1 Tbyte Recording Capacity 2.5-inch HDD with 7 mm Height Form Factor for Mobile Notebook PCs

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In the notebook PC market, hard disk drives (HDDs) with a large storage capacity are required for the recording and reproduction of large-volume contents including high-definition videos, while also satisfying mobile performance requirements.
In response to this market demand, Toshiba has developed the MQ02ABF100 2.5-inch HDD, which achieves the largest class capacity of 1 Tbyte in the market for HDDs with a 7 mm height form factor [*1]. Through the application of newly developed technologies such as a thinner platform specialized for a dual-platter mechanism, as well as a dual-stage actuator (DSA) introduced for the first time in Toshiba's 2.5-inch HDDs, the MQ02ABF100 realizes a balance between large capacity and high reliability including enhanced vibration and shock resistance.

1. Introduction

In the notebook PC market, the need for thin and lightweight PCs with outstanding mobile performance is increasing rapidly. At the same time, high-capacity storage is required to record and play back high-definition videos and other high-volume content.
To meet these market needs, Toshiba has released the MQ02ABF100 2.5-inch HDD that provides a storage capacity of 1 Tbyte, the industry's highest-class capacity with 7-mm thickness.
This article provides an overview of the MQ02ABF100 as well as the new technologies that have been developed to realize the combination of high capacity and high reliability.

2. Product highlights

Table 1 shows the key specifications of the MQ02ABF100 2.5-inch HDD designed for notebook PC applications.
In order to achieve a capacity of 1 Tbyte, the new HDD incorporates two high-density magnetic disk platters in a 7 mm thick casing. This is realized by the application of newly developed technologies such as a thinner platform and a thinner spindle motor. These technologies provide the ideal solution for HDDs targeting state-of-the-art notebook PCs and allow for an even higher storage capacity than Toshiba's 500-Gbyte predecessor in the 2.5-inch, 7 mm-thick form factor, the MQ01ABF050.

Table 1 Main specifications of the 2.5-inch MQ02ABF100 HDD for notebook PCs

Characteristics		Spec
Capacity		1 Tbyte
Number of platters		2
Number of read/write heads		4
Average seek time		12 ms
Interface		Serial ATA 3.0/ATA-8
Data transfer rate		6.0 Gbits/s
Rotational speed		5,400 rpm
Buffer capacity		16 MiB
External dimensions		69.85 (W) × 100.0 (D) × 7.0 (H) mm
Weight		99 g (max)
Acoustic noise	Idle	22 dB
	Seek	23 dB
Vibration resistance	Operating	9.8 m/s^2 (1 G, 5 to 500 Hz)
	Non-operating	49 m/s^2 (5 G, 15 to 500 Hz)
Shock resistance	Operating	3,430 m/s^2 (350 G, 2-ms sine wave)
	Non-operating	8,820m/s^2 (900 G, 2-ms sine wave)

ATA: Advanced Technology Attachment MiB: mebibyte = 2^{20} bytes

3. New platform design

3.1 Mechanism design

Two disk platters and four read/write heads are housed in the MQ02ABF100, whose casing is just 7 mm thick, whereas its predecessor, the MQ01ABF050, has only one platter and two read/write heads in the same form factor. Because a thin base and thin actuators are less rigid, the key is maintaining the shock resistance required by 2.5-inch HDDs for notebook PCs.
In order to achieve this, computer-aided engineering (CAE) technology was utilized to perform stress analysis using the finite element method (FEM). Consequently, the mechanical design of the HDD has been optimized, making it possible to pack two platters and four read/write heads into the casing without compromising shock resistance (Figure 1).
Figure 2 compares the cross-sections of the actuator and platter structures of the new and conventional HDDs. As shown in this figure, the thicknesses of the actuator arms, platters, printed circuit board (PCB) and other components have been reduced in order to fit them into the HDD casing. Table 2 shows the reduction in height of major components compared to the predecessor model. Furthermore, the MQ02ABF100 uses a new thinner spindle motor to achieve thickness reduction.
An FEM-based shock analysis was performed on the new actuator and disk structure (Figure 3) in order to optimize

