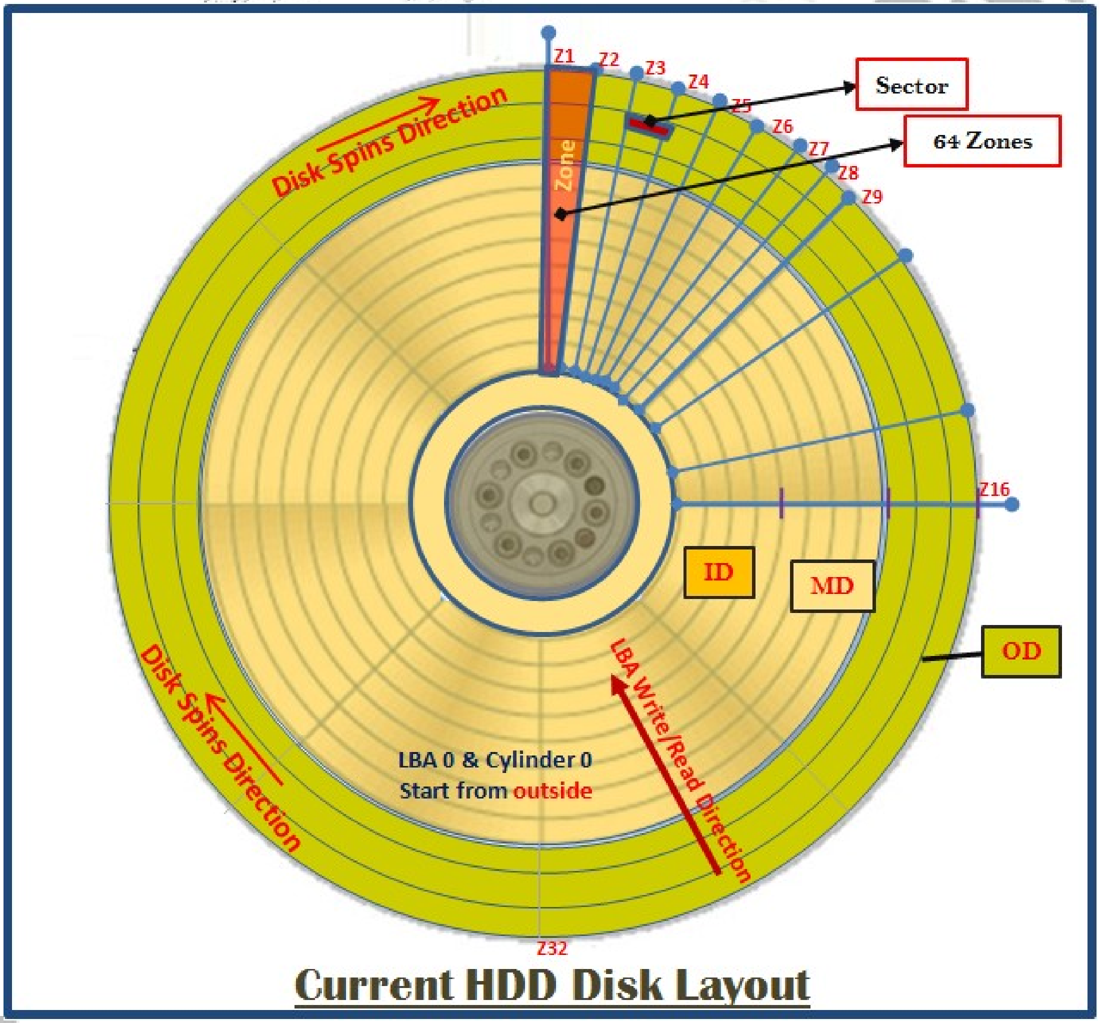

Figure-1: Current HDD Disk Layout

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The G-Drive Layout

Figure-2 shows the disk layout of the new G-Drive. Each platter or disk will be divided with **75% target data LBAs** at the inner cylinders and **25% SMR or temporary LBAs** at the outer cylinders. LBAs will be written outward direction, and LBA zero is started from inside. The G-Drive disk will be divided into **36 clove Rotational Zones**, and the data radius of disk space will be divided into **16 Radius Zones** within the data radius with the same space from each other. These Radius Zones are called the **RaZones**. The 36 Rotational Zones are divided by 10° degree each within 360° degree circle. These 36 Rotational Zones will create total of 36 radius starts with Radius 1 (**R1**) at **0°** degree, Radius 2 (**R2**) at **10°** degree, Radius 3 (**R3**) at **20°** degree, etc... The clove Rotational Zone is called the **RoZone**. The RoZone between 0° degree and 10° degree is called RoZone-1; RoZone between 10° degree and 20° degree is called RoZone-2, RoZone between 20° degree and 30° degree is called RoZone-3, etc… The 16 Radius Zones create 16 Circular Tracks; these tracks will be the Radius Sector Info Tracks (**RaSector Info Track**). The Radius Sector Info Track will contain info record and lifetime counters of its Radius Sectors. The LBAs on the radius that associate with Radius Sector will contain Radius Sector info for each sector within its Radius Sector. With the division of 36 RoZones and 16 RaZones, the G-Drive will have **16 Radius Sectors per RoZone** and **total of 576 Radius Sectors**. The Radius Sector is called the **RaSector**. The LED will be at 0° degree Radius (R1).

Figure-3 shows more details of the disk layout of the new G-Drive in a quart-section disk. With this Geometry Disk Layout and the LED at 0° degree of the disk, the G-Drive will perform greatest seeking to any location, sector or LBA faster and more accurate than the current hard drive technology. The G-Drive will have multiple disks, multiple heads and the same cylinders layout as the current hard drive technology.

