Data Storage In Automobiles – Trending Towards the Use of Solid State Drives

White Paper

Edmond Hui

Abstract

In recent years, the car has slowly transitioned from being primarily a mode of transportation to a source of entertainment and information retrieval. Passengers may listen to MP3s or watch videos from the backseat. The driver can pull up GPS navigation and control wi-fi hotspot connectivity from an in-dash touchscreen display. To store the ever growing amount of data used while driving, such as GPS maps and MP3s (what the community has categorized infotainment[1]), consumers may purchase a car with a built-in hard drive. These hard drives are built more ruggedly to withstand the impacts of everyday driving. The underlying technology of storing data on magnetic plates is the same technology found on drives ubiquitous to desktop and laptop computers.

For decades now, the traditional hard drive technology has been used and improved upon, increasing maximum capacity on a drive every year while reducing cost. An alternative technology that has become popular over the last decade is solid state drives (SSDs). The benefits of using a SSD versus a traditional hard drive are numerous, such as the lack of moving parts to increase reliability as well as the use of memory chips instead of magnetic disks which reduces size and weight. What has held back widespread adoption of SSDs in computing has been the cost. The cost per megabyte of space available on an SSD has been and continues to be more expensive than the equivalent and a traditional hard drive. However, as more companies enter the market for SSDs and the technology has been improved upon, the cost of these drives has gradually decreased. It is time to visit the viability of using SSDs in vehicles.

Background

Traditional hard disk drives used in today's desktop and laptop computers are not suitable for use in cars. Computer systems in cars require data storage solutions to operate efficiently and with minimal data loss and low downtime in extreme conditions. Drives must also be resilient to withstand the shock and impact of everyday driving and ideally handle off-road driving. Hard drives must also be able to withstand extremes in temperature – scorching heat as well as freezing cold.

Several HDD manufacturers have offered solutions to the growing demand for integrated hard drives in automobiles. These companies, which include Toshiba and Western Digital/HGST, increase the durability of existing hard drives by making mechanical improvements such as integrating shock absorption and humidity control[2,3]. These drives can withstand the extreme temperatures that drivers may encounter, and they are rated to operate with minimal error at high altitudes. Several automobile manufacturers including Mercedes Benz, Chrysler, and Infinity already offer an integrated hard drive as an option in their vehicles[4].

Though there has been some early adoption of HDD integration in vehicles, hard drives designed for cars fall behind their desktop computer equivalents with regards to maximum storage capacity and data read/write speeds. While maximum capacity does increase every year and correspondingly error rates and speed improve, the best drive available on the market boasts a 320GB capacity and an average seek time of 16ms, limited by a disk rotational speed of 4200 rpm[5].

The Business Case for SSDs

An alternative to the use of traditional hard drives in vehicles is the adoption of SSDs. Solid state drives is the first major advancement in storage technology in decades. They offer a substantial performance upgrade while being a durable and reliable storage solution.

Solid state drives offer the same functionality as hard drives, but instead of storing data on platters with a magnetic coating, the data is stored on interconnected flash memory chips which do not require power. These chips differ from flash memory found in USB drives – they offer better performance and consequently have a higher price tag. SSDs also come packaged in a variety of form factors but many are built into the 2.5-inch form factor enabling easy swapping into desktops and laptops[6].

Cost

While SSDs and HDDs perform a similar function, to store files for future access, each has its own set of features with corresponding advantages and disadvantages. The first area is pricing. SSDs are more expensive than HDDs per gigabyte. On average, one might pay $600 for a 1TB SSD while the equivalent hard drive may cost only $75[7]. Because HDD technology is older and more established, the cost will remain lower than SSDs in the foreseeable future. However, as the technology matures and is adopted by more users, SSDs will continue to go down in price.

