Performace Evaluation of
HP Z Turbo Drive G2 PCIe SSD

Powered by Samsung NVMe technology

Evaluation Conducted Independently by:

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Executive Summary
Storage technology continues to evolve as evidenced by HP’s latest solid state drive: the HP Z Turbo Drive G2 which features an NVMe PCIe SSD interface. Connecting storage via the PCIe bus enables four lanes of 8 GB/s bandwidth for a total of 32 Gb/s total bandwidth, compared to 6 Gb/s for SATA. This translates to a 4X performance improvement over SATA SSDs. In performance testing using industry standard storage benchmarks, OTSI has found the HP Z Turbo Drive G2 to be 150-320% faster than the Micron M600 SATA SSD and as much as 2800% faster than the Seagate 7200 RPM SATA HDD. Based on benchmarks, the HP Z Turbo Drive G2 has established itself as the storage performance leader.

Background
Traditionally, computers have stored their data on spinning hard drive disk drives (HDDs). Solid state drives (SSDs) offer a much faster and more reliable storage alternative. As storage technology has advanced, SSDs have become more affordable and are now beginning to surpass HDDs in popularity for many applications. SATA and SAS are standard interfaces that can run SSDs but there are other alternatives that can better handle the high performance of SSDs. HP and Samsung have partnered to offer a new form of data storage that runs on a PCI-express (PCIe) bus. Not only does the PCIe interface have greater bandwidth than both SATA and SAS, this bus provides a shorter path to the motherboard.

The greater bandwidth and shorter path to the motherboard found on a PCIe-based SSD theoretically allow it to perform appreciably faster than either a SATA or SAS SSD. As a result, data intensive operations such as video processing, data center services, and cloud storage will significantly benefit from PCIe performance gains.

To prove this theory OTSI employed benchmark tools commonly used in the storage industry to perform a study on a number of storage devices representing both HDD and SSD classes and compared the results against the performance of the HP Z Turbo Drive G2, HP’s second generation PCIe M.2 SSD.

What is an SSD?
An SSD is a storage device that stores persistent data on integrated circuit assemblies instead of a spinning disk like HDDs. The results are a vast increase in the read and write speeds of data. While SSD technology stores memory differently, it still uses the standard existing and emerging I/O interfaces to integrate into a system. SATA, SAS, USB, and PCIe are some of the interfaces SSDs can support. For the purposes of this comparison the SSD drives that OTSI tested use NAND-based flash memory.
PCIe-based SSDs
SSD performance has continually increased over time due to advancements in NAND flash technology. However, the performance increases have recently become bottlenecked by the maximum bandwidth of the SATA interface, which is restricted to one lane at 6 Gb/s. PCIe connected SSDs, on the other hand, can utilize 4 lanes at 8 Gb/s for a total bandwidth of 32 Gb/s. The additional bandwidth of PCIe has allowed SSD performance to continue to scale with the evolution of NAND technology. Consequently, SSD interfaces are beginning to transition from SATA to PCIe, and PCIe is now becoming the preferred interface for high performance SSDs in mobile computers. The HP Z Turbo Drive and HP Z Turbo Drive G2 leverage the PCIe interface to attain throughputs that were previously unattainable with SATA connected SSDs.

What is NVMe?
NVMe stands for Non-Volatile Memory Express. It is a software protocol designed from the ground up to support flash technology. It was purpose built to support high bandwidth, low latency devices that connect directly to the PCIe bus. NVMe significantly improves the performance of PCIe SSDs.

NVMe vs AHCI
The first generation HP Z Turbo Drive utilized PCIe with the AHCI protocol (Advanced Host Controller Interface). AHCI was originally designed for SATA hard disk drives and, as a result, performance bottlenecks can be experienced when it is used with PCIe SSDs. With the introduction of the NVMe protocol, PCIe SSDs can now maximize the low latency and high performance benefits of flash technology.

HP Z Turbo Drive G2 overview
The HP Z Turbo Drive G2 is a half-height, half-length PCIe-based add-in board that plugs directly into a PCIe slot. It is an HP-designed adapter card that is powered by Samsung’s SM951 (M.2 form factor) SSD technology. SM951 contains Samsung’s professional class, MLC flash memory, a 3-core, eight channel UAX controller (designed specifically for PCIe) and firmware. Samsung, the largest producer of SSDs in the world, designs and manufactures all of the components inside its SSDs including the NAND memory, firmware and controller.

There are two or four 128GB Samsung MLC flash memory modules on the SM951 (two on 256GB drives, four on the
512GB). SM951 uses Samsung’s 10nm-class MLC, which succeeds Samsung’s previous generation 20nm-class MLCs.