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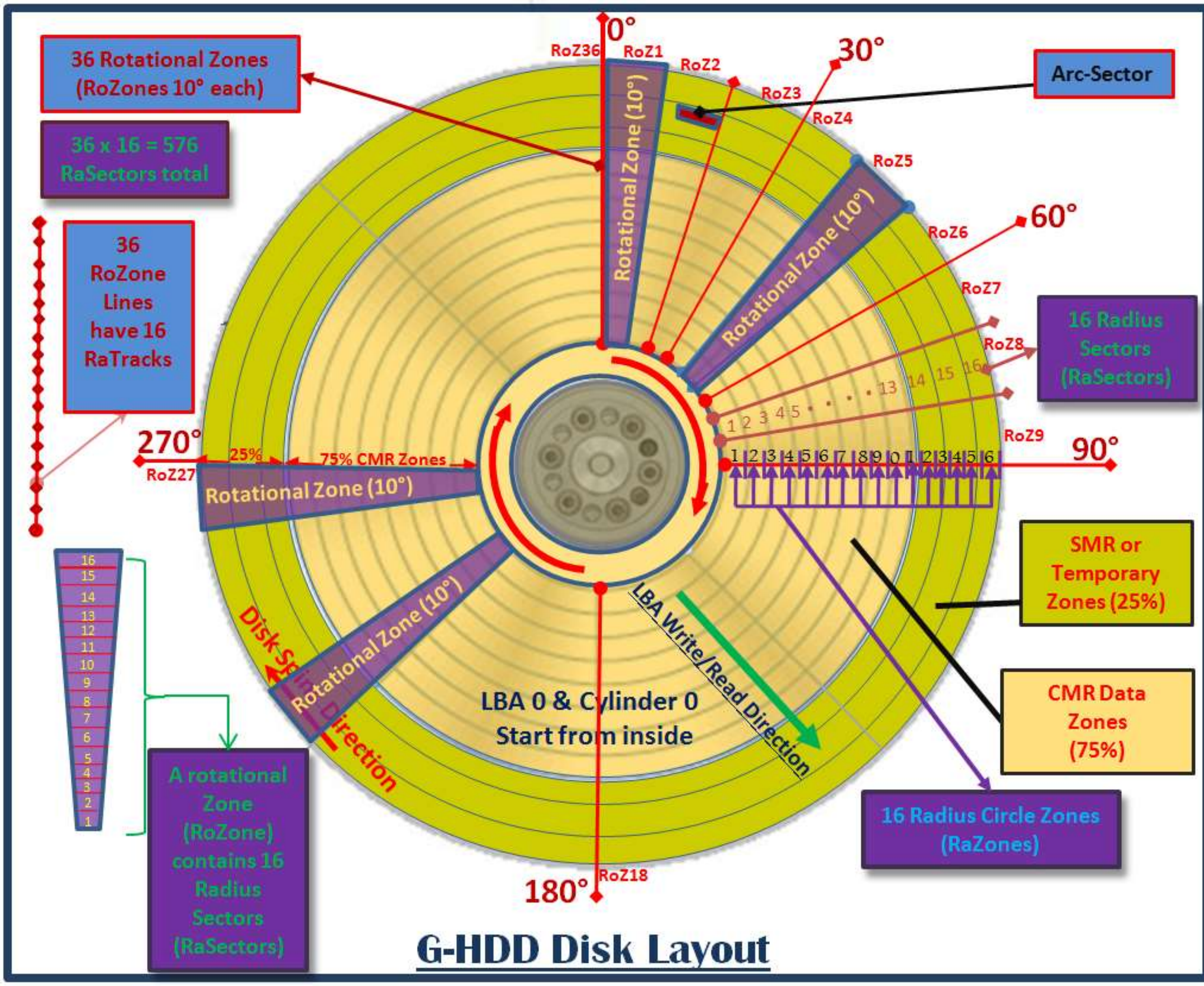

Figure-2: The G-Drive Full Disk Layout

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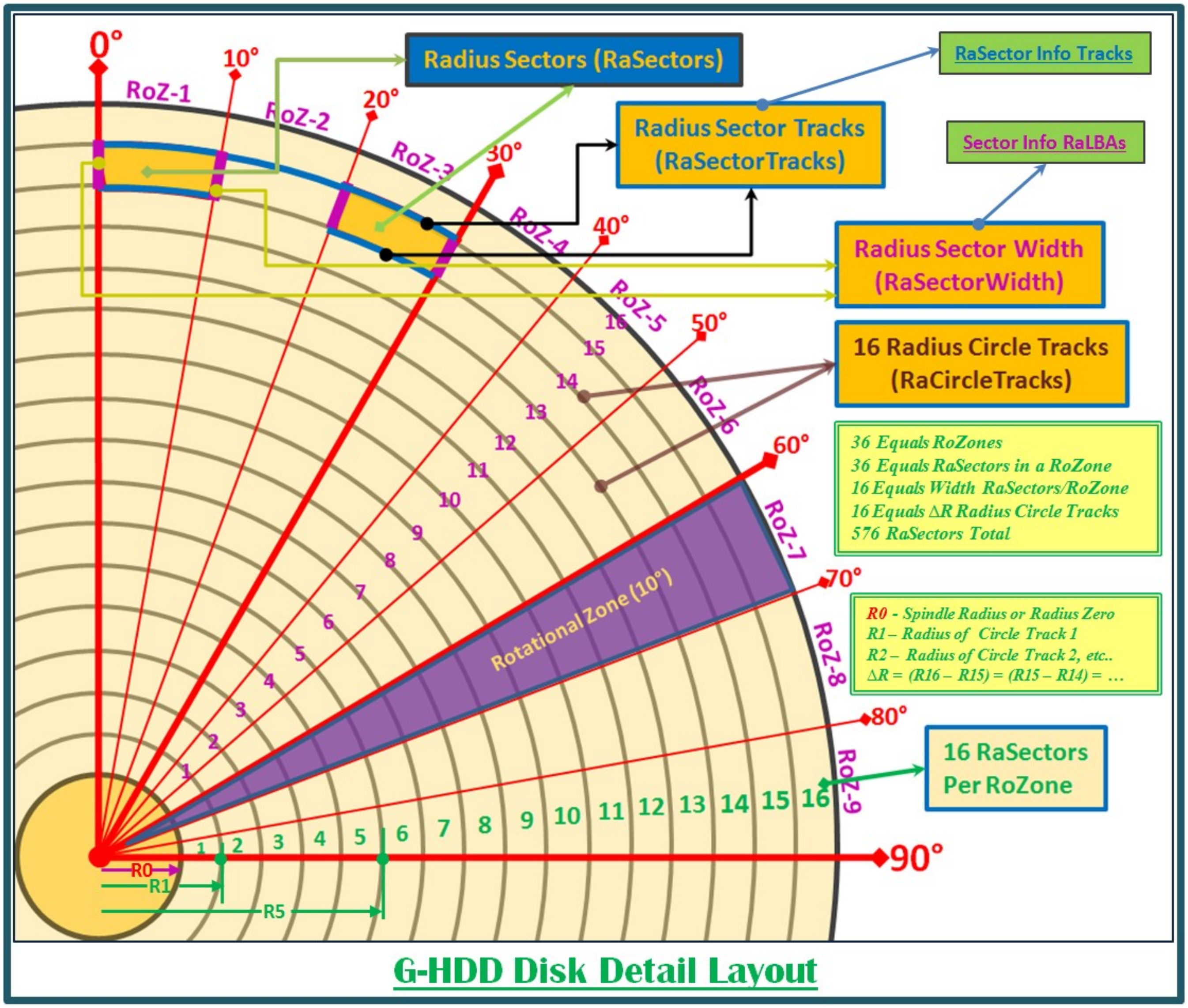

Figure-3: The G-Drive Quart-Section Disk Layout

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Table-1 below shows Radius Sectors dimensions on each Rotational Zone with an assumption of a hard drive with 3.5 inches disk radius and 0.5 inch spindle radius. Radius zero, R0 = 0.5 inch (1.27 cm). R16 = 3.5 inches (8.89 cm). The delta space between each Radius Circular Tracks is (8.89 cm – 1.27 cm)/16 = 0.47625 cm. So, R1 = 1.74625 cm, R2 = 2.2225 cm, R3 = 2.6988 cm, etc… **The drive has 36 RoZones, 16 RaZones, and total of 576 RaSectors**. This Geometry Disk Layout will help Servo Controller track and seek easier.

