
# Designing NVMe SSDs for Industrial Applications

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## Moving Forward –

## SSDs with Native PCIe Interface for Industrial Applications

SSD performance is one of the biggest considerations when designing industrial applications. SSD technology is still evolving from PATA to SATA and the speed of its interface continues to increase. The PCIe interface appeared in the market almost at the same time as SATA 3.0 Gbps (Gen. 2) became popular. But due to the limitations of Flash IC technology and lack of host support, PCIe SSD wasn't successful. That is until today, Flash IC performance has now fully caught up. OS driver support for PCIe storage devices, and chipset native NVMe protocol support are ready to make the next big leap forward. As PCIe SSD has matured and become an important storage option for certain market segments, this paper discusses options for designing NVMe SSDs into industrial applications.

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## Performance Benefits

The throughput of the PCIe interface is the most crucial value for users or system integrators. The following table shows the general bus speeds and differences. The superiority of the PCIe product is plain to see.

| | SATA Gen. 3 | PCIe Gen. 3 x2 | PCIe Gen. 3 x4 |
|---|---|---|---|
| **Interface bandwidth** | 6 Gb/s | 16 Gb/s | 32 Gb/s |
| **Real product throughput** | 560 MB/s | 1.97 GB/s | 3.94 GB/s |

PCIe SSD applications such as data centers, image / video processing, machine vision, and all applications that perform intensive data processing on storage media, all benefit from such performance levels.
In order to ensure the same high-performance levels with NVMe SSD media, which is at least 3 times faster than SATA-based SSD, the data bus signal quality needs to be taken into account. Poor signal quality not only compromises data throughput, but also causes major reliability concerns. The host PCIe bus design that compliments NVMe has to follow open device interface specifications for accessing non-volatile storage media attached via a PCI Express (PCIe) bus, and the system has to be verified by professional third-party signal integrity test labs. By doing so, compatibility between host (motherboard) and device (NVMe SSD) can be further assured.

## Platform Compatibility

**Form Factor Selection**

I/O flexibility and compact design are often requested for industrial applications. As a result, embedded systems or embedded motherboards tend to incorporate different interfaces and sockets for different requirements. Even a small form factor board would still have a MiniPCIe socket, an M.2 socket, and even a PCIe connector for different application scenarios. Having an SSD selection would also enhance overall system design flexibility so several selections of NVMe based SSD for popular PCIe sockets are available for industrial motherboards

- MiniPCIe – one of the most popular sockets for industrial motherboards and available on most boards. By default, supports x1 interface, but with adjustments on both board and device x2 interface is possible.

- M.2 – is becoming popular not only for storage, but also wireless connection modules. The biggest problem with M.2 is their very diverse specifications, which can be categorized in different keys.

| | Lanes | Common application |
|---|---|---|
| B key | x4 | RF, cellular |
| M key | x4 | Storage |
| A + E key | x2 | WIFI |

### Hardware and Software Requirements

NVMe is new protocol for PCIe, it requests a certain level of chipset and OS driver support to work with its full functionality.

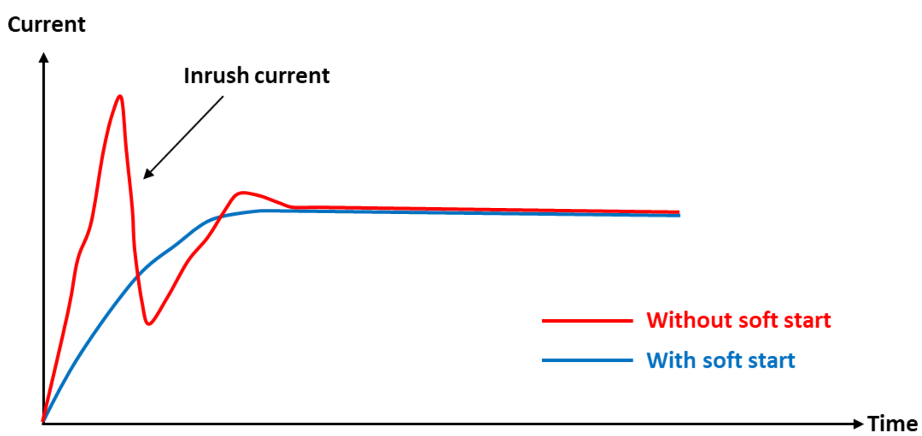
- Hardware – Intel 6th generation core processors (Skylake, Kaby Lake, Coffee Lake)
- OS – Windows 7 requests additional driver installation while Windows 8.1, Linux Kernel 4.4.16 and their newer versions already have the NVMe driver built-in

## Sophisticated Power Management Design

In order to support stable performance and industrial level reliability, the stability of power and voltage inputs for the IC in NVMe SSDs is more important than the other kind of SSD. Several power management approaches should be considered.

