Storage Wars: SSD vs HDD Part 3

Unlocking Workstation Productivity Potential

Executive Summary (TLDR)

For anyone following along, this article presents the 3rd and final installment of the *Storage Wars* series where the goal has been to objectively compare the user experience when upgrading to a Solid Disk Drive (SSD) in place of legacy Hard Disk Drives (HDDs) as the primary storage device in new desktop PCs. We started with general purpose business-class PCs and then moved on to the budget PC segment. For the final round of testing, we focused on professional-grade workstations to complete our understanding of SSD value in all product tiers.

Based upon testing in the 3 aforementioned desktop PC product segments, the following conclusions can be made:

1. SSDs are more expensive than HDDs in terms of dollars spent per capacity of storage ($/GB), but the prices of SSDs are continuously improving with the trends suggesting that they will *eventually* drop below that of HDDs.
2. SSDs provide incredible performance and reliability benefits over HDDs which, in most cases, far exceeds the relative price increase of the SSD.
3. “Hybrid” storage solutions that pair a low-capacity SSD with a higher-capacity HDD can increase system performance by 89% while only increasing system cost by 8-11% for budget-conscious consumers.
4. Upgrading a new workstation PC to SSD technology can improve application responsiveness by over 250% and decrease time spent waiting for large files to load by over 97% making it more and not less imperative to upgrade to an SSD for professional-grade PCs.

If you are interested in a fascinating read about the testing that lead to the arrival of conclusions 1 through 3 above, check out Part 1 and Part 2 from our Storage Wars series. If you read conclusion number 4 above and find yourself thinking:

“***If I upgrade to a more expensive (higher performance) CPU and/or GPU, is it really necessary to spend the extra money for an SSD?***”

then please keep reading!

Background

For the conclusion of this three-part series, we are looking at the upper end of the PC market spectrum: professional-grade workstations. Video and photo editors, content creators, architects, software designers, my personal favorite, thermal engineers, and many other professions rely upon software applications that create incredible compute demands upon PC hardware while also generating large amounts of data that needs to be moved around and stored. Workstation PCs can be configured with top-shelf CPU and graphics hardware designed to provide the horsepower that these users demand.

As though debating between SSD and HDD drive technology and choosing the right drive capacity to cover all of your storage needs without breaking the bank were not enough to think about, some desktop PC vendors, such as Dell and Lenovo, have recently begun presenting customers with another option to consider which is the SSD PCIe "Generation".

PCIe Generations Simplified

For those who don't live and breathe PC hardware for a living but care to know more, here is a quick explanation of what the PCIe SSD generation terminology means:

Figure 1. Standard M.2 SSD pictured for form factor reference.

PCIe stands for Peripheral Component Interconnect Express which is just the name for the connection protocol that the SSD uses to communicate with the CPU. While not a perfect analogy, one can think of PCIe in the same sense that HDMI has become the de facto protocol for video transmission on modern TVs. Similar to the way that HDMI versions have changed over time to accommodate new video formats (starting with 1080p, then to 4K and now 8K UltraHD), the PCIe standard has evolved over time to support ever increasing data transmission rates. PCIe Gen3 (or version 3.0) has been around since 2010 and is still found in many PCs today. PCIe Gen4 (or version 4.0) was introduced in 2017 but not readily available on Intel CPUs until late 2020. When an SSD is connected within a computer via PCIe, it is referred to as an NVMe (Non-Volatile Memory) drive.

Why does any of that matter?

PCIe Gen4 provides 100% more bandwidth than PCIe Gen3 meaning that PCIe-connected devices such as SSDs can, theoretically, operate up to 2X faster when connected to a Gen4 PCIe slot. Unfortunately, there is a catch. To achieve PCIe Gen4's higher speeds, the controller on the SSD drives themselves get slightly more expensive. Furthermore, the PC's motherboard also needs to utilize more expensive materials making the system even more costly than PCIe Gen3. No advancements in technology are free.

OK, PCIe Gen4 is allegedly faster and more expensive than Gen3, how much difference does it actually make?

