

Solid State Drives Make Headway As Technology Matures: Will They Replace The HDD?

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By: Tony Lavia

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Everyone has heard of Moore's Law, but what about Grove's Law: that a new technology must be at least ten times better than the existing one in order to displace it? Are Solid State Drives (SSDs) on the way to becoming the next technology leap-ahead in the computer industry?

An SSD is a solid state storage device that employs the same interfaces and form factors as Hard Disk Drives (HDDs). The storage medium is non-volatile, utilizing integrated circuits in place of rotating magnetic or optical media.

The vast majority of today's SSDs are based on Flash (specifically, NAND) chips, a microprocessor-based controller, and software that integrates these components into a peripheral storage system which mimics a HDD. Compared to a HDD it provides high access speed by eliminating mechanical movement such as head seeks and platter rotation.

So what makes the SSD better? Does it achieve a 10X improvement? The benefits offered are derived from the elimination of all things mechanical: the spindle, the platters, the heads, the actuator and the actuator arm.

There is also the tantalizing prospect of jumping on to the semiconductor power curve (Moore's Law) for accelerated evolution. (Note that, whereas the capacity of HDDs has increased rapidly over the years, the data transfer speed has not kept up, now lagging behind the ability of motherboards to keep the drives busy.)

The solid state nature of SSDs make them particularly suitable for harsh environments, rugged applications (vibrations can play havoc with the microscopically small gap between the recording head and the platter of a HDD), applications requiring massively higher levels of IOPS (for random, mostly "read" operations) and products where form and function trump the added cost.

The biggest impediment to adoption of SSDs at a "replacement" pace is their cost. Measured as dollar/GB, a SSD is priced at 10 to 20 times that of HDD storage. This is not to say that cost represents a barrier, or that there has not been progress in this area— rapid progress, at that.

Also, in the areas of capacity and performance, SSDs used to max out at 32GB, with transfer speeds barely equal to the slowest hard drives. The progress in two years has been astounding: SSDs are now available with 512GB – with data transfer speeds surpassing even the fastest, short-stroked hard drives - at a fraction of their original cost.

Hard drives have also progressed along their own “power curve:” capacity. It is not uncommon to see 1.5TB drives selling in the sub \$200 range. That’s about \$0.13/GB, about 20 times less expensive than corresponding SSDs.

There is still a ways to go before SSD technology will do to HDDs what HDD technology did to tape storage. Nevertheless, there are currently important niches where SSDs can already be cost-justified, such as for (1) enterprise applications involving intensive random IO – here, SSDs leverage other parameters in the Total Cost of Ownership (TCO) equation (such as IOPS, power efficiency, density, cooling); and (2) for applications where the size or durability provides innate product value that could not be achieved with a corresponding, albeit cheaper, HDD.

In the data center environment, for most situations, capacity will continue to trump performance as the determinant of overall TCO. The conventional view is that SSDs will seep gradually onto the scene as a complementary layer in the storage “stack”, taking their place at the pinnacle of the fast/faster/fastest layers of storage technologies. It’s a lofty position, but a limited one: HDDs and tape storage comprise the bulk of the requirements. This is “improvement” - but it is not “replacement”, in the context of Grove’s Law.

However, there are a few wild cards that may change the game:

1. On the technology front, many of the limitations and costs are due to the memory technology itself, i.e. NAND memory chips. New and promising alternative technologies are being developed (e.g. FRAM, PCM, MRAM), which could change the cost/benefit equation in a single stroke. Indeed, developments in NAND itself, in the form of MLC (Multi Level Cell) silicon, may break through the cost entry barrier.
2. On the computer system front, the natural advantages of solid state storage are being held back by systems architectures which have been built to assume and work around the lags and delays of the hunt-and-peck inefficiencies of mechanical storage. By re-vectoring operating systems so as to harness the performance attributes of SSDs, it may be possible to dramatically improve on some of the computer characteristics that irk users beyond proportion.
3. Capacity for capacity’s sake will, for most applications, eventually reach a point where enough is enough. For example, take the case of a business notebook. Usage studies have shown that, even for a road warrior, 64GB of storage is normally sufficient. Let’s double it to 128GB for some extra margin. If a user can see real benefits (such as instant startup), it is unlikely that a \$200 premium, even at today’s prices, would represent any kind of barrier, especially to this sector of the market. As another example, in 2007 Apple decided that 16GB was plenty enough storage for the music applications in the original Ipod – the benefits relating to size and form trumped out the lower cost and extra capacity of the HDD.
4. Cloud computing - spurred on by Netbooks, web-optimized operating systems (e.g. Android), near-laptop capable PDAs, and ASP services rewards performance over storage in the PC by relegating mass storage into the cloud. The key value parameter shifts to performance/dollar from capacity/dollar.

5. The supply chain infrastructure for the SSD could evolve into a more efficient eco-system with inherently lower cost structures and greater ability to optimize for focused applications and environments.