RoZone Info (Assume Disk Radius 3.5 inches [8.89 cmd] with 0.5 inches [1.27 cm] Spindle Radius)			
RaSector No.	Radius (cm)	RaSector Area (cm^2)	RaSector Track Length (cm)
1	1.74630	0.1250	0.30480
2	2.22250	0.1650	0.38790
3	2.69880	0.2040	0.47100
4	3.17500	0.2440	0.60250
5	3.65120	0.2830	0.63730
6	4.12750	0.3240	0.72040
7	4.60375	0.3630	0.80350
8	5.08000	0.3760	0.88660
9	5.55625	0.4680	0.96980
10	6.03250	0.4820	1.05290
11	6.50875	0.5210	1.13600
12	6.98500	0.5610	1.21910
13	7.46125	0.6000	1.30220
14	7.93750	0.6400	1.38540
15	8.41375	0.6800	1.46850
16	8.89000	0.7190	1.55160
Total Area of Data Disk Space = 36 * 6.755 cm^2 ~= 243 cm^2			

Table-1: The G-Drive Geometry RaSectors Calculation

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G-Drive High Level Hardware Design

Figure-4 shows the high level hardware design of the G-Drive. The system has three controllers with two CPUs. The main HDD Controller will handle input and output commands from the host then pass the read/modify commands to the **Host Command Read/Modify Controller**, and pass the write commands to **Host Command Write Controller** via Dual Port RAM which shared memory and registers for these controllers. The Read/Modify Controller will take the read/modify commands from the main controller, and mark command registers with completed when finished the commands. The Write Controller will take the write commands from the main controller, and mark command registers with completed when finished the write commands. Then the main HDD controller will notify and responds to the host when the Read/Modify Controller and Write Controller trigger command complete notifiers. With additional [optional] Writer Port, the G-Drive can able to support additional independent data recording port with only write commands. The Actuator-1 will be controlled by Servo Controller of the CPU-1, and Actuator-2 will be controlled by Servo Controller of the CPU-2. The data on Write/Read channels can be processed when the Servo Controller seeks on target location. The CPU and Controller on each side handle their own interrupts to control the Actuator and Write/Read channel on their side. Each side has their own Flash to store drive Smart Attributes and Lifetime Counters, and the data can be synchronized when the system is free or with background activity process. The Smart Attributes and Lifetime Counters can be calculated and synchronized with the **RaSector Info Tracks** and **Sector Info RaLBAs**.

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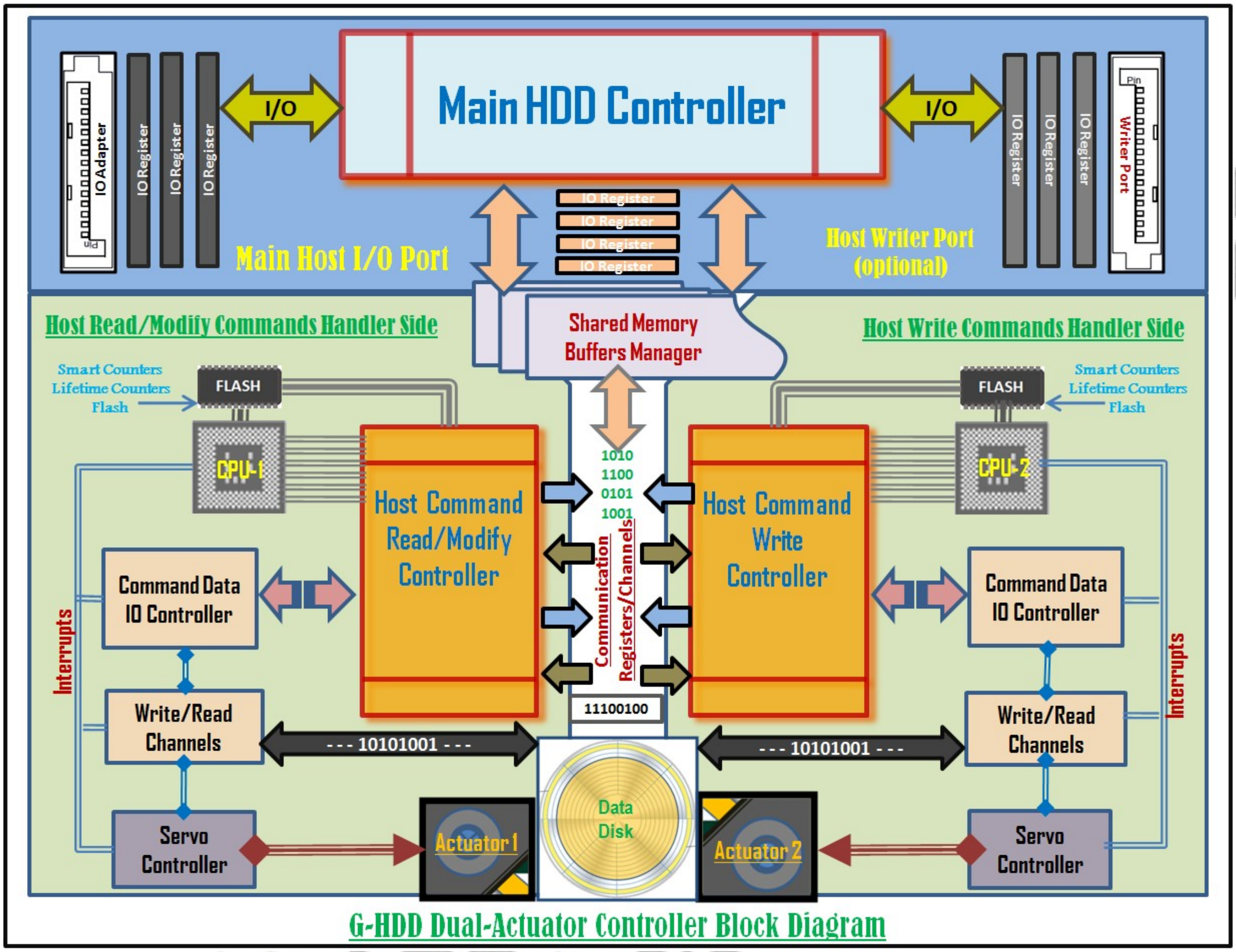