To better answer that question, we have 3 Dell Precision 3650 workstation PCs identically configured except for the storage drive as follows:

- **500 GB 2.5" HDD**
  - A common baseline configuration for primary drive offering substantial storage capacity for most users at a low price point
- **512 GB M.2 Class 40 Gen3 PCIe SSD**
  - Mid-capacity SSD providing balance of storage space and performance operating in the previous generation of PCIe slots which are limited to 4,000 MB/s maximum theoretical bandwidth
- **512GB M.2 Class 40 Gen4 PCIe SSD**
  - Mid-capacity SSD providing balance of storage space and performance operating in the current generation of PCIe slots which are limited to 8,000 MB/s maximum theoretical bandwidth

Additionally, we are including identical SSD-configured workstations from HP and Lenovo to see what performance differences exist between the three primary workstation brands. Details on the workstation hardware configurations included in this test can be found in Table 1 below.

Table 1. Desktop configurations for the HDD and SSD Performance Testing

Hardware Configurations					
Make	Dell	Dell	Dell	HP	Lenovo
Model	Precision 3650 Tower	Precision 3650 Tower	Precision 3650 Tower	Z2 G8 Tower	ThinkStation P350
Form Factor	Tower	Tower	Tower	Tower	Tower
CPU SKU	Intel Core i7-11700	Intel Core i7-11700	Intel Core i7-11700	Intel Core i7-11700	Intel Core i7-11700
CPU TDP	65W	65W	65W	65W	65W
Memory	2x8GB PC4-3200	2x8GB PC4-3200	2x8GB PC4-3200	2x8GB PC4-3200	2x8GB PC4-3200
Storage	500 GB 7.2k RPM 2.5" HDD	512GB M.2 Class 40 SSD Gen 3	512GB M.2 Class 40 SSD Gen 4	512GB M.2 Class 40 SSD Gen 3	256GB M.2 Class 40 SSD Gen 4
Storage Part Number	MQ01ACF050	MZVL2512HCJQ-00BD2	MZVL2512HCJQ-00BD2	HFS512GDE9X073N BE	MZ-VL25120
Video Card	Nvidia T1000	Nvidia T1000	Nvidia T1000	Nvidia T1000	Nvidia T1000
Power Supply Rating	500W	500W	500W	500W	500W
BIOS Version	1.9.2	1.9.2	1.9.2	01.03.02	S0AKT2FA
OS Version	Win 10 Pro build 19044	Win 10 Pro build 19044	Win 10 Pro build 19044	Win 10 Pro build 19044	Win 10 Pro build 19044

Performance Study

As in the previous two installments of this series, we will rely upon a battery of standard benchmark tests to objectively quantify the performance differences brought about by the included drive types and PC brands. The selected benchmarks can be organized into the following 3 categories:

- **Raw Drive Performance**: these types of benchmarks focus on the performance of the drive itself rather than the applications that make use of the drive. Storage operations such as file transfers align well to this type of benchmark.
- **Application Performance**: these benchmarks utilize real-world applications to assess the speed of the overall PC as a combined system. As such, some applications will show heavy storage drive dependence while others will not.
- **User Experience**: These benchmarks focus on some of the less tangible, yet frequently-encountered elements of using a computer such as how long it takes to reboot or extract a zip file.

