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Technology Paper

Beat the Heat: Designing SDVR Systems for Optimal Thermal Performance

Introduction

While the popularity of digital video surveillance systems continues to soar (J.P. Freeman Co. estimates worldwide annual growth at approximately 42 percent), there have been challenges along the way. Surveillance digital video recording (SDVR) system reliability has proven challenging for some, particularly in terms of the hard disc drive (HDD). This is primarily due to the harsh environmental and operational factors (poor ventilation, 24x7 write workloads) typical of SDVR disc drive applications.

Fortunately, following a few simple guidelines for optimal SDVR system design and deployment will substantially enhance drive reliability. The single greatest threat to disc drive longevity is heat. Not only is heat a leading cause of outright component failure, it can also degrade system performance and stability. To understand why heat management is so critical to disc drive reliability, it's useful to briefly review the fundamentals of drive operation.

Disc Drive Basics

HDD storage relies on magnetism to store and retrieve data on the drive's platter(s). Tiny independent magnetic cells in the platter's coating are magnetically reoriented into a specific pattern by the drive's read/write head to write data, and those cells' magnetic orientation can be subsequently detected by that same head to read back that data.

This arrangement is made possible by the extraordinary proximity of the read/write head to the platter surface. Riding a scant few nanometers above the rapidly spinning platter (see Figure 1), the complex read/write head system has been likened to a Boeing 747 flying at 600 miles per hour—six inches off the ground.

The strength of any object's magnetic field rapidly falls off as distance from it increases; this principle applies

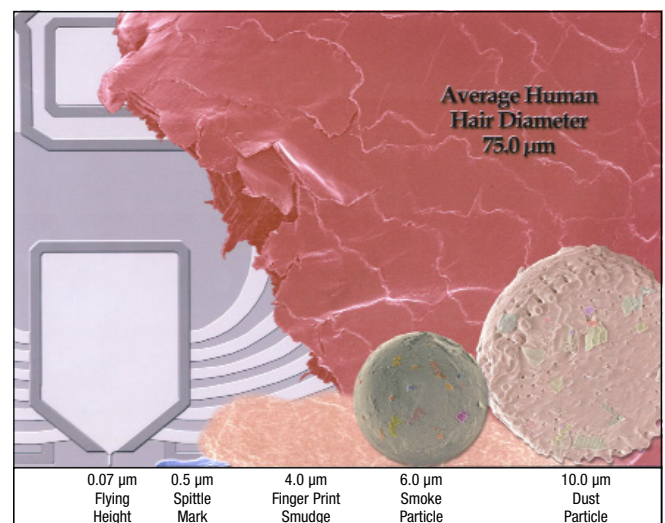


Figure 1: HDD flying height compared to common environmental contaminants

to both the magnetism of the read/write head and the magnetic cells on the disc surface. Thus to reliably write and read information, the head must remain a very close and consistent distance from the platter. Any disruption of the physical or magnetic relationship between head and platter surface can jeopardize the integrity of the drive's data.

Why Heat Is a Killer

Excessive heat can undermine this sensitive relationship in a number of ways. The read/write head rides on a cushion of air pressure above the platter surface; should the drive case become too hot (over 35°C), the air inside expands so much that it affects the *flying height* of the read/write head. While drives are designed to compensate for changes in head/platter spacing, such compensation degrades signal integrity, alters the media's magnetic properties and, in extreme cases, can lead to data loss.

Furthermore, the magnetism of the cells on the platter's surface weakens as the disc becomes hotter; such temperature-induced magnetic instability puts data integrity at risk. Similarly, the read/write head also loses magnetic strength as it becomes hotter; as a result, the head then requires more electrical current to maintain its proper magnetic field strength.

Unfortunately, this extra current produces additional heat in the drive, which further degrades the magnetic field strength of the head. Still more current is required to compensate, which in turn yields even more heat, continuing the vicious cycle. This phenomenon, known as *thermal runaway*, also afflicts the permanent magnet in the voice coil, which controls movement of the drive's actuator/head assembly. Either of these scenarios can result in impaired performance, compromised data integrity and greater risk of drive failure.

Three Ways to Beat the Heat

As can be seen, the harmful effects of heat on HDD performance and longevity are extensive. There are a variety of effective methods to combat excessive system heat, which can be grouped into three main categories: Chassis Design, Power Profile and Operational Practices.

