There's a confusing picture in many consumer products like phones, cameras and music players in which one day it seems that the storage function is done by flash and next day another company announces they're doing the same thing with miniature hard disks. Is there any sense to this seemingly random choice? This article uses pricing trends, technology trends and unique market analysis insights to show that users and oems may be able to reliably predict which storage devices will be most cost effective depending where you are on the future history curve.

Flash Memory vs. HDDs - Which Will Win?

by Jim Handy, Director of NV Memory Services, Semico Research

(this classic article was published here in June 2005)

There are many questions confronting today's managers about the state of small form factor HDDs and flash memory:

- Will solid-state storage replace all rotating media over the long term?
- Where does flash threaten rotating storage and where does it not?
- What applications can take advantage of flash, and what applications cannot?
- How will media's predictable price drops change our work/play habits?

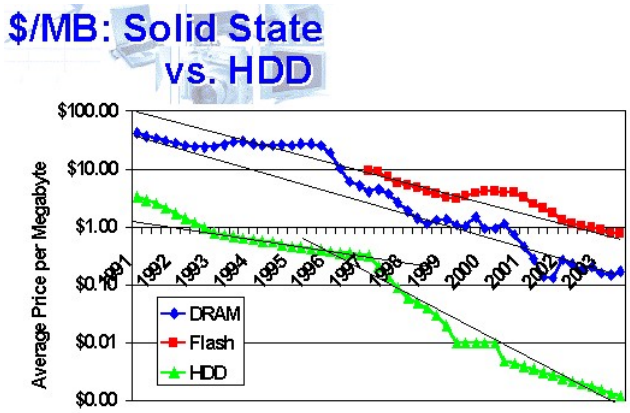
Although digital cameras have solidly moved from rotating storage to flash, and although USB Flash Drives, the little keychain fobs that store hundreds of megabytes of information, have already displaced floppies on many PCs, there is no reason to anticipate an exodus away from today's optical and magnetic storage in PCs and other traditional applications.

There are lots of angles that designers consider when choosing flash versus HDDs. Price per megabyte is often discussed, but this must be weighed against total system cost, which is an equally important factor, as we'll see soon. In many applications physical size and weight limit the use of HDDs (although today's form factors get away from that in very many cases). Energy consumption and robustness are arguments often used by purveyors of solid-state drives, but these factors are important to a more elite audience, so they will not be discussed in this article. But one very important factor is file size, which we will see counterbalances costs to become one of the top reasons for selecting one or the other media type.

Cost is a Key Factor

The single most important factor in any consumer system is cost. As long as the desirable features can be brought to the market for an affordable price, the product should succeed. The big trade-off is cost vs. features. It would be nice if the world would stand still, and a tidy answer to the question of costs could be derived. This is not the case, yet the dynamics of HDD and flash pricing are clear enough that we can draw some important conclusions that we can use to foretell the future.

The following chart illustrates historical price per megabyte trends of flash, DRAM, and HDD. We show DRAM price per MB because flash is a new enough technology that we only have eight years' worth of data. Since both are semiconductor memory technologies, both are driven by the same factors, so both can be expected to follow the same trend line.



"I don't see how SSDs can replace HDDs in the times you've talked about in some of your articles. Based o what's known now - and flash capacity and the times and investments needed... it looks to me like Seagate right - there isn't going to be enough SSD manufactu capacity. Or am I missing something?"

meet Ken - and the enterprise SSD software event horiz

"The user mood is changing from - can I afford to us SSDs? to a realization that - I can't afford not to."

where does all the money go?

Retiring and retiering enterprise DRAM was one of the big SSD ideas which took hold in the market in 2015.