Raw Drive Performance

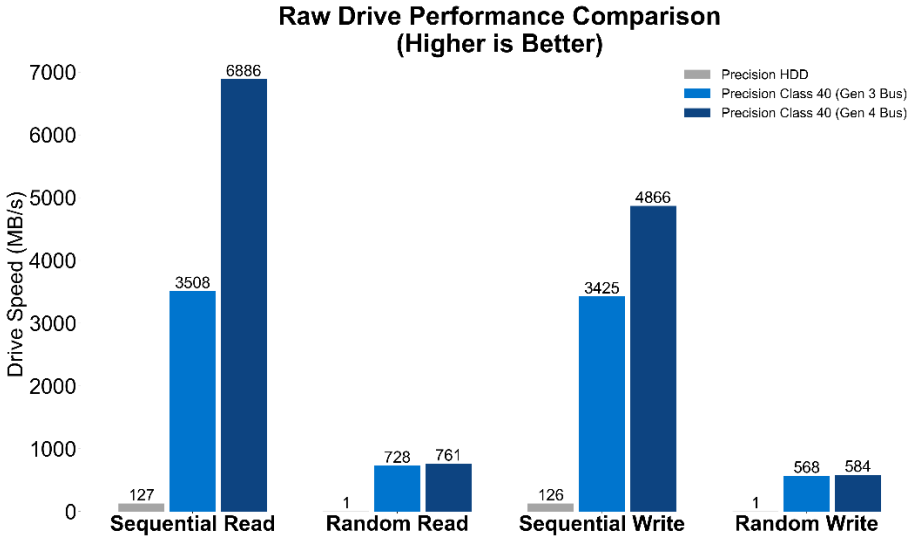

Figure 2. Dell Precision 3650 CrystalDiskMark performance comparison.

Raw drive performance is exactly what it sounds like: how fast is the storage device having virtually no engagement with or dependency upon the rest of the PC hardware.

Few real-world applications behave in this manner, having no dependency on the rest of the PC's hardware configuration, however, there are some notable workflows where this type of performance is of utmost importance. Copying large files, loading large video or photo files into software for editing, indexing an outlook personal folder, and the loading portion of a game are all examples of use cases where the raw drive performance will directly affect the user's experience.

Figure 2, above, shows the raw drive performance comparison for the 3 different drive configurations on the Dell Precision 3650 workstation as measured using the CrystalDiskMark drive benchmark utility (n=5). If you have read any of the previous articles, you won't be surprised that a Class 40 SSD operating utilizing a PCIe Gen3 connection is capable of providing 27 times faster sequential read speed than the HDD. What is impressive, however, is that **the very same Class 40 SSD operating in a PCIe Gen4 slot, is 54 times faster than the HDD in the same workstation**.

Random storage operations, while being insanely fast on any SSD in comparison to an HDD, do not appear to be bottlenecked by the PCIe connection type and show similar performance between Gen3 and Gen4 slots.

Figure 3, to the right, shows the same raw drive performance comparison across the Dell, HP, and Lenovo workstations.

Several workstation PC brands have started offering customers the option to purchase their M.2 NVMe SSD as either a Gen3 or Gen4 configured drive. This is true for Dell and Lenovo, however, for the HP Z2 G8 tower, no option or reference to the PCIe generation is provided to the purchaser. What we found is that while the HP Z2 G8 tower is technically 'capable' of supporting a Gen4 SSD, there is no option for configuring the system with one through the website and the system actually shipped with a Gen3 SSD in a Gen4 SSD slot.

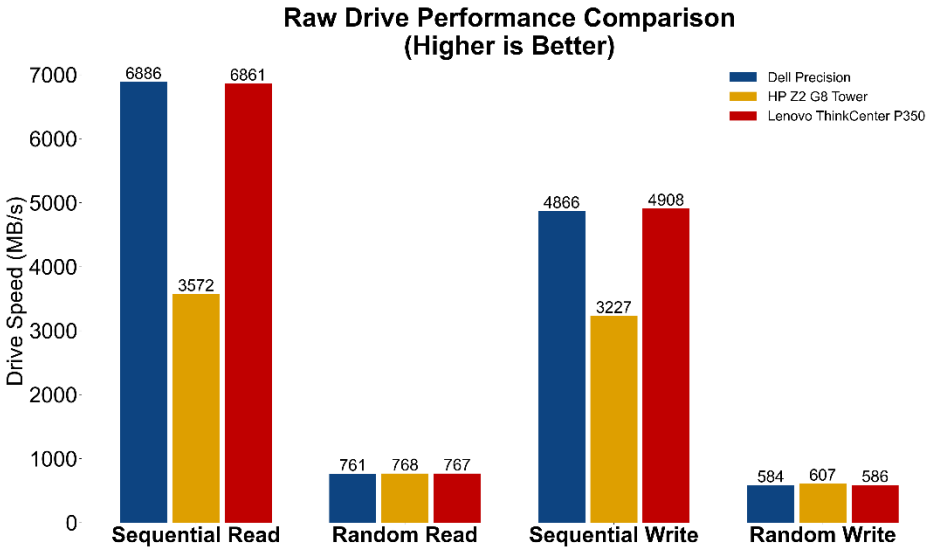

Figure 3. Raw Drive Performance comparison for the 3 included workstation brands.