Chassis Design

Various factors in chassis design can play key roles in determining system cooling capabilities.

SHAPE, SIZE OF SYSTEM CHASSIS:

Tower-style enclosures (vertical form factor) take greater advantage of convection cooling (lower-density warm air naturally rises to the top, creating a vacuum that draws cool air in at the bottom). Desktop-style enclosures (horizontal form factor) can inhibit convection cooling, but properly designed fan cooling (see below) can effectively compensate.

Larger cabinets enable more space between system components, increasing airflow through the chassis and thus cooling capacity.

INSULATING PROPERTIES OF CHASSIS MATERIAL USED:

Metals such as aluminum and steel are relatively efficient thermal conductors, enabling them to transfer heat from internal system components to the surrounding air. Plastic and resin composites are significantly less effective in conducting heat.

AIRFLOW RATE OF CHASSIS, TYPE AND NUMBER OF FANS:

Internal chassis volume, fan output (measured in cubic feet per minute, or CFM) and fan count all influence the airflow rate of the chassis. The larger the chassis, the more air must be moved to attain a given flow rate (CFM) through the chassis. Smaller fans are sometimes used to generate high flow rates in specific areas of the enclosure, while larger high-capacity fans handle overall airflow through the enclosure.

Calculating Your HDD's Thermal Environment

When determining the thermal environment of a SDVR system, it's important to perform temperature measurements under real-world conditions. Do not use a thermal chamber, as it changes virtually every aspect of the test (insulating properties, airflow rate, temperature ramp rates, and so forth).

To estimate the maximum temperature to which an HDD may be subjected, measure HDD temperature (use the drive's base casting) and then subtract the ambient air temperature. This yields the HDD base delta-T, or the net heat output of the drive after factoring out room temperature. Finally, add the SDVR system's maximum temperature specification to the HDD base delta-T to yield the estimated HDD base temperature at maximum system specification.

For a more precise picture of the system's thermal characteristics, the proper test method is to instrument all surfaces of interest, assemble the system and run it in an open area with no airflow and stable temperature (a typical office works well). Monitor the ambient air temperature at least five inches away from the system enclosure. Operate the system in its actual maximum field usage profile, and plot the temperature monitoring points for at least two hours. When the temperatures all stabilize, the test is completed.

Matching fan capacity and speed to the internal volume and shape of the chassis is key to achieving optimal cooling, lower power consumption and reduced acoustics.

SIZE, SHAPE, NUMBER OF HEAT SINKS:

Heat sink efficiency is affected by the sink's mass, surface area and fin configuration. Heavier heat sinks can absorb more thermal energy, while more square inches of surface area speeds transfer of that energy to the surrounding air. Heat sinks with fins perpendicular to the floor tend to be more effective because they enhance convection cooling.

Adding more heat sinks can theoretically yield more cooling capacity, but heat sinks are relatively expensive and the law of diminishing returns soon comes into play. When properly configured and located, only a few sinks can greatly increase system cooling.

Power Profile

The energy requirements of the system's internal components significantly impact its power profile, and in turn its heat production.

POWER SUPPLY EFFICIENCY:

An SDVR system's power supply converts AC line voltage (nominally 120 or 220 volts) to an appropriate DC voltage level (typically 12 volts or less). Different types of power supply designs, such as switched-mode vs. linear mode, can consume significantly different quantities of AC power to deliver the same DC voltage. More efficient power supplies require less AC input for a given DC output, which in turn means less energy is dissipated as heat. Furthermore, such high-efficiency power supplies are typically smaller and thus take up less chassis space, enhancing system airflow.

POWER CONSUMPTION OF SYSTEM COMPONENTS:

An SDVR system's CPU, video subsystem (including MPEG encoder and decoder) and HDD storage all contribute to the system's total power consumption. While the CPU handles overall system functionality, the MPEG encoder works in concert with the CPU, converting analog video signals into digital data that's written onto HDD storage.

Depending on the number of cameras attached to the system and the desired frame rate (frames per second) of the incoming video streams, the ensuing workload can place significant demands on both the encoder and CPU, forcing them to work harder and thus produce more heat. Employing multiple encoders to handle additional video streams exacerbates the thermal challenges.

