AN7: UASP Performance

Doc# 300-27-091 **May 27, 2010**

1 Introduction

This application note summarizes UASP (USB Attached SCSI Protocol) performance using LucidPort's USB300 USB 3.0 to SATA controller. Comparisons are made between UASP, BOT, SATA, and Turbo USB drivers.

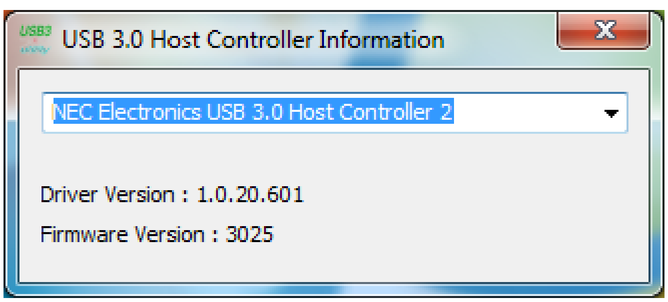
UASP is a new protocol developed by the USB-IF to address some of the performance limitations found in BOT. While all compliant USB 3.0 hosts can support UASP, only devices like the USB300, that support UASP, can take advantage of the new protocol. Contact LucidPort for a UASP driver.

BOT is the standard USB mass storage driver found in all operating systems today. It allows USB storage devices to run without driver installation. The USB300 runs BOT transfers if a UASP driver is not installed on the PC. Turbo USB is a non-standard, performance enhanced, BOT-type driver.

SATA refers to a direct connection between the drive and the motherboard. IDE mode is used, as enabling AHCI in the BIOS often results in compatibility problems.

2 TestBench

Most tests were completed using a LucidPort USB300 RDK board connected to a Renesas Electronics (formally NEC Electronics) USB 3.0 host controller (uPD720200). The USB300 uses 2246 UAS firmware while the Renesas host uses 3025 firmware with 1.0.20.601 xHCI driver.



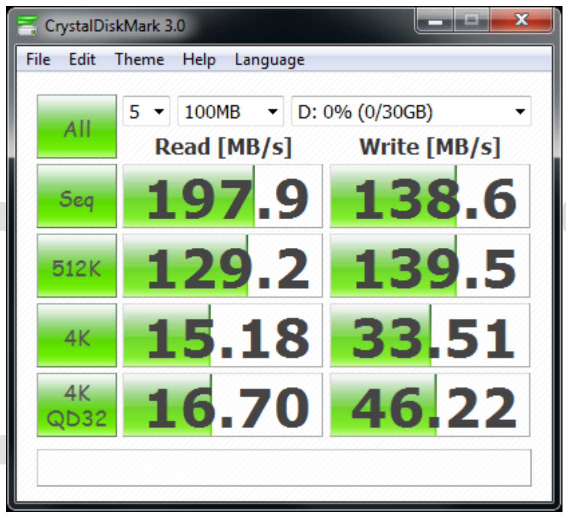
The USB3 host is in a PCI Express Gen2 slot on a Windows 7 (32 bit) PC. The primary benchmarking tool is Crystal Disk Mark v3.0 Beta. This is one of the few benchmarking tools that use queued commands. UASP makes use of queued commands to enhance performance. The PC uses the Gigabyte GA-P55A-UD3 motherboard with an Intel Core i5 CPU at 3.2 GHz and 4GB of RAM. This uses the Intel P55 chipset.

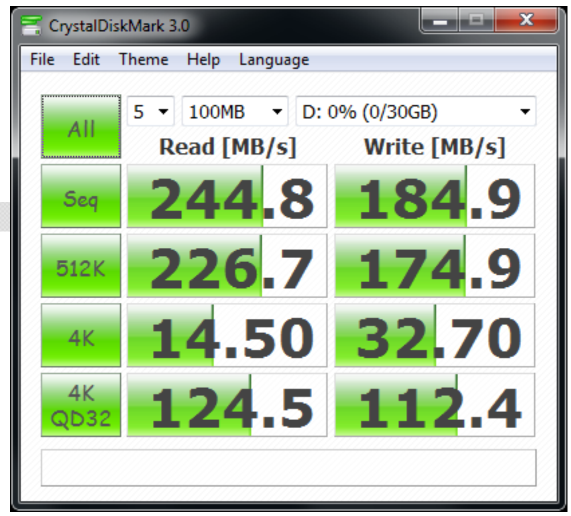
3 Typical Performance Gain

Drives yield the best performance numbers when reading sequential data. However, this is not always feasible because even a single file can be scattered in different locations around the disk.