The end result was predictable - Dell and Lenovo systems destroy the HP workstation on sequential storage operations (those that are limited by the PCIe connection) and all 3 have nearly identical results for random operations (those that are not limited by the bandwidth of the PCIe connection).

Where the rubber hits the road

Content creators buy high-horsepower workstations because they very often work with large volumes of digital media (data). Ultra HD 8K videos can *literally* require up to 121.5 GB per minute of raw footage. Based upon previously shared data, it would take most HDDs over 10 minutes just to load 1 minute of raw footage ***before*** your CPU and/or GPU can get to work processing it. A Gen4 PCIe SSD could load that same minute of footage in 17 seconds.

Buying a high-end workstation configured with an HDD is like buying a high-performance sports car with bald tires; all the horsepower in the world is useless without the ability to transmit that power to the asphalt. **If you are a creator of high-definition content, under no circumstances should you purchase anything but a Gen4 PCIe SSD for your primary storage device** based upon these results. By this same logic, HP electing not to ship a Gen4 SSD in their Rocket Lake Z2 G8 workstation tower is a serious miss.

Application Performance

Now we get back to one of the first questions that was asked: if we are spending the money for high-end CPUs and GPUs, does upgrading to an SSD really add that much additional value to the daily application experience? To answer that question, we will return, again, to the industry's two favorite office application benchmark suites:

- Bapco's SYSMark 25
- Futuremark's PCMark 10

Both of these benchmarks take the PC through a list of common usage scenarios and rate the computer for parameters like productivity, responsiveness, and creative content capabilities. For a more thorough explanation of how each of these application benchmarks work, please see the first article in this series found here.

Figure 4 shows the SYSMark 25 performance scores for the 3 different drive configurations on the Dell Precision 3650. A quick look reveals that **application responsiveness increases by a jaw-dropping 250% for both SSD configurations over the legacy HDD**! Overall application performance across all application types improves by 42% just by choosing the SSD over the HDD. Figure 5, below, provides the same testing for the Dell Inspiron 3891. It is clear that both the budget PC (Inspiron 3891) and high end workstation (Precision 3650) see massive performance improvements from SSDs, however, the benefit is amplified in the Precision workstation. In other words, high end CPUs are held back by HDDs.

At the same time that SYSMark25 is revealing a massive performance improvement for high-end workstation systems using SSDs, it is not suggesting a very strong dependency upon PCIe generation as the SSD in both Gen3 and Gen4 slots provide effectively the same application performance scores.

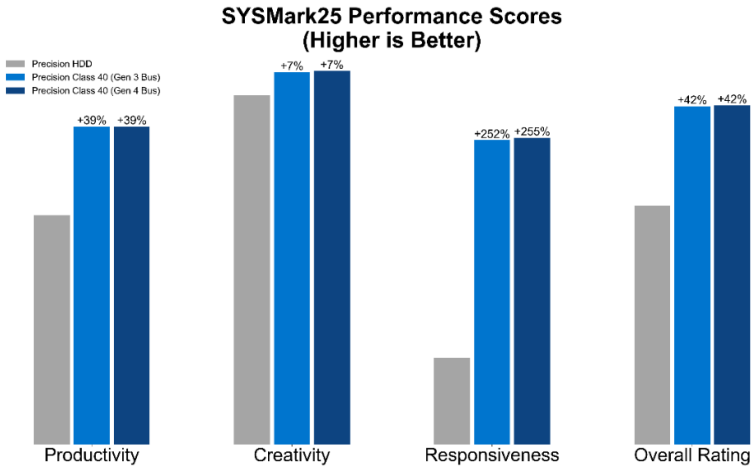

Figure 4. SYSMark 25 Performance scores for Dell Precision 3650 workstation.

