

Western Digital VelociRaptor 1TB (WD1000DHTZ) Review

by **Anand Lal Shimpi** on 4/16/2012 8:00:00 AM

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There was a time when Western Digital's Raptor (and later, the VelociRaptor) was a staple of any high-end desktop build. Rotational media could only deliver better performance by increasing areal density or spindle speed. In a world dominated by hard drives that focused on the former, WD decided to address both. By shipping the only mainstream 3.5" hard drive with a 10,000 RPM spindle speed, WD guaranteed that if you needed performance, the Raptor line was the way to go.

Two years ago [we met the most recent update to the VelociRaptor line](#): the VR200M. While it raised the bar for the VelociRaptor, WD saw its flagship competing in a new world. SSDs were now more affordable, resulting in even more desktop builds including an SSD. Although the high dollar-per-GB cost associated with SSDs demanded that desktop users adopt a two-drive model (SSD + HDD), for storage of large media files a standard 5400RPM or 7200RPM drive was just fine. After all, moving large files is mostly a sequential operation which plays to the strengths of most consumer drives to begin with.

There are still users who need more storage than an SSD can affordably provide, and who demand speed as well. Although photo and video editing is great on an SSD, a big enough project would have difficulty sharing a 128GB SSD with an OS, applications and other data. For those users who still need high performance storage that's more affordable than an SSD, the VelociRaptor is still worthy of consideration. There's just one problem: Moore's Law is driving the cost of SSDs down, and their capacities up. The shift to solid state storage is inevitable for most, but to remain relevant in the interim the VelociRaptor needed an update.

Today Western Digital is doing just that. This is the new VelociRaptor, available in 250GB, 500GB and 1TB capacities:



Read on for our full review!

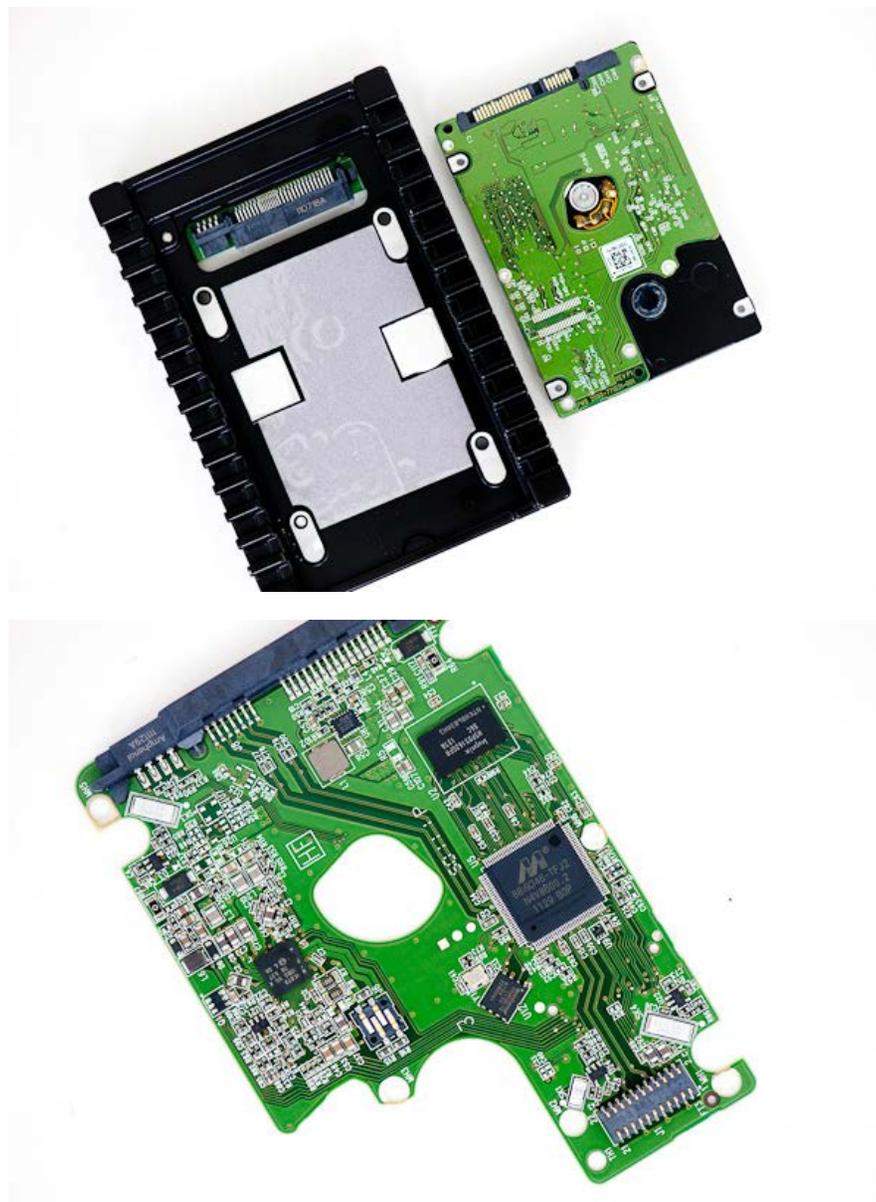
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WD VelociRaptor Historical Comparison			
	WD VelociRaptor VR333M	WD VelociRaptor VR200M	WD VelociRaptor VR150M
Capacity	1000/500/250GB	600/450GB	300/150GB
Interface	6Gbps SATA	6Gbps SATA	3Gbps SATA
Advanced Format (4K Sectors)	Y	N	N
Rotational Speed	10000 RPM	10000 RPM	10000 RPM
Buffer Size	64MB	32MB	16MB
Transfer Rate Buffer to Disk	200 MB/s	145 MB/s	128 MB/s
Platter Density	333GB	200GB	150GB
Warranty	5 years	5 years	5 years