Careful planning of video surveillance zones can trim both the number of cameras and minimum frame rates required for optimum video coverage, reducing hardware costs and cutting the workload (and thus heat output) of the SDVR system's CPU and video encoder.

Choosing HDD storage that combines maximum capacity-per-disc with sophisticated power management capabilities can also significantly contribute to lower system power consumption (see below).

QUANTITY OF COMPONENTS:

A typical SDVR system uses only one CPU, but the number of HDDs it employs can range from one to several or more. Not only does each disc drive impose its power needs on the system's power supply, it also introduces another potential point of failure into the system.

Minimizing the number of HDDs used to meet an application's capacity requirement is one of the simplest and most effective ways to cut system power consumption and heat production. And by occupying fewer drive slots in the system chassis, greater airflow is also promoted.

The growing availability of high-capacity (250, 400 and 500GB), purpose-built SDVR HDDs enables systems to deliver enormous capacity with a minimal number of drives. These new drives also incorporate sophisticated power management features (see below) to enable even greater system power economy and thermal efficiency.

Operational Practices

HDD power management features will play an increasingly important role in minimizing SDVR system heat challenges. Leveraging the ATA-7 command set enables drives to efficiently address both video- and data-specific tasks.

HDD SPIN DOWN:

At any given time, only one HDD in a typical SDVR system is actively writing video images. Though the rest of the drives in the system are idle, they are nevertheless kept spinning; this needlessly consumes power, produces more heat and entails additional wear on the drives.

Specifically designed for SDVR duty, a new generation of drives incorporates intelligent power management features that enable the host to spin down idle drives into sleep mode. The power savings are significant; while an idle drive may consume roughly 8 watts, a sleeping drive needs only 0.25 watts of power. Reducing power consumption by up to 96 percent, these new drives deliver greater energy efficiency, cooler running and longer drive life.

REDUCED CURRENT DRAW AT HDD STARTUP:

A conventional disc drive requires significantly more power at system startup or when awakened than when simply spinning. While bringing a single drive's platter(s) up to speed and energizing the various components within demands substantial power, the load on the system's power supply is particularly severe at startup, when multiple drives are simultaneously powered on.

This increased current draw demands larger (and more expensive) power supplies, whose higher-capacity output also entails more heat. Purpose-built SDVR drives require less startup current (under 2.0 amps), which enables the use of smaller, less costly power supplies. Once again the result is greater efficiency and cooler running.

OPTIMIZE READ/WRITE STRATEGIES FOR DATA ACTIVITY:

SDVR systems focus on video streaming capabilities, but they must also be able to read and write traditional data structures used to manage video databases and related applications. Optimal efficiency can only be achieved by matching the HDD's read/write strategies to the type of data being used.

Purpose-built SDVR drives support the ATA-7 command set, enabling the drive's read/write profile to be specifically tuned for video or data. This ensures video read/writes stream more reliably, while data read/writes are optimized for data integrity. By curtailing extraneous disc activity, this approach also reduces power consumption and operating temperatures.

Summary: SDVR System Thermal Best Practices	
CHASSIS DESIGN	
Shape, size	Tower form factor enhances convection cooling; should be large enough to ensure unobstructed airflow between components
Material	Metal (aluminum, steel) better thermal conductor, aids system cooling
Fans	Speed, CFM capacity optimized for shape, size of system chassis
Heat sinks	Quantity, size/surface area adequate to dissipate component heat
POWER PROFILE	
Power supply	High-efficiency designs consume less power, produce less heat
Power draw	Fewer cameras, lower frame rates cut workload and heat output of system's CPU, video encoder(s)
Component quantity	Minimal number of HDDs in system enhances cooling, reliability
OPERATIONAL PRACTICES	
HDD spin down	HDDs with power management enable spin down of idle drives into sleep mode; reduces power consumption, disc drives run cooler
HDD startup	Purpose-built SDVR HDDs require less startup current; enables smaller, less costly power supplies for higher efficiency, cooler operation
Read/write profile	ATA-7 command set enables HDD read/write profile to be tuned for video or data; cuts extraneous disc activity, power use and heat outputs

Conclusion

Optimizing the thermal performance of your SDVR system can pay a host of dividends: higher HDD reliability and greater data integrity, longer component life, plus improved system performance and stability. In addition, the steps outlined above for lowering system temperatures can also significantly enhance the energy efficiency (and thus cost effectiveness) of your SDVR system.