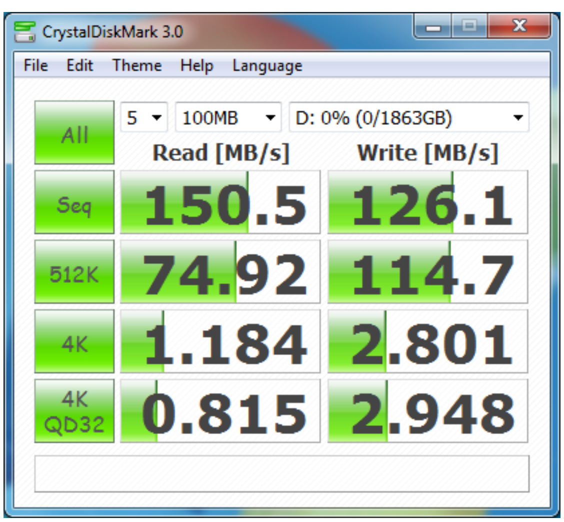
Sequential performance is highly dependent on the drive's internal cache structure. UAS delivers up to 20% improvement to on sequential transfers, but this varies widely from drive to drive. For queued random transfers (where UAS can take advantage of NCQ), UAS can improve performance by up to 100% or more.

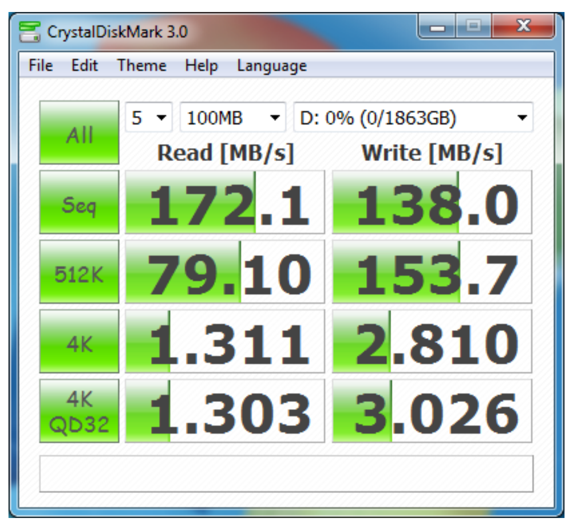
Fast SSD, BOT vs. UAS





Fast HDD, BOT vs. UAS





4 Performance Comparisons

The following matrix compares UAS performance with 5 very different drives. Drives yield the best performance numbers when reading sequential data. However, this is not always feasible because even a single file can be scattered in different locations around the disk. UAS delivers up to 20% improvement to on sequential transfers, but this varies widely from drive to drive. For random transfers (where UAS can take advantage of NCQ), UAS can improve performance by up to 100% or more.

Occasionally, UAS performance even exceeds the performance of the drive when directly connect to SATA on the PC motherboard. One reason is that the SATA interface is running in IDE mode (not AHCI), so NCQ is not utilized. Currently, ACHI mode must be manually selected in the PC's BIOS and unfortunately, may also cause compatibility problems – so it is hardly ever used by consumers.

Sequential Read Performance

Mbytes/sec	**UASP**	**SATA**	**BOT**
Intel X-25E 32GB SSD	244.8	230.7	197.9
WD Caviar Black 2TB HDD	172.6	171.2	150.5
WD Velociraptor 500 GB HDD	126.9	123.8	124.6
Seagate Barracuda 1TB HDD	134.2	126.0	125.7
Samsung HD103SJ 1TB HDD	137.1	138.4	137.7

Sequential Write Performance

Mbytes/sec	**UASP**	**SATA**	**BOT**
Intel X-25E 32GB SSD	184.9	196.4	138.6
WD Caviar Black 2TB HDD	144.0	128.5	126.1
WD Velociraptor 500 GB HDD	123.8	123.5	124.8
Seagate Barracuda 1TB HDD	121.8	123.4	122.9
Samsung HD103SJ 1TB HDD	158.6	151.2	149.2

Random 4K w/ Queuing Read Performance

Mbytes/sec	**UASP**	**SATA**	**BOT**
Intel X-25E 32GB SSD	124.5	18.41	16.70
WD Caviar Black 2TB HDD	1.400	1.387	0.815
WD Velociraptor 500 GB HDD	2.821	1.029	0.937
Seagate Barracuda 1TB HDD	1.803	1.013	0.874
Samsung HD103SJ 1TB HDD	1.783	1.057	1.039