The basic design remains unchanged. Take a 2.5" drive with platters spinning at 10,000 RPM and pair it with a 3.5" adapter that also acts as a heatsink. Internally the drive gets all of the expected updates. Platter density is now up to 333GB (3 platters for the 1TB drive, 2 for the 500GB drive and 1 for the 250GB). All members of the new VelociRaptor family feature a 64MB DDR3 cache. Combine that with some firmware updates and you've got a recipe for larger capacities and higher performance.



The drive is available today and retails for \$319 for the 1TB model, \$209 for the 500GB model and \$159 for 250GB. These prices are a bit lower than what the VelociRaptor VR200M launched at two years ago (the 500GB is significantly cheaper than the old 450GB launched at).

WD VelociRaptor Lineup			
	WD1000DHTZ	WD5000HHTZ	WD2500HHTZ
Capacity	1TB	500GB	250GB
MSRP	\$319.99	\$209.99	\$159.99
Cost per GB	\$0.319	\$0.419	\$0.639

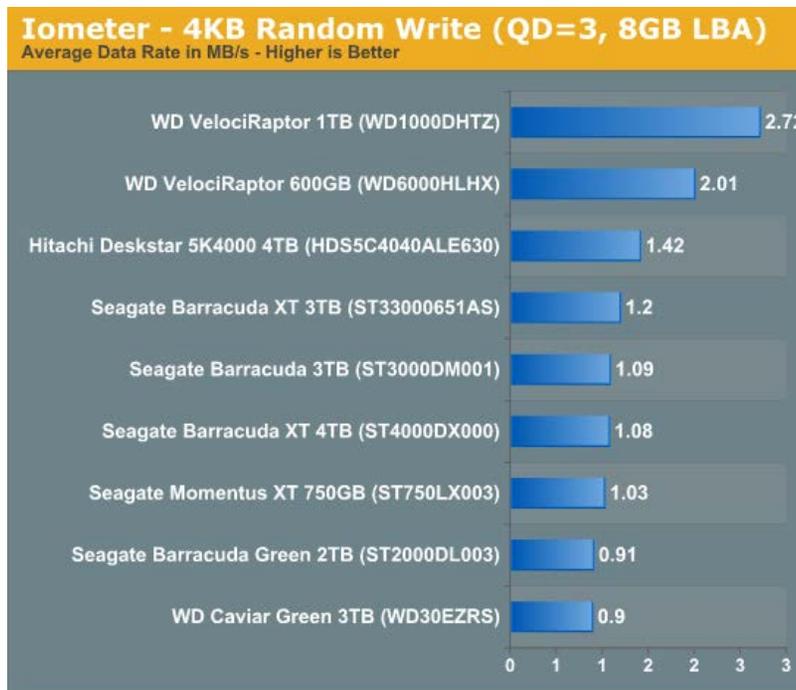
Compared to standard 3.5" drives, the VelociRaptor is quite expensive. You can buy a 3TB 7200RPM drive at roughly \$0.06 per GB, compared to \$0.319 per GB for the most cost

effective VelociRaptor. Compared to an SSD however, the VRs are still cheaper - although not by a ton if you compare to a low capacity drive. Samsung's SSD 830 (128GB) will cost you \$1.36 per GB.

