Rugged Embedded SSDs Sharpen Their Appeal

Thanks to advancing flash semiconductor development, solid-state drive vendors are able to offer faster, denser products. And new form factor standards provide the increased ruggedness military systems demand.

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Developers of military systems are increasingly turning to solid-state drives (SSDs) for use in embedded applications, where temperature, shock and vibration make mechanical storage, such as disk or tape, unreliable. SSDs provide benefits in power dissipation and overall system performance. Commercial development of SSDs continues to accelerate, as more consumers experience the benefits of SSD technology in now-ubiquitous tablets, smartphones and other small form factor computers. Defense systems designers and integrators are reaping the benefits of this rapid commercial development.

The maximum available capacities for solid-state drives are basically doubling this year as NAND flash memory vendors make the transition from 5xnm and 3xnm to 2xnm flash designs. The move to 1xnm next year will double them again, allowing for 1 Terabyte of capacity in a 2.5-inch SSD using SLC flash. This rapid technology progress is a double-edged sword. While it has provided greatly enhanced performance and capacity, it has also driven obsolescence issues, because flash and controller vendors move their fabrication capacity to the latest versions of their products to satisfy the competitive demands of the commercial marketplace. Flash vendors have product availability programs designed to ensure that a number of their designs are available for the longer term to meet the needs of the defense systems and embedded marketplaces, which favor reliability and stability over technology churn. It is important for embedded SSD providers to be plugged into these programs with their flash supplier.

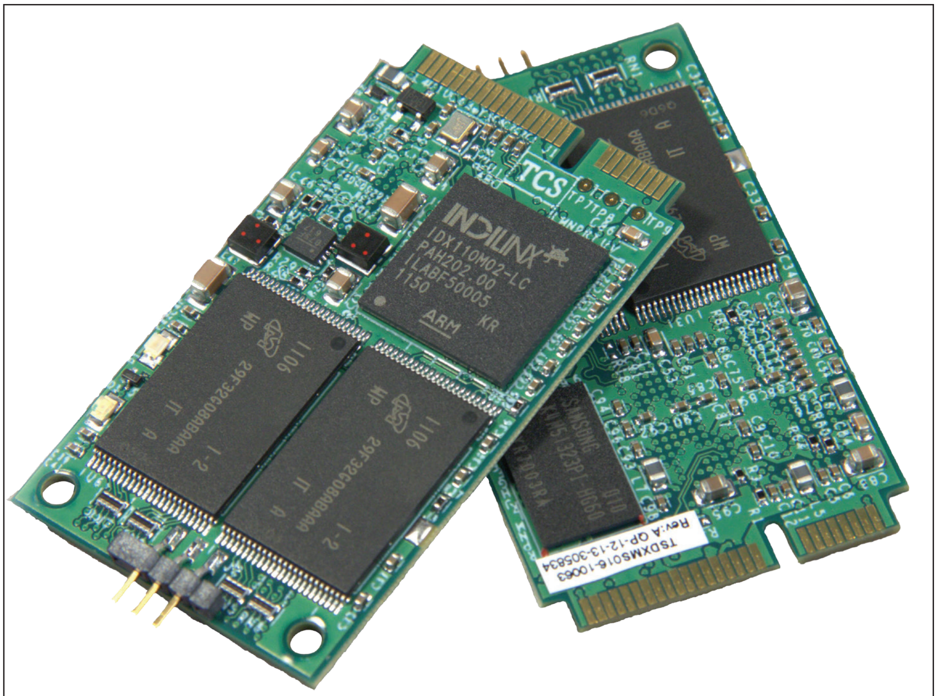

Figure 1

The mSATA drives have full SATA functionality in the JEDEC MO-300B form factor.

From TSOP to BGA Packaging

Another trend in the NAND flash space is a move from thin, small outline packaging (TSOP) to ball grid array (BGA) packaging. As the pin count required for synchronous interfaces (Open NAND Flash Interface (ONFi), Double Data Rate Toggle Mode) has increased, TSOPs can no longer meet the need, and many flash vendors are discontinuing TSOP packaging with the 1xnm generation of NAND flash. TSOPs are sometimes preferred in rugged designs, since the pliancy of the leads helps with resistance to shock, vibration and thermal coefficient of expansion mismatches. BGAs can work in rugged designs, but underfill is recommended for maximum protection against solder failure due to shock or TCE mismatch.

SSD interfaces are moving to the faster SATA revision 3.0 interface standard, which doubles the raw bit rate to 6 Gbits/s. These changes will double the sustained bandwidth performance of these drives to over 500 Mbytes/s. SATA 3.0 is already in use in laptop and desktop PCs, with some commercial controllers already on their second generation of SATA 3.0 controller. Rugged SSDs with SATA 3.0 will enter the embedded market sometime this year.