Random 4K w/ Queuing Write Performance

Mbytes/sec	**UASP**	**SATA**	**BOT**
Intel X-25E 32GB SSD	112.4	77.62	46.22
WD Caviar Black 2TB HDD	3.082	2.954	2.948
WD Velociraptor 500 GB HDD	2.891	2.773	2.774
Seagate Barracuda 1TB HDD	1.676	1.806	1.698
Samsung HD103SJ 1TB HDD	3.793	3.410	3.750

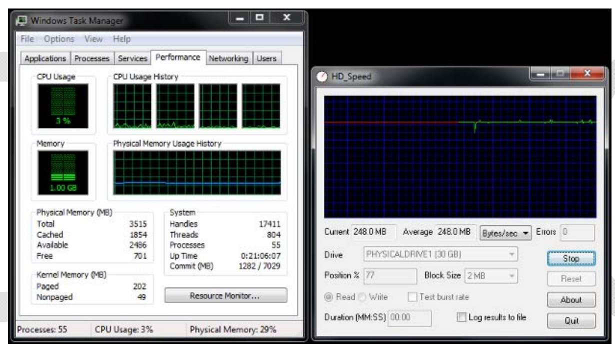
4 CPU Utilization

UASP is designed to reduce CPU utilization. It does this by using larger sizes for each transfer and by reducing the number of interrupts required to service each USB transfer. When compared to BOT, UASP uses less than half the CPU bandwidth of BOT It is even more efficient than connecting directly to SATA on the motherboard (when SATA is operating in IDE mode).

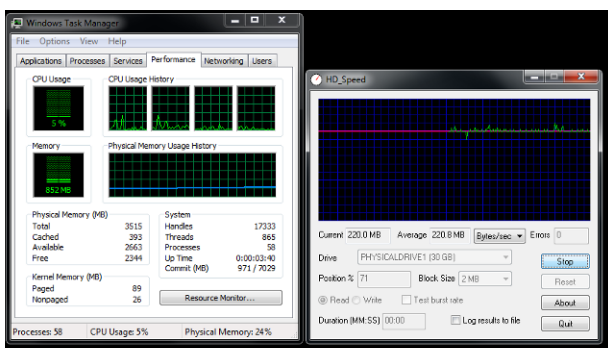
CPU Utilization

% CPU	**SSD**	**HDD**
UASP	3	2
SATA	5	3
BOT	8	7

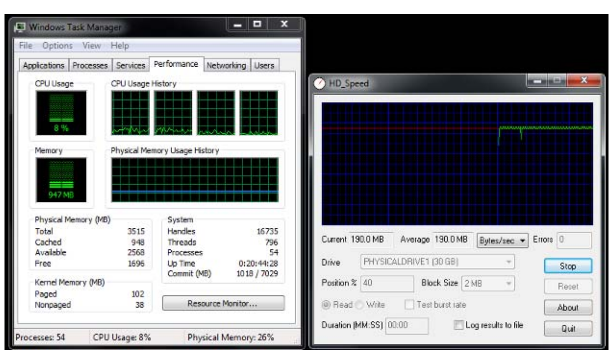
The absolute percentage of CPU used is highly system dependant; however, the relative percentages scale accordingly. The CPU utilization percentage is taken from Windows task manager when running the HD Speed disk benchmarking tool.



UASP, SSD



SATA, SSD



BOT, SSD

5 Random 512K Performance with Different Drives

The data listed here is taken from the random 512K read and write results from Crystal Disk Mark v2.2. It was run with default settings. Readings were taken with the USB 3.0 host plugged into a PCI Express Gen1 slot and again in a PCI Express Gen2 slot. Most motherboard with embedded USB 3.0 hosts are connected to PCI Express Gen2. Most add in card and ExpressCard hosts are connected to PCI Express Gen1.

USB3 Host in PCI Express Gen1 (2.5Gbps) slot

Random Accesses - Mbytes/sec	**BOT**		**UAS**	
	Read	**Write**	**Read**	**Write**
Intel X-25E SSD	112.4	101.1	158.0	107.1
RunCore SSD	110.2	96.50	153.3	109.3
Western Digital Caviar Black HDD	70.73	89.19	77.71	95.98
Western Digital Caviar Green HDD	40.63	55.54	42.77	63.90
Western Digital Raptor HDD	56.38	64.49	64.44	78.70
Seagate Barracuda HDD	53.81	83.10	57.93	91.14
Seagate Barracuda LP HDD	49.05	77.66	49.45	82.13
Seagate Momentus HDD	40.30	56.27	45.50	62.73
Samsung HD103UJ HDD	55.35	78.96	58.62	88.10
Hitachi HDE721010SLA330 HDD	56.03	70.65	56.50	70.86
Toshiba MK1649GSY HDD	34.24	31.56	34.27	36.04