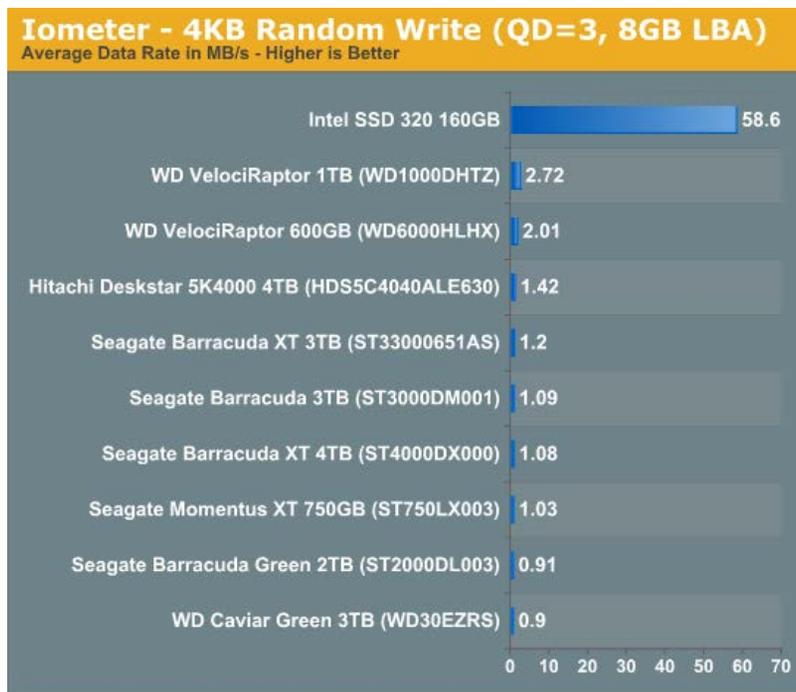
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Random Write Speed

The VelociRaptor's two primary strengths are its 2.5" platter size and 10,000 RPM spindle speed. The combination of the two delivers some of the best random access times you can get from a mechanical hard drive, at least one aimed at the desktop. Indeed we see a tangible performance advantage not only over the latest 3.5" hard drives, but also the previous generation VR. The advantage of the NAND equipped Seagate Momentus XT is just as large.

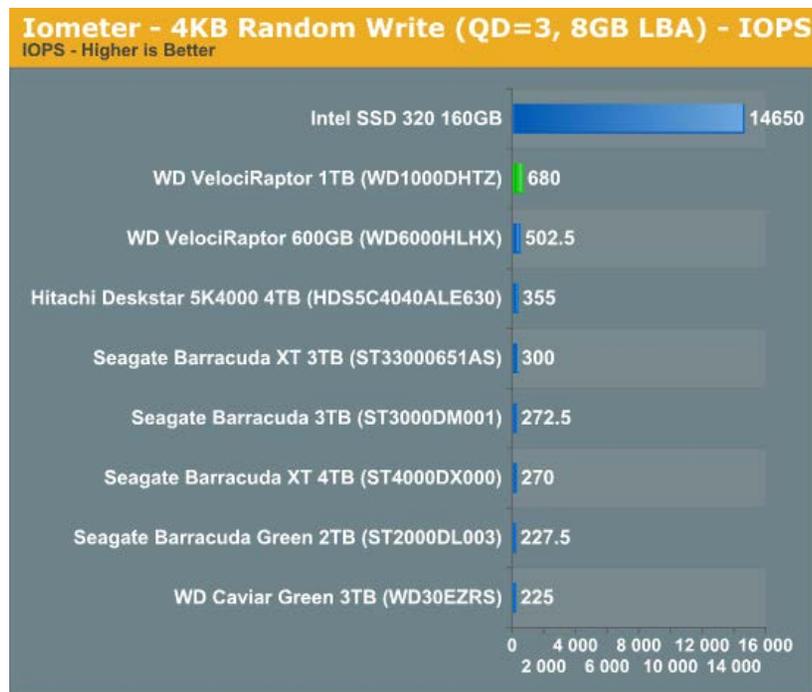


Obviously even the most affordable SSDs deliver better random IO performance compared to the VelociRaptor as you can see by looking at Intel's SSD 320 here:



The new VelociRaptor manages a 35% increase in 4KB random write performance over its predecessor, and more than double the performance of Seagate's 7200RPM Barracuda XT. Unlike SSDs, random read and write performance is symmetric on most hard drives so we only really need to look at a single value here. Intel's SSD controllers have typically offered very high random IO performance, so the SSD advantage here isn't unusual.

