Addressing the challenges of NVMe adoption in high-end photography and cinematography

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Executive summary

The technical requirements for solid-state storage (SSS) for professional still and moving image capture are very demanding due to the high resolutions, high frame rates and high dynamic ranges in these applications combined with the fact that captured content is often irreplaceable. Issues for successfully storing and using this content include performance degradation with extended writes and at elevated ambient temperatures as well as recovery of content in the case of accidents. Fortunately, there are now technical solutions to these issues such as Exascend's SuperCruise and Adaptive Thermal Control technologies as well as dedicated data recovery services.

Introduction

Photography and cinematography professionals have demanding requirements for how their digital content is captured and stored. They need fast and consistent recording for extended content capture sessions. They need 100% data integrity, because the captured content is often irreplaceable and has significant value. They cannot tolerate extended periods where they cannot work because of overheating storage devices. They also need to be able to recover digital content from their storage devices in case of accidental deletion or other incidents that make that content inaccessible. Solid-state storage devices from vendors that focus on the needs of image and video creators are crucial for meeting the needs of this demanding industry. Let us take a closer look at solid-state storage for this industry.

As visual resolution and frame rates increase and higher dynamic range, more bits per pixel video is captured using more cameras in each project, the demand for high performance digital storage for prosumer and professional still and video cameras increases. Solid-state storage solutions are the most popular camera storage today, as shown in Figure 1 from the 2020 Digital Storage in Media and Entertainment Report[1] based on the 2020 survey of video professionals on their digital storage requirements.

Solid-state storage, based on NAND flash memory, provides the high performance that modern video projects require and is also more robust for cameras used in the field that may experience significant vibration and shock in the course of a video project.

Along with the increasing use of solid-state storage devices as primary storage, the NVMe interface (running on the PCIe computer bus) was created to eliminate the overhead in SATA and SAS interfaces (originally designed for hard disk drives) and thus provide drive performance that matches the capabilities of the NAND flash chips used inside an SSD. NVMe is rapidly becoming the dominant SSD interface.

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[1] 2020 Digital Storage in Media and Entertainment Report, Coughlin Associates,
https://tomcoughlin.com/product/digital-storage-for-media-and-entertainment-report/

Figure 1. Percentage of recording media in professional video cameras
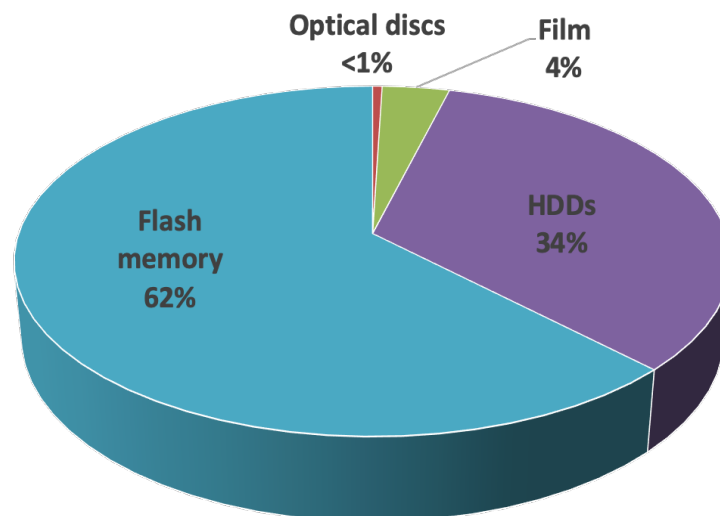
Besides flash memory being the most popular content acquisition storage media, it is also becoming important in post-production and content delivery applications as shown in Figure 2.[1] By 2025, we expect that post-production flash memory spend will increase to about 33% of the total, with VOD and other content distribution spend increasing to about 10%.

