

# MK3001GRRB 2.5-inch Hard Disk Drive for Enterprise Use with 300 Gbyte Capacity and 15,000 rpm Rotational Speed

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Hard disk drives (HDDs) for enterprise use are primary storage devices installed in mission-critical information systems such as servers and storage systems. In this field, HDDs must be able to provide high reliability for long-term continuous workloads (24 hours a day, seven days a week), as well as high performance including a high data transfer rate and high-speed access. Low power consumption has also become essential in recent years.

In response to the needs of the market, Toshiba has developed the MK3001GRRB 2.5-inch HDD for enterprise use with a capacity of 300 Gbyte and a rotational speed of 15,000 rpm. The MK3001GRRB achieves a high data transfer rate of 200 Mbit/s, a fast average seek time of 2.7 ms, and low power consumption of 4.0 W in idle state.

## 1. Introduction

As cloud computing becomes increasingly popular, transaction processing that is faster than ever before is being demanded of servers and storage systems to store and manage various types of information. As the main storage device in mission-critical information processing systems, enterprise-class HDDs are required to have high performance (e.g., high data transfer rates and high-speed access) in addition to high reliability (to realize continuous operation for extended periods of time).

(1) High reliability  
High reliability is required to ensure continuous operation (24 hours a day, 7 days a week) for five years.

(2) High performance  
High data transfer rates and high-speed access are essential for processing large amounts of data within a short period of time.

In addition, the recent promotion of energy conservation and green products has led to requirements for low-power consumption storage device.

In response to these requests, Toshiba developed the MK3001GRRB 2.5-inch HDD. This product achieves high performance and high reliability with 15,000 rpm rotational speed, while delivering low power consumption.

## 2. Drive Overview

**Table 1** shows the brief specifications of the MK3001GRRB 2.5-inch HDD. The drive has a rotation speed of 15,000 rpm and a storage capacity of 300 GB;

**Table 1** Main specifications of MK3001GRRB 2.5-inch HDD for enterprise use

Item	Specifications	
	MK3001GRRB	MK1401GRRB
Interface	SAS 2.0	
Interface speed (Gbit/s)	6	
Storage capacity (GB)	300	147
Disks (QTY)	2	1
Heads (QTY)	4 (Embedded HDI sensor)	2 (Embedded HDI sensor)
Power consumption (W)	Idle mode	4.0
	Low-RPM idle mode	3.0
Rotation speed (rpm)	15,000	
Sustained data trans. rate (MB/s)	147-200	
Avg. seek time (during read) (ms)	2.7	
MTBF (10 <sup>6</sup> h)	1.6	

MTBF: Mean Time between Failures HDI: Head Disk Interface

enabling up to 200 MB/s sustained data transfer rates. Also, it enables high-speed data access with an average seek time of 2.7 ms. Further, it achieves low power consumption, consuming only 4.0 W while in idle mode. For the interface, we employed SAS 2.0 (Serial Attached SCSI [Small Computer System Interface] 2.0), which is the mainstream HDD interface for enterprise use.

In addition to the MK3001GRRB (storage capacity: 300 GB), we have the MK1401GRRB (storage capacity: 147 GB) and encrypting models such as the MK3001GRRR and the MK1401GRRR in the lineup. The basic specifications are listed in Table 1.

In the following sections, we describe the hardware and firmware technologies that we developed to enable both high reliability and high performance.

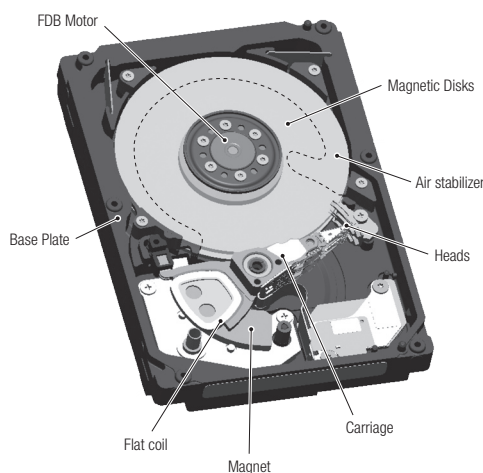
### 3. Hardware Technologies

**Figure 1** shows the drive's internal structure. The mechanical dimensions are compatible with SFF-8201/8223, the industry standard for 2.5-inch HDDs. Although drives for mobile PCs are thin as 9.5 mm thick, this drive is 15 mm thick to have a highly rigid base plate and top cover for high-speed rotation. Through computer aided engineering (CAE) using finite element method (FEM) analysis, we have optimized its mechanical architecture to enable high performance, low acoustic noise, and low power consumption.