Ultimately it's this 21x gap in random IO performance that really contributes to why SSDs feel so much faster than mechanical drives. Client workloads aren't purely random in nature (which is why we confine our client random write tests to an 8GB LBA space), but sprinkle non-sequential accesses in the middle of otherwise sequential transfers and mechanical disk performance drops significantly. Small file requests while launching an application, updating file tables, writing to logs, are all examples of small, pseudo-random IO that happen in the background, which can make overall HDD performance drop significantly. While it's true that most client workloads don't require the sort of random IO performance a high-end SSD can provide, it's the additional headroom that SSDs offer that allow performance to remain high regardless of what's going on in the background. We can look at this data another way, instead of average data rate let's look at the maximum number of IO operations these drives can service in a single second:

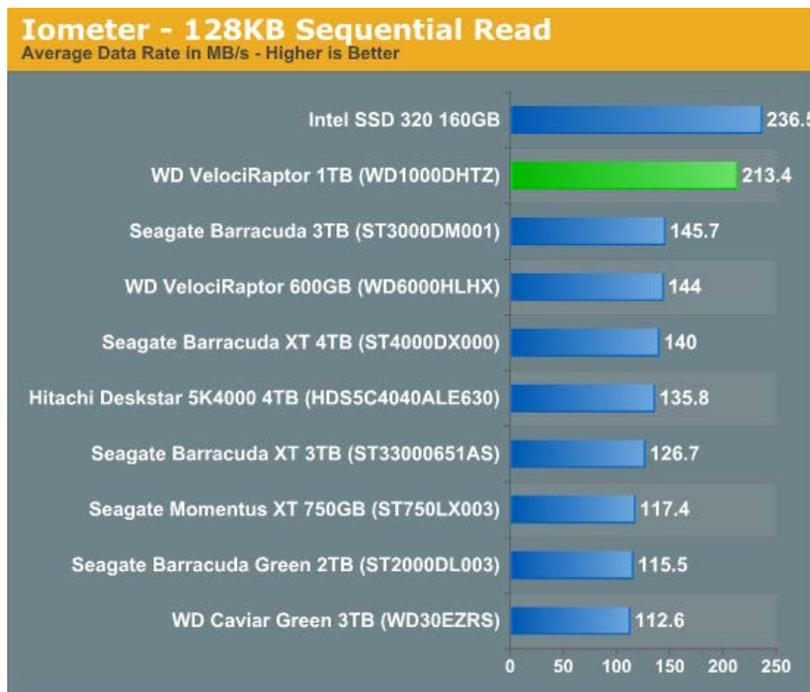


Based on this list, the average hard drive (excluding WD's 10,000 RPM drives) is capable of handling around 275 4KB pseudo-random write operations per second. Clearly that's not sufficient for the majority of client workloads because once you load up full disk encryption, real time virus checking, background email/IM, backup software and go about your normal application usage you always run into IO limited periods where you're waiting on your drive to finish crunching. Upping the spindle speed to 10,000 RPM gives you a bit of a reprieve, more than doubling performance, but that's not always sufficient given the workload.

At the other end of the spectrum we have a standard 3Gbps SSD, capable of servicing nearly 15,000 4KB write operations per second. No desktop application could be shipped that required this type of IO performance as it would be unusable on any hard drive. The added performance in the case of an SSD doesn't deliver 21x the performance of a VelociRaptor, but it offers enough performance headroom that applications and file accesses will remain as fast as possible regardless of what's going on in the background. SSDs use their headroom to offer a consistent IO experience, regardless of workload.

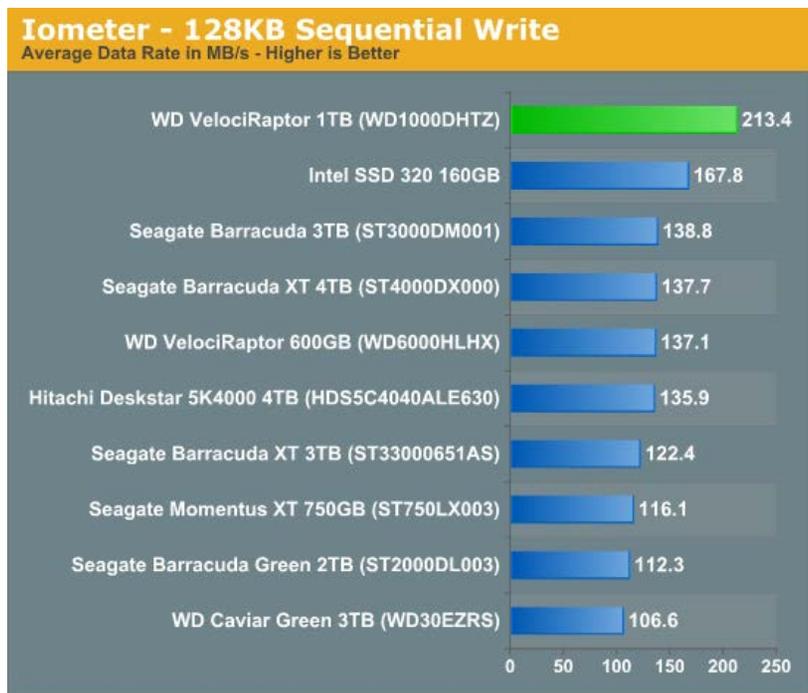
Sequential Read/Write Speed

Sequential performance is easily improved by increasing platter density, buffer sizes and pushing for more aggressive prefetch in the drive's controller. As a result, the SSD advantage isn't nearly as significant. Furthermore, the new VelociRaptor delivers such a large increase in sequential speed that it's able to approach the performance of 3Gbps SSDs:



It's because so much of client workloads are sequential in nature that some users don't really feel a dramatic difference in going from a hard drive to an SSD. The only thing I can add is that the users who are constantly frustrated by the speed of their hard drive will be the ones to most appreciate the move to solid state storage. Shifting focus back to the VelociRaptor however, its sequential read speed is quite competitive with mainstream 3Gbps SSDs. Start comparing to 6Gbps drives and the VR is significantly outgunned.

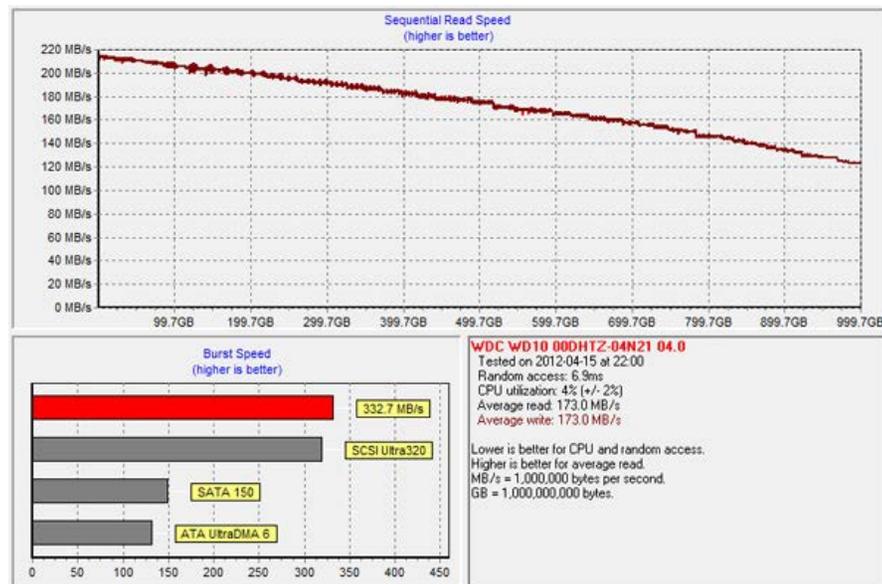
Again, reads and writes don't vary with the VR but compared to the 160GB Intel SSD 320 there's a shift in the standings:



Again, compared to larger or faster SSDs the VelociRaptor would surely lose, I tried to pick an SSD that was more representative of what you could get on a budget or with an older drive. Either way the gains over other mechanical drives are respectable, the new VR definitely delivers in sequential speeds as far as hard drives are concerned.

Performance Across All LBAs

Although logical block addressing works linearly, hard drives are made up of one or more circular platters. Platters are written from the outside inward in order to maximize performance (you cover more data in a single rotation of an outer track vs an inner track). I used HDtach to characterize the new VelociRaptor's performance across all LBAs:



The inner most tracks on the VelociRaptor are still accessible at 123MB/s - faster than any 3.5" drive we've tested here. One benefit to using 2.5" platters is remarkably consistent performance across all tracks. Average performance across all tracks is 173MB/s.

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AnandTech Storage Bench 2011

Two years ago we introduced our AnandTech Storage Bench, a suite of benchmarks that took traces of real OS/application usage and played them back in a repeatable manner. I assembled the traces myself out of frustration with the majority of what we have today in terms of SSD benchmarks.

Although the AnandTech Storage Bench tests did a good job of characterizing SSD performance, they weren't stressful enough. All of the tests performed less than 10GB of reads/writes and typically involved only 4GB of writes specifically. That's not even enough exceed the spare area on most SSDs. Most canned SSD benchmarks don't even come close to writing a single gigabyte of data, but that doesn't mean that simply writing 4GB is acceptable.

Originally I kept the benchmarks short enough that they wouldn't be a burden to run (~30 minutes) but long enough that they were representative of what a power user might do with their system.

Not too long ago I tweeted that I had created what I referred to as the Mother of All SSD Benchmarks (MOASB). Rather than only writing 4GB of data to the drive, this benchmark writes 106.32GB. It's the load you'd put on a drive after nearly two weeks of constant usage. And it takes a *long* time to run.

1) The MOASB, officially called AnandTech Storage Bench 2011 - Heavy Workload, mainly focuses on the times when your I/O activity is the highest. There is a lot of downloading and application installing that happens during the course of this test. My thinking was that it's during application installs, file copies, downloading and multitasking with all of this that you can really notice performance differences between drives.

