

2.5-inch Hard Disk Drives for Mobile Applications: Hornet-15L

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Fujitsu has developed the Hornet series of 2.5-inch compact hard disk drives (HDDs). These drives are suitable for use in mobile applications such as notebook personal computers. This paper introduces the Hornet-15L (MHR2xxx) drives, which are our latest 2.5-inch super-slim HDDs. The HN-15Ls feature an areal recording density of 56.5 Mbit/mm² (36.4 Gbit/in²), which makes them the highest density drives in the world. This paper introduces the head, medium, mechanical, and electronic technologies of the Hornet drives.

1. Introduction

These days, most notebook personal computers (PCs) are equipped with 2.5-inch HDDs. The required functionality for 2.5-inch mobile application HDDs differs from that of 3.5-inch HDDs in many respects. For example, 2.5-inch HDDs must be more shock resistant and quieter. This paper discusses the trends of mobile application HDDs and the features and technology of the latest Hornet series of 2.5-inch HDDs ("Hornet" is a Fujitsu internal development code).

2. Trends in 2.5-inch HDDs

The 2.5-inch HDD is used in various applications, for example, notebook and compact desktop PCs. HDDs are also expected to become common in consumer electronic devices, audio-video products, global positioning system (GPS) equipment, and other non-PC applications including some specialized server application environments. The trends of 2.5-inch HDDs, including their market demands, are summarized below.

1) Large capacity

Notebook PCs are used in the same way as desktop PCs. The same data is processed using

the same software applications. In addition, notebook PCs are often used as a way of saving space. This means that notebook PCs require the same storage capacity from their built-in 2.5-inch HDDs as desktop PCs. Audio-video applications require an even greater capacity.

2) Shock resistance

Because of their portability, mobile devices such as notebook PCs and personal digital assistants (PDAs) and their HDDs must be highly shock resistant.

3) Low power consumption

Most portable equipment is driven by battery. Because a notebook PC requires a long battery life, it is essential to use an HDD with a low power consumption. Low power consumption is also an important consideration in terms of energy conservation.

4) Quietness

Since the PC is widely used in homes, the requirement for quietness becomes increasingly important. In addition, HDDs are beginning to be used in MP3 players, game machines, and video applications. Consequently, acoustic noise from HDDs needs to be suppressed as much as possible.

3. Features of the Hornet series

This section describes the features of the 2.5-inch Hornet series of HDDs, presents some technical information, and outlines the AT Attachment (ATA) interface. **Table 1** lists the major specifications of the new HN-15L drive and its predecessor, the HN-14L. Head load/unload was introduced in the HN-14L series. The Hornet-15L series has head load/unload and also Fujitsu's "silent HDD" technology.

The silent HDD technology uses fluid dynamic bearing (FDB) motors, which greatly reduce non-repeatable run-out (NRRO), offer improved reliability in harsh environments, and greatly reduce acoustic noise (**Figure 1**).



Figure 1
Logo for Fujitsu's silent HDD

Table 1
Major specifications of Hornet series.

Item	HN-14L [~] (MHN2300)	HN-15L [~] (MHR2040)
Formatted capacity (GB)	30	40
Height (mm)	9.5	
Number of platters	2	
Heads	G-MR	
Rotational speed (rpm)	4200	
Average seek time (ms)	12	
Max. recording density (kBPI) [~]	578 [~]	592 [~]
Typical track density (kTPI) [~]	50.4 [~]	61.5 [~]
Max. areal density (Gbit/in ²)	29.1	36.4
Max. transfer rate (Mbyte/s)	30.7	32.5
Shock resistance at non-operating (G)	800 (2 ms)	900 (1 ms)
Power consumption at idle (W)	0.75	0.65
Weight (g)	98	99

3.1 Features of the Hornet-15L series

The HN-15L drives are designed for use in all 2.5-inch HDD applications. **Figure 2** shows a photograph of the HN-15L mechanism. It uses 20 GB platters to provide capacities of 10 GB, 20 GB, 30 GB, or 40 GB in a super-slim 9.5 mm form factor. The new mobile drives offer exceptional performance with an unmatched maximum transfer rate of 32.5 Mbyte/s and an average seek time of 12 ms. With a weight of just 99 g, a 4200 rpm spindle speed, and a 2 MB buffer, these new mobile hard drives from Fujitsu are ideal for intensive mobile computing applications.