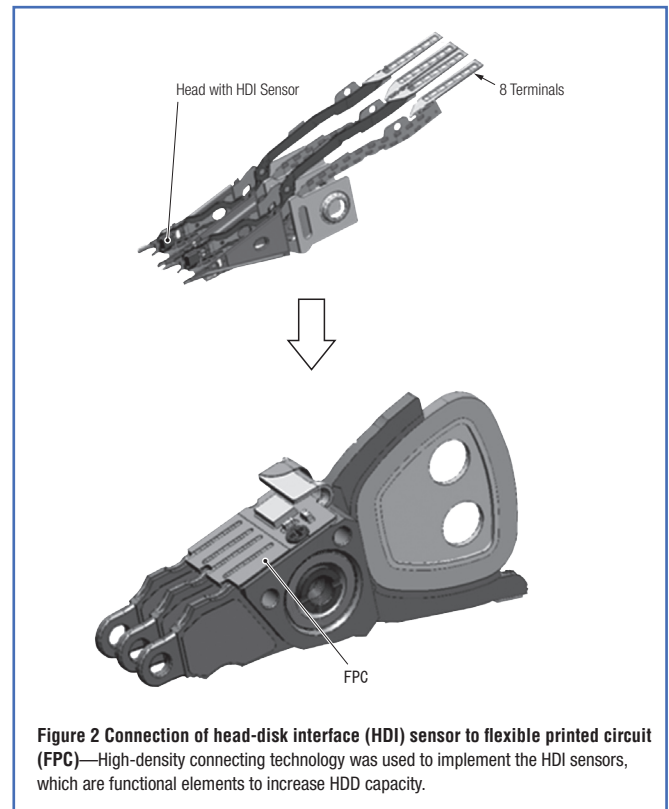
We use fluid dynamic bearings (FDB) motor for their low vibration and acoustic noise properties. Bearings are the most critical mechanical component; they decisively influence HDD operating life and reliability. For this reason, the bearing design we use is the same as field-proven conventional bearings. We used glass substrate disks with an outer diameter of 57 mm and a plate thickness of 1.27 mm. An air stabilizer is placed between magnetic disks as indicated by the dotted line in Figure 1. This air stabilizer, which covers 3/4 of the disk periphery, is able to reduce the disk vibration and windage generated by such high-speed disk rotation. Lower vibration and windage is able to reduce positioning errors (disturbance force) during the positioning control of the head over the target track.

Within the disk enclosure of MK3001GRRB (with a storage capacity of 300 GB), four heads are mounted on a carriage. The carriage is in turn mounted on a base via a pair of small-sized ball bearings. The carriage is actuated by a voice coil motor (VCM), which includes a flat coil and magnets.

To achieve a storage capacity of 300 GB, the heads include a newly developed head disk interface (HDI) sensor



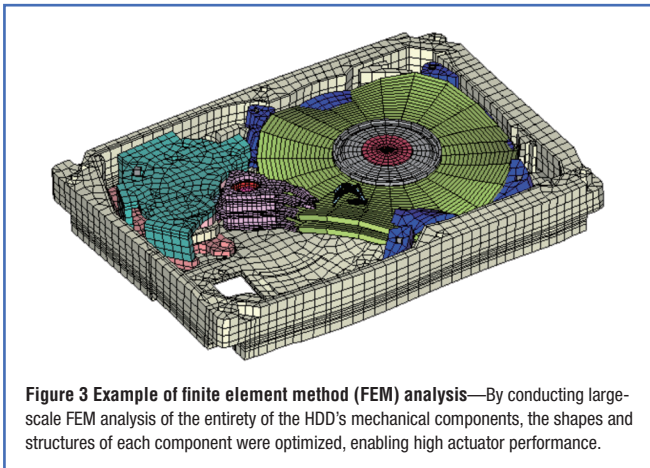
**Figure 1** Internal structure of MK3001GRRB—High reliability, high performance, low acoustic noise, and low power consumption were achieved by optimizing the design of the HDD's mechanical components.