2) I tried to cover as many bases as possible with the software I incorporated into this test. There's a lot of photo editing in Photoshop, HTML editing in Dreamweaver, web browsing, game playing/level loading (Starcraft II & WoW are both a part of the test) as well as general use stuff (application installing, virus scanning). I included a large amount of email downloading, document creation and editing as well. To top it all off I even use Visual Studio 2008 to build Chromium during the test.

The test has 2,168,893 read operations and 1,783,447 write operations. The IO breakdown is as follows:

AnandTech Storage Bench 2011 - Heavy Workload IO Breakdown	
IO Size	% of Total
4KB	28%
16KB	10%
32KB	10%
64KB	4%

Only 42% of all operations are sequential, the rest range from pseudo to fully random (with most falling in the pseudo-random category). Average queue depth is 4.625 IOs, with 59% of operations taking place in an IO queue of 1.

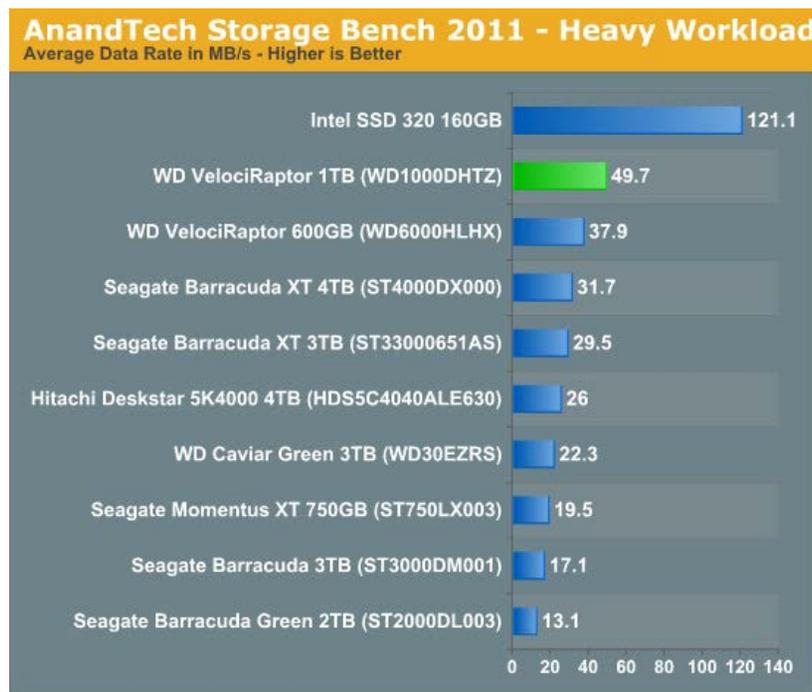
Many of you have asked for a better way to really characterize performance. Simply looking at IOPS doesn't really say much. As a result I'm going to be presenting Storage Bench 2011 data in a slightly different way. We'll have performance represented as Average MB/s, with higher numbers being better. At the same time I'll be reporting how long the SSD was busy while running this test. These disk busy graphs will show you exactly how much time was shaved off by using a faster drive vs. a slower one during the course of this test. Finally, I will also break out performance into reads, writes and combined. The reason I do this is to help balance out the fact that this test is unusually write intensive, which can often hide the benefits of a drive with good read performance.

There's also a new light workload for 2011. This is a far more reasonable, typical every day use case benchmark. Lots of web browsing, photo editing (but with a greater focus on photo consumption), video playback as well as some application installs and gaming. This test isn't nearly as write intensive as the MOASB but it's still multiple times more write intensive than what we were running in 2010.

As always I don't believe that these two benchmarks alone are enough to characterize the performance of a drive, but hopefully along with the rest of our tests they will help provide a better idea.

The testbed for Storage Bench 2011 has changed as well. We're now using a Sandy Bridge platform with full 6Gbps support for these tests.

