Selecting the Right Embedded SSD Storage Solution

Introduction

For embedded systems designers, selecting the optimal solid state drive (SSD) form factor has never been more difficult. That is because the industry joke, “standards are great -- everybody ought to have one”, unfortunately rings true especially when referring to SSDs.

The density evolution of NAND flash components has made enormous SSD capacities a reality in a growing list of small form factors. SSDs are not limited to traditional 3.5”, 2.5” or 1.8” hard drive form factors and storage suppliers have used this freedom to develop SSDs in a wide array of form factor shapes and sizes. This broad selection of SSDs makes it a challenging and sometimes confusing task to select the right SSD for a given embedded system requirement.

A good first step in the process of choosing the right SSD is to have an understanding of SSD history. CompactFlash has been the Godfather of embedded form factors for the past ten years. CompactFlash truly did it all: it connected to standard Intel or AMD chipsets in TrueIDE or PATA SSD mode; it connected to Freescale or Cavium processors, Altera or Xilinx FPGAs or custom ASICs via PCMCIA memory or I/O modes; and, it was “eject-able”. Today’s new embedded systems designs are moving to serial storage interfaces with higher speeds and reduced pin-counts and in doing so, CompactFlash is going the way of the fax machine and the DVD player – still widely in use but slowly being replaced by new technology.

The reality today is that there is no “one size fits all” SSD technology or form factor poised to take the place of CompactFlash, which impacts future embedded systems designs. The lack on an SSD “hero” that fully supports the storage needs of embedded systems further complicates the task for designers that must contend with a long list of complex requirements. To make an informed decision, developers must evaluate if a particular SSD has the endurance and availability to meet their longer lifecycle demands, supports cost-effective and widely adopted sockets and connectors, and is compatible with universally deployed storage interfaces. This paper will cover the important considerations in order to find the most appropriate embedded SSD storage solution.

Selecting the Storage Interface

The choice of which storage interface to use is made after the main chipset/FPGA/ microcontroller and software architecture decisions are concluded. Designers will typically choose one of several storage interfaces that are available “for free” on their chipset and will most likely choose the one that will allow them to leverage their previous storage. Regardless of the chipset chosen, non-Intel or AMD-based designs may include SATA and one or more lanes of PCI Express (PCIe), USB and SD/SPI/eMMC are frequently available. Intel- and AMD-based designs support SATA 3G (SATA II) as a minimum and most support SATA 6G (SATA III). The verdict on interface usually is narrowed by the designer’s familiarity and the software architecture specified. OEMs with current applications based on previous generations of ATA/ATAPI device code (i.e. systems that used CompactFlash in True IDE mode) often believe the transition to SATA to be the optimal approach. If the SATA interface is not available, the most common choices are PCIe, USB and SD. There is significantly more industry software experience writing code for USB than for Secure Digital (SD) cards, but the inherent performance limitations may render this option unusable in higher speed applications. That is where PCIe may come in, but comes with the potential tradeoff of increased software complexity. PCIe requires either AHCI (ATA Host Controller Interface), NVM Express (NVMe) or a vendor specific driver to operate as a storage device. AHCI limits performance to SATA speeds, so why not use SATA? Few companies have the time or resources to qualify multiple vendor-specific drivers, so that leaves NVMe. While NVMe is gaining traction as an SSD-specific standard, few truly embedded systems are able to take advantage of the tens of thousands IOPS that an NVMe/PCIe solution can offer. So OEMs need to ask themselves if PCIe is worth the software development required to implement a new standard.

Comparing SSD Form Factors

The viability of SSDs in computing applications has been enabled by quantum leaps in controller technology that effectively manage NAND flash devices as storage media. In turn, SSDs have given system designers mechanical degrees of freedom that cannot be achieved when disk drives are the only storage solution. Where before it was a discussion of 3.5”, 2.5” or 1.8” HDD form factors (Okay, we can include 1” microdrives, too), now there is an abundance of options available for almost any interface. Industrial SD cards are available in standard full size and microSD card form factors, which are standardized by the SD Association (http://www.sdcard.org). USB drives are available in thumb drive form factors, 10-pin high and low profile or even 9-pin embedded modules. The 10-pin embedded USB module is not officially regulated by any industry standards body, but thanks to industry R&D – in this case, “rip-off and duplicate” - OEMs can source mechanically equivalent modules from multiple sources. Not so with the thumb drives. The options for PCIe include miniCard, the emerging M.2 (formerly next generation form factor or NGFF) form factors, 2.5” and full-height, full length PCIe cards with multi-lane support. Even SATA SSDs have more than seven “industry-standard” form factors including 2.5”, 1.8”, MO-297 or Slim SATA, MO-300 or mSATA, CFast, and MO-276 or microSSD.