The SM951 has a four-lane PCI Express 3.0 interface and is based on the NVMe protocol. SM951 NVMe replaces XP941, which powered the first generation of HP Z Turbo Drives, upgrading XP941’s PCIe Gen2 x4 link to Gen 3 speeds, and moving to the NVMe controller from the AHCI controller. Gen 3 speeds double the aggregate bandwidth to 32 Gb/s and boost the max sequential read and write to 2150 MB/s and 1500 MB/s, respectively.

Benchmark setup and system configurations
To keep testing uniform, all tests in this benchmark were performed on an HP Z440 workstation. For the side-by-side benchmarks, two identical HP Z440 workstations were used. Because the HP Z Turbo Drive G2 can work as a boot drive, or a data drive, and as both with two drives in the same system, both types were benchmarked *. All the tests were run twice: once with one drive as the boot device and a second time with two identical drives (one as a boot drive and the other as data storage). In the dual-drive configuration, the benchmark numbers presented are only for the data drive. To ensure uniform performance, the system was disconnected from the network, the system power plan was set to high performance, all the devices were set to never sleep or hibernate, the firewall was disabled, and the anti-virus software was turned off.

(Note: While the HP Z Turbo Drive G2, as well as the other devices used in this effort, can function as both boot and data storage devices that is not true of all SSDs. Some SSDs can only serve as data storage devices, such as Fusion-io’s ioExtreme PCI Express.)

* The complete system configuration is listed in the Appendix.

Storage devices evaluated
Three storage options were tested:

- HP Z Turbo Drive G2 512GB (PCIe)
- Micron M600 512GB SSD (SATA)
- Seagate 500GB 7200 HDD (SATA)
Benchmark programs used
The following benchmark programs were used:

- BlackMagic Disk Speed Test
- IOMeter
- AJA System Test
- SPECwpc

BlackMagic, IOMeter and AJA are strictly storage benchmarking tools. SPECwpc contains benchmark components for both storage and other areas such as CPU and graphics speed. Where possible benchmarks presented here used both small and large sample storage sizes to simulate a variety of test conditions. The benchmarks were installed on and invoked from the drive being tested. Generally, all benchmarks showed that the data drive performed as well or better than the boot drive - an expected result.

BlackMagic’s Disk Speed Test is a widely used tool for testing the throughput of a storage device for video related operations and the device’s ability to serve various video formats. The benchmarks were run with sample sizes of up to 5 GB and an average of the results was tabulated. The drive was tested for 10 minutes or more to accumulate stable results.
IOMeter Benchmark

**IOMeter** is a powerful tool for measurement and characterization of I/O subsystems within both single and clustered configurations. It was initially created by the Intel Corporation and has since been given to the open source community. IOMeter has been widely used in the industry and can be configured to simulate a large variety of storage utilization profiles through the parameters it provides in its user interface. It can measure both storage throughput and the number of I/O operations per second (IOPS).
AJA System Test is a straight-forward tool provided by AJA Video Systems for checking the video processing performance of any storage device. It was tested in 3 modes (Disk Read + Write, Sweep Video Frame Sizes and Sweep File Sizes). In each of those modes, it was tested with video resolutions of 1280x720, 1920x1080, 2048x1556 pixels, and sample sizes of 1, 4, 8 and 16 GB. In total, each configuration was clocked for 20 different types of operation.
SPECwpc is an extensive benchmark suite consisting of multiple professional applications and tools designed to measure all key aspects of workstation performance. It was developed by representatives from major hardware vendors including HP, AMD, Fujitsu, Dell, Intel, Lenovo, NEC, and NVIDIA. Thirty two workloads were used to test different areas of computing for 6 key industrial categories: Media & Entertainment, Product Development, Life Sciences, Financial Services, Energy and General Operations. The scores from individual tests are aggregated to compute normalized scores of the 6 industrial categories. SPECwpc measures much more than storage performance, and therefore, the numbers represent both storage-only as well as general performance. SPECwpc needs to be installed since it checks for certain system requirements before it can run correctly. It requires MS HPC Pack 2008 R2 MS-MPI redistributable and will install it if not already present. This benchmark was run in its entirety with all of the default values, even though many of those do not measure storage performance and takes several hours to complete.
Benchmark Results
The raw and original composite numbers from all benchmarks have been tabulated. The raw numbers are uniformly combined to create overall scores. All the test scores are normalized against the slowest drive. The normalization only simplifies the values and does not favor one drive over another.