USB3 Host in PCI Express Gen2 (5 Gbps) slot

Random Accesses - Mbytes/sec	**BOT**		**UAS**	
	Read	**Write**	**Read**	**Write**
Intel X-25E SSD	142.9	167.5	239.7	187.7
RunCore SSD	135.1	94.37	207.2	158.0
Western Digital Caviar Black HDD	79.00	119.50	83.76	157.2
Western Digital Caviar Green HDD	42.27	67.07	42.76	70.40
Western Digital Raptor HDD	56.63	76.41	60.97	90.32
Seagate Barracuda HDD	57.82	84.80	58.25	93.53
Seagate Barracuda LP HDD	49.61	82.07	51.57	84.97
Seagate Momentus HDD	40.09	59.33	41.68	64.12
Samsung HD103UJ HDD	59.26	82.86	60.68	89.83
Hitachi HDE721010SLA330 HDD	57.68	69.94	61.16	72.14
Toshiba MK1649GSY HDD	34.24	31.79	34.22	36.82

6 Simultaneous Transfers and “Turbo USB”

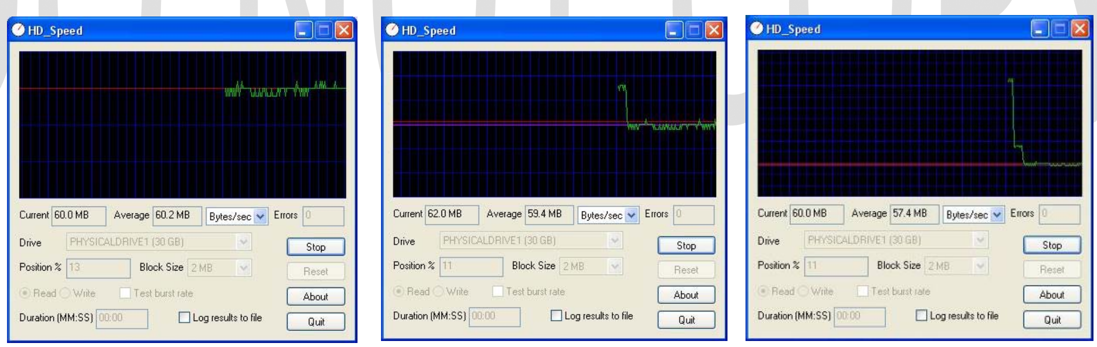
Both Microsoft and the Linux community have announced intentions to release free UAS drivers in the near future. In the meantime, some “Turbo USB” drivers on the market have similar qualities as UAS. Unfortunately, they are non-standard. This means that these drivers only work with a subset of operating systems, hosts, and devices.

“Turbo” drivers exhibit the same type of delays found in standard BOT drivers. This is most evident when multi-tasking. The following shows three HD Speed benchmarks run simultaneously using standard BOT, “Turbo”, and UAS drivers with both a SSD and a HDD (read from disk). This is run under Windows XP as “Turbo” drivers are not compatible with all operating systems.

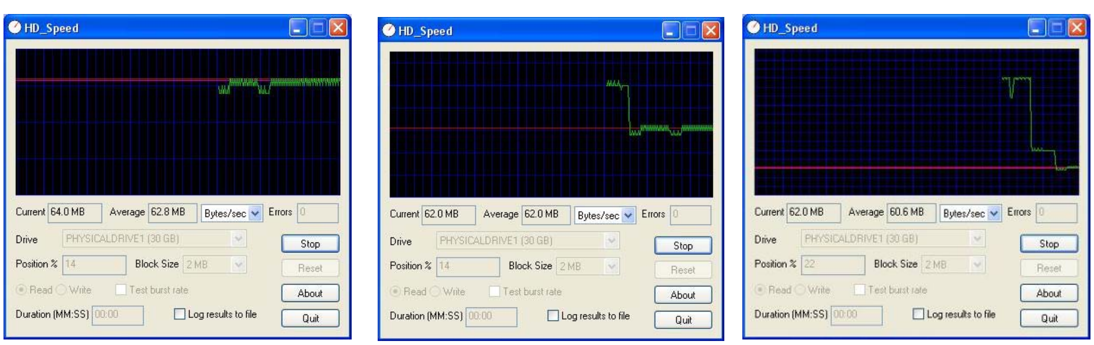
Average read speeds

Mbytes/sec	Intel X-25E SSD	WD Caviar Black HDD
BOT	60.2	30.8
Turbo	62.8	27.0
UAS	86.0	40.4

