



White Paper: **Testing Power and Sideband Signals on Solid State Drives**

Testing Power and Sideband Signals on Solid-state Drives

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Summary

Testing power and sideband signal functionality on solid-state storage devices, such as NAND flash-based SSDs, is essential to ensure their proper functioning, reliability, and compatibility within various computing environments.

This necessitates comprehensive power and sideband testing to ensure that SSDs meet the demands of the everyday world with professional test tools like Teledyne LeCroy's OakGate SSD Test Solutions.

This paper explores the reasons why testing power and sideband functionality for SSDs is important to guarantee their proper operation, data integrity, and longevity, as well as to ensure compatibility with a variety of hardware and regulatory standards.

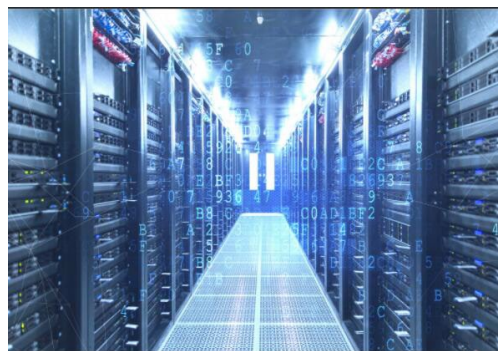
It's a critical part of the quality control process and contributes to the overall reliability and performance of SSDs in real-world applications.

Introduction

Solid-state storage has revolutionized the world of data storage and retrieval, replacing conventional hard disk drives (HDDs) in many applications. While SSDs offer numerous advantages, including faster data access, lower power consumption, and enhanced durability, they are not immune to issues such as data loss, performance degradation, and unexpected failures. This necessitates comprehensive testing to ensure that SSDs meet the demands of modern computing.

An important issue is the behavior of SSDs during power failures and fluctuations which happen relatively frequently in data centers, especially in parts of the world with unstable power grids. Determining how solid-state storage devices utilize power and sideband signals in real-world environments are an important step towards designing new robust storage systems.

Reasons for Testing SSD Power and Sideband Signals



Data centers provide mission-critical computing functions essential to the daily operation of top U.S. economic, scientific, and technological organizations. These data centers consume large amounts of energy to run and maintain their computer systems, servers, and associated high-performance

components—up to 3% of all U.S. electricity powers data centers. And as more information comes online, data centers will consume even more energy.

As such, corporate sustainability goals have been incorporated throughout the world to help lower energy consumption. Data centers and Hyperscaler's are now measured on their power sustainability and power usage goals and require SSD vendors to test SSD performance during normal system shutdown, abnormal system shutdown, power surges, low and/or idle power states, and voltage fluctuations. This in turn, has prompted SSD vendors to highlight lower active

power consumption, better power efficiencies and/or reduced cooling efficiencies to differentiate from their competitors.

Another vital aspect of solid-state storage power and sideband signal testing is evaluating the endurance and longevity of SSDs. NAND flash memory has a finite number of write-erase cycles, and excessive writes can lead to data corruption or drive failure. In response to this Hyperscaler's are creating new protocols such as Flexible Data Placement and Zoned Namespaces to improve drive reliability and power consumption. These technology benefits include reduced write amplification, reduced media over-provisioning, leading to reduced power utilization.

Benefits of Testing Power and Sideband Signals

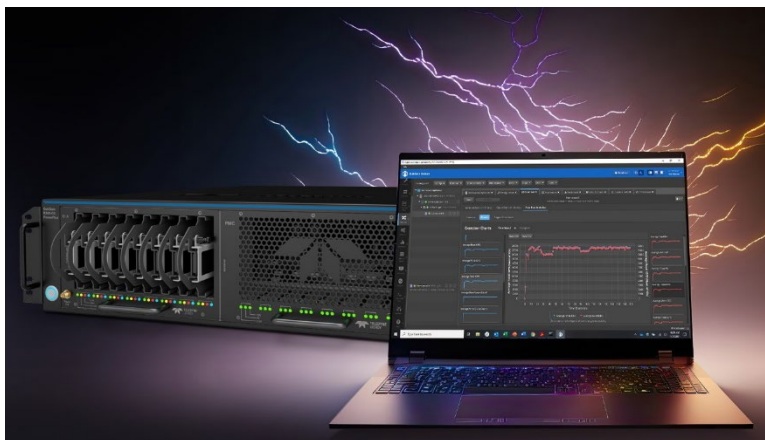
Power and sideband signal testing for SSDs offer several benefits, which contribute to the overall reliability, performance, and compatibility of these storage devices. Here are the key advantages:

- **Enhanced Data Integrity:** Power and sideband signal testing helps ensure that data stored on the SSD remains intact and free from corruption during power fluctuations or electromagnetic interference. This is crucial for data integrity, especially in applications where data loss is unacceptable, such as in data centers or industrial environments.
- **Improved Reliability:** By subjecting SSDs to various power and electromagnetic scenarios, manufacturers can identify and rectify potential weaknesses in the design and components. This results in SSDs that are more reliable, less prone to failure, and better equipped to handle challenging operating conditions.
- **Extended Lifespan:** Understanding how SSDs respond to power fluctuations and sideband signals allows manufacturers to optimize error correction mechanisms and reduce wear and tear on NAND flash cells. As a result, the lifespan of the SSD can be extended, making it more cost-effective in the long run.
- **Optimized Performance:** Power and sideband signal testing enables manufacturers to fine-tune the SSD's performance in different power environments. This ensures consistent and reliable performance, even under less-than-ideal power conditions, benefiting users in a variety of settings.
- **Enhanced Compatibility:** SSDs that undergo rigorous power and sideband signal testing are more likely to be compatible with a wide range of hardware and power profiles. This broad compatibility is essential for SSDs used in various computing environments, preventing compatibility issues that can disrupt operations.
- **Regulatory Compliance:** Many industries and applications have strict regulations governing the use of storage devices. Power and sideband signal testing helps SSD manufacturers meet these compliance requirements, ensuring that their products can be used in regulated environments without issues.
- **User Satisfaction:** SSDs that pass thorough power and sideband signal testing are more likely to meet user expectations for reliability, data security, and performance. This enhances user satisfaction and trust in the product.



- **Prevention of Data Loss:** Power testing can help identify how an SSD handles sudden power loss. This is particularly important in applications where data loss could have significant financial or operational consequences, such as financial institutions or healthcare settings.
- **Quality Assurance:** Conducting these tests as part of quality control procedures helps manufacturers identify and rectify any defects or issues early in the manufacturing process. This reduces the likelihood of product recalls and warranty claims.
- **Market Competitiveness:** In a competitive market, consumers have numerous options when choosing SSDs. Manufacturers that invest in thorough testing can stand out by offering products that are not only faster and more reliable but also more thoroughly vetted.
- **Long-Term Reputation:** A manufacturer's reputation is closely tied to the quality of its products. Consistently delivering tested, reliable SSDs can help build a positive long-term reputation, fostering trust among consumers and business partners.

SSD Power and Sideband Testing Made Easy with Teledyne LeCroy



Teledyne LeCroy OakGate SSD Test Solutions tests ALL required PCI Express® 5.0 power and sideband signal capabilities without costly 3rd-party power interposers.

Our solutions were specifically designed to make comprehensive SSD power and sideband signal testing easy. OakGate's SSD test and validation appliances and software are the industry's most advanced with an unprecedented level of functionality, performance, and ease of use for testing storage devices.

OakGate's products have been hardened over fifteen years in intense test environments at major SSD customer sites worldwide. Our products have been deployed by top tier components suppliers, drive manufacturers, and storage system OEMs worldwide.

OakGate's integrated SSD test software called SVF/Enduro was developed from the ground up to provide the following comprehensive power and sideband signal test coverage:

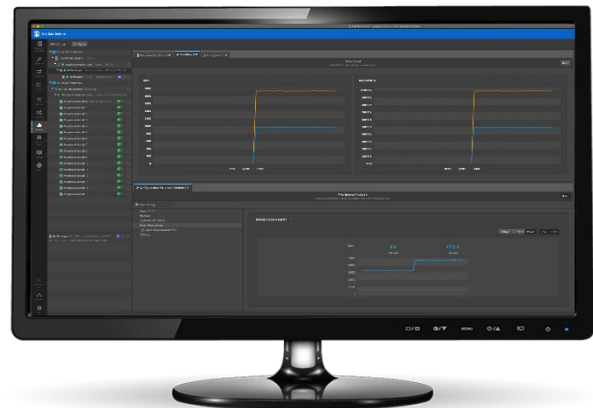
1. **Power Consumption Testing**
 - a. Idle Power Consumption: Measuring the power consumption when the SSD is in an idle state.
 - b. Active Power Consumption: Measuring the power consumption during read and write operations.
 - c. Start-up Power: Assessing the power draw during the SSD's boot-up sequence.