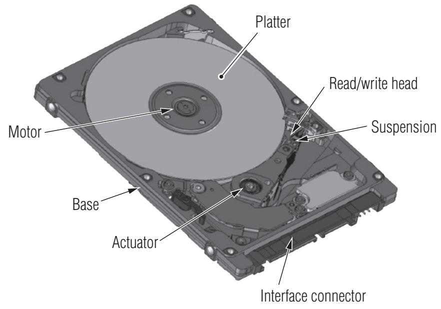

Figure 1 Internal structure of MQ02ABF100 —
The MQ02ABF100 provides a capacity of 1 Tbyte in a 7 mm-thick casing by using a newly developed thin platform, a thin spindle motor, and a base optimally shaped through shock analysis.

the base shape and thereby minimize the wobbling of disk platters due to shocks and vibrations. Figure 4 shows the optimized base shape and PCB layout. The MQ02ABF100 includes the following improvements over its predecessor in order to reduce its thickness:

(1) he interface connector has been moved to the opposite side, compared to the predecessor.
(2) The PCB footprint has been reduced by approximately 57% as described in the next section.
(3) The thickness of the base beneath the disk platters has been increased to secure shock resistance.

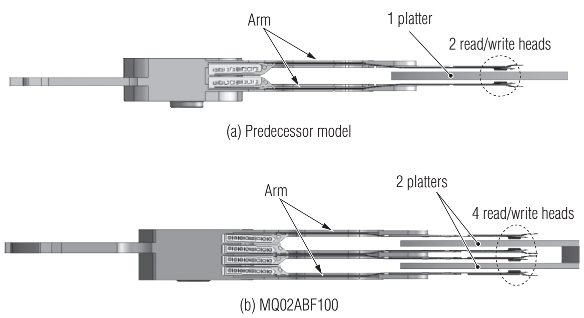

Figure 2 Comparison of structure and disk of conventional model and MQ02ABF100 —
A casing with a thickness of 7 mm contains two platters and four read/write heads because of the reduction in thickness of the actuator arms and platters.

Table 1 Security standards for self-encrypting drives (SEDs)

Main component	Reduction over predecessor model
Platter thickness	-21 %
Platter spacing	-9 %
Arm thickness	-8 %
PCB thickness	-17 %
IC mounting height on PCB	-40 %

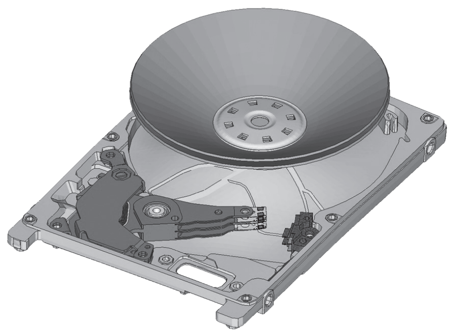

Figure 3 Example of result of shock analysis using finite element model —
An FEM-based shock analysis was performed to optimize the base shape and thereby minimize the wobbling of disk platters due to shock application.

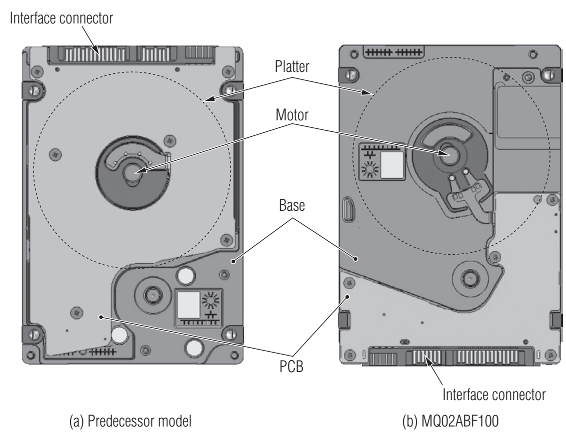

Figure 4 Comparison of base shape of predecessor model and base shape optimized for MQ02ABF100 —
The interface connector was placed on the opposite side, compared with its position in its predecessor model, and the PCB size was reduced. The empty space was used to place a thicker base below platters in order to improve shock resistance.