Figure-4: G-Drive Hardware Block Diagram

G-Drive Main Process

Figure-5 shows the main process of the G-Drive. Actuator-1 Controller process host Read/Modify commands directly from/to target disk LBAs. Actuator-2 Controller handles host Write commands; the controller write data to the SMR or temporary zones. When the system is free, Actuator-2 Controller performs read from the beginning of the SMR temporary zones and pass data to the Actuator-1 Controller to handle write data to the target locations. When one of the Actuator Controller is free, this controller will read and re-organize the data from temporary zones to target locations.

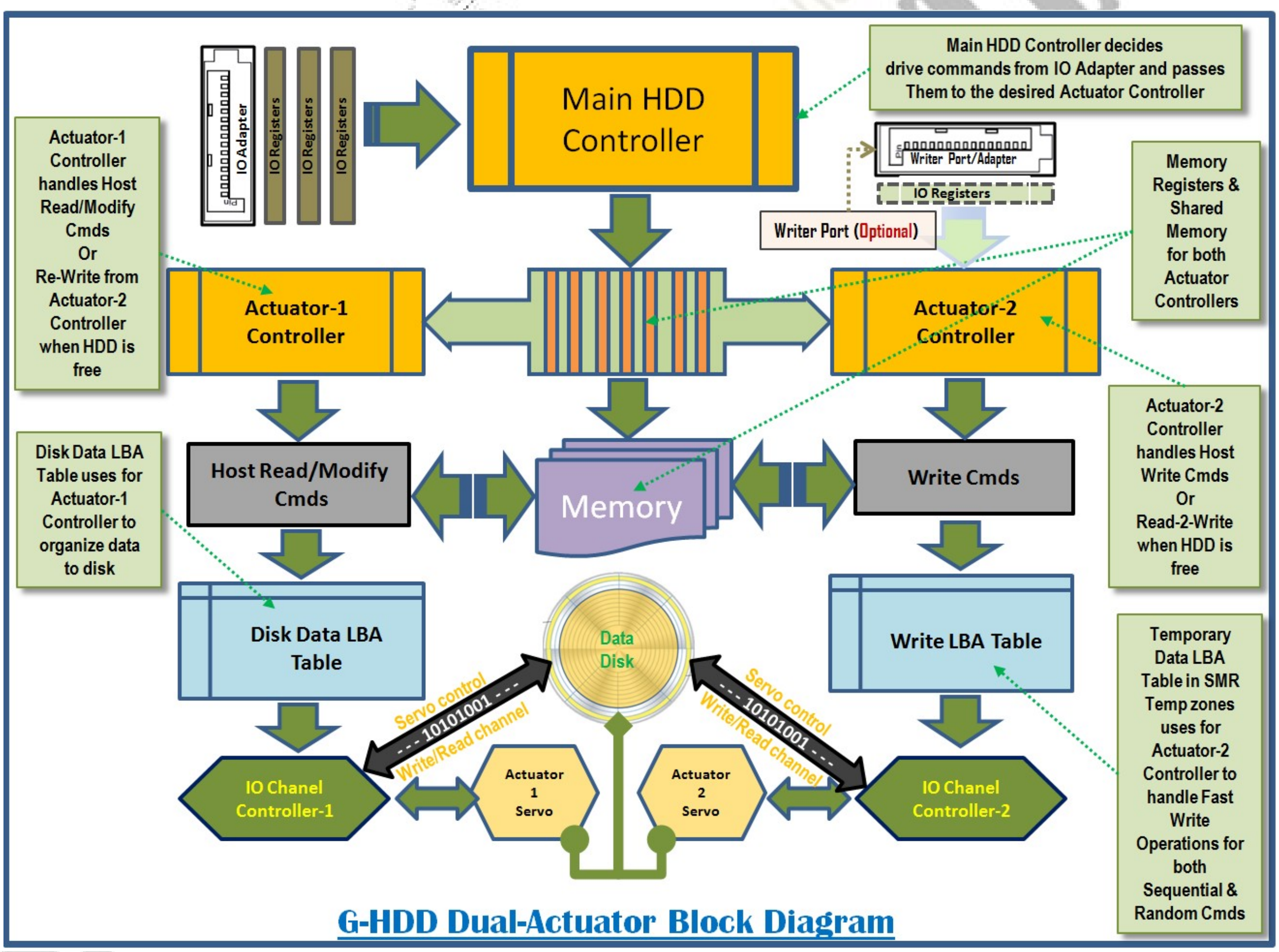

Figure-5: G-Drive Process Block Diagram

G-Drive Process Flow Details

Figure-6 shows **four scenarios of the process flow of the G-Drive**. First, both A1C and A2C controllers are busy. Second, A1C controller is busy with host Read/Modify commands while A2C controller is free from host. Third, A2C controller is busy with host Write commands while A1C controller is free from host. Four, both A1C and A2C controllers are free from host commands.

1. **Both A1C and A2C controllers are busy:**
   When both controllers are busy processing commands from host, A1C controller will handle host Read/Modify commands directly to the target LBAs, and A2C controller will handle Write commands to the SMR temporary zones.
2. **A1C controller is busy and A2C controller is free from host:**
   When A1C controller is busy and A2C controller is free from host, A1C controller handles host Read/Modify commands directly to the target LBAs. A2C controller has no host commands to process; then this controller will read the beginning written data in SMR temporary zones to their target disk LBAs and reset or empty SMR zones that have been moved and go to next data in SMR temporary zones. This process will be repeated until no more data in SMR temporary zones or interrupts trigger from the main controller to tell this controller to process new incoming Write commands from host.
3. **A1C controller is free from host and A2C controller is busy:**
   When A1C controller is free from host and A2C controller is busy processing Write commands from host. A2C controller handles host Write commands to the SMR temporary zones. A1C controller has no host commands to process; then this controller will read the beginning written data in SMR temporary zones by A2C controller to their target disk LBAs and reset or empty SMR zones that have been moved and go to next data in SMR temporary zones. This process will be repeated until no more data in SMR temporary zones or interrupts trigger from the main controller to tell this controller to process new incoming Read/Modify commands from host.

