Emerging Storage Technologies – Solid State Drives (SSD)

By Dan Comperchio

Abstract: The following white paper is part of a quarterly series developed by Willdan Energy Solutions. The intent of the series is to provide the intelligence we have collected through implementation of data center energy efficiency programs nationally. We seek to identify technologies and strategies that can become actionable items in utility-run data center programs. This quarter's white paper focuses on solid state drives (SSD) which have evolved from highly cost-prohibitive specialty memory devices into a disruptive technology in the data center industry. With benefits of higher performance, less energy use and falling prices, solid state drives now play a larger role in equipment choices in data centers.

Overview

In today's computing environments, storage devices are commonplace at all levels of performance, from multi-million dollar mainframes to off-the-shelf servers and consumer grade personal computers. Initially developed in 1956 by IBM, the hard disk drive (HDD) has experienced vast performance improvements; however the basis for the technology has remained similar to the original IBM unit that was roughly the size of two refrigerators. Solid State Drives (SSD) are a new generation of storage devices that are poised to replace HDDs and provide the next level of performance and energy savings within computing environments.

Current Technology

In September of 1956, IBM released the 350 Disk Storage Unit, which was over five and a half feet tall, two and a half feet deep and five feet wide with a total storage capacity of less than four MB. The technology was based on large magnetic disks (20 inches across), called platters, rotating at 1,200 RPM and an actuator arm that moves to read and write data[1].

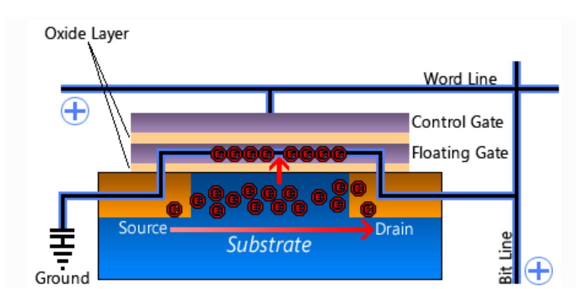
IBM 350 Disk Storage Unit being loaded by a forklift for transport[2]

Today's modern hard drives have vastly surpassed the early storage devices with platters more commonly either 2.5" or 3.5" spinning between 4,200 RPM up to 15,000 RPM in high-performance units. Storage capacity has increased by a factor of nearly 2 million with eight TB HDDs commercially available[3]. Costs have also dramatically improved from multiple thousands of dollars per GB down to less than $0.05 per GB[4]. However, 60 years since the technology was first introduced, modern hard drives still rely on actuator arms reading and writing to spinning disks.

Modern 3.5in hard disk drive with actuator arms and platters visible[5]

Solution

Originally introduced in 1984 by Toshiba, flash memory has historically been used in computers and servers as main memory for operation of the central processing unit (CPU) due the higher speed of retrieving data. However, since cost has historically been significantly higher than HDDs, flash memory has typically been deployed in smaller capacities. Unlike traditional HDDs, flash storage requires no moving mechanical components as information is stored based on the charge of a transistor. The main components of flash memory devices are a set of transistors, called the control gate and floating gate, separated by a thin layer of dielectric material that electrically isolates the floating gate.



Typical layout of a flash storage device with the isolated floating gate, depicted here as a binary '0'[6]

When storing data, voltages are applied across the word and bit lines, and a negative charge is imposed on the floating gate by electrons getting trapped in the floating gate. During information retrieval, this corresponds to binary information storage – a charged state represents a '0' while an uncharged state represents a '1'. The main advantage of this setup, and a key difference from typical random access memory (RAM), is that the charge on the floating gate remains after voltage is removed, resulting in data being maintained when power is removed from the device.

The technology initially expanded to small capacity devices, such as memory cards and USB flash drives. These devices were limited to consumer applications because their cost exceeded 20 times that of HDD. In recent years, an emerging application of flash memory on the market is solid-state drives (SSD) which have comparable capacities to traditional HDDs and offer significant performance improvements. Solid-state drives offer much faster start-up times, have much lower read latency and can write information up to 10 times faster on high-end SSD devices. The importance of the faster read and write speeds translate to faster boot and launch times for applications, improved financial transaction ability, quicker access to streaming content, as well as a growing list applications and businesses that benefit from improved storage performance.

In addition to improved performance of the drives, the lack of mechanical equipment results in lower energy use from SSDs. For a hypothetical data center with 1 MW of IT load and an average server power draw of 400 W, the facility may house 2,500 servers. The following comparison outlines the possible energy savings for upgrading the storage on half of the servers from a traditional HDD to a SSD. With the other components held constant, solid state drives result in over 1,000,000 kWh and nearly $85,000 in annual energy savings and a payback of less than six years.