The Need for Eject-ability

In many instances, the selection of an appropriate SSD solution is not obvious from the broad selection of options embedded developers have today. A good approach is to use a process of elimination. One of the first basic decisions is to determine the need for “eject-ability.” CompactFlash supported it and if it is still needed, there are really only a few options.

The first and most obvious choice, especially for OEMs migrating away from CompactFlash is CFast. CFast is the follow-on specification from the CompactFlash Association (CFA) and supports the SATA 3G (SATA II) interface in CFast 1.1 and will support SATA 6G (SATA III) in CFast 2.0. From a motherboard real estate perspective, CFast is almost a drop-in replacement for CompactFlash. In spite of this, the connector and sockets are different, and since CFast was never really adopted in consumer electronics applications, OEMs are not able to leverage the advantages of mass-produced sockets and connectors compared to other form factors. However, OEMs will find a ready supply of available industrial CFast cards that have been specifically designed for embedded systems.

Another SSD form factor option that meets the requirement for eject-ability is the 1.8” SATA. While 1.8” is thought to be a dying or almost dead form factor for hard drives, many companies are opting for 1.8” SATA SSDs as an alternative to 2.5” form factors to meet serviceability needs. At a 5mm thickness, the 1.8” form factor is also ideal for 1U server and blade applications.

The final eject-able options are SD and microSD cards. There is a great deal of industry familiarity with this form factor from consumer electronics designs. Smaller than CompactFlash, SD and microSD card sockets are plentiful and inexpensive. SD cards are probably the best option if all that is needed is a commercial grade, MLC- based solution – as those are plentiful and inexpensive. Low capacity, SLC-based industrial SD cards are also available from a few manufacturers.

Designs that Require Fixed Storage

If a fixed storage solution is required and there isn't a restriction on size, or the design is migrating from an HDD, then a 2.5" SATA SSD is an excellent choice. The 2.5" SATA SSD form factor matches the size of the 400 million 2.5" HDDs shipped each year. Depending on the capacity and endurance required, an SSD can provide a cost reduction or a ruggedized enhancement to hard drives. And, for systems that require a 3.5" form factor, a 2.5" SATA SSD with an adapter can be incorporated. Just be aware of the multiple Z-heights available on the SSD market. The 9.5mm height is considered to be "standard" today as single platter HDDs have used this for years. Many SSDs targeted at the high-performance notebook market are 7mm high. Intel, with its ultrabook specification, is pushing storage vendors for 5mm high drives, so look for SSDs in this height to be coming soon.

For applications that require a form factor smaller than 1.8", the considerations get a bit more complex, and a key question becomes one of a socketed versus a soldereddown solution. Soldered-down BGA solutions are most often deployed in applications where space is at a premium, or where the shock and vibration demands of the application make socketed solutions undesirable. SATA-IO standardized the microSSD (MO-276) in revision SATA-IO 3.1RC. The most common consumer applications are for handheld or tablet devices that are only expected to have a three-year product life under a light workload. Conversely, industrial-grade solutions must meet the needs of ultra-rugged environmental applications. One word of caution, however, there are many "SATA BGA" solutions that do not conform to the SATA-IO pin-out, meaning multi-sourcing these components may prove difficult. While there are a few pin-outs associated with MO-276, the most common is a 156 ball array.

Socketed solutions excel where storage upgrades, serviceability and capacity are key design issues. Socketed solutions in general provide longer life support, can be upgraded, easily serviced and have a broad supplier ecosystem. In addition to 1.8", 2.5", CFast and microSSD mentioned above, other socketed solutions include Slim SATA (MO-297), mSATA (MO-300) and M.2.

Slim SATA SSDs are an attractive solution for customers that want to migrate away from 2.5" storage, but want to keep that same socket. Slim SATA implements a standard SATA socket but in a form factor with a volume (54mm x 39mm x 5mm) that is roughly 15% of a 2.5" SSD, making them ideal for networking, embedded, industrial and AdvancedTCA applications.

mSATA was the initial standard winner of the ultrabook market. PC makers that did not define their own form factor embraced the familiar PCIe miniCard socket and form factor, with manufacturers that needed something smaller choosing half-miniCard. Industrial embedded OEMs looking to leverage off of SSDs for notebook computing chose this form factor for many boot drive and mobile computing platforms.

