



Technology Paper

Taking Storage to Extremes

**Seagate® EE25.2 Series™ Drives
vs. Other Drives, Flash SSDs**

Background

It wasn't so very long ago that most business computers were limited to the staid confines of server rooms or office desktops. But thanks to the growing availability of affordable notebook computers and ubiquitous access to wireless networks, a profound shift towards more portable computing power has occurred.

Initially this shift most obviously manifested itself in the legions of business users who abandoned their desktop computers in favor of notebook models, enabling them to bring their work from one static interior environment (office desk, home office, airport lounge, etc.) to another. As the power and flexibility of portable computing became more apparent, expanding its benefits into outdoor and mobile applications looked to be a straightforward proposition.

In reality, this presented durability challenges to computer enclosures, displays and, most notably, hard drives. It's important to remember that while standard notebooks are often carried, they're usually not in full operating mode when transported (users either put them to sleep or shut them down altogether). This reduces stresses on notebook drives, which, while more shock-tolerant than desktop drives, are not designed for continuous duty while being moved.

Extreme Storage Profile

Conversely, the extreme operational and environmental factors that characterize mobile and outdoor applications make extraordinary demands on hard drives. Not only are the drives constantly in use (often powered on 24x7), they're simultaneously subjected to a broad range of arduous physical challenges: severe temperatures (sub-zero frost to sweltering heat), punishing vibration and shock, as well as stifling humidity and extreme altitude.

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Such daunting conditions can be encountered in a wide variety of storage applications, including:

- Automotive entertainment, navigation and data delivery systems
- Industrial PCs used for process monitoring and data acquisition
- Military field imaging and information systems
- Digital signage and advertising displays
- Mobile/portable medical equipment

To withstand these grueling deployments, mobile and outdoor storage devices must be able to deliver the requisite ruggedness, durability and protection from hostile elements. Additionally, these devices should also satisfy the familiar demands for high performance, generous capacity and cost effectiveness.

Below is a competitive analysis of several storage devices currently employed in mobile and outdoor storage applications, highlighting their relative strengths and weaknesses. As can be seen, this analysis clearly demonstrates the fundamental superiority of Seagate EE25 Series ruggedized hard drives, which are purpose-built to efficiently address the unique challenges of extreme storage environments.

Seagate EE25 Series Drive vs. Standard 2.5-Inch Drive

Both office professionals and consumers have come to rely on the flexibility and mobility afforded by notebook computers. Conventional 2.5-inch notebook drives are engineered to offer the capacity, durability and low power consumption that such users demand.

Outdoor and mobile applications, which superficially require this same suite of capabilities, might seem to be another viable deployment opportunity for notebook hard drives. Unfortunately, it soon becomes clear that the brutal environmental conditions typical of such applications pose challenges well outside the design brief of standard notebook drives.

Whether in automotive, industrial or military storage settings, such drives encounter stresses that can cause premature failure:

- On a summer day, the GPS system inside a parked automobile can be exposed to interior temperatures in excess of 65°C, while winter could see that same car's interior drop to -20°C or lower. Furthermore, long-duration (11-ms) shock, such as the impact encountered by a drive mounted in a vehicle that hits a pothole, produces a different shock waveform than that for which a standard hard drive is designed (for example, the 2-ms shock of a notebook falling from an office desk onto the floor).
- In factory environments, industrial process control devices often run 24x7 and are routinely located close to powerful machine tools, dies and welding equipment. The excessive heat and vibration in such settings can quickly cause a standard notebook drive to malfunction.
- As one would expect, military applications impose a demanding range of environmental stresses on hard drives, from scorching desert heat to punishing sub-zero cold at extreme elevations. In addition, military vehicles operating under such conditions often must negotiate rugged terrain that metes out far more shock and vibration than civilian roads and highways.

The fact that standard 2.5-inch notebook drives suffer under such circumstances does not reflect poorly on them; rather, it is simply the predictable result of deploying a storage device in environments for which it was not designed.

By contrast, the Seagate EE25 Series hard drive is specifically designed to withstand the temperature, vibration, shock, altitude and humidity extremes that typify outdoor and mobile storage applications. Incorporating Seagate RunOn™ technology, a comprehensive feature suite that ensures reliable performance in punishing physical surroundings, the EE25 Series drive is simply in another class when compared to conventional notebook drives (superior specifications highlighted).

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Summary: Seagate® EE25 Series™ Drive vs. Standard 2.5-Inch Drive		
	EE25 Series 5400.2 Drive	Standard 2.5-Inch Drive*
Temperature (Operating, °C)	-30 to +85	0 to +60
Shock (Operating, 2 ms/11 ms, Gs)	300/ 150	350 /Fails Test
Vibration (5 to 500 Hz, Gs)	2	1
Altitude (m)	-300/+5000	-300/+3048
Rotational Speed (RPM)	5400	5400

*Manufacturer's specifications for Seagate Momentus® 5400.3 hard drive

Seagate EE25 Series Drive vs. Toshiba MK8050GAC Drive

Of course, some would argue that the obvious technical superiority of EE25 Series drives over conventional notebook drives comes as little surprise. The more appropriate comparison would be to a competing vendor's 2.5-inch drive specially built for extreme storage environments. The summary table below illustrates how Toshiba's automotive hard drive stacks up against the EE25 Series drive (superior specifications highlighted).