In large-scale deployments of storage, typical of a data center with dedicated storage devices and storage integrated into servers, the reduction in price of solid state drives is leading to increased interest in the technology at larger scales.

HP ProLiant DL385p G8 Hard Disk Drive vs. Solid State Drive Comparison							
Storage Configuration	**Average Power (W)[7]**	**Server Qty**	**Total Power (kW)**	**Total Energy (kWh)**	**Storage Cost ($/GB)[a]**	**Storage Cost ($)**	**Electric Cost ($)[b]**
(8) 600 GB 3.5in 15k HDD	283	1,250	354	3,098,850	$ 0.39	$ 2,340,000	$ 216,920
(8) 600GB 3.5in SSD	186	1,250	233	2,036,700	$ 0.47	$ 2,820,000	$ 132,386
		Savings	**121**	**1,062,150**		**$ (480,000)**	**$ 84,534**

a. Costs based on market data for server-class hard drives and competitive cost solid state drives[8]
b. Electric utility rate assumed as $0.07/kWh

Conclusion

Flash memory technology has greatly increased the performance of storage devices and is available on all levels of computing from high-end enterprise servers down to laptop and mobile devices. However given the cost barrier of the technology, early adoption is primarily driven by large enterprise data centers and cloud providers looking for improved performance for end users. The use of solid state drives in large data centers is still limited to applications where the benefit of higher performance storage justifies the higher cost of SSDs. For more wide scale adoption of SSDs within data centers, the payback on the technology will need to approach the typical 24 month payback operators look for, or 36 months with utility incentives assisting to reduce the payback for earlier adoption. Based on the previous example, the cost difference between SSDs and HDDs would need to be closer to $0.03/GB-$0.04/GB and with current industry price trends[10]; SSD pricing may approach this target in the next five years.

The potential for energy savings at the storage level across all sizes of data centers is compelling. With the top three colocation markets in the US alone accounting for over 650 MW of leased power[9] the potential for SSD improvements over traditional hard disk drives potentially exceeds 120 million kWh[11]. However, due to the high cost of the technology, continued support through incentives and education of energy costs savings will help facilitate further adoption of the technology in the marketplace.

Sources:

1. *IBM 350 Disk Storage Unit. IBM, n.d. n.p. Web. 05 Sept. 2014* *http://www-03.ibm.com/ibm/history/exhibits/storage/storage_350.html*
2. *"A Large Piece of Storage Technology History" CBL Data Recovery, 22 Feb. 2014 n.p. Web. 05 Sept. 2014* *http://www.cbldatarecovery.com/blog/data-recovery/*
3. *"Segate Ships World's First 8TB Hard Drives" Seagate, 26 Aug 2014 n.p. Web. 05 Sept. 2014* *http://www.seagate.com/about/newsroom/press-releases/*
4. *McLellan, Charles. "Storage in 2014: An Overview" ZD Net, 08 Jan. 2014 n.p. Web. 05 Sept. 2014* *http://www.zdnet.com/storage-in-2014*
5. *"SAS Hard Drives, WD Xe" Western Digital, n.d. n.p. Web. 05 Sept. 2014* *http://www.wdc.com/en/products/*
6. *Hallock, Robert. "The Hows and Whys of SSDs" Icrontic, 25 Sept. 2008 n.p. Web. 05 Sept. 2014* *http://icrontic.com/article/how_ssds_work*
7. *HP Power Advisor configuration tool. Hewitt-Packard, n.d. n.p. Web. 05 Sept. 2014* *http://www8.hp.com/us/en/products/servers/solutions*
8. *Aldershoff, Jen. "SSD Price per GG Drops Below $0.50 – How Low Can They Go?" Myce, 07 March 2014 n.p. Web. 05 Sept. 2014* *http://www.myce.com/news/*
9. *Ostermick, Jessica. "Q1 2014 National Data Center Market Update" CBRE, 18 Aug. 2014 pg. 1 Web.. 05 Sept. 2014*
10. *Floyer, David. "The Emergence of a New Architecture for Long-term Data Retention." Wikibon, 9 July 2014 n.p. Web. 05 Sep. 2014* *http://wikibon.org/wiki/v/The_Emergence_of_a_New_Architecture_for_Long-term_Data_Retention*
11. *Storage energy savings assumed based on 30% utilization of the leased power, 21% of IT power dedicated to storage (per below) and a 34% savings from SSD over traditional HDD, per data from (7).*
    Floyer, David. "Networks go GrEEN." Wikibon, 07 May 2011 n.p. Web. 05 Sept 2014http://wikibon.org/wiki/v/Networks_Go_GrEEN