The HN-15L drives have the following features:

- 1) 40 GB formatted capacity
- 2) 8820 m/s² (900 G) non-operating shock resistance
- 3) 2nd generation load/unload technology
- 4) FDB motor technology
- 5) ATA-100 interface
- 6) Large 2 MB buffer memory
- 7) Low power consumption
- 8) Stacked media servo track write (STW) technology
- 9) Lead-free printed circuit board assembly

The drives have an areal density of 56.5 Mbit/mm² (36.4 Gbit/in²), which is the highest density in the world. This was accomplished



Figure 2
Hornet-15L mechanism.

by using the latest recording technologies, for example, specular giant magneto-resistive (G-MR) heads, synthetic ferrimagnetic media (SFM), and an MEEPRML (modified extended extended PRML) read channel.

The high shock resistance was achieved by using a ramp load/unload mechanism and a FDB motor. The combination of the ATA-100 interface and the high-capacity 2 MB buffer provides a fast data transfer rate. The drives' precise power control feature greatly reduces the power consumption during operation. Stacked media STW technology helped to achieve a high track density design as well as increased productivity. Stacked media STW technology is covered in more detail elsewhere in this special issue.¹⁾

As part of Fujitsu's environmental philosophy and the "Green Life 21" initiative, the HN-15L drives are produced in a lead-free environment, making them the first series of HDDs to be manufactured using a lead-free process. More information on Fujitsu's environmental activities can be found at <http://eco.fujitsu.com/en/>.

3.2 AT Attachment (ATA) interface

The AT Attachment (ATA) interface is the standard interface for HDDs used in today's PCs. The HN-15L products support an ATA-5 interface and an Ultra-DMA 100 mode.

1) Faster data transfer mode

Recent PCs feature the faster ATA interface. The Ultra-DMA 100 mode (transfer rate of 100 Mbyte/s) is first defined in the ATA-6 DRAFT. In this paper, "ATA-100 interface" is used tentatively to indicate the Ultra-DMA 100 specification. The ATA-100 interface is already available in the HN-15L products.

2) Other ATA commands

The HN-15L products support most of the ATA-5 command set, including power saving functions, SMART (Self-Monitoring, Analysis, and Reporting Management), and security commands.

4. Key technologies

This section discusses the key technologies used in the HN-15L products.

4.1 Increased capacity

The improvements outlined below have made it possible to achieve a large capacity and the world's highest recording density. Compared to 3.5-inch HDDs, 2.5-inch HDDs have a limited disk surface, so an even higher recording density must be realized to meet high-capacity requirements. Consequently, in terms of recording density, the recording technology for 2.5-inch HDDs is always ahead of that for 3.5-inch HDDs; the HN-15L series is no exception here. The improvements are as follows.

1) Use of specular G-MR heads

Fujitsu's new read head technology adds a specular layer to the read head structure. The added layer improves the signal-to-noise ratio and the sensitivity of the read head, enabling the detection of lower-amplitude and more closely spaced data signals. The resulting areal density increase enables a remarkable 20 GB of data storage per 2.5-inch diameter platter.²⁾

2) Use of SFM

SFM employ stabilizing layers that reduce the signal decay due to thermal fluctuations of the media. The new SFM technology provides up to three times the recording density of the previous generation of media technology. SFM consist of two or more magnetic layers that are antiferromagnetically coupled by a nonmagnetic spacer. These media enable thermally stable high-resolution recording with a low $Mr\delta$ value, which is the product of the remnant magnetization Mr and thickness δ . The term "ferrimagnetic" is used because the magnetization coupling of the recording layer and stabilizing layer is similar to the structure of a ferrimagnetic material's spin configuration.³⁾

3) New MEEPRML read channel

Use of the latest high-speed MEEPRML read channel has improved read/write performance and

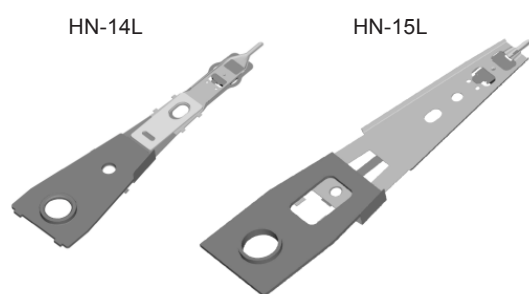


Figure 3
Load/unload suspensions of the Hornet series.

increased capacity.

