

# The Micron® 9400 NVMe™ SSD Performance With NVIDIA® Magnum IO GPUDirect® Storage Platform

This paper examines the performance and response time benefits of combining the Micron® 9400 SSD and NVIDIA Magnum IO GPUDirect Storage (GDS) on an NVIDIA DGX A100 system.

Micron internal engineering analysis of AI training workloads shows that different IO sizes are seen depending on model and data formats. Therefore, this document focuses on small (4KB), medium (128KB), and large (1MB) transfer sizes in two test scenarios.

It shows that GDS enables greater storage performance for AI workloads on busy systems and that the Micron 9400 SSD provides advantages over a leading competitor's performance-focused NVMe SSD.<sup>1</sup>

This paper also compares the Micron 9400 SSD to a leading competitor's data center NVMe SSD (Competitor A) using a busy system. Results show that the Micron 9400 SSD enables higher performance and better response time, and that storage can impact GPU utilization in your deployments.

The Micron 9400 SSD sets a new performance benchmark for PCIe® Gen4 storage in AI deployments. Decades of Micron storage experience have led to an SSD that packs in up to 30TB of capacity while managing critical workloads like caching, online transaction processing, high-frequency trading, artificial intelligence, and performance-focused databases requiring extreme performance.

## NVIDIA Magnum IO GPUDirect Storage (GDS)

GDS is a technology that enables a direct memory access (DMA) data transfer path between an SSD and graphics processing unit (GPU) memory as shown in Figure 2. NVIDIA is a pioneer in artificial intelligence (AI) from introducing the GPU in 1999 to the first release of GDS in 2021.<sup>2</sup>

Micron internal engineering analysis of AI training workloads shows that different IO sizes are seen depending on model and data formats. Therefore, this paper presents performance comparisons of small (4 Kilobytes), medium (128 Kilobytes), and large (1 Megabyte) IO sizes. All tests described in this document are performed using an NVIDIA DGX A100 system with 8X SSDs and 8X A100 GPUs in each test configuration.<sup>3</sup>

### Key findings

#### NVIDIA Magnum IO GPUDirect Storage (GDS)

Up to 6.4x higher busy system performance and up to 7.3x better response time than legacy IO

#### Micron 9400 SSD

The Micron 9400 SSD demonstrates up to 42% higher performance and 40% better response time on a busy, GDS-enabled system compared to a leading competitor's data center NVMe SSD



Figure 1: Micron 9400 SSD (U.2/U.3)

1. Competitor identified in Forward Insights, SSD Insights Q4/22 analyst report.  
 2. Additional information is available here: <https://www.nvidia.com/en-us/about-nvidia/corporate-timeline/>.  
 3. Additional information is available here: <https://www.nvidia.com/en-us/data-center/dgx-a100/>.

# NVIDIA GDS improves busy system performance compared to legacy IO

When a high-performance AI system like the NVIDIA DGX A100 runs a training workload, other complex, resource-intensive workloads like data pre-processing for AI model training can compete for system resources (a busy system). This section demonstrates the impact on AI training storage bandwidth to the GPUs when a simulated data pre-processing workload runs using 4KB, 128KB, and 1MB IO sizes when GDS is enabled, and when it is not (legacy IO).

Tests are run using the NVIDIA GDSIO tool, a synthetic IO benchmarking tool that uses cuFile APIs for IO. The NVIDIA GPUDirect Storage Benchmarking and Configuration Guide can be found [here](#). In this test, we use GDSIO transfer type 0 (Storage -> GPU) and 2 (Storage -> CPU -> GPU) to perform random read IO operations for different block sizes (4K, 128K, 1MB) using a file size of 5GB.

The data pre-processing workload is generated using the Google Stressful Application Test ([stressapptest](#)) configured as noted in Table 1.<sup>4</sup> The pre-processing workload results in 86% CPU utilization across both 64-core CPUs and system memory loading at 205 GB/s (roughly 50% of the total available memory bandwidth). Figure 2 represents the data path for a busy system when GDS is enabled while Figure 3 represents the legacy IO data path (GDS not enabled) for a busy system.

| Loaded Subsystem             | Loaded Value         |
|------------------------------|----------------------|
| CPU Utilization              | 86%                  |
| Memory Bandwidth Utilization | 205 GB/s (about 50%) |