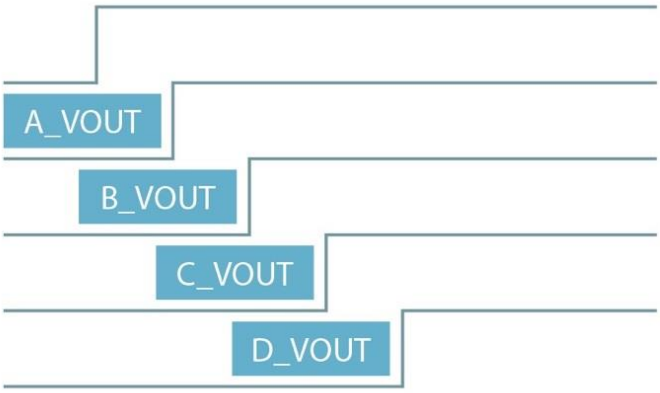
### Automatic Internal Soft Start Operation

Reduce inrush current during instant power on, so the voltage level will be stable and not lead to data read / write errors.



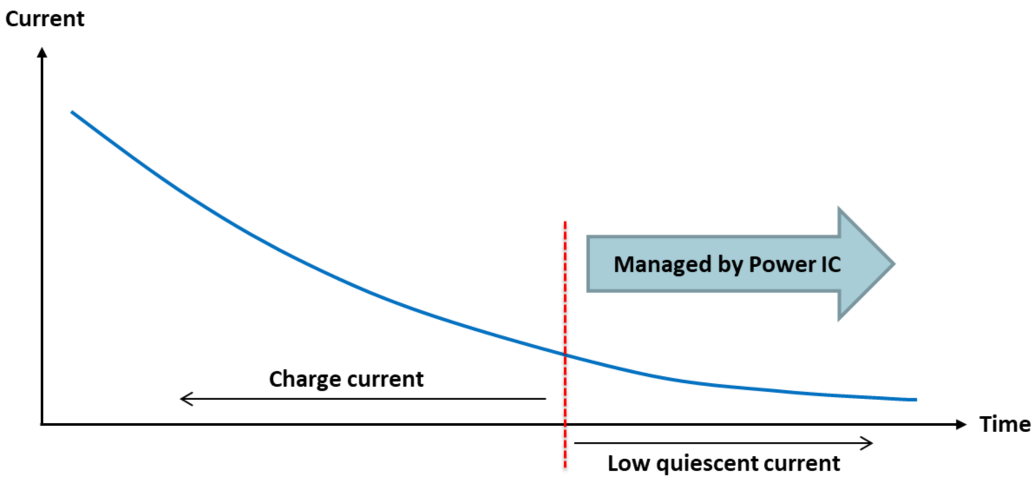
**Power Sequence Control**

There are multiple components (Flash IC / Controller IC / DDR IC) requesting separate power supply. A power sequence control function based on programmable on/off sequencing of multiple power supplies ensures the SSD internal power sequence will be well organized to achieve high working efficiency and stability.




**Low Power Mode Control**

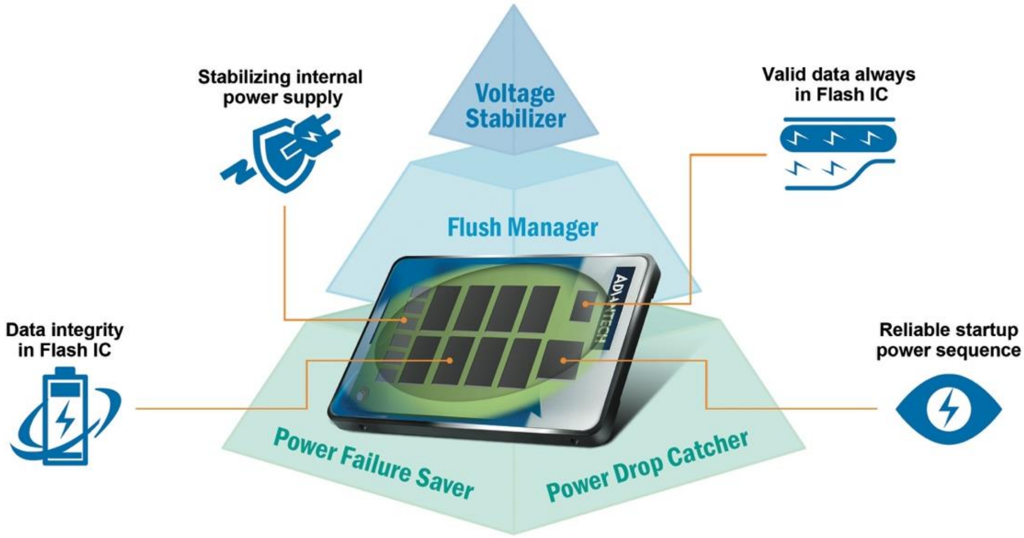
In low power mode setting, the SSD operates in light load mode. To keep SSD working efficiently it relies on stable power switching, driving loss protection, and quiescent current. Normally a power management IC will be needed to ensure stable 30 uA quiescent current.




**Power Failure Protection**

A proper power failure protection mechanism has to be implemented in order to maintain the highest level of data protection. This complete scheme combines four different functions – Power Failure Saver, Power

Drop Catcher, Flush Manager, and Voltage Stabilizer. Details can be referred to another designated white paper (link).