4.2 Improved shock resistance

The HN-15L products utilize Fujitsu's second-generation head load/unload technology with a new suspension mechanism. FDB motor technology has also been implemented. The new generation of Fujitsu mobile drives feature an 8820 m/s^2 (900 G) non-operating shock resistance, making them ideal for rugged applications.

Before the HN-15L, Fujitsu improved the shock resistance in HDDs by developing an ultra-lightweight wireless suspension CAPS (Cable Patterned Suspension) mechanism. In the HN-15L products, a newly developed high modulus suspension suitable for load/unload has been implemented. We have successfully improved the shock durability by using the new design. The new suspension will be precisely assembled into drives with Fujitsu's swaging technology.

Figure 3 shows photographs of the HN-14L and HN-15L suspensions, and **Table 2** lists their major specifications.

4.3 Lower power consumption

Fujitsu's HDDs reduce power consumption by placing unused circuits in low-power mode. The power-saving modes, which include Idle, Standby, and Sleep, help reduce power consumption. Each LSI chip is designed to enable power control on a block-by-block basis. In Idle mode, an optimal power control algorithm achieves power consump-

Table 2
Major specifications of suspensions.

Item	HN-14L	HN-15L
Gram load [~] (mN) [~] ~ (gf)	6.86 [~] 0.7	29.4 [~] 3.0
Sway frequency (kHz)	10.0	11.6
Lift-tab stiffness (mN/mm)	250	1600
Weight (mg)	51.4	75.2

Table 3
Acoustic noise specifications.

Item	Idle	Random [~] seek
Sound power (Bels)	2.60	2.90
Sound pressure (dBA) at 30 cm	24.0	28.0

tion levels of only 0.65 W in the HN-15L drives. In addition, a wide variety of operational modes have been classified, ranging from a general operating mode to a mode in which only essential parts operate, further reducing power consumption. A power-saving timer setting is generally used for system control.

4.4 Lower acoustic noise

In order to reduce the acoustic noise, we use an FDB motor. **Table 3** lists the acoustic noise specifications of the HN-15L drives.

The FDB motor not only reduces the acoustic noise but also improves the shock resistance. In the case of conventional ball bearing motors, when a shock is applied to the spindle motor, the balls dent the race surface in the motor, which can cause vibration or noise. However, in the case of an FDB motor, the internal fluid spreads the shock over a wide area, making a dent much less likely.

5. Conclusion

The Hornet-15L (HN-15L) series of 2.5-inch hard disk drives offer increased performance with 20 GB platters. When these products are coupled with the ATA-100 interface, their robustness,

small size, and low power consumption make them ideal for a wide variety of applications. These drives are ideal for uses in, for example, industrial control systems, in-car systems, MP3 players, game machines, video applications, and traditional notebook PCs and compact desktop PC systems. The drives' superior performance has been achieved using Fujitsu's high-density recording technologies. They can withstand shocks of up to 8820 m/s^2 (900 G) thanks to their head load/unload and FDB motor technologies. The use of FDB motors also helps reduce the acoustic noise of these drives. Since the introduction of lightweight, slim notebook PCs, the trend toward even thinner profiles, increased performance, and greater functionality has been accelerating.

The demands for larger capacity, greater functionality, and lower power consumption for the 2.5-inch HDDs used in mobile applications are expected to soar. Today's 2.5-inch drives repre-

sent the leading edge of HDD technology. Continued success in the HDD industry will depend on the speed with which even higher recording densities can be developed and marketed. Fujitsu will continue to develop cutting edge products like the Hornet drives and make them available on the market.

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