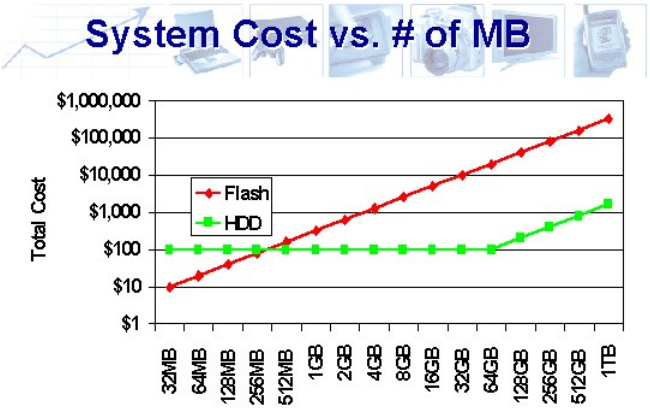
The chart is plotted using a logarithmic vertical axis. This helps us to read the chart because steady growth is drawn as a straight line on a semi logarithmic format. Straight lines have been overlaid on top of the data to illustrate how steady the trends really are.

Flash prices can be expected to continue to drop at an annual rate of 30-40%. DRAM has followed a **32%** average annual price decline for over 30 years. The wavy portions of the line indicate price flattening during shortages. The one place where DRAM prices drop significantly below trend occurred during a period of prolonged below-cost pricing. As a result of this policy foreign competitors' wrists were slapped by the US and European governments. The portions of the curve that rise above the trend line indicate profits during shortages - nobody can begrudge a memory manufacturer taking profits by holding prices firm during a shortage.

HDDs underwent a change in the late 1990s, where the shallow price decline, which was on a collision course with semiconductor memory, suddenly became much steeper. Semico does not closely track the HDD market, but we have been told that this is where the GMR head started to be used. The new slope accelerates HDD's price per megabyte decline to a point where it looks like semiconductor memories will not be able to catch up. This chart indicates that HDD is priced three orders of magnitude lower than flash, but the flash data is an aggregate over all densities of chip - the higher density chips used for mass storage are about 1/30th of this price, while the HDD line is based upon the least expensive version. Additionally, the small form factor HDDs that are used in portable applications are several times as expensive as the HDD trend line would indicate. All in all there are only about two orders of magnitude between the average mass-storage flash and the average HDD.

For the sake of simplicity, let's not assume that there will be any more breakpoints in either curve (which is an adequate assumption for the near term) and let's look at these two price declines as if they are roughly parallel. These two assumptions will help develop arguments that can be refined by the reader at a later point.

With the kind of price drops the preceding figure illustrates, where does flash threaten rotating storage and where does it not? At first flush it appears that there is no contest. Why is anyone currently using flash? The answer requires for us to look at the big picture, to understand where pricing is at a system level. The following chart compares flash prices against HDD prices across a wide range of capacities for a set point in time. The numbers are approximations made in 2004, and the reader may want to plug in more relevant numbers. We argue that this won't change the nature of the chart that much, just the placement of the breakpoints. This chart was developed to compare a $100 64Gb HDD to a $10 32MB flash card.



The chart differs from the earlier version as it has log scales on both axes. This helps to show that for a doubling in capacity, prices will double, as long as the doubling requires for another unit to be added to the system.

It is clear from the chart that HDDs have a floor price. The lowest price for this exercise was estimated at $100. Below this level flash becomes the less expensive option, as long as the smaller capacity of the flash does not get in the way.
At the point where the two cross over the price of that much flash has become equal to the floor price of the HDD. For the numbers used here that occurs with slightly more than 512MB of flash. At this juncture HDD and flash add the same cost to the system, yet HDD offers the designer 100 times as much storage.

Looking farther away from the origin we see a point where the HDD price starts to rise. This is the capacity at which multiple drives must be used, so pricing suddenly becomes proportional to storage requirements. An example of such an application would be a RAID array or a collection of blade servers. The HDD and flash lines track from this point on, but the flash line is over 100 times the price of the HDD. There are few applications that would gravitate towards flash at such an expense, but this is the realm of solid-state drives, which offer faster seek times, extreme mechanical ruggedness, and low power consumption at a considerable premium.

