APPLICATION NOTE

USB 3.0 Host Controllers' Maximum Bandwidth Measurements

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USB 3.0 Host Controllers' Maximum Bandwidth Measurements

1 Introduction

This document presents the test results gained by the Basler Technical Support department after various test measurements with different USB 3.0 host controllers.

NOTICE	
	The presented test results are not intended to be absolutely precise and should be treated instead as strictly informative and without any warranty.

The purpose of the conducted tests was to:

- define the maximum supported bandwidth of different host controllers
- identify any incompatibility issues
- identify any dependency on PCIe bus generation of the PC
- identify any dependency on the camera setup, e.g. if a camera (cameras) is connected directly to a port or via a hub
- others.

2 Test Setup

This document presents the test results for the following USB 3.0 Host Controller brands, which are used in most of the currently available USB 3.0 PCIe adaptor cards or mainboard chipsets:

- Intel
- Renesas
- Texas Instruments
- Fresco
- ASMedia
- VIA
- Etron

The following hardware components and software tools were used for the tests:

- Different brand PCs with different CPU, Motherboard and Chipsets
- Multiple Basler ace USB 3.0 cameras, i.e. acA2500-14um/uc, acA1300-30um/uc and acA640-90uc
- IOI USB 3.0 hub with 4 ports (U3H414E2 with one TI USB 3.0 host controller) and Exsys USB 3.0 hubs with 4 ports (EX-1185HMVS with one Genesys Logic USB 3.0 host controller; EX-1184HMV with one VIA Labs USB 3.0 host controller)
- 3m USB 3.0 cables specified by Basler (Basler- part no. 2000033239)
- Basler pylon Viewer (download from www.baslerweb.com)

3 Test Results

All Camera Models Except the acA2000-165u and the acA2040-90u

USB 3.0 Host Controllers' Maximum Bandwidth Measurements							
PC	**Chipset**	**Host Controller**	**Driver Version**	**PCIe Bus Generation (PC)**	**Camera Setup**	**Maximum Possible Bandwidth, [MB/s]**	**Comments**
DELL OptiPlex 7010, Windows 7 Professional x64, Intel Quad Core i7-3770 @ 3.4GHz (**Ivy Bridge**), RAM= 16GB	Intel® Q77 Express Chipset	Built-in **Intel** USB3.0 adapter (4x ports) with **Intel** USB 3.0 eXtensible-Host Controller	1.0.6.245	Direct chipset integration	3x acA2500-14 -> 140.1MB/s x 4 = 420.3 1x acA2500-14 -> 29.7MB/s = 29.7	**450.0** (3)	4 cameras connected directly to the four single ports of the adapter.
Lenovo T430, Windows 7 Enterprise x86, Intel Core i5-3320M CPU @ 2.6GHz (**Ivy Bridge**), RAM= 8GB	Intel 7 Series/C216 (QM77) Express Chipset	Built-in **Intel** USB3.0 adapter (2x ports) with **Intel** USB 3.0 eXtensible-Host Controller	1.0.4.225	Direct chipset integration	3x acA2500-14 -> 134.6MB/s x 3 = 403.8 1x acA1300-30 -> 26.7MB/s = 26.7	**430.5**	3 cameras connected via a hub(1,2) to the first port of the adapter, the 4th camera (acA2500) connected directly to the second port.
		Delock PCIexpress Card for **Laptops** (2x ports) with **Renesas** Electronics USB 3.0 Host Controller	2.1.28.0 / 2.1.39.0	Gen.2	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 15.0MB/s = 15.0	284.2	All 3 cameras connected via a hub(1,2) to a port of the adapter.
					2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 57.2MB/s = 57.2	326.4	2 cameras (acA1300 & acA2500) connected via a hub(1,2) to the first port of the adapter, the third camera connected directly to the second port.
		Delock PCIexpress Card for **Laptops** (1x port) with **Renesas** Electronics USB 3.0 Host Controller	2.1.39.0	Gen.2	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 15.0MB/s = 15.0	284.2	All 3 cameras connected via a hub(1,2) to a port of the adapter.