Summary: Seagate® EE25 Series™ Drive vs. Toshiba MK8050GAC Drive		
	EE25 Series 5400.2 Drive	MK8050GAC Drive*
Shock (Operating, 2 ms/11 ms, Gs)	300/ 150	300/NA
Shock (Nonoperating, 1 ms, Gs)	900	800
Seek Time (average, ms)	11	16
ARotational Speed (RPM)	5400	4200
Available Interfaces	ATA, SATA	ATA only

*Manufacturer's specifications for Toshiba MK8050GAC drive

These specifications offer a rebuttal to the notion that drives are essentially commodity items with very little to differentiate them from their competition. While the EE25 Series and MK8050GAC drives have some similarities (such as identical operating temperature ranges of -30°C to +85°C), further investigation reveals that the EE25 Series drive includes a clearly more comprehensive suite of capabilities for extreme environments.

Shock tolerance (both operating and nonoperating), seek time and rotational speed (as well as connectivity flexibility) all underscore the superiority of the Seagate EE25 hard drive. Unlike Toshiba MK8050GAC drives, EE25 Series drives don't impose a performance penalty compared to conventional notebook drives (note Toshiba's substandard seek time and 4200-RPM rotational speed) in order to deliver enhanced ruggedness for challenging storage applications.

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Seagate EE25 Series Drive vs. Hitachi Endurastar J4K50 Drive

Comparisons to another competitor's rugged 2.5-inch drive yields remarkably similar results, as the EE25 Series drive once again shows the benefits of its technically sophisticated feature set. Here, the summary table shows how the Hitachi Endurastar J4K50 drive fares in a head-to-head matchup with the EE25 Series drive (superior specifications highlighted).

Summary: Seagate® EE25 Series™ Drive vs. Hitachi Endurastar J4K50 Drive		
	EE25 Series 5400.2 Drive	MK8050GAC Drive*
Shock (Operating, 2 ms/11 ms, Gs)	300/150	250/NA
Shock (Nonoperating, 1 ms, Gs)	900	800
Seek Time (average, ms)	11	13
ARotational Speed (RPM)	5400	4260
Available Interfaces	ATA, SATA	ATA only

*Manufacturer's specifications for Hitachi Endurastar J4K50 drive

Simply put, the Seagate EE25 Series drive delivers superior results across the board, besting the Hitachi Endurastar J4K50 in every measured category. Not only does the EE25 Series drive offer greater ability to withstand shock (both in operating and nonoperating modes), it also delivers faster seek times and higher rotational speed than its challenger. The ability to specify either an ATA or SATA interface sharpens the EE25 Series drive's competitive edge still further.

Perhaps even more revealing of the EE25 Series drive's superiority is Hitachi's inclusion of the following disclaimer for the Endurastar J4K50 drive: "Intended for less than 20 percent duty cycle industrial applications and other non mission critical applications." Seagate makes no such disclaimer for the EE25 Series drive; indeed, EE25 Series drives are purpose-built for the very types of demanding environments (military, law enforcement, etc.) that the Hitachi drive must avoid.

But if the EE25 Series drive is the clear winner in any comparison to its rivals, surely it will suffer when paired off against the vaunted strengths of flash SSD storage? A down-to-earth analysis of the relative strengths of the two storage devices proves otherwise.

EE25 Series Hard Drive vs. Flash Solid-State Drive (SSD)

At first glance, flash SSDs seem to offer insurmountable advantages over EE25 Series hard drives: lighter weight, lower power consumption, superior ruggedness and higher performance. But in the harsh light of real-world practicality, the theoretical benefits of flash SSDs lose much of their luster. For many users, the strengths of flash SSDs quickly pale in significance compared to their staggering cost penalty, some US\$500 to US\$1200 more than EE25 Series drives of comparable capacity.

There is a narrow range of storage environments in which the fast random reads, low power consumption and extreme shock resistance of flash SSDs will take precedence over issues of capacity, read/write performance and cost. But for the vast majority of outdoor and mobile applications, flash SSDs are simply not the storage panacea they are perceived to be.

As discussed below, any advantages that flash SSDs promise in terms of weight, power consumption, ruggedness and performance prove largely academic in actual storage applications.

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Weight

The Seagate EE25.2 Series drive weighs just under 25 grams (approximately one ounce) more than a Samsung 2.5-inch PATA SSD. But reviewing those figures in isolation does not tell the full story. To wit, a Panasonic Toughbook-30 notebook computer weighs 8.4 pounds; in that context, the one-ounce difference between the EE25.2 Series drive and Samsung SSD accounts for well under one percent of the system's weight, an insignificant amount.