## Figure 2. Media and entertainment flash memory revenue by application
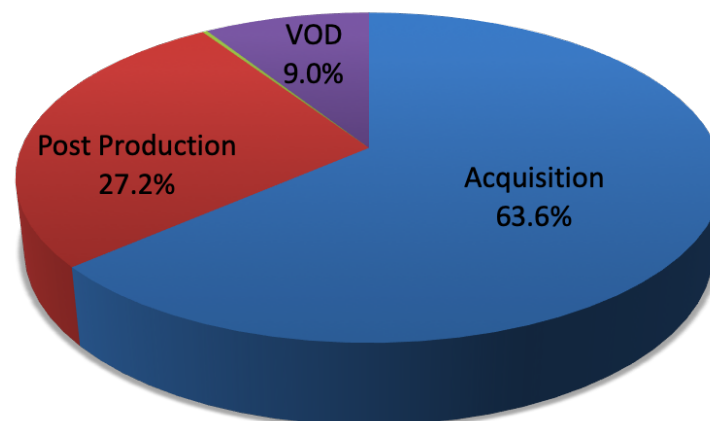
Making the most of flash memory for media and entertainment requires being able to balance data retention, endurance and storage capacity, while taking into account the environment that the SSDs will be working in (e.g., elevated temperatures in the field or on set). With the growing use of flash memory, and particularly NAND-flash based SSDs, in media and entertainment applications, it is important to work with an SSD vendor who is knowledgeable about the media and entertainment industry and the unique storage needs for different media and entertainment applications.

Challenges

One issue faced with some SSDs is that as the SSD gets full, the write performance drops as shown in Figure 3. This drop in performance can also occur if the SSD is not sufficiently

overprovisioned (OP, maintaining an adequate amount of unused or erased memory) and consequently, slower garbage collection processes begin to impact the write performance. Figure 3 below shows what can happen when an SSD is continuously written for period of time.

Figure 3. Typical SSD after continuously writing for an extended period

Sequential Write in MB/s
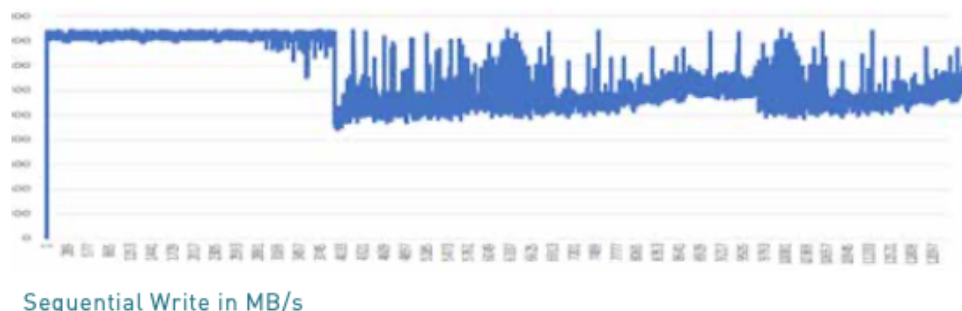
This is due to additional overhead with more frequent garbage collection (identifying and erasing blocks with obsolete data) so there are memory cells available for writing. Inconsistent write response in the SSD could result in performance issues with high-resolution, high-frame rate camera capture.

In the field, battery-powered cameras will have a limited life and this can impact shooting if the power consumption in the SSD that captures the content is too high. High power consumption can also contribute to additional heat generation, which can cause SSD performance issues in the field or in the studio.

As a higher-performance interface than SATA or SAS, NVMe running on the PCIe bus generates more heat. Heat build-up in SSDs increases the temperature, which, if not controlled, can damage the SSD and the content stored on it. Most SSDs control this heat build-up using thermal throttling. Thermal throttling slows the SSD performance when the SSD gets too hot and then speeds up the SSD performance when the temperature comes back to a normal range. At elevated ambient temperatures this can result in rapid performance cycling as shown in Figure 4.
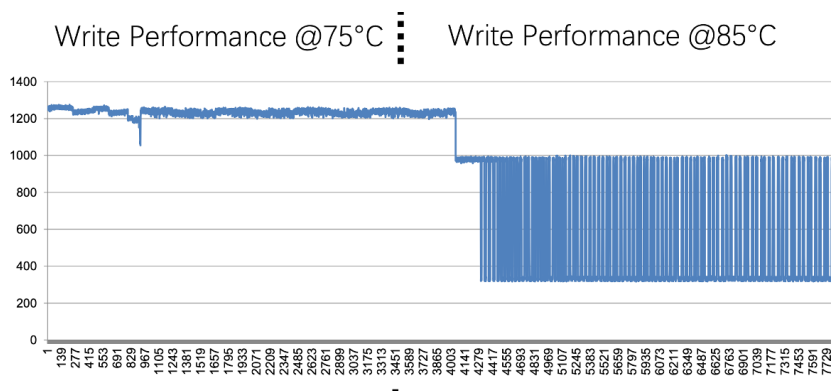
Filming and other media operations work best with more consistent performance, even in elevated temperature environments.