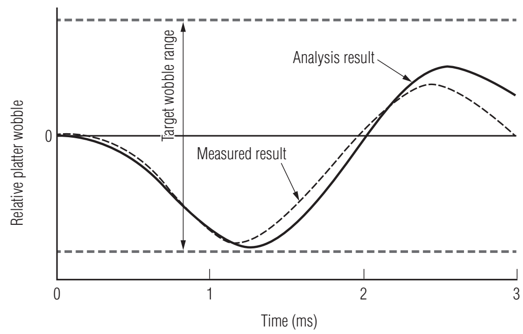

Figure 5 Result of analysis and measured data of disk amplitude when shock applied —
It was confirmed that the new HDD satisfies the target platter wobbles and that the analysis results approximately match the measured data.

Figure 5 compares the simulated and measured platter wobbles caused by a physical shock. It shows that the new structure satisfies the shock resistance requirement. Furthermore, the simulated curve tracks the measured curve fairly well, demonstrating the validity of an FEM-based design.

3.2 PCB design

The PCB has been designed as follows to achieve an approximately 57% reduction in footprint size (as shown in Figure 4) and a 40% reduction in the IC mounting height.

(1) Reduction in the part count by developing a system-on-a-chip (SoC) with an embedded DRAM
(2) Use of a Land Grid Array (LGA) to increase the number of pins in a unit area and thereby reduce the size of the main IC
(3) Selection of low-profile capacitors, resistors and other discrete electric components
(4) Use of a multi-layered PCB to improve trace routing flexibility

Consequently, the PCB size has been reduced by approximately 57%, compared to that of the predecessor model (Figure 6). The maximum height of the components that populate the PCB has also been reduced by approximately 40%.

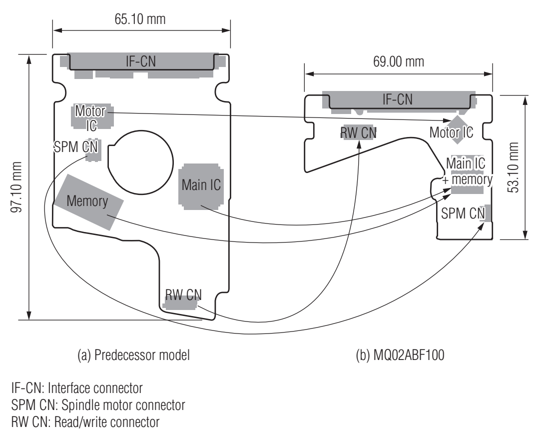

Figure 6 Reduction of printed circuit board —
The PCB footprint was reduced by approximately 57% over that of the conventional model.

Early in the development cycle, there was a concern that a reduction in usable PCB area would decrease layout flexibility, restricting the capacitor placement as well as the width of and spacing between ground traces, and thus cause an electromagnetic interference (EMI) problem. In order to prevent any EMI problem, the result of an S-parameter analysis[*2] was used in creating a PCB layout.

3.3 Improvement of the positioning accuracy of read/write heads

As described previously, the thickness of disk platters has been reduced in order to stack two platters vertically to improve storage density. However, as a result, the rotational vibration of the platters increased, making it difficult to maintain their positioning accuracy.

To address this problem, the newly developed HDD uses a dual-stage actuator (DSA) in addition to a voice coil motor (VCM). While the VCM moves the entire actuator assembly, the DSA accurately positions the head element over the correct data track using piezoelectric elements placed in the vicinity of the read/write head (Figure 7). The MQ02ABF100 is the first 2.5-inch HDD for notebook PCs to use a DSA.