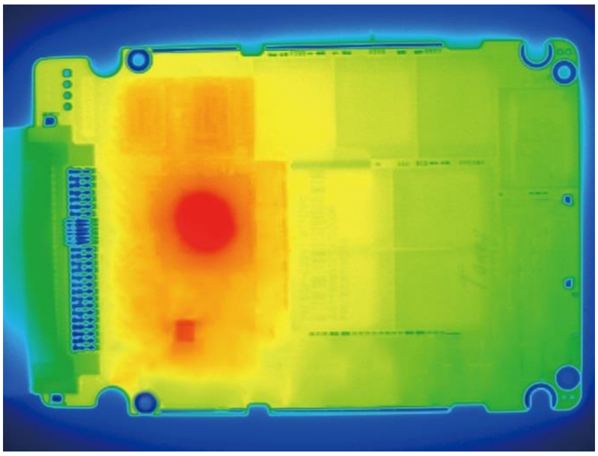



## Thermal Solution Makes NVMe SSD Suitable for Industrial Applications

NVMe SSDs made with high frequency processors (controller) consume more power, which also generates more heat than traditional SSD. For reliable usage in industrial applications, even wide temperature scenarios, Advantech's SQFlash NVMe series products are designed with several features that make them even more reliable.

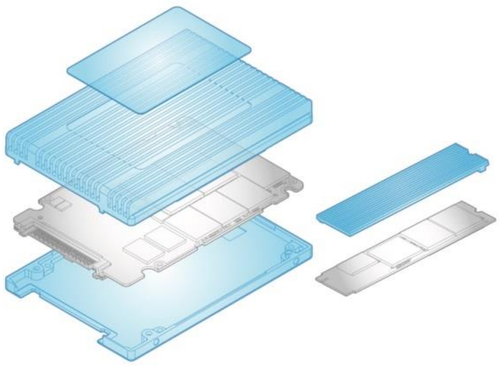
**Pre-design Thermal Simulation**

Thorough thermal simulation before and after PCB layout checks thermal weak points and deploys proper solutions to reduce massive heat buildup in real applications.



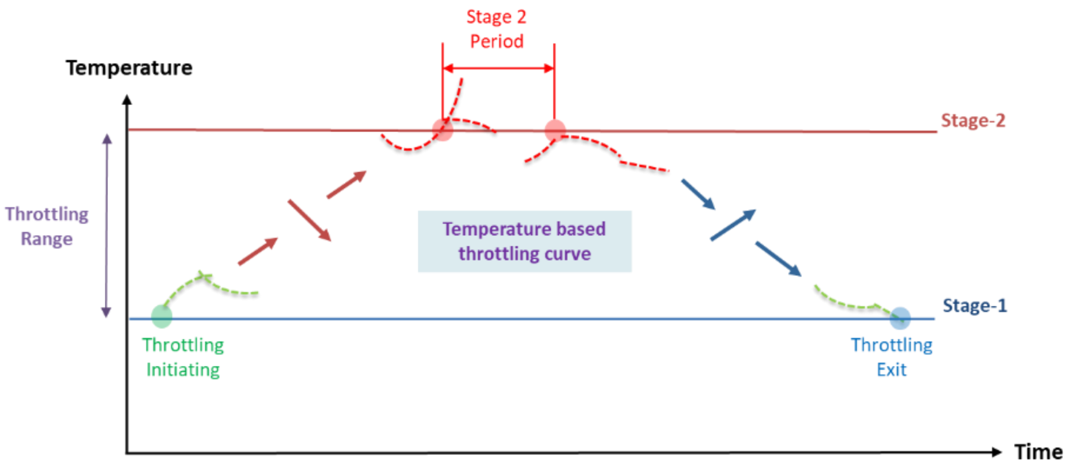
## Industrial Heatsink Design

For ruggedized applications that require high performance, NVMe SSD is the only option. Heat generation from SSDs is a big obstacle and prevents NVMe SSDs being implemented in many industrial application fields. Sophisticated thermal solutions with industrial grade heatsink designs can greatly improve their thermal performance and stable operation, enabling NVMe SSDs to be adopted in wide temperature / ruggedized environments.



## Thermal Throttling Management

When an SSD controller detects overheating by the internal sensor, a built-in intelligent firmware feature throttles the overall SSD performance to force the controller IC to cool down and prevent hang-ups or even physical damage to a device. The throttling mechanism is also divided into several stages to prevent sudden speed drops. After temperature returns to normal levels, the SSD automatically resumes full speed operation.



**Real-time Temperature Monitoring**

Built-in thermal sensor in the NVMe SSD can monitor SSD working temperatures and present SMART data. Thermal information can be accessed easily from the operation site or even be acquired through cloud ready solutions like Advantech WISE-PaaS platform with SSD PMQ (Predictive Maintenance Quality) function. Users can even set thresholds for the system to alarm or adjust workloads automatically.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