SMART® Modular Technologies
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Technical Brief

Choosing an SSD for Reliability

Tech Topics

This Tech Topic is the first of a series explaining the factors to consider when selecting SSDs for rugged applications. Applications for rugged or extreme environments demand more robust design and production than standard, commercial solid state drives, or SSDs, require.

More reliable performance is required in rugged applications, whether it is defense or industrial applications, because of the critical nature in which they're asked to perform. For additional guidance, please contact SMART RUGGED and we'd be pleased to consult with you on your specific application's needs.

Question: Where do I begin in choosing an SSD for reliability in rugged applications?

SSDs (Solid State Drives), based on flash storage, provide high-performance storage for most applications across a wide variety of industries. Some of these applications involve harsh environments that require rugged capabilities above and beyond products designed for consumer or enterprise applications. In essence, these drives must provide reliability across all applications.

The term "reliability" is a broad term that factors in several different characteristics:

Operating Temperature

Electronic devices are designed to operate across a defined temperature range—typically either Commercial Temperature (C-Temp) 0°C to +70°C or Industrial Temperature (I-Temp) -40°C to +85°C. Because flash technology is impacted by temperature, SMART RUGGED SSDs are designed and tested to work across cold and hot environments. RUGGED SSDs are encased in a thicker and more protective enclosure than standard SSDs. This ensures that outside factors will not compromise the performance of the drive.

One of those factors is operating temperature. Choose a drive where specifications show that it has been tested to perform in extreme temperatures. If you don't, the drive is more apt to perform less reliably or die. Another consideration when picking an SSD is whether the individual components, not just the drive, have been tested on how they respond in extreme temperatures and how many times they have been tested. A manufacturer that specializes in manufacturing these kind of drives will have the data to back up their claims.

In addition to the temperature of the operating environment, SSDs themselves can generate significant heat. Manufacturers can also employ firmware techniques to reduce read and write speeds to limit internal temperature rises.

MTBF (Mean Time between Failures):

Most electronic devices are rated in Mean Time between Failures. Mean Time between Failures is the average number of operation hours before a failure is expected. MTBF is an industry-standard calculation (Telcordia SR-332, Issue 4 Parts Count Method) based on numerous specifics related to and including internal component packaging, pin configurations, component density and internal component substrate architecture.

MTBF of SSDs is typically rated in the millions of hours, so an MTBF of 1 million hours describes that the average lifespan of a device is over 114 years. Industrial SSDs typically have ratings between 2 million hours (about 228 years) or 5 million hours or 570 years. MTBF for an SSD is an important metric because it factors into higher system level MTBF calculations, but other reliability metrics are usually more relevant for SSDs.

Reliability Demonstration Test (RDT) is a test performed on solid state drives (SSDs) over extended periods of time to demonstrate that each SSD meets the strictest quality requirements. All testing parameters aim to validate the mean time between failures (MTBF) rating of the drive. Instead of providing MTBF simulation results based on Telcordia SR-332, manufacturers of industrial drives will conduct actual drive-level testing to validate the rated MTBF value.

Electrostatic Discharge

All electronic devices are subject to damage from electrostatic discharge (ESD), which is the shock that sometimes occurs when you touch something metal. SMART RUGGED drives are designed and tested to withstand common sources of electrostatic discharge to prevent damage during handling in harsh environments.

Industrial SSD manufacturers, like SMART Modular, conduct system level and component level testing to prevent ESD occurring. The most typical type of ESD occurs from contact, but radiation can also factor into ESD. Industrial manufacturers take both of these factors into account when testing ESD

Shock and Vibration

One of the key advantages of SSDs is that they have no moving parts. This means that they are typically more reliable than traditional hard disks in environments where there is motion. This could be in a laptop, a phone, an airplane, or a tank. The flash media used in SSDs is not vulnerable to shock and vibration, but the electronics of the SSD, like the circuit board and its components, can be damaged. For example, if the circuit board flexes repeatedly, the electrical connections can break.

SSDs can be designed to withstand shock and vibration conditions by using heavy-duty enclosures, thick circuit boards, component underfill, etc.

Underfill goes between the electronic components and the PCB (printed Circuit Board) and strengthens solder joints while reinforcing resistance against vibration and thermal shock. When subject to greater temperature changes, the difference in coefficient of thermal expansion between the silicon chip and the PCB substrate often causes relative shifts during thermal shock test, resulting in solder joints falling off or fracturing. The underfill technique effectively strengthens the solder joints between solder balls and circuit boards, increasing the product's resistance against vibration and reducing thermal stress damage. Thus, increasing product reliability and ultimately increasing the product's lifespan.

SMART RUGGED's SSDs are designed for durability in the harshest environments and tested to specific standards beyond what the industry normally requires. SMART RUGGED sales and support staff can help with the selection of the best SSDs for specific applications.