The DSA has two piezoelectric elements attached to the suspension's base plate. When voltage is applied to the DSA, the piezoelectric elements expand and contract either in the same or opposite phases. This action displaces the head element at the tip of the actuator in the direction of data tracks. Since the DSA only needs to move a load beam section at the tip of the actuator, the moving mass is small and light, making it possible to increase its vibrational resonant frequency. This allowed Toshiba to increase

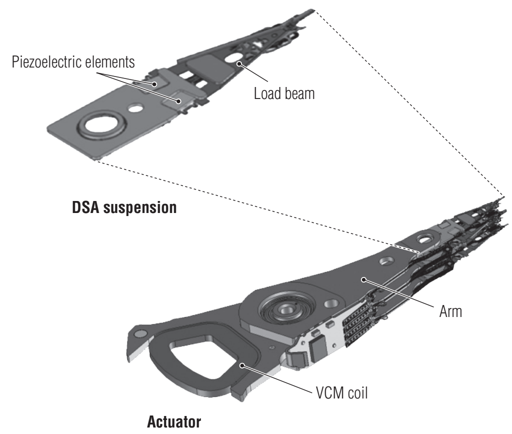

Figure 7 Newly developed actuator with DSA suspension —
The PCB footprint was reduced by approximately 57% over that of the conventional model.

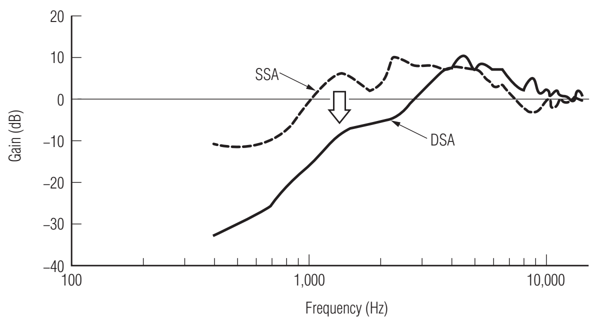

Figure 8 Comparison of servo compression characteristics of single-stage actuator (SSA) and DSA —
At 2 kHz and below, the DSA provides over 10 dB better servo compression performance than an SSA.

servo bandwidth and thus improve the servo compression performance in the low-frequency region (below 2 kHz) by over10 dB compared to the predecessor HDD using a VCM-based single-stage actuator (SSA) (Figure 8).
The higher servo bandwidth resulted in a reduction in the head positioning error due to platter vibrations, primarily at frequencies below 2 kHz. As shown in Figure 9, the DSA has approximately 40% less positioning error than the conventional SSA. Consequently, the new HDD provides higher storage density than its predecessor on a smaller magnetic disk.

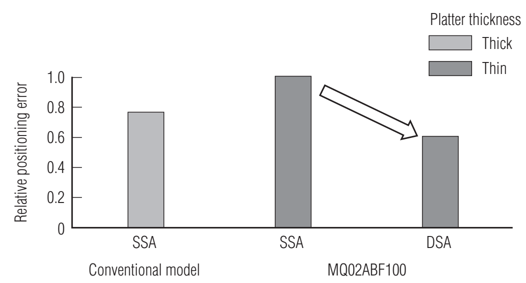

Figure 9 Improvement of head positioning accuracy with DSA —
The use of a DSA has resulted in an approximately 40% reduction of head positioning error.

4. Conclusion

Housed in a casing with a thickness of 7 mm, the newly developed 2.5-inch HDD for notebook PCs has a capacity of 1 Tbyte. This HDD incorporates a thin platform specifically designed for a dual-platter mechanism, a thin spindle motor, a DSA and other innovations in order to improve vibration and shock resistance and thus combine large capacity and high reliability.
Toshiba will continue to develop high-performance and high-quality products that meet customer needs.

(*1) As of October 2013 for 2.5-inch HDDs (as researched by Toshiba)
(*2) Parameters that represent the pass and reflection characteristics of a radio-frequency circuit

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