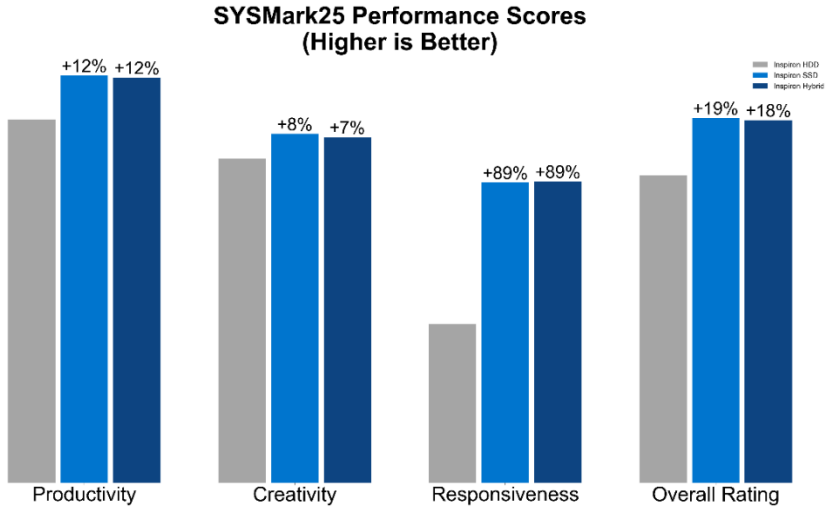

Figure 5. SYSMark 25 Performance scores for Dell Inspiron 3891 desktop.

PCMark 10 tells a similar story where the application performance improvement brought about by SSD is large and pronounced. Unlike SYSMark, PCMark does suggest a slightly stronger application performance benefit when running a Gen4 SSD compared to a Gen3 SSD. Figure 6 shows the PCMark 10 results for the 3 different drive types in the Dell Precision 3650 and Figure 7 shows the same test comparing the SSD-configured workstations from Dell, HP, and Lenovo.

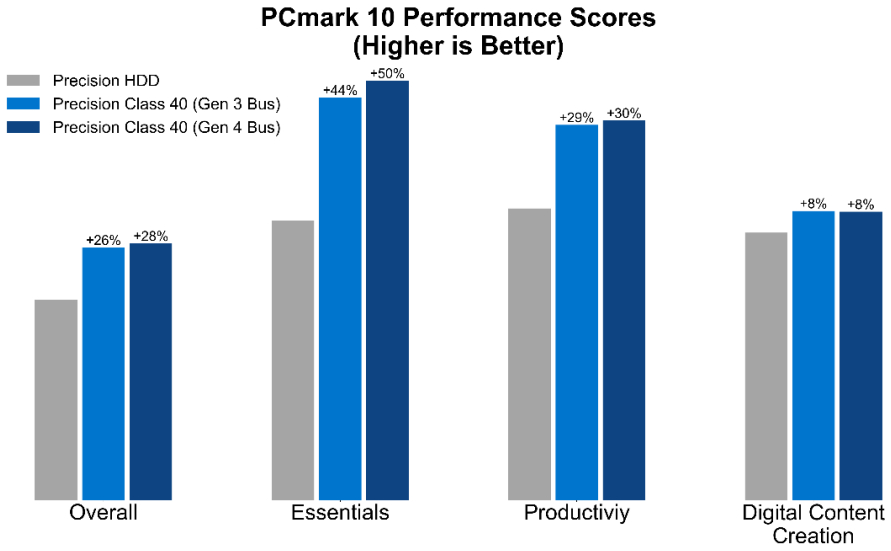

Figure 6. PCMark 10 Performance scores for Dell Precision 3650 workstation.