**Figure 2** Connection of head-disk interface (HDI) sensor to flexible printed circuit (FPC)—High-density connecting technology was used to implement the HDI sensors, which are functional elements to increase HDD capacity.

which responds to subtle heat fluctuations between the head and disk, between which there is a very small clearance. In recent years, HDDs have included heaters which are embedded in the heads' read/write elements. By controlling heater power, the clearances between read/write elements and magnetic disk surfaces can be finely controlled, thereby achieving a high recording density. The HDI sensor is a functional element for controlling clearance accurately. When mounting the HDI sensor, as each head has a total of eight terminals—the existing six terminals for read, write, and heater plus two additional terminals—these terminals must be connected to the flexible printed circuit (FPC) with high precision. **Figure 2** shows a schematic drawing in which heads with HDI sensors are attached to the FPC, which is in turn mounted on the carriage.

To enable high speed seeking (average = 2.7 ms), it is important to design a high-performance actuator with both a powerful VCM and a lightweight and vibration-proof carriage. When designing the VCM, we ensured high efficiency by optimizing shapes and materials through magnetic field analyses. For the carriage design, we conducted a large-scale FEM analysis (**Figure 3**) for the entire piece of hardware and optimized the shapes and structures of the mechanical components to prevent undesirable vibrations and improve the damping of vibrations, particularly those caused by large VCM forces during the acceleration or deceleration of the carriage.



**Figure 3 Example of finite element method (FEM) analysis**—By conducting large-scale FEM analysis of the entirety of the HDD's mechanical components, the shapes and structures of each component were optimized, enabling high actuator performance.

## 4. Firmware Technologies

The drive's firmware consists of the following two function structures.

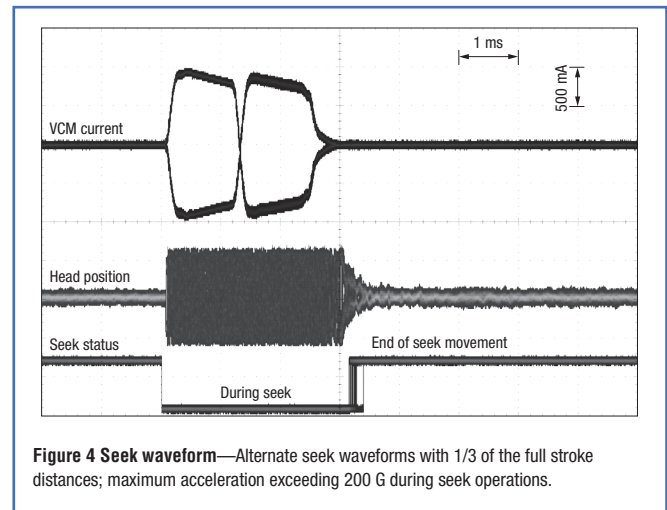
- (1) Servo control functions  
Controls the FDB motor, the VCM for head positioning and seeking, etc.
- (2) Controller firmware functions  
Controls the interface that handles commands from the host as well as the interfaces with the servo control and cache control functions.

### 4.1. Servo control functions

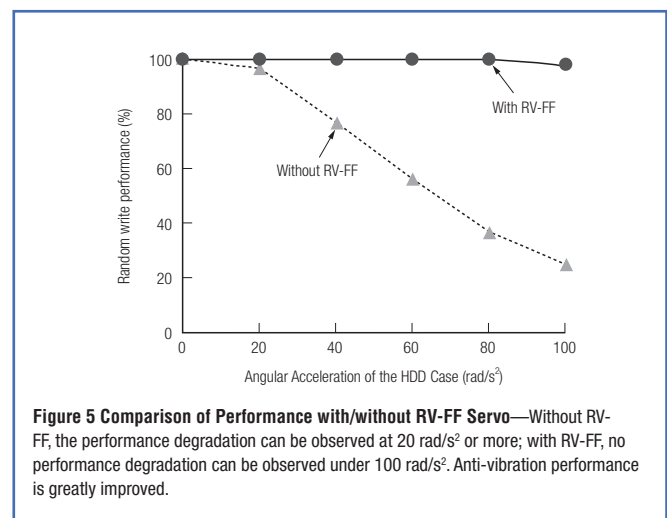
The drive achieves an average seek time of 2.7 ms. The drive accelerates and decelerates the carriage with a maximum acceleration exceeding 200 G; its maximum speed reaches 3 m/s. After such rapid acceleration and deceleration movements, the drive must quickly and stably follow the target track. Although the width of one track is only approximately 90 nm, the heads must be positioned exactly above the center of the tracks. For this reason, we had to significantly improve the servo feedback control loop gain. We also optimized the current waveforms during seeking by taking into consideration the resonance frequency of the actuator in order to reduce residual vibrations and carriage acoustic noise (**Figure 4**).