2. **Power Loss Protection:**
 - a. Uninterrupted Power Supply (UPS) Testing: Verifying that the SSD can complete pending write operations and flush data to non-volatile memory when power is suddenly cut off.
3. **Voltage Variation Testing:**
 - a. Voltage Tolerance: Determining the SSD's ability to operate within specified voltage range.
 - b. Brownout Testing: Assessing how the SSD behaves when the voltage temporarily drops below the specified range.
4. **Power Range and Transients Testing:**
 - a. Power Range Tolerance: Evaluating the SSD's resistance to sudden voltage range changes.
 - b. Transient Response: Testing the SSD's response to short-duration voltage transients.
5. **Temperature and Power Testing:**
 - a. Temperature Testing: Assessing how power conditions vary as the SSD's operating temperature changes.
6. **Error Recovery and Correction:**
 - a. ECC (Error-Correcting Code) Testing: Verifying the SSD's ability to correct errors, especially in the presence of electrical noise or power fluctuations.
 - b. Bad Block Handling: Assessing how the SSD handles and recovers from bad blocks due to power-related issues.
7. **Start-up and Initialization under Different Power Scenarios:**
 - a. Cold Boot Testing: Evaluating the SSD's performance during a cold boot when powered on from a completely powered-off state.

Power Up with OakGate SSD Test Solutions

All OakGate PCIe 5.0 SSD Test Platforms-R350, R300, DE200-include the new power and sideband signal capability in OakGate's SVF/Enduro v5.3+ software. This includes support for:

- Independently access the 3.3V, 3.3V aux, 5V, and 12V power rails
- Power Sampling Rate of 250,000 per second (250Kz)
- Power on/off to each port/device
- Support for NVMe Active Power States
- Full Hot-plug Support (Hot Swappable Devices Under Test)
- Power measurement under various low power states
- A number of charting and graphing options



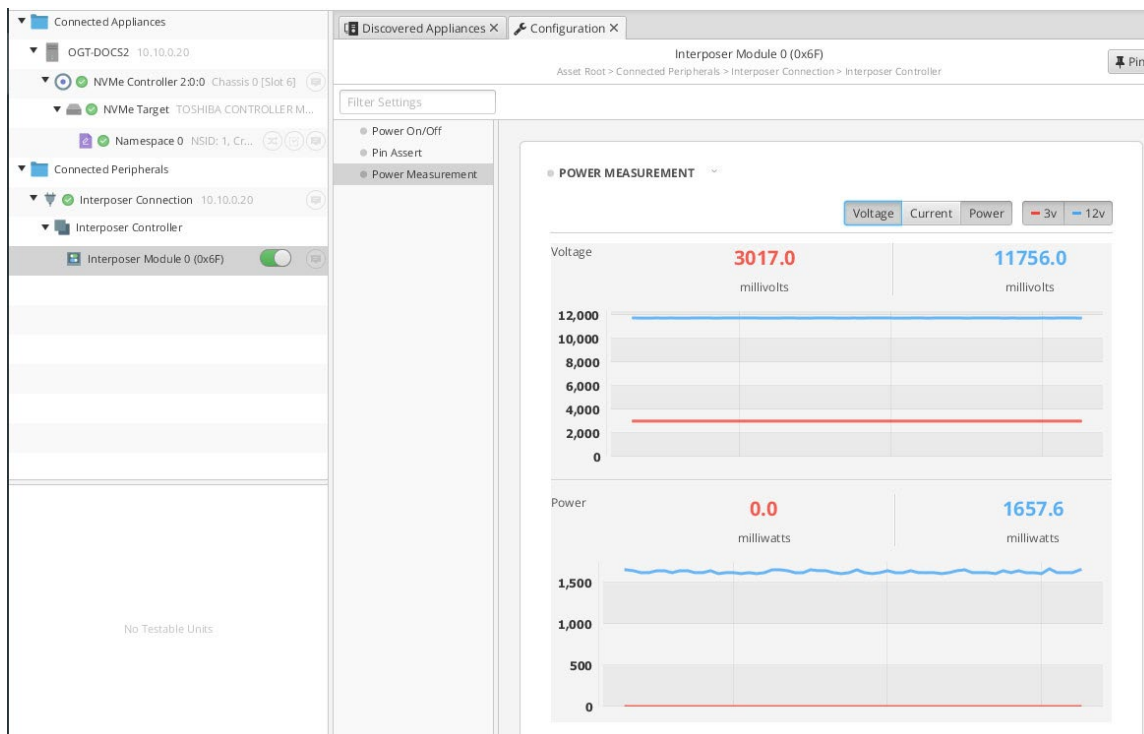
Additionally, all OakGate platforms include sideband signal control for REFCLK, PERST#, PWRDIS, DUALPRTEN#, WAKE#, SMBRST#, SUSCLK, and Amber LED. In addition they supports the sideband signal monitoring of CLKREQ# and the SRNS/SRIS Spectrum Clocking Modes.