AnandTech Storage Bench 2011 - Heavy Workload



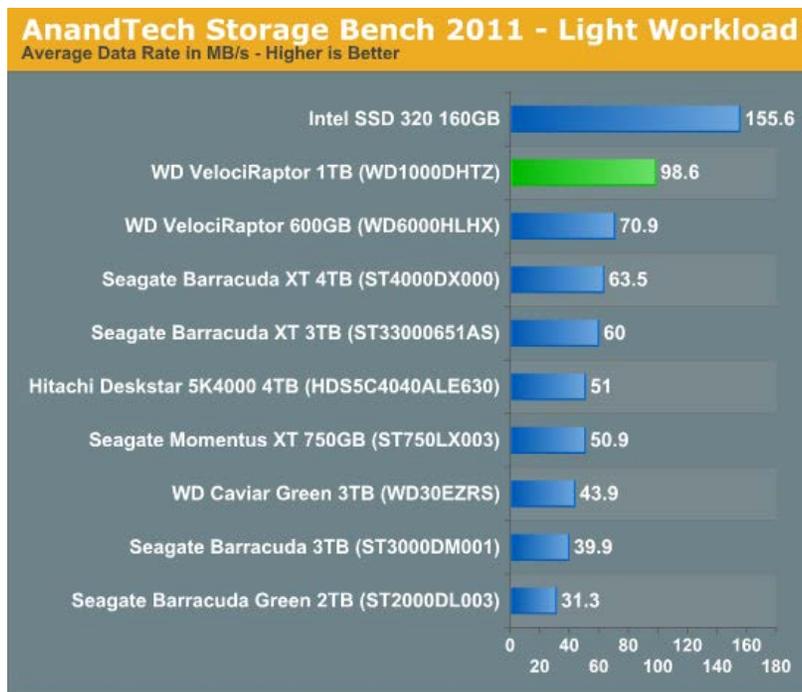
The old VelociRaptor remained the fastest mechanical drive we'd tested using our heavy workload, and the new one pushed the bar up by another 31%. It's the SSD comparison that makes the VR a tough choice for a primary drive, but if you need a really fast hard drive to augment your SSD the VelociRaptor is quick. Note that the Momentus XT lacks write caching at this point, which hurts its chances in our write intensive heavy workload.

AnandTech Storage Bench 2011 - Light Workload

Our new light workload actually has more write operations than read operations. The split is as follows: 372,630 reads and 459,709 writes. The relatively close read/write ratio does better mimic a typical light workload (although even lighter workloads would be far more read centric).

The I/O breakdown is similar to the heavy workload at small IOs, however you'll notice that there are far fewer large IO transfers:

AnandTech Storage Bench 2011 - Light Workload IO Breakdown	
IO Size	% of Total
4KB	27%
16KB	8%
32KB	6%
64KB	5%

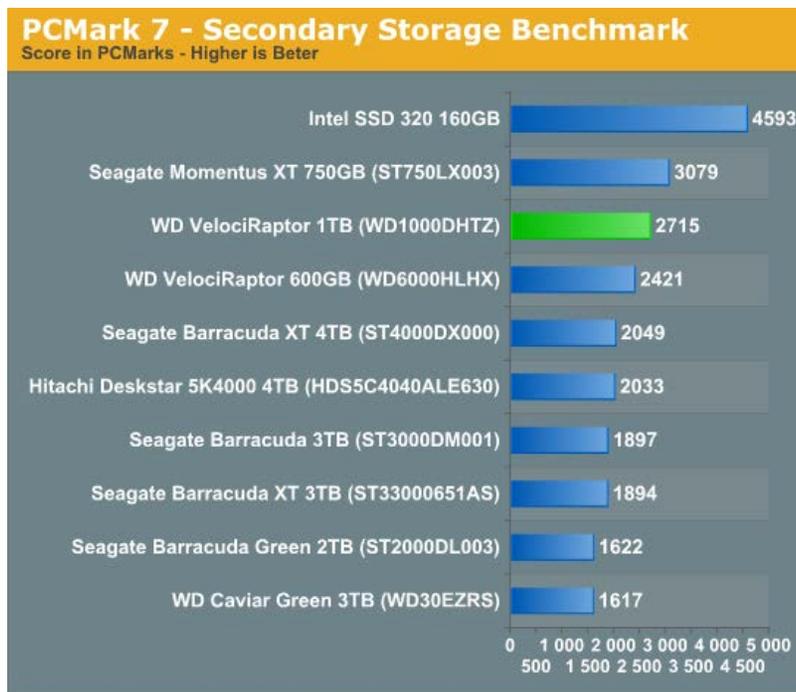


Once again we see a significant step forward compared to the old VelociRaptor, and any other hard drive for that matter. The new VR distances itself from its predecessor by 39% and from the fastest 7200RPM 3.5" drive we've tested by 55%. It's the almighty SSD that the VelociRaptor can't beat.

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PCMark 7 Performance

For workloads that are particularly read intensive and small enough to make good use of the on-board NAND, the Momentus XT cannot be beat. The VelociRaptor does come very close however, and it does win in enough other benchmarks to make it clearly the better overall performer. Philosophically I understand why Western Digital opted against equipping the VR with any NAND (cached operations do sort of defeat the purpose of having a 10,000 RPM spindle speed), but that doesn't change the fact that it would've made for one pretty impressive hard drive.



Power Consumption

Despite its 2.5" form factor (the drive itself), the VelociRaptor's 15mm height prevented it from being used as a notebook drive. Even if you had a thick enough notebook, the VR's power consumption is more in-line with a 5400RPM 3.5" drive than a standard 2.5" mobile drive. That being said, as a 10,000RPM 3.5" drive the VelociRaptor is quite power efficient. Idle power is competitive with WD's Caviar Green (and lower in the case of load power).