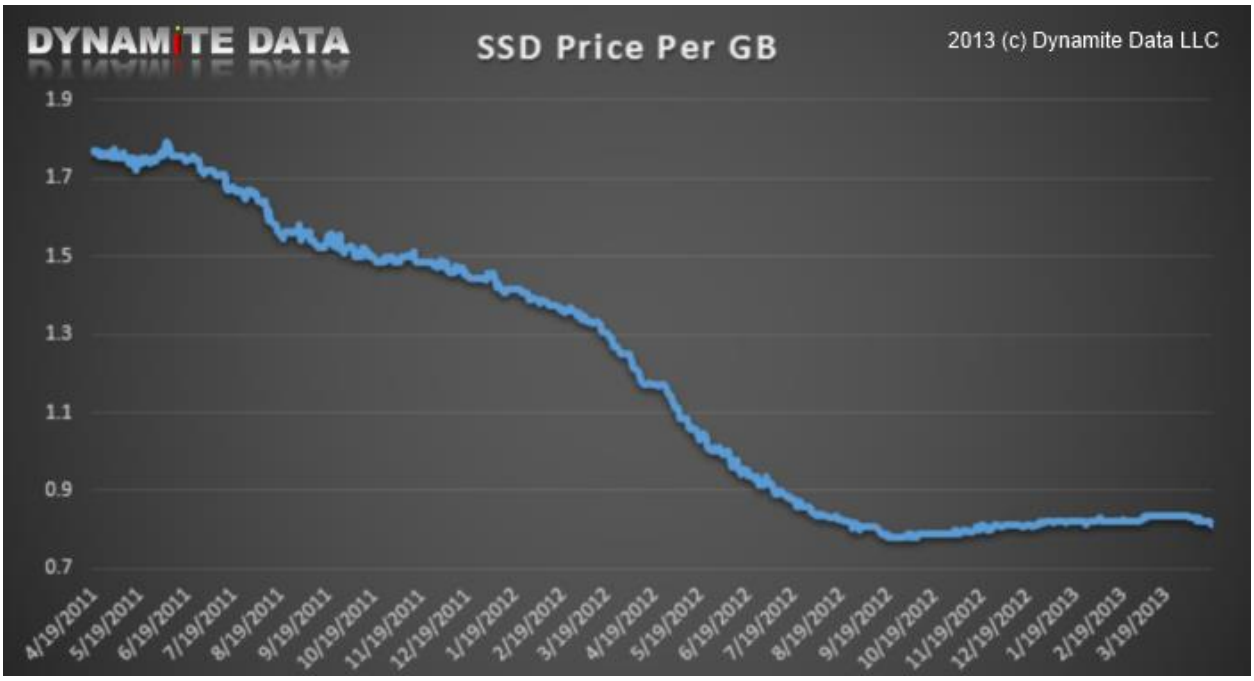

Figure 1 – SSD price trend from 4/11 to 3/13

This figure shows the cost trend over a recent 2-year period for solid state drives. We see a gradual decline in cost per gigabyte and at the time of this writing, that cost is about $.60.

A majority of hard drives installed in cars have a maximum capacity of 64GB. The storage requirements for typical infotainment applications can be summarized as follows[8]:

Function	Storage Need
GPS/Navigation	4-15GB
Digital Music	4-20GB
High Definition Video	10GB
Gaming and Applications	1-20GB

The average consumer may pay $150 for an integrated hard drive with 40-60GB capacity as an option when purchasing a new car[9]. The actual cost for the drive may be much lower given car manufacturer and dealer markups. An equivalent SSD costs $50 and after markups, will likely be higher than the cost of a rugged HDD, but the difference may be close.

Speed

A personal computer with an installed SSD can boot up in seconds whereas a hard drive requires time to speed up to specifications and continue to be slower during normal operation. SSDs also avoid the problem of fragmentation. Hard drives operate best when the data they have to read is stored in contiguous blocks. Although technology has improved, fragmentation is still an issue as the disk fills up and the data blocks for large files must be scattered around the disk platter, requiring read heads to perform longer searches[10]. Solid state drives do not require read heads and large files can be stored anywhere on its chips. The following compares a Samsung SSD with a typical hard drive with the same maximum capacity and above average rotation speed[11]. The SSD wins out in all data read/write categories.

840 SSD (500GB)	Category	2.5" SATA HDD (500GB, 7200rpm)	Difference
NAND FLASH	Media	Magnetic Platters	
540 / 330	Seq. R/W Speed (MB/s)	60 / 160 (*140/70)	x 3~8 / 2~5
98,000 / 70,000	Ran R/W Speed (IOPS)	450/400	217 / 175
0.1	Data Access Time (ms)	10~12	x100~120
78,700	Benchmark Score (PCMark Vantage)	5,600	x 14

Figure 2 – read write comparison SSD vs HDD

The practical application of faster drives in vehicles is to reduce wait times for reading data for specific situations. When powering up the car, loading the onboard operating system will take at most seconds. This allows the driver to bring up GPS navigation and maps quickly if he is in a hurry. For any functions that require random access such as shuffling to another song, read times are also improved. Another great benefit is the quick loading of applications and videos to accommodate the entertainment needs of impatient children.