The new OakGate R350 SSD Test Platform supports full voltage margining and glitching. The R350 includes an integrated power management module which allows SSD engineers to analyze voltage and current over time and under stress to help improve SSD power consumption in their designs. Customers no longer need to purchase 3rd-party power interposers which significantly reduces their overall total cost of ownership.

Included below are examples of the comprehensive power and sideband test coverage with every OakGate SSD Test Solution:

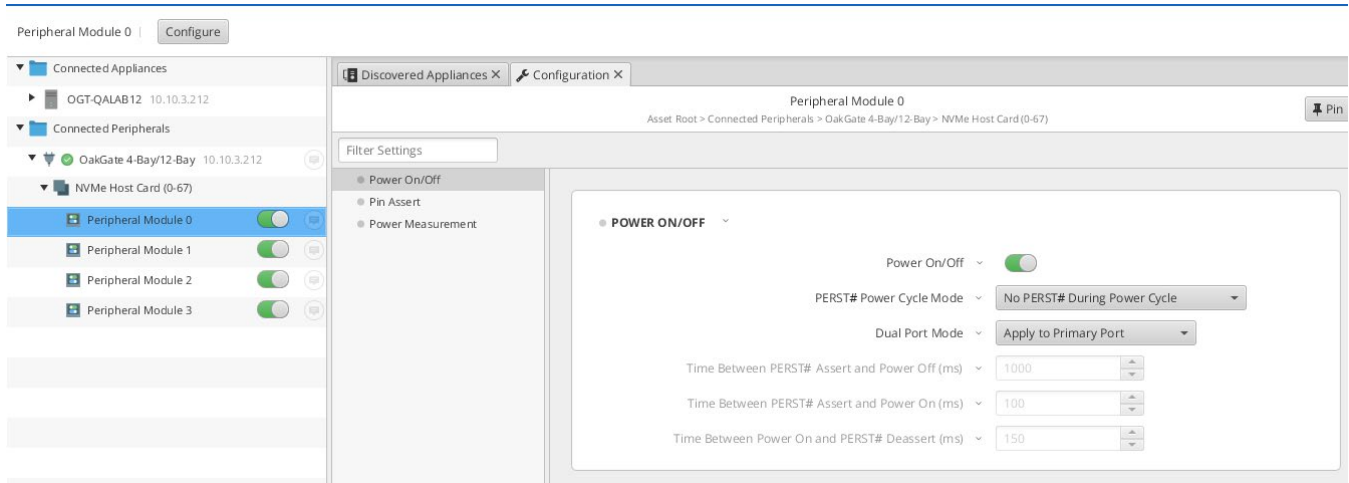
Power Measurement: The Power Measurement capability for PCIe devices measures voltage (mV), current (mA), and power (mW) at every second (w/ 128 samples per second) for the 3.3V, 3.3V aux, 5V, and 12V power rails.

The example below shows 3V (red) and 12V (blue) voltage sources of the associated port. The results are displayed based on the selected Voltage, Current, Power, 3V, and 12V buttons.