The key drawback to mSATA is its small size, which limits capacity. OEMs typically want a path to high capacities and, therefore, need a standard that can accommodate them. In addition, with more capacity (more NAND) comes increased performance and SSD makers find that they can saturate the SATA 6G interface.

Because the logical path leads to multi-lane PCIe, the solution seems to be the M.2 form factor, which not only defines four different PCB lengths, and it also supports two lanes of SATA 6G or four lanes of PCIe that necessitates the adoption of a brand new connector. Expect to see M.2 shipping in 2014 ultrabooks and eventually capture that market.

Fixed storage is not limited to SATA. Embedded USB or eUSB is the most popular solution for USB-based fixed devices. It is important to note that while the USB command set and protocol is standardized by USB-IF, there is no specific industry standard associated with the eUSB form factor, so careful consideration must be given to mechanical dimensions. Multiple eUSB iterations exist and the most common connector scheme is the 10-pin eUSB (two rows of five pins each) in a 2.54mm standard profile or 2mm low profile. The 10-pin eUSB provides the best opportunity for multi-sourcing but some vendors also offer a 9-pin option.

Embedded SSD Evolution Driven by Market Needs

The determination for which SSD is best is application and system dependent. And, market needs have driven the evolution of SSD form factors and features. That is why Virtium designed its four classes of StorFly industrial embedded SATA SSDs to match virtually any embedded system workload requirement.

For cost and multi-sourcing reasons, embedded system engineers prefer to source high-volume components into their designs. When discussing which industrial embedded SSD form factors "will win," it is necessary to understand what is driving their adoption. Ultrabooks, notebooks and tablets are the biggest drivers of small form factor SATA solutions. Hard drive manufacturers generally sell 9.5mm 2.5" drives into notebooks and they have recently made inroads into the enterprise as well. The shrink to 7 and 5mm thickness for notebooks has been achieved by some HDD manufacturers that meet the needs of smaller, lighter, thinner and low power laptops. 9.5mm and 7mm SSDs are already available and look to see 5mm 2.5" SSDs coming soon.

Ultrabook vendors that are 100% committed to SSD find mSATA (MO-300), microSSD, M.2 or proprietary form factors as better SSD options. MicroSSD solutions are the most space-efficient, and are probably fine for consumer electronics devices with a projected three-year life, or for small size, ultra-rugged industrial applicaitons, but the socket-based SSD solutions are most often a better choice for embedded systems that need to be deployed for five to ten years or more.

SD cards are obviously driven by the consumer electronics market. They are the memory expansion card of choice, but recently are taking a backseat to eMMC and other solder-down solutions in the high-volume smart phone space. Industrial SD cards are finding use in VMware load applications and as memory cards in industrial programmable logic controllers.

CFast, Slim SATA, 1.8" and eUSB SSD solutions are largely being driven by the embedded and server markets. CFast is seen as a viable solution for industrial automation customers because it is the most straightforward SATA alternative to CompactFlash. Slim SATA is used for primary storage as a space-optimized replacement for 2.5" HDDs. Replacing 1.8" HDDs are 1.8" SATA SSDs, which are also being used as high density and easily-serviced SSD alternatives compared to 2.5" SATA SSDs for hot-swap carriers in 1U and blade applications. Furthermore, networking line cards and industrial embedded systems based on Cavium, Freescale, FPGA or custom ASIC designs have adopted eUSB.

The Importance of Sourcing Embedded SSDs

As presented in this paper, it is easy to see that selecting the right SSD for an embedded systems application is not obvious from the broad selection of options that developers have today. There is no one SSD form factor that fits all industrial embedded system needs. The SSD must complement other design choices such as the main chipset, FPGA or microcontroller, the available storage interface, application capacity requirements and software architecture.

Included in the evaluation process must also be the discussion of SLC versus MLCbased SSDs as well as the true differences between client, enterprise and industrial SSDs. OEMs that have intimate knowledge of the workload and deployment requirements can positively impact overall system cost by choosing the right SSD. Virtium's StorFly SATA SSD portfolio helps developers take the guesswork out of selecting the right embedded SSD. StorFly SSDs allow embedded system OEMs to define the optimal trade-off of endurance, performance, capacity and operating temperature versus cost and longevity.

Virtium manufactures memory and storage solutions for the world's top industrial embedded OEMs. For 18 years we have designed, built and supported our products in the USA - fortified by a network of global locations. Our world-class technology and unsurpassed support provide a superior customer experience that continuously results in better industrial embedded products for our increasingly interconnected world.

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