Table 1: Emulated data pre-processing workload

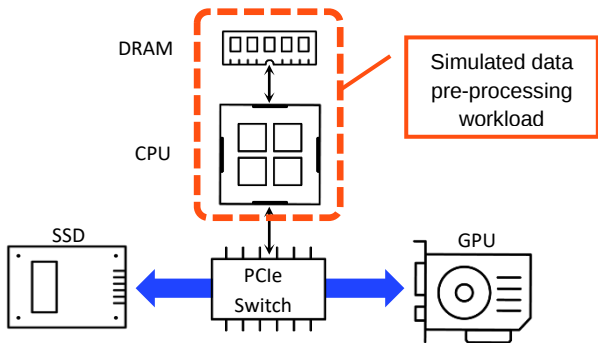


Figure 2: GDS IO path

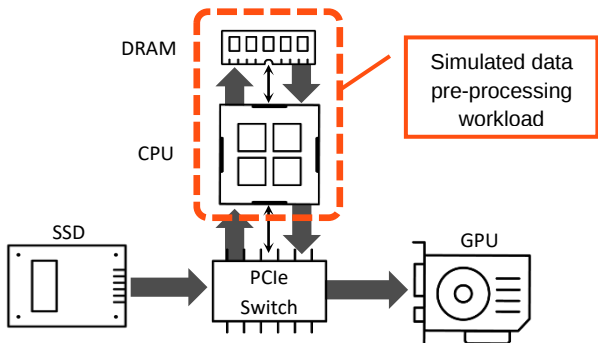


Figure 3: Legacy IO path

Figures 4, 5, and 6 represent the performance and response time impact of enabling GDS compared to the legacy IO path. In each of these figures, performance increases along the horizontal axis (farther right is better) and response time (latency) increases along the vertical axis (lower is better).

## 4KB transfer, busy system: GDS shows 6.4x higher performance and 7.3x better response time than legacy IO

4KB performance is measured by scaling the GDSIO thread count (TC) from 8 to 2048 across 8 SSDs. This equates to a per drive IO depth of 1 to 256 on each of the 8 drives under test.

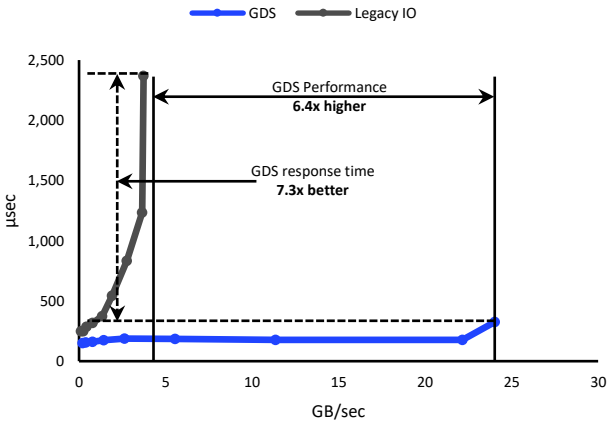


Figure 4: 4KB transfer performance and response time, busy system, GDS versus legacy IO

4. Additional information is available here: <https://github.com/stressapptest/stressapptest>.

Enabling GDS (blue) shows up to 6.4x higher performance and 7.3x better response time than the legacy IO configuration (grey) when TC = 2048 seen at the far righthand side of Figure 4.

### 128KB transfer, busy system: GDS shows 1.6x higher performance and 1.6x better response time than legacy IO

128KB performance is measured by scaling the GDSIO TC from 8 to 1024 across 8 SSDs with reduced maximum TC due to the increased transfer size. This equates to a per drive io depth of 1 to 128 on each of the 8 drives under test. Figure 5 represents the 128KB transfer size performance for each IO path.

Enabling GDS shows up to 1.6x higher performance as well as 1.6x better response time than legacy IO when TC = 1024 as seen at the far righthand side of Figure 5 (TC = 1024 is used in Figure 5 due to the increased transfer size relative to the data in Figure 4).

### 1MB transfer, busy system: GDS shows 1.5x higher performance and 1.5x better response time than legacy IO

1MB performance is measured by scaling the GDSIO TC from 8 to 512 across 8 SSDs. This equates to a per drive IO depth of 1 to 64 on each of the 8 SSDs under test. Figure 6 represents the 1MB transfer size performance for each IO path.

Enabling GDS shows up to 1.5x higher performance as well as 1.5x better response time when TC = 512 compared to legacy IO as seen at the far righthand side of Figure 6 (TC = 512 is used in Figure 6 due to the increased transfer size relative to the data in Figure 5).

Figures 4, 5, and 6 clearly show the performance and response time advantages of the GDS IO path when compared to the legacy IO path.