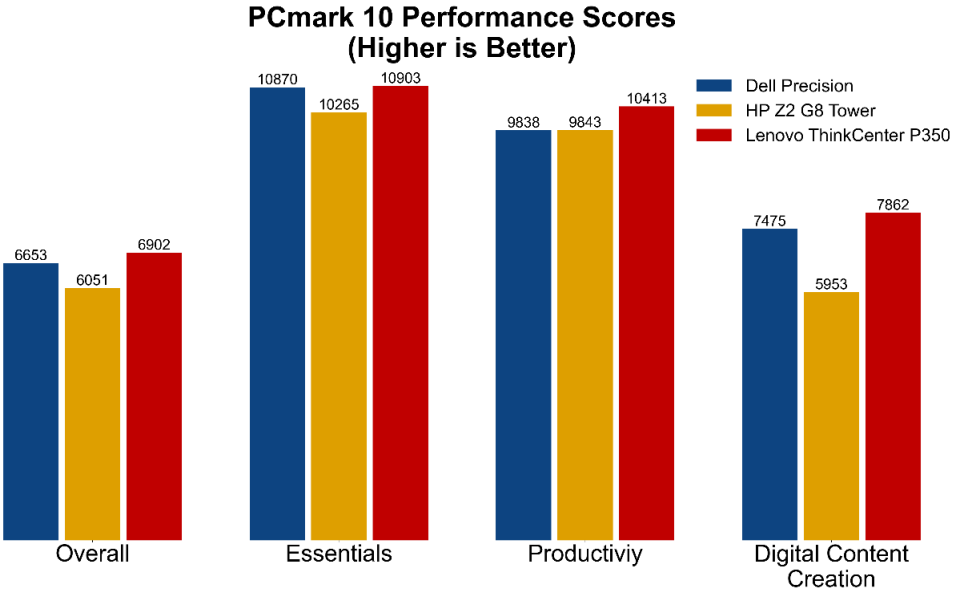

Figure 7. PCMark 10 Performance scores for Dell Precision 3650, HP Z2 G8 Tower, and Lenovo ThinkCenter P350.

Taking a closer look at Figure 7, the HP Z2 G8 tower seems to trail decently far behind the Dell and Lenovo systems in several testing categories. Based upon the results of Figure 6, some, but not all of this performance gap can be attributed to HP's election to ship a Gen3 SSD with their workstation. The bigger problem for HP, in this case, appears to be related to their packaging of the Nvidia display driver. For additional context on HP's performance lag in the PCMark 10 test, please see the Additional Detail section at the end of this article.

Figure 8 below shows the PCMark 10 application start times for the 3 Dell Precision storage configurations and is pretty revealing in that even with the well-endowed Dell Precision 3650 workstation, opening up a word processor application still takes roughly 10 times longer with an HDD compared to an SSD. Figure 9 shows that HP's decision to ship with a Gen3 SSD does cost them in application start time compared to Dell and Lenovo shipping with Gen4 SSDs.

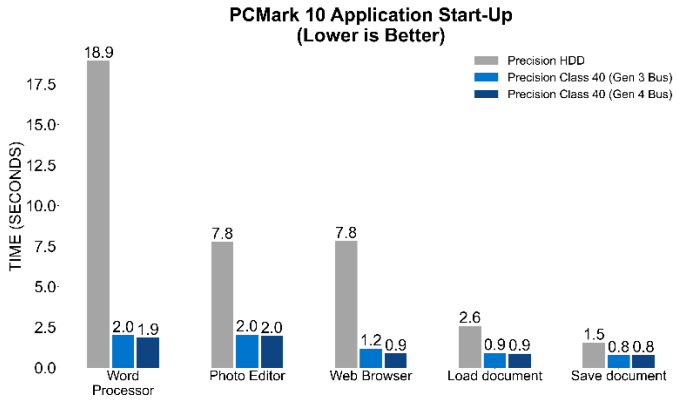

Figure 8. PCMark 10 Application Start times for Dell Precision 3650

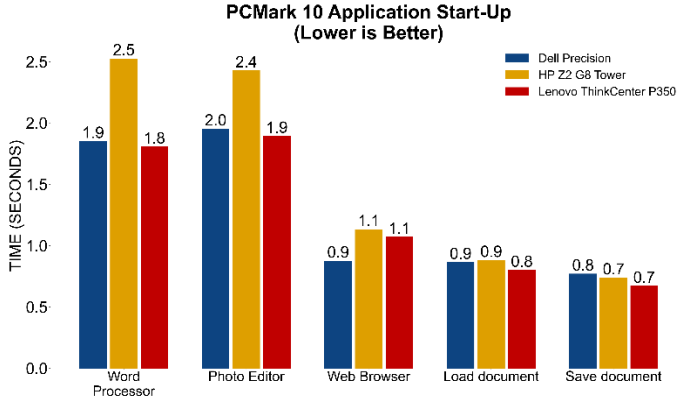

Figure 9. PCMark 10 Application Start times for all 3 workstation brands.