4. **A1C and A2C controllers are free from host:**
When both A1C and A2C controllers are free from the host, then both controllers will synchronize with each others to move the temporary data that have been written in SMR temporary zones to their target disk LBAs. When this scenario happens, A2C controller starts reading the beginning data in SMR temporary zones and passes the data to A1C controller and let the A1C controller write the data to their target disk LBAs. By passing read data from A2C controller to A1C controller to handle data migrating to their target disk LBAs is to minimize the tracks seek process for both Actuators. This process repeats until no more data in SMR temporary zones or interrupts trigger from the main controller to tell either one of these controllers to handle its responsible host commands.

Note that SMR temporary zones is occupied 25% of the disk and target data CMR zones is 75% of the disk. However, the SMR temporary zones can be CMR zones but the temporary zones is used for fast Sequential Write performance and this could be replaced by other recording technology media. The random Write operations will be written in sequential in the temporary zones for greatest hard drive performance. When the disk is full up to 75% or more, the main HDD controller will divide the remainder of available LBAs by half; and the 50% of the available LBAs is used for temporary zones for A2C Controller for Write commands.

For greatest performance of the G-Drive, **new additional drive commands are introduced in this patent** as shown in **Reference-1** on last page. These **new Modify Sector commands** are allow the Cloud-OS able to modify data directly to the disk LBAs or sectors without caching or writing to temporary zones. This feature is useful when there is big data file on the disk, and it is needed to modify just some blocks or update partial data of the file.

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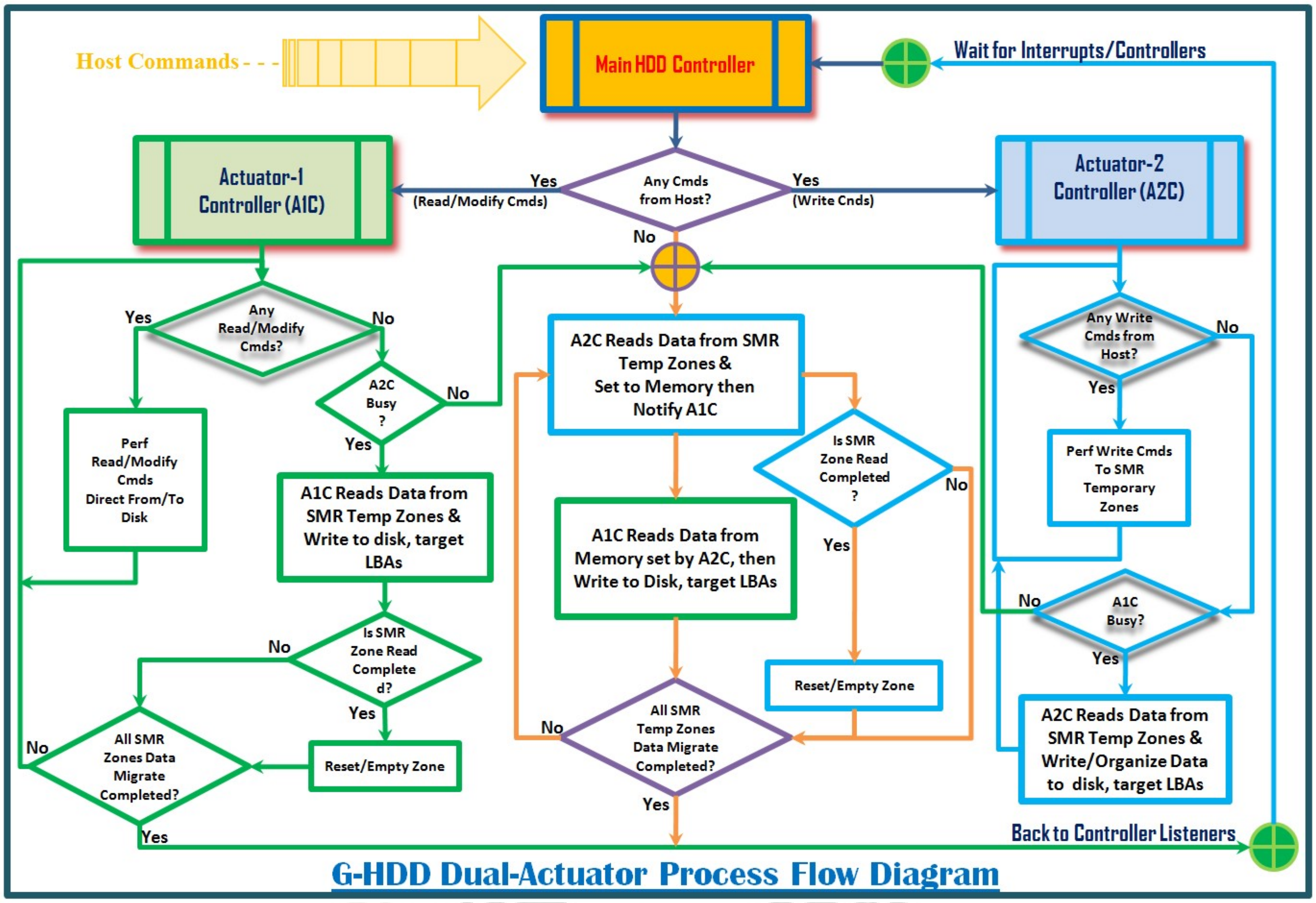

Figure-6: G-Drive Process Flow Diagram

G-Drive Sample LBA Division and Zones Mapping

Table-2 shows the LBA range divisions of a sample 1TB hard drive with 4 disks. Each disk has total of 488374272 (75%) target data LBAs and 122093568 (25%) temporary LBAs with zone length of 0x2000 hex LBAs.

1TB G-Drive	Total LBAs	CMR LBAs (75%)	SMR Temp LBAs (25%)	Zone Length
Disk1 (Head1)	488374272	366280704	122093568	2000h
Disk2 (Head2)	488374272	366280704	122093568	2000h
Disk3 (Head3)	488374272	366280704	122093568	2000h
Disk4 (Head4)	488374272	366280704	122093568	2000h
Entire Disk	1953497088	1465122816	488374272	

Table-2: 1TB of G-Drive with 4 Disks LBAs Division

Table-3 below shows the LBAs mapping on each disk. Disk-1 has inner start data LBA = 0x00h, and temporary zones start LBA = 0x15D50000h. Disk-2 has inner start data LBA = 0x1D1C0000h, and temporary zones start LBA = 0x32F10000h. Disk-3 has inner start data LBA = 0x3A380000h, and temporary zones start LBA = 0x500D0000h. And disk-4 has inner start data LBA = 0x57540000h, and temporary zones LBA = 0x6D290000h.