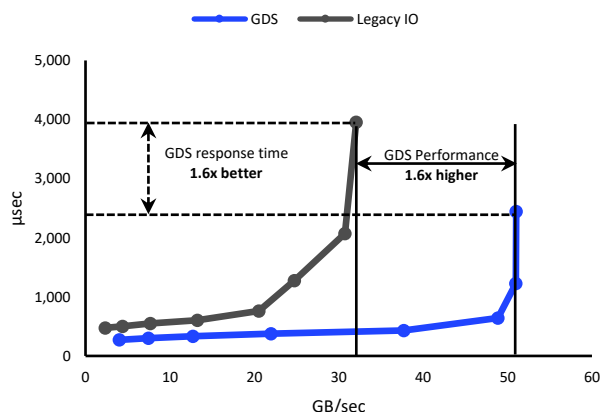


Figure 5: 128KB transfer performance and response time, busy system, GDS versus legacy IO

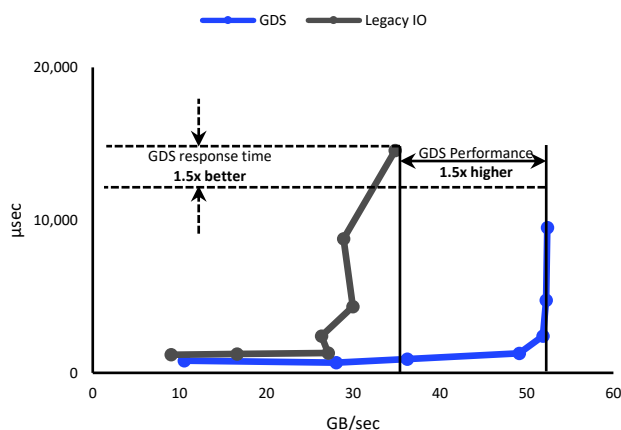


Figure 6: 1MB transfer performance and response time, busy system, GDS vs legacy IO

The Micron 9400 SSD delivers higher performance and better response time when GDS is enabled on a busy system than does Competitor A

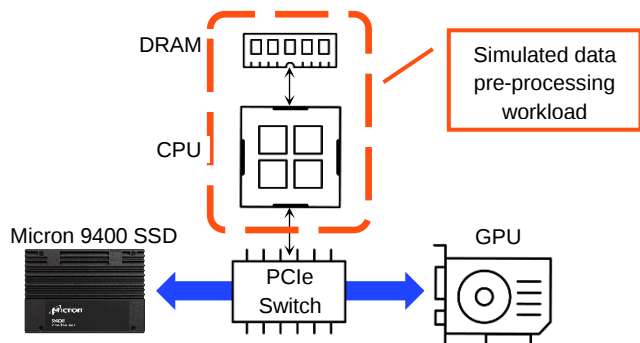


Figure 7: Micron 9400 SSD, busy system, GDS IO path

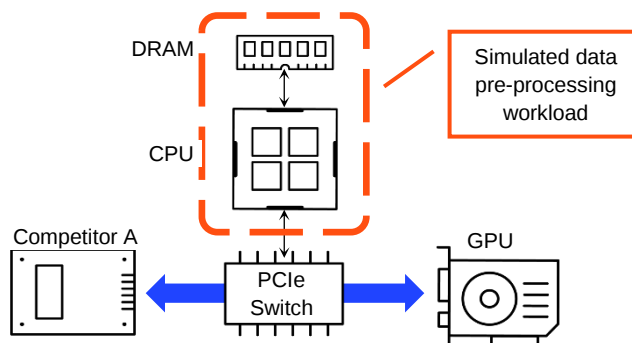


Figure 8: Competitor A, busy system, GDS IO path

Enabling GDS clearly offers higher performance and better response time than legacy IO. This section uses GDSIO to compare performance and response time results for two different data center NVMe SSDs on a busy system. The Micron 9400 SSD is shown in Figure 7 and a competitor's NVMe data center SSD (Competitor A) is shown in Figure 8.

#### 4KB transfer (GDS enabled): Micron 9400 SSD shows up to 42% higher performance and 40% better response time than Competitor A

Figure 9 represents performance and response time results with a 4KB workload on a busy system.

The Micron 9400 SSD shows higher performance and better response than Competitor A at all tested thread counts. The highest performance and response time improvement of the Micron 9400 SSD compared to Competitor A is noted in Figure 9. This Micron 9400 SSD reaches 42% higher performance and 40% better response time compared to Competitor A.

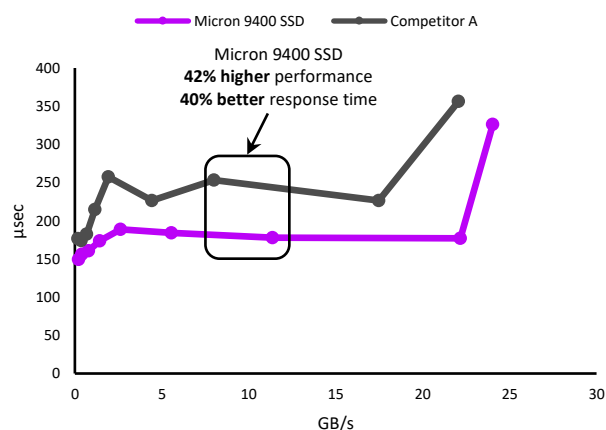


Figure 9: 4KB transfer performance and response time, busy system. Micron 9400 SSD versus Competitor A

#### 128KB transfer (GDS enabled): Micron 9400 SSD shows up to 32% higher performance and 25% better response time

Figure 10 represents performance and response time results with a 128KB workload on a busy system.