If there is a sudden system failure and resulting power loss in an SSD during filming, the content that had not been saved yet on the SSD will be lost. This can result in redone shots or losing the opportunity to catch transitory irreplaceable events due to this power loss.

No matter what precautions a digital imaging technician (DIT) or video professional takes, there is always a chance that something unexpected will happen, such as accidental deletion of content or physical damage to the storage device. Redoing a

scene may require an extensive investment in money and time to set up the scene again.

Figure 4. SSD write burn-in performance from 75 to 85 ºC with typical thermal throttling

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Solutions
Exascend's SuperCruise firmware algorithm can optimize and stabilize write performance as the SSD gets full and for extended periods of SSD writing as shown in Figure 5.

SuperCruise provides adjustable overprovisioning of available flash memory cells combined with an advanced firmware algorithm that monitors the ratio of free block production and consumption in the SSD, and regulates the response speed to maintain this ratio and provide consistent write performance over time. Consistent write performance helps make sure that all the content from your camera is captured on the SSD.

Exascend uses Marvell's SSD controllers based on TSMC's 12 nm lithographic process. This high-density architecture increases the chip's performance while decreasing power consumption, extending battery life and reducing SSD heat generation.

**Figure 5. Less dramatic extended period write performance using Exascend's
SuperCruise technology**
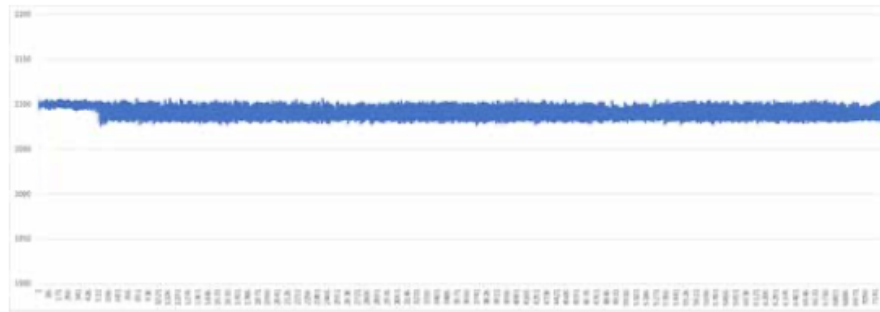
Sequential Write in MB/s

Exascend's Adaptive Thermal Control technology reduces the impact of thermal throttling
in their SSDs. The Exascend firmware algorithm takes multiple iterations to reach the
equilibrium point, where the SSD can sustain high performance even at more elevated
ambient temperatures as shown in Figure 6.

**Figure 6. SSD write burn-in performance from 75 to 85 ºC with Adaptive Thermal
Control**
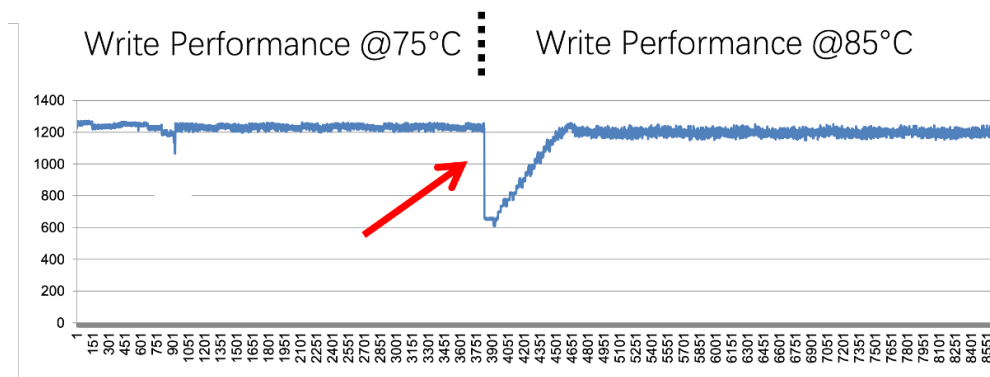
Thus, after a short period of iterating, the SSD performance is consistent at elevated
ambient temperatures using Adaptive Thermal Control. This protects the SSD hardware
and the data inside the SSD while providing consistent long-term performance, which is
important in many media operations.

Exascend's power loss protection (PLP) is enabled by an optional tantalum capacitor in
their SSDs that guarantees that all in-flight data is safely stored in the SSD when there is
a sudden and unexpected loss of power. If power loss is detected the data in transit is
flushed from the volatile DRAM to non-volatile flash memory and the SSD makes sure
that its mapping table is still usable after power is restored. This can avoid having to
reshoot scenes or losing transitory hard to reproduce video in the case of sudden
unexpected power loss.