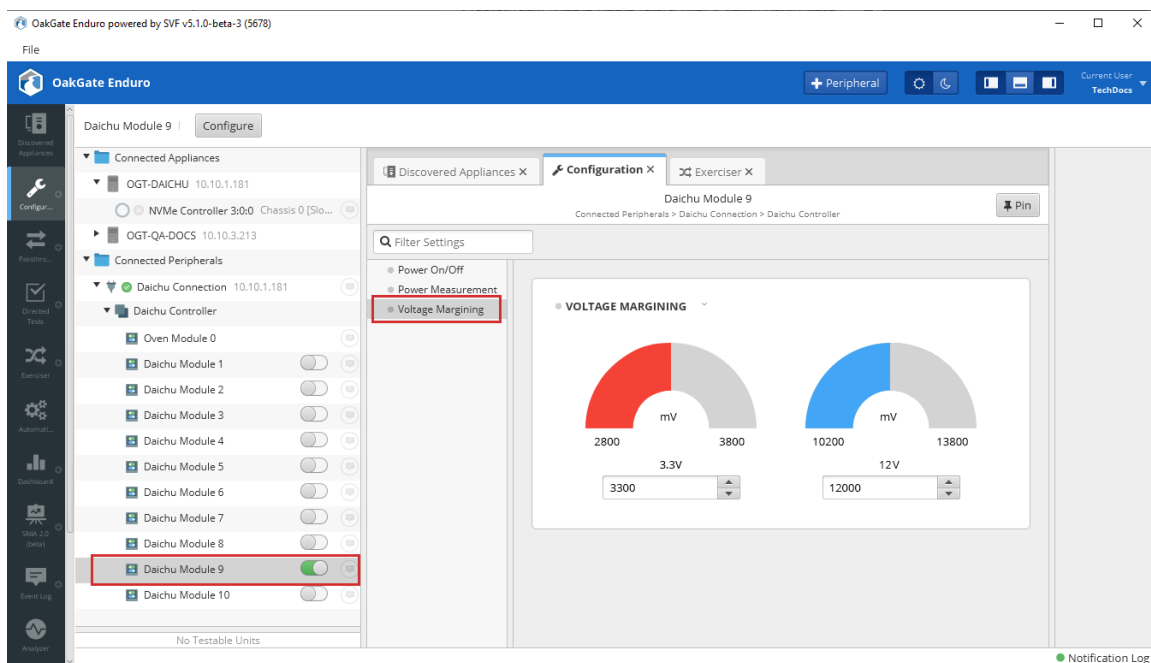
Power On/Off with (PERST#): The Power On/Off capability toggles the power on and off (along with PERST#/Dual-Port Settings, if appropriate) for the associated port. The PERST# signal is an auxiliary signal provided by the OakGate appliance to the PCIe power interposer card or OakGate peripheral. This signal causes a fundamental reset, which sets or returns all port states to their initial conditions, as specified by the PCI Express Base Specification and PCIe CEM specification.

The PERST# signal indicates when the power supply is within its specified voltage tolerance and is stable. It initializes a component's state machines and other logic once power supplies stabilize.

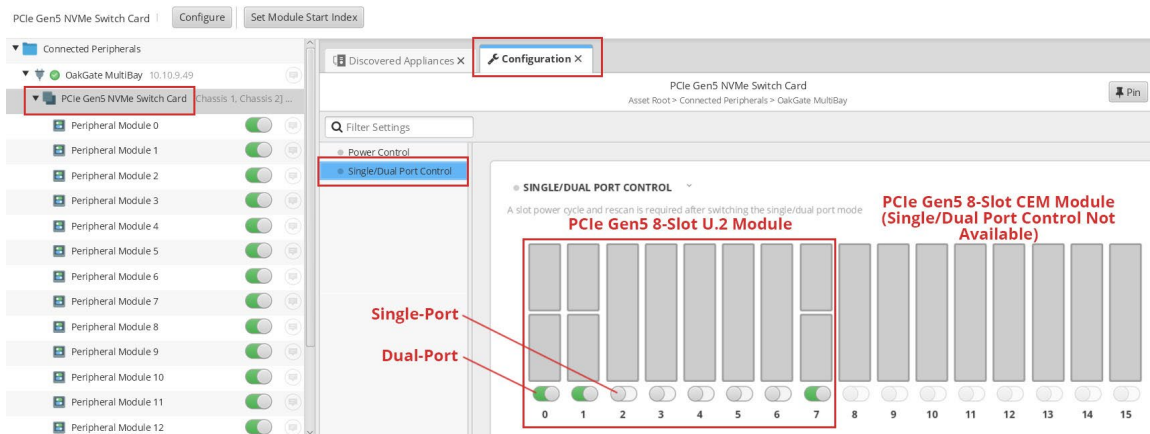


Voltage Margining: Available with the R350 platform only. Voltage margining is the process of intentionally adjusting the device's supply voltages within its operating range (for example, a 3.3V $\pm 20\%$ supply voltage has an operating range of $\sim 2.6\text{--}4.0\text{V}$) and then evaluating the device's performance during these voltage changes. This type of testing helps to determine whether the device can tolerate voltage changes that may occur over time.