To boil this down, we see that for very small storage requirements flash gives a lower overall system cost. Once flash approaches the floor price of the HDD, then HDD wins hands-down from a pricing standpoint, and any decision to use flash would have to include more considerations than simply cost.

Combining the Charts

What do the two charts show us together? We were unable to come up with a reasonable representation of this in a picture, so we'll have to describe it in words.

First, let's assume that HDD and flash price per megabyte will continue behave as they do in the first chart and

Over 20 companies have already announced product for this market among which are Memory1, 3DXPoi etc

But what are the underlying reasons that will make i feasible for slower cheaper memory to replace most the future DRAM market without applications noticing?

latency loving reasons for fading out DRAM

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popular SSD articles on StorageSearch.com

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year of the enterprise SSD goldrush - that's what I predict 2012. Wonder why?

SSD market analysts - I compiled this filtered list as a recommended resource for all those people who need paic custom reports and detailed SSD market help.

SSD jargon - You can't have a meaningful discussion abo intricacies of SSD design without using these words.

track each other's decline over time. Next, let's assume that the floor price remains intact (which is roughly the case for any given form factor of HDD, although the price will not necessarily be $100) then we find that the shape of the second chart remains the same over time, yet the two lines move to the right at a rate of one doubling in capacity about every year.

The net effect here is that flash will become the better choice for larger and larger applications over time. HDD will continue to be the less expensive choice for applications where flash's price equals or exceeds the floor price of an HDD.

This means that applications that need an HDD today may be able to cut costs by going to flash in future years if the file sizes don't expand over time.

So now we have the question: "How much capacity is needed by **my** application?"

File Sizes

File size is the final key factor in this equation - what is the size of all of the files that must be stored upon the media?

Certain files will not grow over time. A good example of this sort of file is an MP3 song (approx. 1.5MB for a 3-minute song). Feature films are also unlikely to grow much in size. Today's 90-minute feature film consumes about 2GB of storage. Arguably HDTV will double this, but this is not an ongoing increase - it is a one-time event unlikely to be replicated for over a decade. Another one-time event that works in the opposite direction is the migration of videos from the MPEG-2 compression standard to MPEG-4, a change that is likely to cut the storage requirements of a film to as little as a tenth of its MPEG-2 size.

What about camera megapixel requirements? Many in the digital camera business believe that camera megapixel offerings are about to stagnate at a certain level (although there is no agreement if this is 3 megapixels, 5 megapixels, something between these two, or something larger). What Semico knows for a fact is that while HDD and flash capacities double approximately every year, camera megapixels have historically grown at a much smaller rate of about 19% per year. For the sake of argument we will assume that camera megapixels will continue to grow at this very low rate.

Other files will grow as fast as or faster than the growth of the capacity of the media. A prime example of this is software, whose size seems only to be limited by the maximum practical HDD size in the system. The data files that go with this software are equally unconstrained in growth.

For those applications that don't grow and for those that grow very slowly, the decline in cost in the first chart implies that the amount of storage in the system (a camera, a TiVo, an MP3 player, or what-have-you) will increase steadily allowing users to store an ever-increasing number of fixed-length files in the system. Napster's recent advertising campaign in the US points out that you could spend $10,000 to fill your iPod to capacity with songs. Not only are users unlikely to embrace this idea, but insurance carriers are even less likely to offer replacement value for the loss of such a well-filled iPod. Even if songs cost nothing, how much data is manageable through the interface of a portable device?

Here's another similar example: By Semico's estimate the average capacity flash card in 2008 will be able to store almost 1,000 photos taken by the average camera purchased that year. We wonder how likely it will be that users will wish to manage 1,000 photos through the camera's interface.

It is reasonable to expect users to max out on the number of these relatively fixed-size files that they wish to manage on a portable device. Although we don't know what this number is, we believe that the maximum manageable number of fixed-size files a user can deal with will limit the memory size desired by the user. In turn, this should cause systems to eventually migrate from HDD to flash.