These new SATA 3.0 controllers are also required to take maximum advantage of the higher-density NAND flash. The smaller geometries of 2xnm and 1xnm NAND flash lead to lower charge levels, tighter voltage tolerances, lower signal to noise ratios and higher raw bit error rates. Maintaining the endurance, data retention and corrected error rate specifications requires more powerful error correction codes. Most controllers have transitioned from Reed-Solomon ECC to Bose-Chaudhuri-Hocquenghem (BCH) codes, which are more efficient at smaller symbol sizes (in this case, 1 bit). The latest controller designs are moving to Low-Density Parity-Check (LDPC) codes, which can be even more efficient, but are somewhat complex to implement.

Two Types of Rugged Solutions

SSDs for rugged embedded use have generally fallen into two types. One is packaged in hard-disk form factors, such as 3.5-inch or 2.5-inch cases, allowing drop-in replacement for hard disk drives. The other is ruggedized versions of consumer electronic form factors, such as the compact flash (CF)

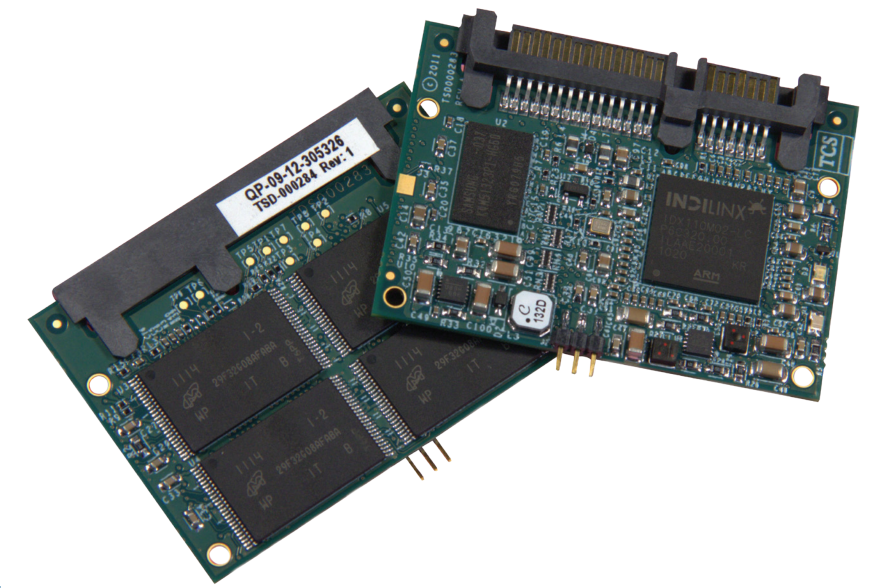

Figure 2

The SlimLite SATA offers full SATA functionalty in the JEDEC MO-297A form factor.

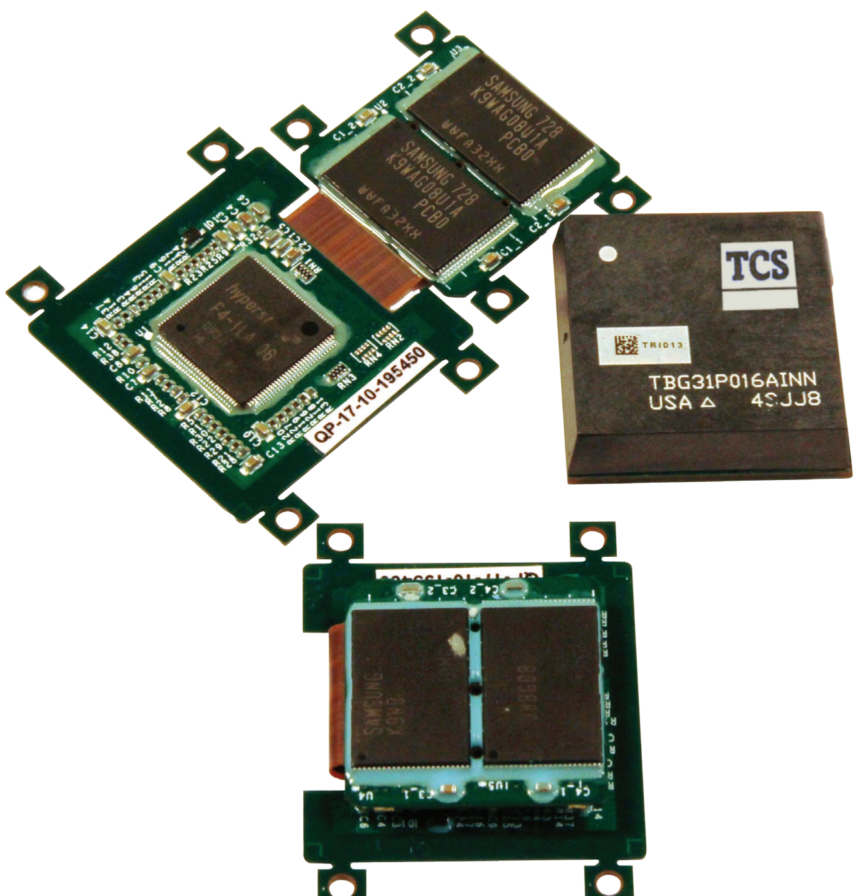

Figure 3

BGA form factor SSDs, like the TCS BGADrive, are very rugged when mounted on a printed circuit board with underfill. Once mounted the part is effectively epoxied to the board, and is not removable or repairable.

or secure digital (SD) cards used on digital cameras and cell phones. These have the benefits of an extremely small form factor and removability.