**Overall storage score:** Combines the normalized storage-only benchmark numbers from all tests into one number for each drive type. (Figure 1)

![Combined Storage Test Score](image)

*Figure 1: Combined Storage Score (a composite of all storage related benchmarks for both boot and data drives).*
**Total score:** Combines scores from all tests into a single normalized number. These tests include storage as well as CPU, RAM, and graphics results. (Figure 2)

![Total System Test Score (Includes Storage Tests)](image)

*Figure 2: Total normalized scores for both boot and data drives*
Total I/O operations per second (IOPS): Represents the number of IOPS from the IOMeter benchmark for both boot and data drives. (Figure 3)

Figure 3: IOPS (I/O per second) for both boot and data drives
**Read/Write throughput:** Represents the average of all the read/write tests from the BlackMagic benchmark for both data and boot drives. (Figure 4)

![BlackMagic Read/Write Test Score](image)

**Figure 4:** BlackMagic results for both boot and data drives
Analysis

- As the charts above show, the HP Z Turbo Drive G2 proved to be the fastest storage in every test case.

- The HP Z440 PCIe slot 4 provides the fastest performance and is the recommended slot for the HP Z Turbo Drive G2.

- The HP Z Turbo Drive G2 has instances where the read and write performance exceeded the 1.9 GB/sec threshold.

- The raw benchmark data indicates that the CPU, graphics, and RAM components of the benchmark were not affected by the speed of storage.

- The storage related benchmarks behave consistently. The SATA SSD drive is faster than the SATA HDD drive, and the PCIe SSD numbers are faster than all else by 200% (or more in some cases). Storage performance follows a pattern of improvement as one goes from SATA HDD to SATA SSD to PCIe SSD drives (HP Z Turbo Drive G2).

- In most cases, the performance of the data drive is as fast as or better than the boot drive.

- In the previous benchmarking of the first generation HP Z Turbo Drives, the HP Z Turbo Drive 512GB proved faster than the first generation HP Z Turbo Drive 256GB PCIe SSD because the 512 GB drive has more NAND modules, allowing for more parallel IO operations. Although the 256 GB version of the second generation HP Z Turbo Drive was not included in the current benchmark we believe that the first generation’s advantage of 512 GB drives over the 256 GB version extends to HP Z Turbo Drive G2 PCIe SSDs as well.

Conclusion
This benchmark effort proved the HP Z Turbo Drive G2 to be the fastest drive among those tested. It vastly outperformed the other drives while testing very large variations of storage transactions with varying file sizes. The HP Z Turbo Drive G2 offers a clear speed benefit to storage-intensive applications such as video processing, data centers, cloud, and CAD applications.
Appendix

Test System Configuration: HP Z440

Computer Type: Desktop
Manufactured by: Hewlett-Packard
Product ID: F5W13AV
Serial Number: 2UA4501LL8
BIOS version: M60, v01.58
Processor: Intel® Xeon® CPU E5-1660 v3 @ 3.0GHz
Enabled Processor Count: 16
Total Memory: 32 GB
Graphics Card & Driver: NVIDIA® Quadro® K4200 -- driver version 347.52
Operating System: Windows 7 (64-bit)
Current Culture: en-US

HP Z Turbo Drive G2’s published specs:

<table>
<thead>
<tr>
<th></th>
<th><strong>HP Z Turbo Drive G2 256GB</strong></th>
<th><strong>HP Z Turbo Drive G2 512GB</strong></th>
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<tbody>
<tr>
<td>NAND Type:</td>
<td>MLC</td>
<td>MLC</td>
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<tr>
<td>Sequential Read Bandwidth (128KB):</td>
<td>2150 MB/s</td>
<td>2150 MB/s</td>
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<td>Sequential Write Bandwidth (1MB):</td>
<td>1260 MB/s</td>
<td>1550 MB/s</td>
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<tr>
<td>Random Read IOPS (4KB):</td>
<td>300K</td>
<td>300K</td>
</tr>
<tr>
<td>Random Write IOPS (4KB):</td>
<td>100K</td>
<td>100K</td>
</tr>
<tr>
<td>Endurance (Total Bytes Written):</td>
<td>146 TB</td>
<td>292 TB</td>
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<tr>
<td>Weight:</td>
<td>3.9oz (111g)</td>
<td>4.0oz (113g)</td>
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<tr>
<td>Form Factor:</td>
<td>Half-height, half-length</td>
<td>Half-height, half-length</td>
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<tr>
<td>Supported platforms:</td>
<td>HP Z440, HP Z640, HP Z840 Workstations (for both 256GB and 512GB)</td>
<td></td>
</tr>
</tbody>
</table>
Resources


HP Z440 workstation: www.hp.com/go/z440


HP Z Turbo Drive G2: www.hp.com/go/zturbo

BlackMagic Speed Test: www.blackmagic-design.com

IOMeter Test: http://www.iometer.org/doc/matrix.html

AJA System Test: https://www.aja.com/en/software

SPECwpc suite: http://www.spec.org/gwpg/wpc.static/wpcv1info.html

This whitepaper located at: www.otsi-usa.com/whitepapers/HP_ZTurboDriveG2_SSD_WhitePaper.pdf


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