Exascend's data recovery services can help recover valuable content when an SSD
experiences sustained damage and is no longer responsive or if content has been

accidentally deleted. In addition to factory data recovery services, Exascend offers on-site resolution and data recovery services. The level of engineering know-how required to successfully recover data is only possible with manufacturers that are responsible for 100% of their products' hardware and firmware design.

Exascend solid-state drives

The media and entertainment (M&E) industry is one of Exascend's major market segments and the company is a pioneer in creating storage for M&E applications. Exascend created the first digital cinematography-optimized PCIe Gen 4 NVMe SSD with up to 2 TB capacity designed for 4K, 6K and 8K cinematography with over 2 GB/s sustained write rate and less than 6 W active power consumption for video cameras and post production workflows.

It also provides cinematography camera manufacturer-certified CFast and CFexpress memory cards that are used in professional video camera applications. Exascend products for media and entertainment offer high performance, low latency and stable quality of service as well as adjustable performance and power consumption.

Exascend provides custom product design services for flash memory devices. The company has extensive experience working with its NAND and controller vendors (which includes almost all the major NAND flash memory manufacturers and controller provider, Marvell) in creating game-changing products.

The company owns key technology, engineering and manufacturing capabilities, provides direct technical support and offers comprehensive design customization using in-house hardware, firmware, development, engineering and manufacturing resources. These customization services include personalized hardware and firmware, comprehensive testing and quality assurance, manufacturing prowess and extensive technical support.

Exascend implements the Trusted Computer Group (TCG) Opal 2.0 security specifications on its SSDs. It also provides wide temperature SSD operation (from 40–85 ºC operational temperatures). The company uses proven proprietary algorithms to provide efficient wear leveling and to protect the SSD from read, program and erase disturb. Exascend's products are developed to provide ultra-fast response time and high quality of service. Over-provisioning on the SSD can be configured to required levels in order to achieve a specific performance or targeted endurance.

Exascend products provide accelerated boot and data protection features. In the server and network market its products can be used as boot/cache or journaling NVMe SSDs or as frequently-accessed enterprise SSDs. The company also offers a full line of industrial SSDs for edge computing applications, automation, telecommunication, transportation (including autonomous driving), medical and telemetry applications.

Selected Exascend case studies

Unique NVMe storage solution for a leading cinematography camera manufacturer:
For high performance cinematography recording, not only is consistent performance critical, power consumption and power loss protection are very important as well. In this project, Exascend provided a leading cinematography camera manufacturer with high-performance storage solutions with very low power consumption.

Exascend achieved this goal by selecting quality components and ICs optimized for low power, along with an optimized PCB design. Exascend also characterized NAND components from various vendors to select the lowest power options. In addition, Exascend's firmware and controller hardware configuration was precisely tuned to match the customer's exact performance requirements, ending up with a truly power-optimized design. Various power modes were also implemented for idle, standby and slumber, allowing the solution provided by Exascend to improve the manufacturer's camera battery life under all operating conditions.

Optimized cinematography storage solution with custom data protection features:
Exascend implemented a special interactive camera storage feature for a customer, providing the customer with a truly a custom design. In order to avoid accidental data deletion during media transfer, the camera user can configure the storage device to be writeable only in the camera, and once the storage device leaves the camera, the storage becomes read-only. This solution ensures that the user's precious footage stored on the SSD does not risk accidental deletion.

About Exascend

Exascend America is based in Sunnyvale, California. Exascend was founded in 2006 and focuses on high performance and durable solid-state drives and memory products for media and entertainment, industrial and enterprise applications. In addition to its products, Exascend also supports its customers with its comprehensive SSD design and data recovery services. The company's mission is to provide innovative, tailored storage technology solutions that empower users to push the boundaries of what is possible.

About the author

Tom Coughlin, President, Coughlin Associates is a digital storage analyst and business and technology consultant. He has over 40 years in the data storage industry with engineering and management positions at several companies. Coughlin Associates consults, publishes books and market and technology reports and puts on digital storage-oriented events. He is a regular storage and memory contributor for forbes.com and M&E organization websites. He is an IEEE Fellow, Past-President of IEEE-USA and is active with SNIA and SMPTE. For more information on Tom Coughlin and his publications and activities go to www.tomcoughlin.com.