Power consumption is down compared to the previous generation as well. Once again, compared to an SSD however the drive isn't anywhere near efficient.

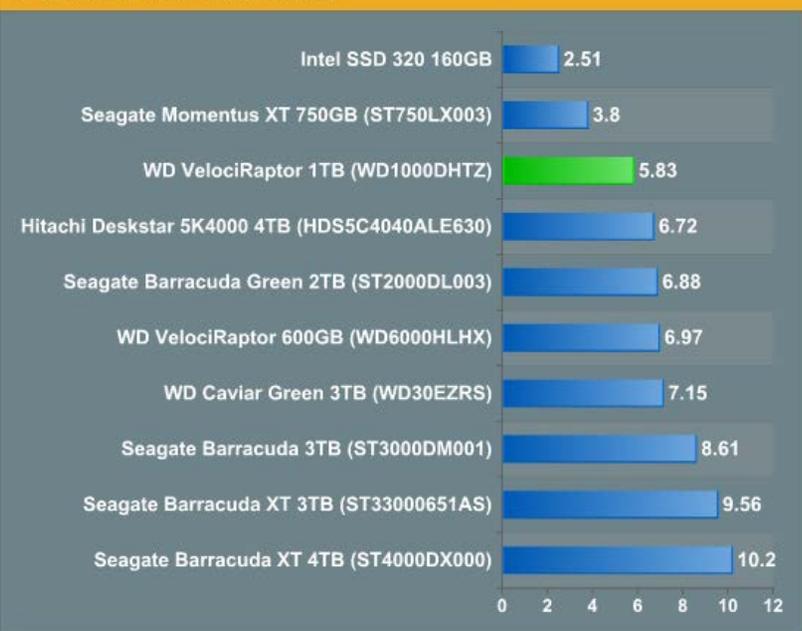
Drive Power Consumption - Idle

Drive Power in Watts - Lower is Better



Drive Power Consumption - Sequential Write

Drive Power in Watts - Lower is Better



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Final Words

The new VelociRaptor does reclaim its title as world's fastest client hard drive, and I do appreciate the fact that WD hasn't raised prices on the drive in the past two years either. Compared to any 3.5" drive on the market today, the new VR is significantly faster without a doubt. Random IO performance is at least double most 3.5" drives, and sequential performance is almost 50% better than the fastest competitors. Most impressive is the fact that power consumption is actually competitive with modern 3.5" green drives as well, another benefit of the VR's 2.5" package.



The biggest problem for the new VR today is the same issue we had two years ago: SSDs are much faster, and are quickly becoming more affordable. As a primary drive I wouldn't recommend the VelociRaptor simply because you can get a better overall experience with an SSD. We have a number of very reliable, reasonably affordable (128GB), high-performing SSD options to choose from. Intel's lineup, Samsung's SSD 830 and Crucial's m4 all come to mind.

As secondary storage, the new VelociRaptor appeals to those users who need more capacity than an SSD can affordably offer, for active use. Launching applications, games, and working on (not just streaming for playback) large data files are all going to be quicker on the VR than on a standard 3.5" drive. If you're building the ultimate workstation, you could use an SSD + VR for internal storage coupled with some larger, slower drives in RAID as a backup or for your more passive data (movies, music, edited photos). For most users however, I'd honestly recommend an SSD plus a couple of large, 5400/7200RPM drives in RAID-1 for everything you can't store on your SSD. While the Raptor line was quickly embraced by the enthusiast, I believe it has transitioned exclusively to a workstation role.

I have to admit I was disappointed to see that Western Digital went conservative on the new VelociRaptor design and didn't include any on-board NAND to really mix things up. What I was hoping for was a combination of the VelociRaptor and Seagate's Momentus XT. Perhaps that doesn't make sense given the available SSD caching solutions available today, but I don't see the harm in pairing even a small amount of NAND with the drive. I don't see hard drives going away anytime soon, so we might as well try to make accessing them as quick as possible.

Then there's the extreme option. I would love to see a manufacturer treat a hard drive as an SSD with a mechanical counterpart, rather than a hard drive with some NAND on it. I'm curious to see what a VelociRaptor (or any other 2.5" HDD) with 64GB of NAND used as a read/write cache would behave like. If users are able to fit all of their program, apps and data into a 128GB SSD, I have to believe that a well managed cache can deliver compelling performance with half that space.



Unfortunately most hard drive companies seem slow to adopt NAND into their designs, so I suspect much of this will have to be a dream for now. The new VelociRaptor is a great evolution of the design and it's truly a very fast hard drive. Just as before, if I needed to buy a high-performance mechanical hard drive, it's the one I'd pick.