Summary: Seagate® EE25 Series™ Drive vs. Samsung Flash SSD		
	EE25 Series 5400.2 Drive	Samsung 2.5-Inch SSD*
Weight (grams)	102	77
Total System Weight (Panasonic Toughbook plus storage device, grams)	~3516	~3491

*Manufacturers' specifications for Samsung 2.5-inch PATA SSD

Power Consumption

Thanks to the power-savings features built into the Seagate EE25.2 Series drive, power use is only nominally higher than that of a flash 2.5-inch SSD. More importantly, the storage device (whether hard drive or SSD) accounts for less than ten percent of total system power consumption. A system's video display and ASICs demand far more power, and are thus the prime determinants of net system battery life.

Power Consumption: Seagate® EE25 Series™ Drive vs. Samsung Flash SSD		
	EE25 2.5-Inch Drive (80 GB)*	Samsung 2.5-Inch SSD (16 GB)*
MobileMark Battery Life	PATA: 328 minutes SATA: 316 minutes	PATA: 324 minutes

*Figures obtained at Seagate Longmont, CO testing laboratory

Ruggedness

While both drives offer high levels of shock and vibration tolerance, the EE25.2 Series drive can endure a wider range of operating temperatures. To be sure, the Samsung SSD's shock and vibration tolerance is significantly greater, but in reality, such lofty limits are largely academic. In actual use, many other system components would likely fail long before the shock or vibration thresholds of the Samsung SSD were approached, rendering such capabilities essentially overkill.

Ruggedness: Seagate® EE25 Series™ Drive vs. Samsung Flash SSD		
	EE25 2.5-Inch Drive	Samsung 2.5-Inch SSD
Temperature (Operating, °C)	-30 to +85	0 to +70
Vibration (Gs)	2 (5 to 500 Hz)	20 (10 to 2000 Hz)
Shock (Operating, Gs)	300 (2 ms)/150 (11 ms)	1500 (0.5 ms)

*Figures obtained at Seagate Longmont, CO testing laboratory

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Performance

Flash SSDs are indeed much faster than hard drives when randomly reading data, but that is an unrealistically narrow application model. In that vein, the Seagate EE25 Series drive is much faster than the SSD when writing data. But in the real world, most extreme storage applications (such as military radar data updates or ruggedized notebooks at construction sites) require frequent *random reads and writes* of data. Under such circumstances (80%R, 20%W), lab testing proves that the EE25 Series drive delivers performance virtually identical to that of a flash SSD.

Performance: Seagate® EE25 Series™ Drive vs. Samsung Flash SSD			
Benchmark	EE25 Series 2.5-Inch Drive (80 GB)*	Samsung 2.5-Inch SSD (16 GB)*	Advantage
PCMark04	3460	4800	SSD (+38%)
Sustained Sequential Reads	59 MB/s	50 MB/s	Hard Drive (+18%)
Sustained Sequential Writes	52 MB/s	29 MB/s	Hard Drive (+79%)
Random Reads (8 KB)	70 IOPS	2450 IOPS	SSD (+3500%)
Random Writes (8 KB)	112 IOPS	23 IOPS	Hard Drive (+487%)
Random Reads and Writes (80%R, 20%W)	79 IOPS	80 IOPS	None

*Figures obtained at Seagate Longmont, CO testing laboratory

Cost

Simply put, Seagate EE25 Series drives of any capacity boast far lower cost per GB than either 32-GB or 64-GB 2.5-inch flash SSDs. Specifically, the street price differential between EE25 Series drives and flash SSDs can range from US\$500 to over US\$1200! Part of the SSD's cost premium comes from its need to use more expensive single-level cell (SLC) flash memory to ensure satisfactory performance and a sufficient number of read/write cycles.

Cost: Seagate® EE25 Series™ Drive vs. Samsung Flash SSD		
	EE25 2.5-Inch Drive	Samsung 2.5-Inch SSD
Capacity (GB)	80	64
Street Price* (US\$)	204.99	1296.99
Cost per GB (US\$)	2.57	20.27

*Prices obtained at www.CDW.com, June 27, 2008; Seagate Model #ST980818AM, Samsung Model #MCCOE64GEMPP

To put flash SSD's cost in a different perspective, its price *must drop by 50 percent every year until 2011* for it to then be cost-competitive with hard drive storage (based on Seagate projections). And the flash SSD's reliance on more expensive SLC memory will make that ambitious goal even more difficult to attain.

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Conclusion

The Seagate EE25 Series family of ruggedized hard drives represents a profound advance in hard drive durability and flexibility, enabling hard drive storage in a broad variety of extreme environments. Significantly outperforming both standard 2.5-inch notebook drives and its rugged 2.5-inch hard drive competition, EE25 Series drives combine advanced engineering with the remarkably low cost per GB that characterizes hard drive storage.

Flash SSDs offer theoretical advantages in terms of weight, power consumption, ruggedness and performance, but in practice these benefits are largely unrealized, overshadowed by the enormous price premium that flash SSDs impose. In real-world applications, the Seagate EE25 Series drive delivers comparable functionality at far lower cost.

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