Moisture/Humidity

Most electronic devices are sensitive to contaminants including moisture, dust, etc., and SSDs are no exception. Conformal Coating is a thin plastic-like film over the electric components applied after assembly to protect against moisture, dust, chemicals, and temperature extremes. To survive harsh environments, SMART RUGGED can optionally provide Conformal Coating on SSD electronics.

There are several ways that conformal coating is applied. One is a brush-on method, which is cost effective, but can be highly inconsistent. Dip coating offers better consistency, but is only available with some kinds of products. Hand spray coating can be extremely effective, as long as the job is performed by an experienced technician who is able to thoroughly coat the device without uneven application. Selective automated spray is considered to be the gold standard for application, because it provides the most consistent results possible. It is also highly recommended that the coating is dried and cured before it provides complete security.

Conformal coating offers advantages beyond the ability of the coating itself to protect the device from environmental contaminants. Conformal coating can also protect devices from physical attacks, shocks, and vibration. Conformal coating has insulating properties and reduces the need to use complex, sophisticated enclosures to protect electronic circuits. SMART Modular doubles down on protecting its drives with protective enclosures and conformal coating.

Radiation

When SSDs are in airborne applications at altitude, they may be exposed to levels of radiation that can interfere with the operation of electronic devices. Radiation can cause transient bit changes in processors, RAM, etc.

SMART RUGGED designs SSDs to work at altitude, including error detection and correction capability. They are able to detect and correct single bit errors known as Single Event Upset (SEU). Because the drive is able to correct the error, drive operation is not impacted.

Although much rarer, it is possible for multiple bits to change as a result of radiation. Although multiple bit errors cannot be corrected, they are detected. When this happens, the drive restarts itself to return to a known good state.

Endurance (Wear)

The physics of flash technology is based on a phenomena discovered back in the 1920s known as “quantum tunneling.” In common language, it describes how you can push a charge into a storage medium, which is the foundation for flash technology. One of the inherent side-effects of tunneling is that the media is damaged slightly each time you push, i.e. write, a charge into it. The result is commonly referred to as “wear”, and it means that the flash drives “wear out” with long-term use. “Wear-leveling” SSDs maximize their life span by evenly spreading out the wear of the drive over the media.

The endurance of a flash drive is how long—or more accurately how much can you write—before a drive wears out. There are a few different metrics for describing endurance, but they all describe how much you can expect to write to a drive before it wears out:

- TeraBytes Written (TBW): This is the total amount of information you can expect to write to a drive. Naturally, TBW is dependent on capacity.
- Total Drive Writes (TDW): This is the number of times you can write to the entire drive. It is “normalized” by dividing by capacity so that TDW is common across drive capacities (within the same product).

$$TotalDriveWrites = \frac{TeraBytesWritten}{Capacity}$$

Drive Writes Per Day (DWPD): This is the number of times you can write to a drive each day of its expected lifespan. The lifespan is determined by the warranty period—which is not necessarily equal to the expected useful lifespan.

$$DriveWritesPerDay = \frac{TotalDriveWrites}{WarrantyDays}$$

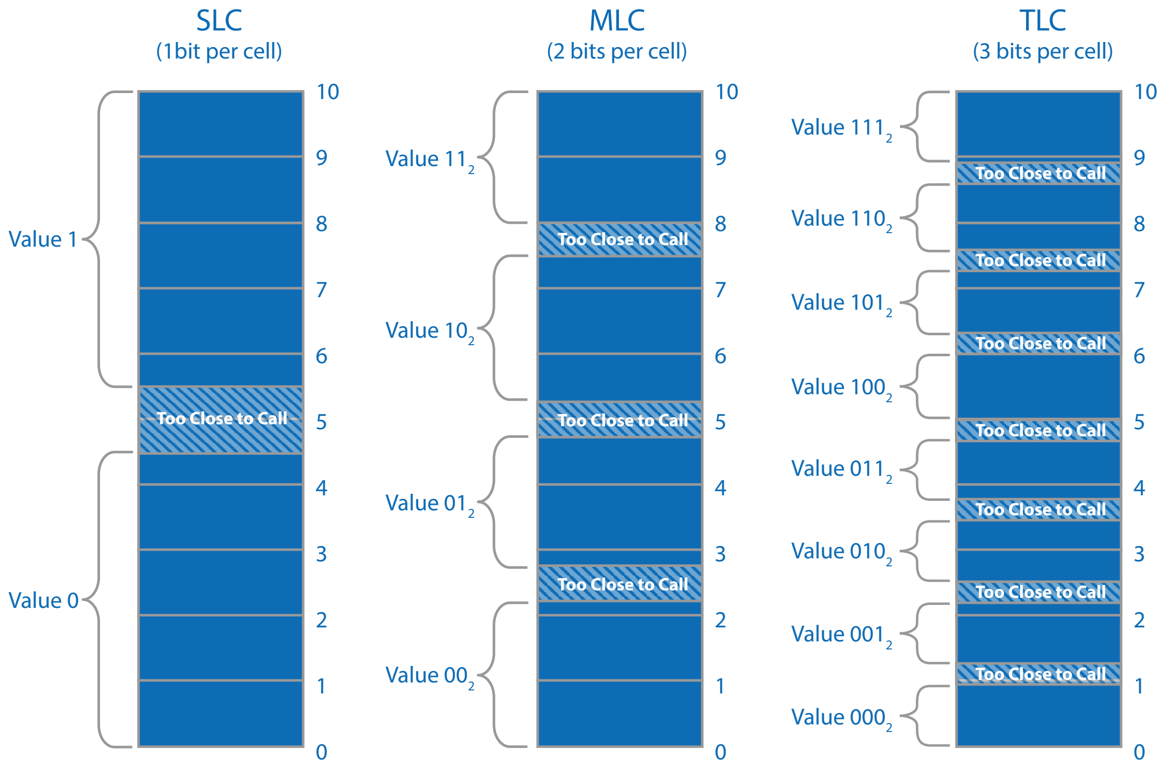
The endurance ratings are dependent on the workload. The architecture of SSDs processes small writes less efficiently than large writes, so endurance ratings should specify the workload (e.g. JEDEC® Enterprise Class Workload).