As part of our efforts to realize the above, we also increased the sampling frequency of the servo controller, used faster processors, and optimized servo controller loop shapes.

Enterprise class HDDs use require consideration of not only the vibrations inside HDDs but also the influence of external vibrations. In servers and storage systems, multiple built-in HDDs as well as the cooling fans may cause vibrations. To suppress the performance degradation caused by such vibrations, we used rotational vibration feed forward (RV-FF) technology to improve the above-mentioned actuator feedback control. We



**Figure 4 Seek waveform**—Alternate seek waveforms with 1/3 of the full stroke distances; maximum acceleration exceeding 200 G during seek operations.



**Figure 5 Comparison of Performance with/without RV-FF Servo**—Without RV-FF, the performance degradation can be observed at 20 rad/s<sup>2</sup> or more; with RV-FF, no performance degradation can be observed under 100 rad/s<sup>2</sup>. Anti-vibration performance is greatly improved.

also expanded the RV-FF frequency band. These two improvements contributed to a significant improvement for the external vibration stress (**Figure 5**).

We can also reduce power consumption by powering down circuits individually and reducing the rotation speed of the disks that are not carrying out read/write operations after the drive carries out seek movements or while it is in an idle state. We also optimized the FDB spin-up control, head loading and unloading controls, and reduced acoustic noise.

By adopting such technologies, we enabled high performance, low power consumption, and low acoustic noise.

### 4.2. Controller firmware functions

This drive is compatible with the SAS 2.0 industry standard and enables an interface speed of up to 6 Gbits/s.

The following sections describe the drive's maintainability and high reliability as well as its high functionality, high performance, and low power consumption.

#### 4.2.1. Maintainability and high reliability

The drive has a self-monitoring analysis reporting technology (SMART) function, which warns of critical HDD failures in advance, to realize a full-fledged implementation of a logging function for detailed failure analysis. The drive also has a self-test function, a self-diagnostic function which allows the status of the HDD to be diagnosed if the system requires it.

End-to-end data protection (an error detection function executed upon any component failure) and a disk-surface-defect avoidance function ensure data reliability at all times. Furthermore, the following processes are executed in the background, which may improve reliability during continuous long-term operation.

- (1) Background media scan (BMS) function  
Performs a full scan of the data area at regular intervals to detect recoverable errors in advance and automatically recover them.
- (2) System area (SA) saving function  
Improves the log function by periodically saving system information on the HDD into the SA, which is isolated from the user-accessible areas.

#### 4.2.2. High functionality, high performance, and low power consumption

We optimized and improved the following three basic HDD functions.

- (1) Reordering function  
Executes command processing in the shortest possible period of time by optimizing the execution order of received commands (up to 128 commands).

- (2) Data queuing function  
Reduces processing time by executing the write operations of several commands together after storing write data in the cache area.
- (3) Cache function  
Temporarily holds data to be read or written to/from magnetic disks, improve command responses, and optimizes processing in response to various access forms from the host.

By expanding the data buffer capacity from 16 MB of the previous model to 32 MB, we improved cache hit rates and realized high performance.

Furthermore, we realized both high performance and low power consumption by introducing a multi-level automatic power saving algorithm and command-driven forcible power saving as power saving functions.

An optional self-encryption drive (SED) function, which allows the HDD itself to internally encrypt data, and a data integrity field (DIF) function, which allows data protection to be controlled at the system level, are supported.

## 5. Conclusion

We developed a high-performance 2.5-inch enterprise class HDD with a rotation speed of 15,000 rpm and an average seek time of 2.7 ms. During development, we employed new technologies for the mechanical components, servo control section, and controller firmware section to enable high reliability and high performance. Going forward, Toshiba will continue to push forward with the development of HDDs for the enterprise market featuring both higher performance and higher quality.



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