This sounds very negative from the viewpoint of the HDD maker, but new applications promise to come to the rescue.

New Applications Will Change How We Work & Play

Just as the TiVo is changing how people watch television, and as digital media is changing how people take and share photos, the availability of the right kind of storage will change other aspects of our lives.

Video consumes prodigious amounts of storage. TiVo and other personal media recorders will continue to consume larger and larger HDDs for years to come, never once entering into a realm where flash can compete. Many people will find themselves with a stash of hundreds of hours of un-watched video, waiting for that "some day" when they can get caught up.

One application that Semico expects to emerge from ever-decreasing media prices will be camcorders that are based either upon HDDs or flash cards. Many examples are on the market today, but either they are either too expensive (in the case of HDD and quality flash camcorders) or they offer insufficient quality (the other flash camcorders, which record low-resolution images.) Once we have reached the magical juncture of quality and price, the market should open up and perhaps explode.

We are sure that other similar applications will emerge, and that creative minds will imagine ways to use growing HDD capacity that we have never even dreamed of.

What to Expect Going Forward

Here are some rules of thumb that will help with any decisions about when flash will appeal and when HDD will be the better choice:

the SSD Reliability Papers - links and abstracts of articles the subject of SSD reliability and data integrity.

the problem with Write IOPS in flash SSDs - this classic a helps you understand why all flash SSD benchmarks inco suggest you're going to get much higher performance fron types of flash SSDs than you will actually see in your app

Data Integrity Challenges in flash SSD Design - looks int detailed techniques to achieve data reliability.

What's the best / cheapest - PC SSD? - I often get emails readers who ask the above question.

notebook SSDs - market overview.

auto tiering SSDs / SSD ASAPs - market guide to Auto-tu Accelerated Pools of storage.

this way to the Petabyte SSD - This article describes the f storage architecture of the datacenter, explains the econon SSDs replacing HDDs for bulk storage and suggests a roa getting there.

the 3 fastest PCIe flash SSDs list - or is it really lists?

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A to Z - SSD stuff

1.0" SSDs
1.8" SSDs
2.5" SSDs
3.5" SSDs
19" rack SSDs

1976 to 2013 - SSD history

Analysts - SSD market
Articles and blogs - re SSD

Bad block management in flash SSDs
Benchmarks - SSD - can you trust them?
Best / cheapest SSD?
Big market picture of SSDs
Branding Strategies in the SSD market

Chips - storage interface / processors
Chips - SSD on a chip & DOMs
Cloud storage - with SSD twists
Controller chips for SSDs
Cost of SSDs - why so much?

more A to Z in SSD

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"Thanks for the offer, but...
we don't want to deploy any new hard drive arrays.
Not even if you're giving them to us free!"

This classic article described the pivotal future storage market climate in which enterprise users will cease to regard hard drive arrays attractive or usable - even if the cost of buying a new hard drive array drops away to ZERO! - this way to the petabyte SSD

1. Flash will be the leading choice in portable applications where a limited number of small files are used because it will offer the lowest overall system cost.
2. Other limited-capacity applications will also gravitate towards flash.
3. In applications where file size or the total number of files to be stored is of more concern than total system cost, HDDs will prevail.
4. Everything will change over time, as declining prices cause flash to replace HDD in portable applications where storage requirements reach some natural limit.
5. New applications will emerge to take advantage of lower prices afforded by HDDs.

...Semico Research profile, flash, HDDs

...Later:- 2008 - Sun's CEO Jonathan Schwartz,
cited the above article in his blog Anything But a Flash in the Pan
...

The SSD market during its short history (spanning only 40 years) has managed to accrue an imaginative body of literature which includes truths, half truths, mysticism, misunderstandings. myths, legends - and in some cases - downright balderdash - when it comes to the subject of SSD costs, pricing and justifications.

Exiting the Astrological Age of Enterprise SSD Pricing

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See also:- 100 popular SSD articles on StorageSearch.com