Flash storage has been around for many years, and the technology continues to evolve. Each technology advancement improves density resulting in lower cost/MB, but these improvements typically come with tradeoffs. As a general rule, higher flash densities have shorter endurance, higher error rates, and lower performance.

The first distinction is between NOR flash and NAND flash. NOR flash is optimized for random access with each location directly accessible for both read and write. NAND flash is optimized for high-density—at the expense of direct accessibility. NOR flash has its applications, but for the purposes of SSD storage we'll focus on the different types of NAND flash. The main difference is in how much information is stored in each "location" or cell.

Name	Meaning	Bits/Cell	Notes
SLC	Single-Level Cell	1	• SLC was the first generation of NAND flash, so it wasn't referred to as "SLC" until the introduction of subsequent generations
MLC	Multi-Level Cell	2	• The "Multi-Level" turned out to only be 2 levels.
TLC	Triple-Level Cell	3	
QLC	Quad-Level Cell	4	

The following diagram shows how the charge of an individual cell can store more than one bit of information.



It might seem like QLC is better than TLC which is better than MLC which is better than SLC, but that's really only true in terms of density ($/Mb). There are other tradeoffs. With the increasing number of bits per cell, margin for error (i.e. the charge being "too close to call") gets smaller. The charge in each cell must be more precise causing it to be more subject to errors. As a result, SLC can be appropriate for applications in which reliability, particularly write endurance, is more important than capacity or price per Mb.

Although SLC, MLC, TLC, and QLC are different generations of product, it is possible to use MLC, TLC, and QLC in a mode similar to SLC in which each cell contains only one bit. This is called pseudo SLC, or pSLC, and it can be a good compromise between increased endurance and $/Mb.

When a specific part of an SSD starts to wear out, the drive's controller will logically replace the failing media with "spares". The amount of extra "spare" storage a drive has is referred to as "overprovisioning". A drive with more overprovisioning can offer greater endurance because it spreads the write wear activity over more media.

Retention

Retention is the amount of time that data remains valid when a drive is not powered on. One of the characteristics of flash technology is that the stored charges "leak" over time, causing the data to degrade. The SSD's controller refreshes the stored charges in the background, so retention is only an issue for drives that are disconnected.

For many applications, retention is not an important factor, but for others it is. For example, SSDs are not a good choice as backup media—the data on an SSD inherently has a limited shelf life.

The "leakage" is exacerbated by high temperature and drive wear, so the retention is usually stated as a period of time at a wear level and a specific temperature. For example: 5 years at 90% life remaining at 25°C.

As a general rule, the retention is inversely proportional to the density—the higher the density, the shorter the retention period.

Summary

Reliability may be the most critical factor in choosing an SSD. Industrial and military applications usually require operation in harsh environments that exceed the capabilities of most SSD products. Choosing the best SSD requires an understanding of the operating environment for the application, and SMART RUGGED has been designing storage products for rugged environments for over 20 years.

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Headquarters/North America:
T: (+1) 800-956-7627 • T: (+1) 510-623-1231
F: (+1) 510-623-1434 • E: info@smartm.com

Latin America:
T: (+55) 11 4417-7200 • E: sales.br@smartm.com

Asia/Pacific:
T: (+65) 6678-7670 • E: sales.asia@smartm.com

EMEA:
T: (+44) 0 7826-064-745 • E: sales.euro@smartm.com

Customer Service:
T: (+1) 510-623-1231 • E: customers@smartm.com