A third type that has become increasingly popular over the past year or so is embedded modules in JEDEC standard form factors. These provide standard disk interfaces, so they are easy to interface to, both electronically and from a software perspective. These new form factors emerged in 2009 and 2010 in the commercial world, driven by the need for small SSDs for slim form factor laptops, such as the MacBook Air and Intel-based netbooks and ultrabooks. These form factors offer new improvements in the key area of SWaP (size, weight and power). The same features that make these suitable for small, light laptops make them perfect for military and rugged industrial embedded use.

The JEDEC (Joint Electronic Devices Engineering Council) standards group has released several standards for small form factor embedded SSDs. Slim SATA is based on JEDEC standard MO-297, which was released in May 2009. It uses a low-profile connector that is compatible with standard SATA cables and allows for a complete SSD in a very small form factor (only 39 mm x 54 mm).

JEDEC SSD Standards

Meanwhile mSATA, released as JEDEC standard MO-300, evolved from the mini PCI Express form factor commonly used in laptops for wireless interface cards. This allows for systems that can add a variety of interface cards and SSDs flexibly, in a small number of slots. mSATA cards are even smaller than Slim SATA, at only 29.85 mm x 50.80 mm.

As shown in Figure 1 and Figure 2, the mSATA and Slim SATA form factors allow for only four NAND flash in a thin small outline package (TSOP). Stacking can be used to increase the number of flash, but this has proven to be less reliable in high shock and vibration environments, and is thus unsuitable for the most rugged defense applications. Even so, four TSOP NANDs using the latest 2xnm single-level cell (SLC) flash technology can provide up to 64 Gbytes of capacity of high-reliability, industrial temperature range, solid-state storage in a very small package.

The requirements of your application are the best guide when choosing between Slim SATA and mSATA. Slim SATA has the benefit of standard SATA cabling and the possibility for more rigid mounting, as it has four mounting points. Slim SATA can be mounted remotely and cabled to the CPU motherboard using standard SATA cables. mSATA is suited for a "daughter-card" application that is held on one side by the connector.

One thing to be cautious about in using mSATA and Slim SATA in high vibration or shock environments is the mounting of the modules in the system. mSATA, in particular, can be a challenge, since the board is held on one end by the connector with a large span to the screw holes on the other end of the mSATA module. A high amount of flex can occur in the center of the board, even under moderate vibration. Component staking can be used to ensure that the solder joints do not weaken or fail due to excessive flexure. In fact, TCS has made TSOP staking standard on its mSATA modules for this reason.

PCB Embedded SSDs

Several companies have also developed form factors that can be integrated directly on a system printed circuit board (PCB). Most of these are designed as ball grid arrays (BGA), due to the size of the package and the number of required I/O signals, particularly for Parallel ATA. Companies vary in their approaches to doing a drive in a BGA form factor. Several companies use chip-on-board techniques to provide packages as small as 12 mm x 18 mm x 1.5 mm. While these can provide benefits in size and weight, they can be limited in performance and capacity.

TCS uses its rigid flex technology to package normal, off-the-shelf controllers and flash in a small, 31 mm x 31 mm x 6 mm package. This provides the performance and capacity benefits of multiple flash packages, while still gaining significant SWaP advantages over even Slim SATA and mSATA boards. A BGADrive has the same four TSOP flash parts as these boards in about half the space.

BGA form factor SSDs, like the TCS BGADrive (Figure 3), are very rugged when mounted on a printed circuit board with underfill. Once this is done, the part is effectively epoxied to the board, and is not removable or repairable. Slim SATA and mSATA are better options if removability and upgradability are requirements.

Board-Level SSDs

There is significant development in the area of board-level SSDs—called storage blades by some companies—as well. These can be custom designs that use storage interconnects, such as Serial ATA, Fibre Channel or Serial-Attached SCSI (SAS), but are packaged as blades or as mezzanines on single board computers to provide higher capacities than are possible in the smaller disk form factors. There is a lot of buzz and excitement in the commercial space about PCI Express SSDs from companies such as Fusion-IO. These provide benefits in density as well as performance over SSDs that rely on disk interconnects. Most of these use MLC and other commercial temperature range components, and are thus not suitable to rugged military use. The developments are pushing the state of the art, however, and will benefit rugged embedded SSDs in the longer term.

These are exciting times in the SSD industry. The capability of the products is increasing, and they are available in a variety of forms that cover the breadth of military and rugged industrial embedded applications. Whether you need small and light or the ultimate in capacity and performance, there is likely a COTS SSD that can meet your specific need.

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