1TB G-Drive	Total LBAs	Start CMR LBA	Start SMR Temp LBA	Zone Length
Disk1 (Head1)	488374272	0 (00h)	366280704 (15D50000h)	2000h
Disk2 (Head2)	488374272	488374272 (1D1C0000h)	854654976 (32F10000h)	2000h
Disk3 (Head3)	488374272	976748544 (3A380000h)	1343029248 (500D0000h)	2000h
Disk4 (Head4)	488374272	1465122816 (57540000h)	1831403520 (6D290000h)	2000h

Table-3: 1TB of G-Drive with 4 Disks LBAs Mapping

G-Drive Host Write Operations

1. Host Sequential Write Operations:

Table-4 shows a sample sequence of 5 sequential commands. The table on the left shows the host commands sequences with LBAs from 0x00h to 0xA00h (0x600h + 0x400h blocks) and the table on the right shows the commands written into SMR Temporary Zones with LBAs from 0x15D50000h to 0x15D50600h. Table-5 below shows the Write LBAs Connection Map of these 5 commands sequences. This table shows all 5 commands in sequences with total of 2560 blocks with continues target disk LBAs from 0x0h to 0xA00h. With this LBAs Connection Mapping, the controllers can move and reorganize data to their target locations for LBAs 0x00h to 0xA00h can be just in one Write command for performance optimization to target data LBA (0x00h) with block of 2560.

Host SEQ Write Operation		
Cmd No.	Write LBA	Blocks
1	0 (00000000h)	512 (200h)
2	512 (00000200h)	512 (200h)
3	1024 (00000400h)	256 (100h)
4	1280 (00000500h)	256 (100h)
5	1536 (00000600h)	1024 (400h)
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SEQ Write Operation (Temporary)	
Write SMR LBA	Blocks
15D50000h	512 (200h)
15D50200h	512 (200h)
15D50400h	256 (100h)
15D50500h	256 (100h)
15D50600h	1024 (400h)
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Sequential Write Cmds From Host → Write Sequentially to Temp SMR Zones

Table-4: 1TB of G-Drive during Host Sequential Write Operations

SEQ-2-SEQ Write LBA Connection Map			
Write SMR LBA	Disk CMR LBA	Blocks	Cmds Sequence
15D50000h	0 (00000000h)	2560 (A00h)	1,2,3,4,5
15D50A00h	2560 (00000A00h)		

Table-5: 1TB of G-Drive during Host SEQ Write Operations LBA Connection Map

2. Host Random Write Operations:

Table-6 shows a sample sequence of 5 random Write commands. The left one show the host random Write commands and these commands will be written sequentially into the SMR Temporary zones start at LBA 0x15D50000h to 0x15D50800h. Table-8 below shows these random commands in LBAs Connection Map with the order command sequences of 3, 5, 1, 4, and 2. This connects all these 5 commands with start target LBA from 0x00h to 0xA00h with total 2560 blocks. Table-7 shows the second round of another 5 random (6, 7, 8, 9, and 10) commands sequence. These commands are combined to have 2 different LBA ranges start from 0xB00h to 0xE00h of 2 commands (8 and 6), and another start from 0x2000h to 0x2700h of 3 commands (7, 10, and 9). Table-8 below shows these random commands in LBAs Connection Map with the order of target command LBA sequences. With this LBAs Connection Mapping, the controllers can move and reorganize data to their target locations for LBAs 0x00h to 0xA00h can be just in one Write command, LBAs 0xB00h to 0xE00h can be just in another Write command, and LBAs 0x2000h to 0x2700h can be just in one or two Write commands (depends on available data buffer size) for greatest performance optimization of the G-Drive.

Host RND Write Operation		
Cmd No.	Write LBA	Blocks
1	1024 (00000400h)	256 (100h)
2	1536 (00000600h)	1024 (400h)
3	0 (00000000h)	512 (200h)
4	1280 (00000500h)	256 (100h)
5	512 (00000200h)	512 (200h)
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SEQ Write Operation (Temporary)	
Write SMR LBA	Blocks
15D50000h	256 (100h)
15D50100h	1024 (400h)
15D50500h	512 (200h)
15D50700h	256 (100h)
15D50800h	512 (200h)
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Random Write Cmds From Host → Write Sequentially to Temp SMR Zones

Table-6: 1TB of G-Drive during Host Random Write Operations (Round-1)

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Host RND Write Operation (2nd Round)		
Cmd No.	Write LBA	Blocks
6	3328 (00000D00h)	256 (100h)
7	8192 (00002000h)	1024 (400h)
8	2816 (00000B00h)	512 (200h)
9	9728 (00002600h)	256 (100h)
10	9216 (00002400h)	512 (200h)
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SEQ Write Operation (Temporary)	
Write SMR LBA	Blocks
15D50A00h	256 (100h)
15D50B00h	1024 (400h)
15D50F00h	512 (200h)
15D51100h	256 (100h)
15D51200h	512 (200h)
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RND Write Cmds From Host → Write Sequentially to Temp SMR Zones

Table-7: 1TB of G-Drive during Host Random Write Operations (Round-2)

RND-2-SEQ Write LBA Connection Map			
Write SMR LBA	Disk CMR LBA	Blocks	Cmds Sequence
15D50000h	0 (00000000h)	2560 (A00h)	3,5,1,4,2
15D50A00h	2560 (00000A00h)		
15D50A00h	2816 (00000B00h)	768 (300h)	8,6
15D50D00h	3584 (00000E00h)		
15D50D00h	8192 (00002000h)	1792 (700h)	7,10,9
15D51400h	9984 (00002700h)		

Table-8: 1TB of G-Drive during Host RND Write Operations LBA Connection Map

G-Drive Dual Actuator Layout

Figure-7 shows a sample of Dual Actuator layout of the G-Drive of 2 CPUs.