The peripheral must support voltage margining and must be connected and associated to the appropriate port. Peripherals that support voltage margining include some Daichu chambers and the OakGate R350 PowerPlus Appliance, which includes a Power Management Control (PMC) card.

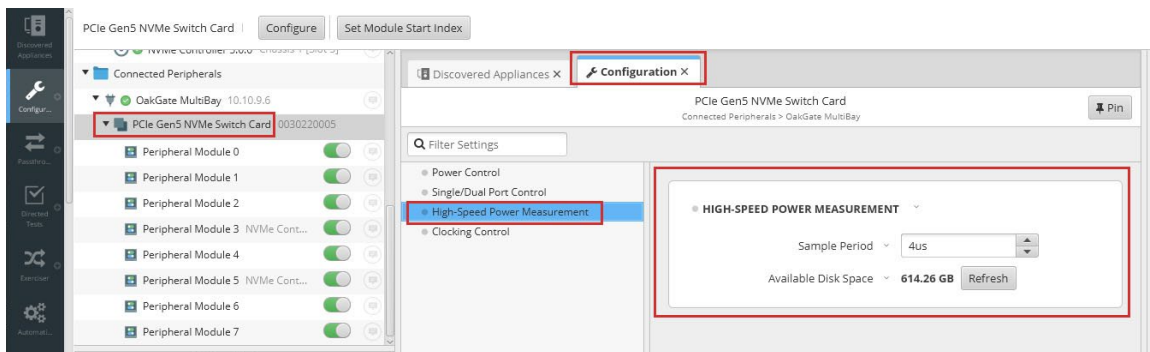


Single/Dual Port Control: This SINGLE/DUAL PORT CONTROL capability for a module/enclosure and for an individual peripheral module enable users to switch a PCI slot between single-port and dual-port for a single/dual-port capable device within an OakGate PCIe Gen5, U.2 or EDSFF, 8-bay module or 16-bay enclosure.

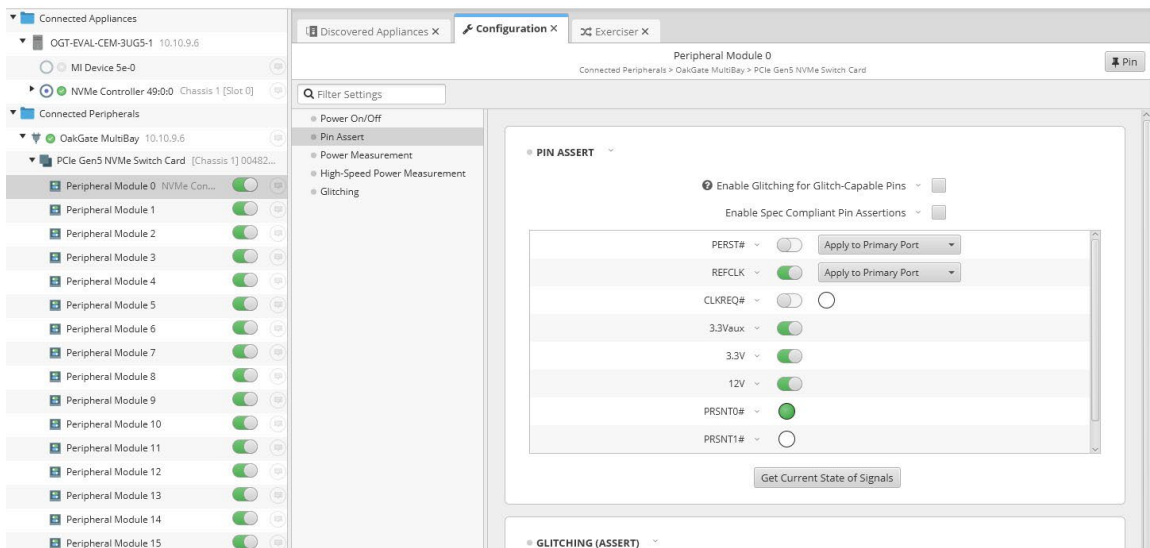


High-speed Power Management: This capability can be used to verify if the drive meets the Open Compute Project Datacenter NVMe SSD Specification, Version 2.0, section “9.2 Power Consumption Measurement Methodology” and provides two main features:

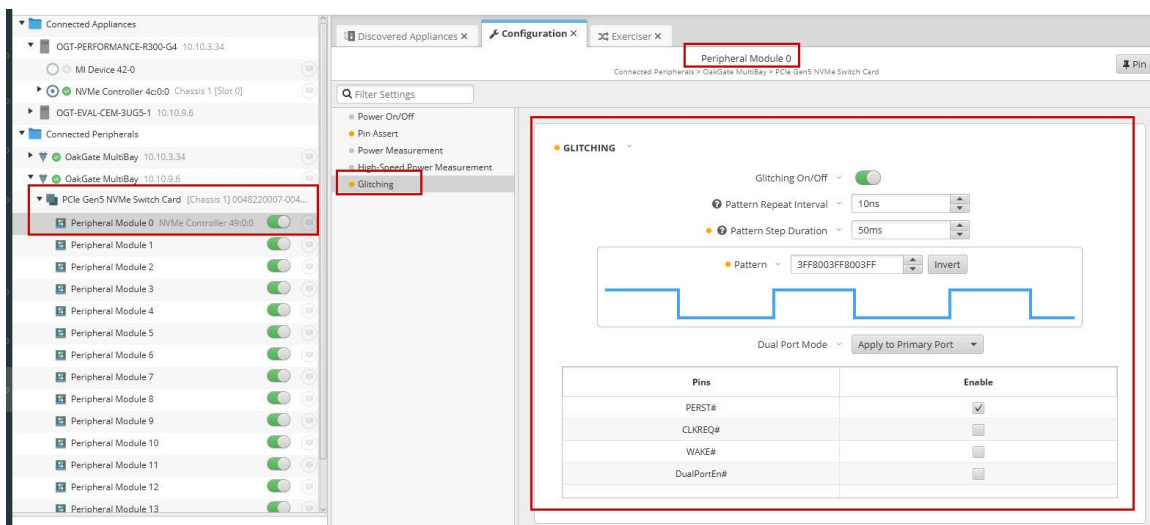
- **Data Capture** – capture (on the appliance) and export power measurements for the 12V, 5V, and/or 3.3V drive power rails at a high-speed sample rate of up to 250kHz for a selected device (peripheral module).
- **Data Analysis** – set and monitor average and peak power limits of combined 12V, 5V, and/or 3.3V drive power rails at a high-speed sample rate of up to 250kHz for a device (peripheral module) without needing to store any data on the appliance.



Sideband Pins: provides a list of PCIe pins and their initial states. Some pins’ states can be changed by the user with a toggle switch, where other pins’ states are read-only. The list is based on the peripheral type and its form factor (such as CEM, EDSFF, M.2, U.2, and U.3).



Sideband Glitching: The GLITCHING panel enables the user to simulate an unstable signal when the pin transitions from asserted to deasserted. That is, the user can configure a 64-bit electrical high/low pattern and then have that pattern run for a configured number of repetitions when the pin is toggled from on (green) to off (all gray). After the configured number of repetitions has run, the final state is off.



Summary

In conclusion, solid-state storage testing is of critical importance in today's technology landscape. It ensures the performance, reliability, and longevity of SSDs, which are integral components of modern computing systems. Moreover, it contributes to data security and compatibility, providing users with the confidence that their data is safe and their storage devices work seamlessly with their systems.

Solid-state Storage power and sideband testing contribute to the development of storage devices that are more reliable, robust, and capable of withstanding adverse power conditions and electromagnetic interference. These benefits ultimately lead to improved data integrity, longer lifespan, better performance, and greater satisfaction for end-users, making SSDs more dependable in a wide range of applications.

By implementing these comprehensive power and sideband testing procedures with professional SSD test and validation tools from Teledyne LeCroy, solid-state storage manufacturers can ensure that their products meet high-quality standards, perform reliably in various conditions, and provide customers with a positive user experience.

As the demand for solid-state storage and new protocols to reduce write amplification continues to grow, so too does the need for comprehensive power and sideband signal testing to meet the ever-increasing expectations of consumers and businesses alike. This, in turn, helps build trust and a positive reputation in the market. By investing in solid-state storage testing, manufacturers can produce high-quality SSDs, and consumers can make informed decisions about their storage solutions, ultimately contributing to a more reliable and secure digital ecosystem.

For more information and/or demonstration of OakGate SSD Test Solutions and other Teledyne LeCroy products, visit <https://www.teledynelecroy.com/oakgate> or contact us by email at sales@oakgatetech.com.