User Experience Benchmarks

The final performance comparisons were obtained through an averaged series of timed operations common to PC usage and are presented for the 3 Dell Precision drive configurations in Figure 10 below. The timed operations include:

- **System Power On**: The time from power button pressed until waiting at Windows log-in screen
- **System Reboot**: The time required from initiating a system restart until back at the Windows log-in screen
- **Extract 5GB Zip File**: Decompression of a single 5GB system file from a .zip format using the Windows native compression tool – unzipping a file compressed on the primary SSD to the secondary HDD on Hybrid config.

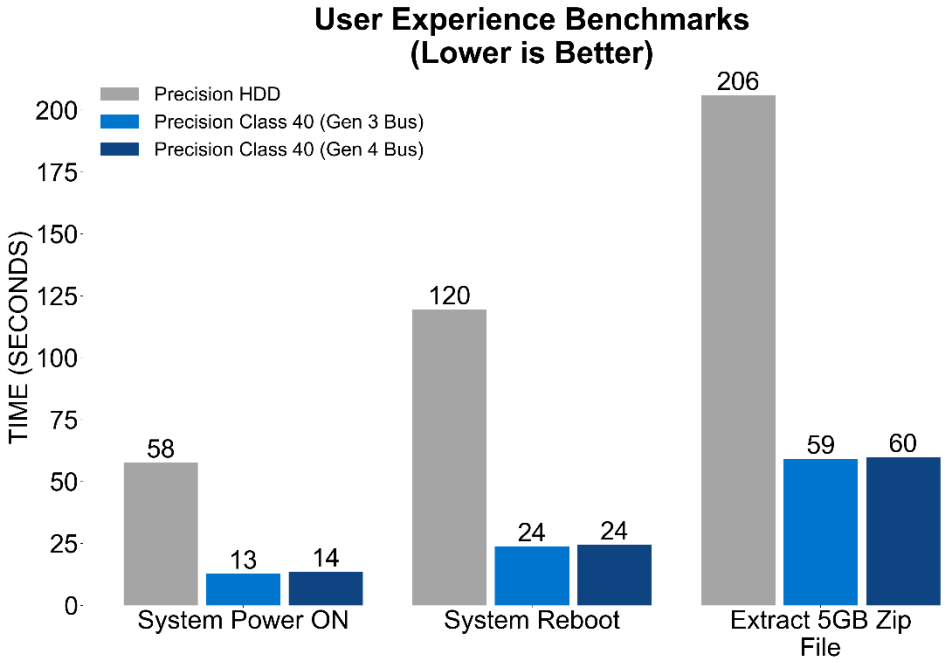

Figure 10. User experience benchmarks between HDD, SSD, and hybrid, on the Dell Precision 3650 (n=5).

Figure 10 is offered up without explanation. Does anyone buying a workstation-class product really have 2 minutes to spare staring at their PC screen waiting for a reboot?

Conclusion

The objective with this final installment in the SSD vs HDD series was threefold:

- Understand the performance benefits for PCIe Gen4 vs Gen3 on the primary storage device for common usage scenarios
- Compare the application and storage performance of the big three workstation vendors
- Determine whether SSDs are still a necessary and valuable upgrade over HDDs when purchasing high-end workstation PCs

The impact of purchasing a Gen4 SSD compared to a Gen3 SSD will vary depending upon the end user application. Either option is immensely faster than a legacy HDD but application performance differences between the two PCIe generations tend to be fairly small in this case. For users who spend significant amounts of time working with very large files (i.e. video rendering), the nearly 2x increase in sequential read speeds found in Gen4 SSDs would be well worth the moderate cost premium that they currently require.

The Dell and Lenovo workstation PCs performed very similarly in most benchmark categories with Lenovo edging Dell out in the PCMark 10 overall category. The HP Z2 G8 Tower workstation fell behind in several performance categories, due to shipping a Gen3 SSD and having a display driver bug that pushed many of the PCMark 10 OpenCL workloads to the integrated GPU instead of the onboard Nvidia T1000.