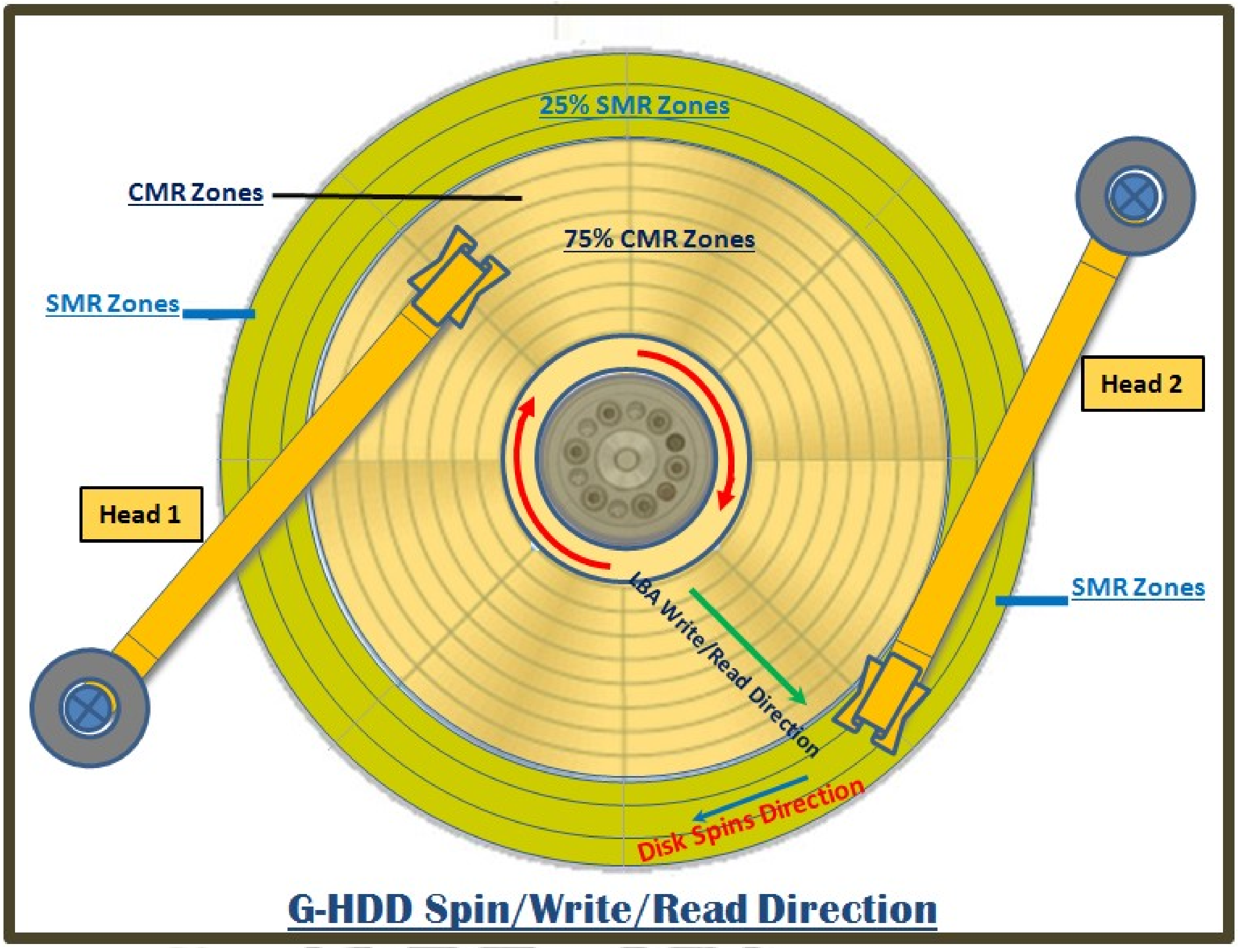

Figure-7: G-HDD Dual-Actuator Layout

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G-Drive RPM/Servo Tracking LED Sensor

Figure-8 shows a sample of the LED with a photo sensor. The LED is attached to the disk spindle at the disk Radius-0 at 0° degree (R0). The LED will flash when rotate to the photo Sensor at a fix point (**0° degree Position**) of the drive, and the controllers will be notified the R0 is passing by the 0° Degree Position. This feature will help the Servo controllers to monitor, track, and seek a Write/Read head to the specific location on the disk. With combination of the disk Geometry, the G-Drive controllers can use RPS (Rotation Positioning System) technique to calculate and locate a specific LBA or Zone with a list of RaZones that the head flies over while seeking inward or outward by the RPM of the disk and the speed of the head and actuators motion.

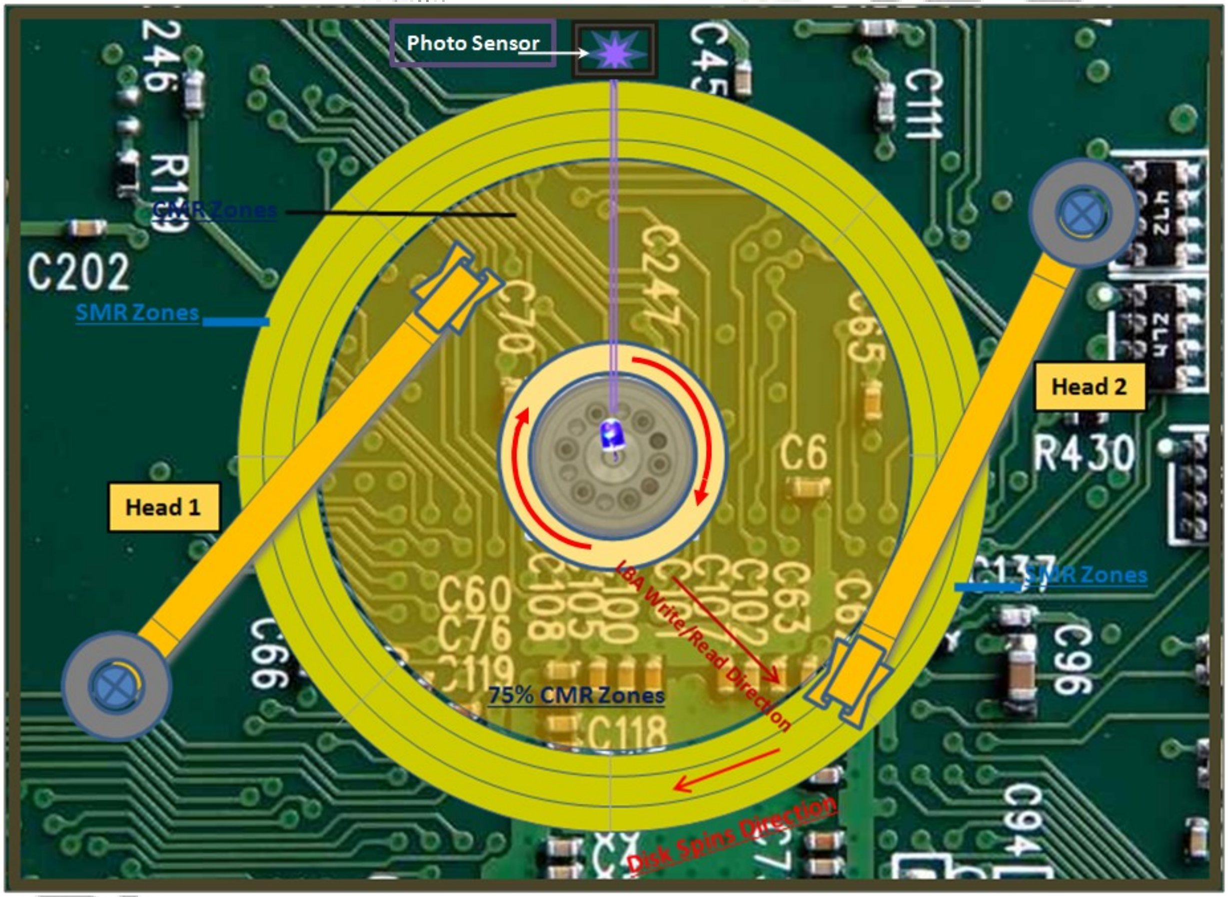

Figure-8: G-Drive RPM/Servo Tracking LED-Photo or Laser Sensor

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G-Drive Components and Actuator Layout

Figure-9 shows a sample G-Drive components and Actuators layout.