Durability

SSDs do not require moving parts and are thus not susceptible to the wear and tear that mechanical components face. In the environment of everyday driving, data storage units are exposed to regular shock and vibrations. They must also operate with minimal data loss and corruption in extreme temperatures ranging from below freezing to high heat. To account for a treacherous operating environment, manufacturers of hard drives for cars incorporate features to mitigate the potential harsh effects of shock, temperature, and change of altitude. Current automobile hard drives operate at speeds with a lower rpm than seen on desktop or laptop drives. The hard drive's spindle motor which spins the disk platters requires a great deal of power to start in freezing temperatures. At the other extreme, high temperatures would affect the motor's lubrication system and performance can be affected. The result is that today's automobile hard drives operate at a safe 4200rpm, increasing durability but also adversely affecting data transfer rates[12].

Hard drives must also compensate for vibrations and shock during driving. Manufacturers have incorporated into their drive designs shock sensor technology and consistent distancing between the read/write heads and disk platters[13]. This also helps at higher altitudes where thin air reduces the distance between head and platter, potentially causing mechanical failure.

Solid state drives are not susceptible to the same problems caused by operating environment. They can withstand 40 times the vibration and 5 times the shock than a typical HDD for personal computing[14]. They also can operate at a wider temperature range – the lack of moving parts eliminates the heat caused by said parts during normal operation. Humidity is also less of a factor for SSDs – they are rated to operate at up to 90% humidity or more[15]. Thus SSDs can operate in a wider range of environmental conditions without the need of intervention that a traditional hard drive would require.

Summary

Moving away from the use of existing hard drive technology in favor of adopting solid state drives in automobiles makes sense from a business standpoint and that will likely be the trend in the near future. As both traditional hard drive manufacturers and memory storage companies continue to improve upon SSD technology, prices for the drives will continue to go down while maximum capacity will go up. Though still not cost-effective for PC end users, the storage capacity of SSDs is ideal for cars. With GPS navigation and digital music as potentially the biggest users of storage, current SSD capacities allow for reliably storing this data with room to spare.

Along with cost benefits, a key characteristic of SSDs is operation under harsh environmental conditions. SSDs do not require the necessary improvements that hard drives need for error-less operation in a car. The lack of the mechanical element of spinning platters and use of read heads favors SSDs which do not require moving parts and the complications that come associated with such parts. Additionally, SSDs can handle up to 1500G of shock and operate in extreme heat or cold. Traditional hard drives must integrate components to handle these environmental extremes, adding complexity to a fragile system.

Finally, SSDs outperform HDDs in terms of performance. Hard drives have an advantage over SSDs when it comes to writing data but SSDs have significantly better random read times. In the real-world application of utilizing stored data on a car's hard drive, SSDs are a more suitable fit. Digital music comprises a majority of the data and quick reads for retrieving songs on a playlist or shuffling to random song is a benefit that SSDs have. Even for sequential reads such as when playing a video, read times are comparable between SSDs and HDDs.

Sources

1 http://en.wikipedia.org/wiki/Infotainment

2,13 http://www.hgst.com/tech/techlib.nsf/techdocs/235FD62D9173101B88257BF300266F70/$file/\ESJ4K320_ds.pdf

3,5 https://storage.toshiba.eu/export/sites/toshiba-sdd/media/products/datasheets/mk4036gac-e_datasheet.pdf

4 http://www.pcmag.com/article2/0,2817,2003286,00.asp

6,7,10 http://www.pcmag.com/article2/0,2817,2404260,00.asp

8,12 http://storage.toshiba.eu/export/sites/hddrevolution/_download/Auto_HDD_white_paper_FINAL_.pdf

9 http://forums.storagereview.com/index.php/topic/27949-hard-drives-for-cars/

11,14 http://www.samsung.com/de/business-images/resource/case-study/2014/01/Whitepaper-SamsungSSD-0.pdf

15 http://www.ni.com/white-paper/7482/en/

Images

Figure 1: Courtesy of extremetech.com

Figure 2: http://www.samsung.com/de/business-images/resource/case-study/2014/01/Whitepaper-SamsungSSD-0.pdf