To address the final objective, it was established that many customers purchasing tower workstations are using them for digital content creation. At a bitrate of 121.5 GB per minute of raw 8K footage, it would take an HDD-equipped workstation 10 minutes to load a single minute of footage before the CPU or GPU can even begin rendering the clip. An SSD-equipped workstation would require just 17 seconds to load the same minute of footage. Furthermore, it was observed that application responsiveness on the Dell Precision 3650 increased by 255% when utilizing a Gen4 SSD compared to the same system equipped with a legacy HDD. System reboot times on the Precision go from 120 seconds using an HDD to just 24 seconds using an SSD. Not only are SSDs a necessary and valuable upgrade for high-end PC builds, they are, objectively, more valuable **because** they are coupled with high-end PC builds. The types of software applications that create such demands upon CPUs and GPUs virtually always coincide with the production or consumption of massive amounts of data and having that data anchored down by a slow HDD destroys productivity. SSDs are, therefore, essential to unlocking the maximum productivity potential for workstation PCs.

Additional Details

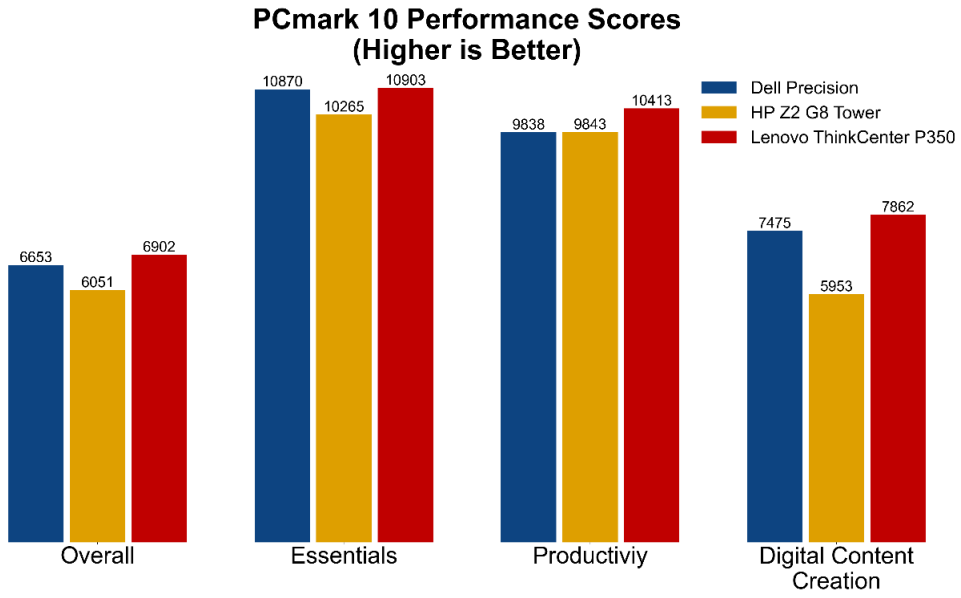

Figure 7. PCMark 10 Performance scores for Dell Precision 3650, HP Z2 G8 Tower, and Lenovo ThinkCenter P350.

Each workstation tested in this study effectively includes two Graphics Processing Units (GPUs). The Intel i7-11700 CPU in each system has an Intel Iris integrated GPU (GPU in the same package as the CPU). In addition to the integrated Intel Iris GPU, each of the tested workstations was configured with a Nvidia T1000 discrete GPU with the 4K external monitor attached to the discrete GPU. Many of the applications in PCMark 10 utilize the OpenCL framework which effectively creates software that can be run on either the Intel CPU's integrated GPU or the Nvidia discrete GPU. Without a lengthy discourse on GPU performance characteristics, suffice to say that the Nvidia T1000 GPU is substantially more powerful than the integrated Iris GPU onboard the Intel CPU. Unfortunately for HP, their display adapter driver available for the Z2 G8 Tower at the time of this testing sends all of the OpenCL workloads present in the PCMark 10 benchmark to the integrated Intel GPU rather than taking advantage of the powerful Nvidia T1000. We would expect HP to remedy this issue in future driver releases.

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