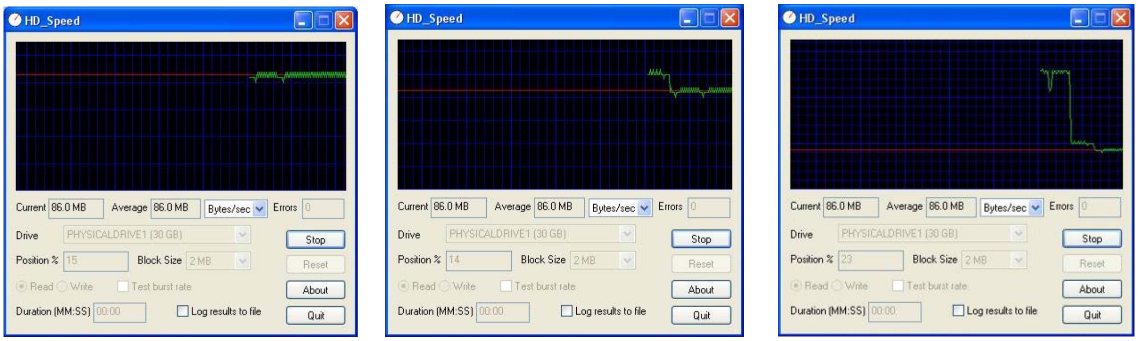
Intel X-25E SSD, BOT



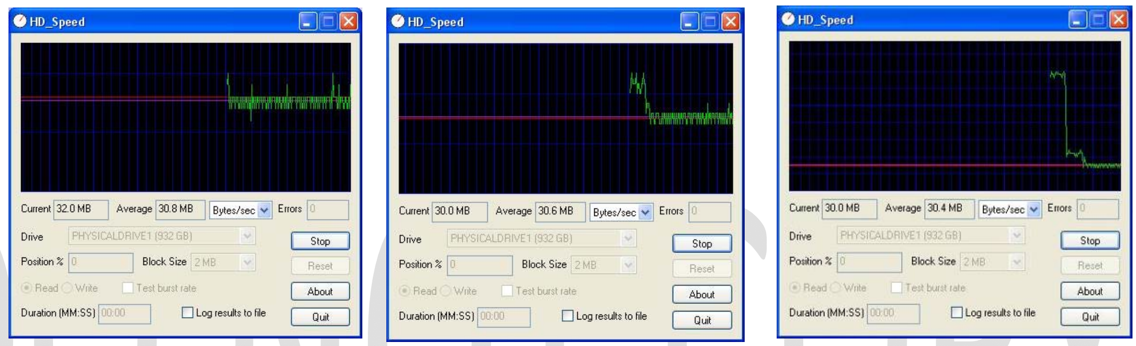
Intel X-25E SSD, Turbo



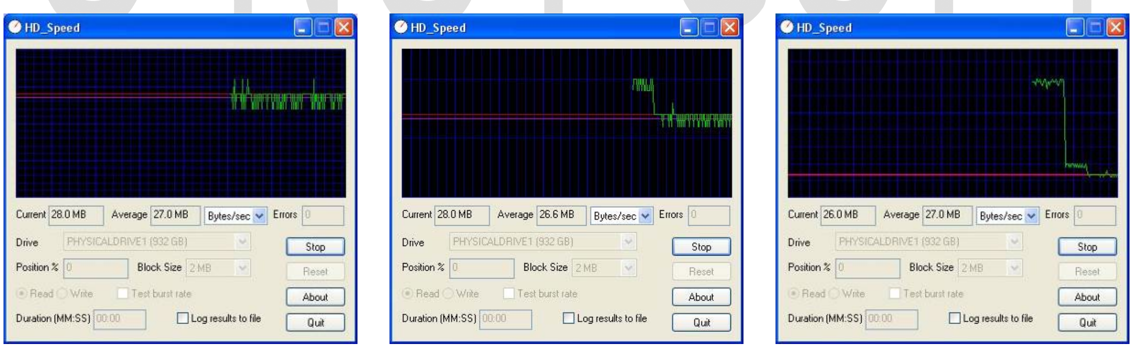
Intel X-25E SSD, UAS



WD Caviar Black HDD, BOT



WD Caviar Black HDD, Turbo



WD Caviar Black HDD, UAS