Let's briefly look at one aspect of (5) above, in the area of industry standardization. Today, the HDD industry has developed a sophisticated system of testing, for every phase of development and production: DVT, EVT, RDT, out-of-the-box testing, production testing, QA testing, Qualification, etc. The bad news: there is no process standardization – everyone does their own thing. The attendant costs of these systemic inefficiencies percolate, of course, on down to the end user.

The nature of SSD technology cries out for simplified and standardized operational testing among the various players. A hard drive is composed of many and varied components. They can behave differently depending on the operational environment.

It is best to demonstrate this point via an example. On a modern hard drive, the head assembly floats barely above the surface of the platter. Its performance is affected by vibration, created by fans and power supplies and transmitted to the drive casing and then to the heads.

When such a drive is being tested by the manufacturer, the drive must be isolated from such vibrations so that the test equipment itself does not become the source of performance errors, which would be reported in the test results.

Each of the links in the supply chain may perform such tests to screen or otherwise validate the required performance and quality. However, at the end point, when the OEM installs the drive into the product (eg. a storage array system, set-top box, server), the drive must be able to operate in the not-so-perfect environment of the end product.

So, for example, an OEM vendor of enterprise SAN/NAS products would likely test the drives again, inside the vibrational environment of the system within which it will operate.

However, SSDs are impervious to vibration. Therefore, they can be tested once and only once, at the manufacturing source, and we would possess the knowledge that they will operate the same when they are eventually working inside the end product. This aspect of SSD's allows for further process efficiencies by making it possible to outsource the testing process to a third party (refer to sidebar).

In order to achieve the benefits of the above scenario, there must be agreed upon standards in place. For instance, before anyone else will accept a supplier's results, the test procedures need to follow an industry standard which guarantees repeatability, consistency, comparability and relevancy.

Indeed, there are industry groups (e.g. SNIA, IDEMA) already working on the development of such standards, focusing initially on performance measures. But "testing" is not just about performance - there is also reliability, endurance, margin, etc. to consider. Standardizing on all these attributes requires that a "test platform" be defined and agreed upon, that is to say a common hardware/software and climatic environment test system.

In the HDD world, it has always been challenging to compare the performance and quality among the products of different suppliers. Without standards, this problem will be exacerbated in the world of SSDs, since there will be many more vendors, each with their own claimed area of differentiation. Standardization would minimize testing costs and facilitate accurate comparisons between products.

End users (e.g. OEMs, CMs) could then select the product with the best attributes to meet their requirement without an exhaustive test procedure. Even the laborious process of product qualification may reduce itself to an analysis of a manufacturer's output test data.

Much more can be said about the test procedures required for SSDs, since they are the same as HDDs in terms of providing storage services to the main computer system, but very different in that they have different failure points, performance, error characteristics, reliability, and endurance. This is an interesting but lengthy topic, for another time.

So, when will SSDs become a replacement for HDDs? I believe it is a matter of "if" not "when". Another way to state Grove's Law is this: "Technology always wins".

SSDs Change The Face Of Testing

It is not surprising that the SSD sector attracts a crowd of hopeful vendors. Relative to the manufacturing of HDDs, which requires a fortune in capital equipment and infrastructure, making SSDs has "garage business" requirements. At the risk of oversimplification, the latter consists of assembling off-the-shelf semiconductor components (e.g. Flash chips and a controller microprocessor), and melding them into a storage system through the magic of software.

Therefore, it is not surprising that many of these would-be "Seagates" are in startup situations; i.e. money is tight, milestone functionality must be demonstrated to investors, and credibility is paramount. Further exacerbating the situation is that most such companies come to the SSD sector from a history of memory or microprocessor technology, with little experience or skill in storage systems. Additionally, they generally lack test engineering know-how.

There are many varieties of test equipment, from bench-top testers which operate at room temperature, to environmental chambers which can stress SSDs at extreme temperatures, humidity, and even atmospheric pressure.

Different types of testers are required at different phases of testing, and for different types of OEM qualifications - depending on the ultimate application. Purchasing all of the different types of testing equipment would necessitate spending a daunting amount of capital expenditure for a small company.

It makes great financial sense to be able to buy "testing" in small bits, only when needed, and without having to build out an infrastructure of capital equipment and staff. It is tantalizing to

imagine the idyllic scenario, whereby a company's resources are fully focused on creating competitive differentiation and accelerated market entry.

In this process, the client would compile the test scripts which would be executed by the testing company on their equipment, and the test results would be provided to the client for analysis and product validation.

In fact, the test process could be done interactively with the client, by providing a real time link to the testing system and a live link for uploading output data as it is being produced. It allows the client to stay engaged and focused on the "forest", without getting lost in the details of the "trees" – the test machinery and process itself.

Lastly is the issue of credibility. A newcomer to storage, who does not have a history within this sector, needs an extra measure of conviction among their potential clients. Nothing inspires belief like a "seal of approval" from an industry recognized testing company using standard and reproducible procedures.

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