The Micron 9400 SSD shows higher performance and better response than Competitor A at all tested thread counts. The highest performance and response time improvement the Micron

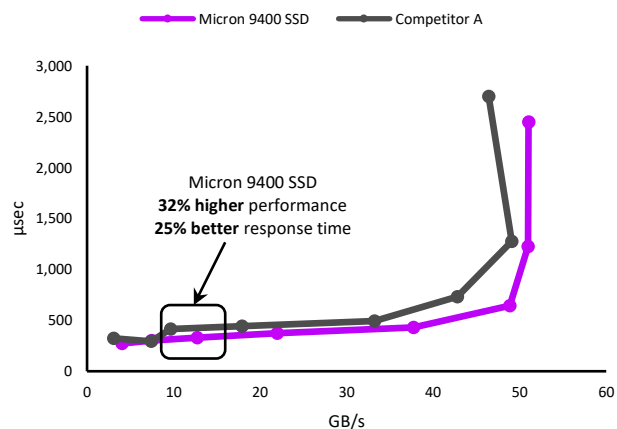


Figure 10: 128KB transfer performance and response time, busy system. Micron 9400 SSD versus Competitor A (both with GDS enabled)

9400 SSD shows compared to Competitor A is noted in Figure 10. This Micron 9400 SSD reaches 32% higher performance and 25% better response time compared to Competitor A.

**1MB Transfer (GDS enabled): Micron 9400 SSD shows 8% higher performance and 9% better response time**

Figure 11 represents performance and response time results with a 1MB workload on a busy system.

The Micron 9400 SSD shows up to 8% higher performance and 9% better response time than Competitor A.

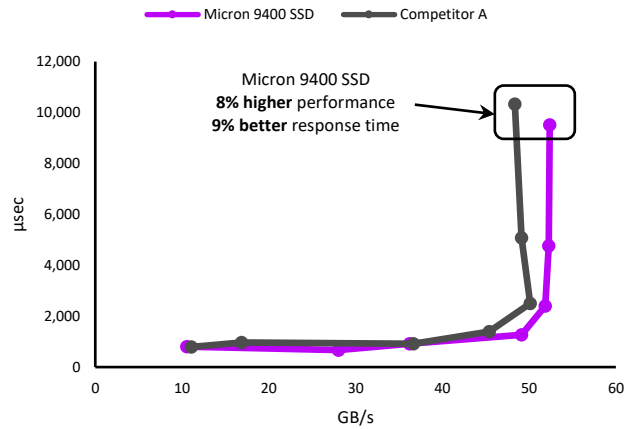


Figure 11: 1MB transfer performance and response time, busy system. Micron 9400 SSD versus Competitor A (both with GDS enabled)

Conclusion

High-performance AI training servers are usually kept busy and are rarely idle in operational deployments. Test results show that when systems are busy, a GDS-enabled workload delivers significantly higher storage performance and better response times than the legacy IO path, ensuring the GPUs stay fully loaded with data.

Combining GDS with the Micron 9400 NVMe SSD offers superior performance and response time over a competitor’s performance-focused NVMe SSD, regardless of the small (4KB), medium (128KB), or large (1MB) IO size present in any specific use case. These results reveal that the Micron 9400 is the right choice for AI workloads that use data pre-processing.

## NVIDIA DGX A100 configuration

Tables 2 and 3 outline the NVIDIA DGX A100 system and software configurations used.

| NVIDIA DGX A100 configuration |                                                           |
|-------------------------------|-----------------------------------------------------------|
| CPU                           | 2X AMD EPYC 7742 64-Core Processors                       |
| Memory                        | 16X Micron 64GB DDR4 RDIMMs @ 3200MT/s (1TB total memory) |
| Network                       | 8X NVIDIA A100-SXM4-40GB                                  |
| Micron SSDs                   | 8X Micron 9400 NVMe SSD                                   |
| Competitor A SSDs             | 8X Data center, NVMe SSD                                  |

**Table 2: Hardware configuration**

| Software configuration       |                    |
|------------------------------|--------------------|
| DGX version                  | 5.2.0              |
| OS                           | Ubuntu 20.04.4 LTS |
| Kernel                       | 5.4.0-107-generic  |
| CUDA                         | 11.6               |
| Nvidia Mellanox OFED Version | 5.4-3.1.0.0        |
| AMDµprof                     | 3.5-671            |
| stressapptest                | 1.0.9              |

**Table 3: Software configuration**

[micron.com/9400](https://micron.com/9400)

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