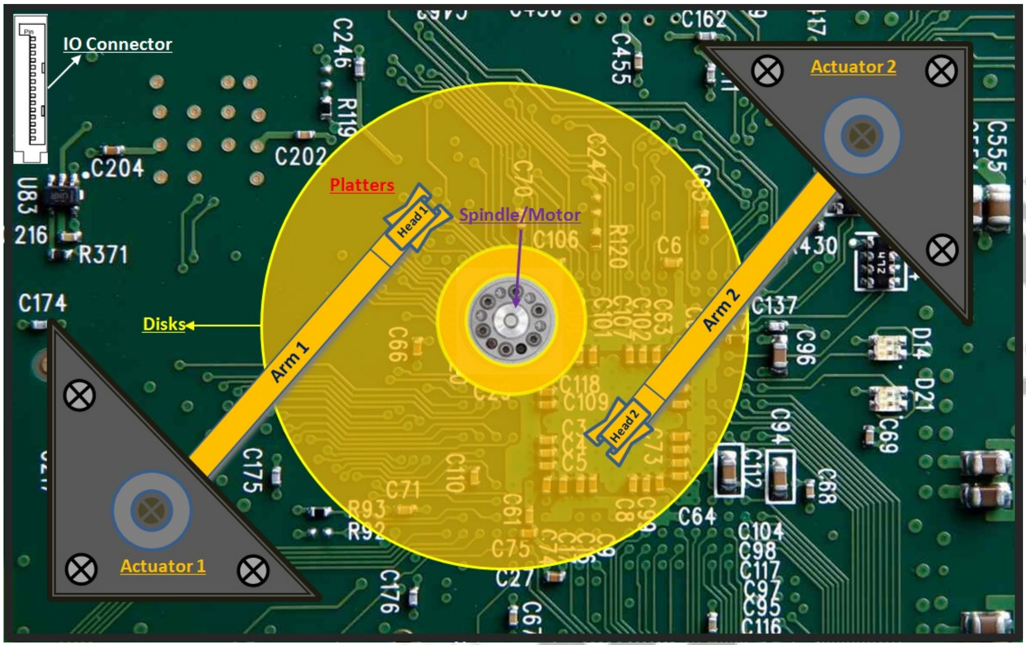

Figure-9: G-Drive Components/Actuators Layout

G-Drive 3.5 Inches Open Cover Sample

Figure-10 shows a sample 3.5 inches G-Drive open cover sample.

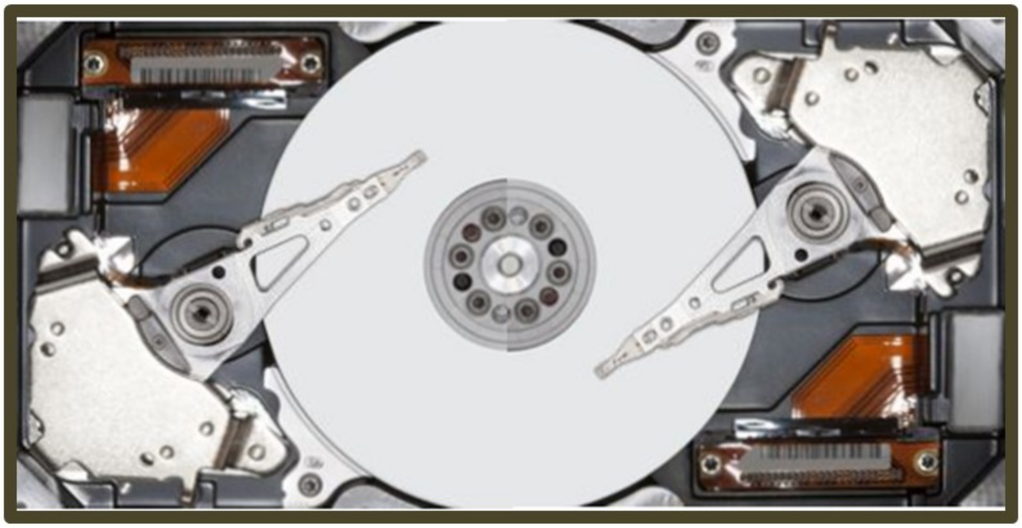

Figure-10: G-Drive 3.5 inches Open Cover Sample

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Conclusion

The patent **G-Drive** – Greatest Performance Hard Drive is designed with **State-of-the-Art Geometry** of 360° degree Disk Layout in combination of LED Radius at 0° degree detection will be a **big promise for the future storage disk hard drive**. The **Cloud-OS** was invented with the **RDMA technology** to allow each user has a chance to access their data on every rotation of the hard drive disk. This patent will be a great improvement for Data Center with Cloud-OS supports. The G-Drive will provide the fastest data recording for video systems and great for flying object recorders, like aircrafts recording while flying at low altitude. The G-Drive is a perfect hard drive for the Cloud-OS computer systems. With this perfect computer system, the world will have great Data Center with fast data storage and great Cloud-OS network; this will bring the world to the next level of computing infrastructure. This is a big promise for the future of our younger generations. Our younger generations will use these as the great tools to invent beyond what we have today.

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References

- void writeSectors(int cylinder, int head, int sector, int blocks, Buffer data);
- void writeSectors(long lba, int blocks, Buffer data);
- void writeSectorsExtended(long lba, int blocks, Buffer data);
- void readSectors(int cylinder, int head, int sector, int blocks, Buffer data);
- void readSectors(long lba, int blocks, Buffer data);
- void readSectorsExtended(long lba, int blocks, Buffer data);
- void modifySectors(int cylinder, int head, int sector, int blocks, Buffer data);
- void modifySectors(long lba, int blocks, Buffer data);
- void modifySectorsExtended(long lba, int blocks, Buffer data);

Reference-1: Introduce new Modify Sectors commands to support Write to direct target LBAs