Lenovo N581, Windows 7 Professional x86, Intel Pentium® CPU B960 @ 2.2GHz (**Sandy Bridge**), RAM= 4GB	Intel 7 Series/C216 (HM76) Express Chipset	Built-in **Intel** USB3.0 adapter (2x ports) with **Intel** USB 3.0 eXtensible-Host Controller	1.0.5.235	Direct chipset integration	3x acA2500-14 -> 140.1MB/s x 3 = 420.3 1x acA2500-14 -> 26.7MB/s = 10.2	**430.5**	3 cameras connected via a hub(1,2) to the first port of the adapter, the 4th camera connected directly to the second port.
					2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA2500-14 -> 31.9MB/s = 31.9	312.1	All 3 cameras connected via a hub(1,2) to a port of the adapter.
DELL Precision T3600, Windows 7 Enterprise x86, Intel® Xeon® Quad Core CPU E5-1620 @ 3.6GHz, 3601MHz, RAM= 4GB	Intel C600/X79	**ASUS** USB3.0 adapter with **Renesas** (**D720200**) Host Controller (2x ports, PCIe x1)	2.1.28.0 / 2.1.39.0	PCIe x16 Gen.3, 75W	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 36.2MB/s = 36.2	305.4	All 3 cameras connected via a hub(1,2) to a port of the adapter.
					2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 57.2MB/s = 57.2	326.4	2 cameras (acA1300 & acA2500) connected via a hub(1,2) to the first port of the adapter, the third camera connected directly to the second port.
				PCIe x4/x1 Gen.2, 25W	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 23.8MB/s = 23.8	293.0	All 3 cameras connected via a hub(1,2) to a port of the adapter.
					2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 57.2MB/s = 57.2	**326.4**	2 cameras (acA1300 & acA2500) connected via a hub(1,2) to the first port of the adapter, the third camera connected directly to the second port.
		AsRock USB3.0 adapter with **Renesas** Host Controller (2x ports, PCIe x1)	2.1.28.0	PCIe x16 Gen.3, 75W	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 36.2MB/s = 36.2	305.4	All 3 cameras connected via a hub(1,2) to a port of the adapter.
					2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 45.0MB/s = 45.0	314.2	2 cameras (acA2500-14 & acA1300-30) connected via a hub(1,2) to the one port of the adapter, the third camera connected directly to the second port.
		IOI USB3.0 adapter with **Renesas** (**D720202**) Host Controller (2x ports, PCIe x1), U3-PCIE1XG202-10	3.0.23.0	PCIe x16 Gen.3, 75W	3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 62.0MB/s = 62.0	342.2	*All 4 cameras connected via a hub(1,2) to a port of the adapter.
					3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 62.0MB/s = 62.0	**342.2**	*3 cameras connected via a hub(1,2) to the 1st port of the adapter. The 4th camera connected directly to the 2nd adapter port.

DELL Precision T3600, Windows 7 Enterprise x86, Intel® Xeon® Quad Core CPU E5-1620 @ 3.6GHz, 3601MHz, RAM= 4GB	Intel C600/X79	**IOI** USB3.0 adapter with **4 x Renesas** Host Controllers (4x ports, PCIe x1)	3.0.23.0	PCIe x16 Gen.2 (25W)/Gen.3 (75W)	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 42.9MB/s = 42.9	312.1	*The adapter requires an external power supply. Otherwise no cameras are recognized. **All 3 cameras connected via a hub(1,2) to a single port of the host controller.
				PCIe x4 Gen.2, 25W	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 74.5MB/s = 74.5	343.7	*The adapter requires an external power supply. Otherwise no cameras are recognized. **All 3 cameras connected directly to single ports of the adapter.
				PCIe x4 Gen.2, 25W	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA2500-14 -> 123.6MB/s = 123.6	**392.8**	*The adapter requires an external power supply. Otherwise no cameras are recognized. **2 cameras connected directly to 2 single ports of the adapter, the 3rd camera connected via a hub(1,2) to the third port of the adapter. ***4 cameras might not be able to work properly (under revision). ****The same total bandwidth is reached if all 3 cameras are directly connected to 3 ports of the adapter, if the adapter is plugged into PCIe x16 Gen.3.
				PCIe x4 Gen.2, 25W	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA2500-14 -> 119.0MB/s = 119.0	388.2	*The adapter requires an external power supply. Otherwise no cameras are recognized. **All 3 cameras connected directly to 3 single ports of the adapter. ***4 cameras might not be able to work properly (under revision).

DELL Precision T3600, Windows 7 Enterprise x86, Intel® Xeon® Quad Core CPU E5-1620 @ 3.6GHz, 3601MHz, RAM= 4GB	Intel C600/X79	**Fresco** Logic xHCI (USB3) Controller FL1009 Series (2x ports, PCIe x1)	3.5.36.0	PCIe x4 Gen.2, 25W	1x acA2500-14 -> 134.6MB/s = 134.6 1x acA2500-14 -> 127.5MB/s = 127.5	262.1	*The adapter requires an external power supply. Otherwise no cameras are recognized. **2 cameras connected via a hub(1,2) to the single port of the adapter. ***The Maximum Transfer Size (USB Request Block size) must be set to < 1MB.
					2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 57.2MB/s = 57.2	326.4	*The adapter requires an external power supply. Otherwise no cameras are recognized. **2 cameras (acA2500-14 & acA1300-30) connected via a hub(1,2) to the one port of the adapter, the third camera connected directly to the second port. ***The Maximum Transfer Size (USB Request Block size) must be set to < 1MB.
		Fresco Logic xHCI Controller FL1000 Series (1x port, PCIex1)	3.5.36.0	PCIe x16 Gen.3, 75W	1x acA2500-14 -> 134.6MB/s = 134.6 1x acA2500-14 -> 50.4MB/s = 50.4	185.0	*2 cameras connected via a hub(1,2) to the single port of the adapter. **The Maximum Transfer Size (USB Request Block size) must be set to < 1MB.
		ASMedia ASM104x USB3.0 xHCI Host Controller (2x ports, PCIe x1)	1.10.1.0	PCIe x4 Gen.2, 25W	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 42.9MB/s = 42.9	312.1	All 3 cameras connected via a hub(1,2) to a port of the adapter.
					2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 62.0MB/s = 62.0	331.2	2 cameras (acA2500-14 & acA1300-30) connected via a hub(1,2) to the first port of the adapter, the third camera connected directly to the second port.
		Sedna VIA USB eXtensible Host Controller (4x ports, PCIe x1)	6.1.7600.133	PCIe x4 Gen.2, 25W	1x acA2500-14 -> 134.6MB/s = 134.6 1x acA2500-14 -> 130.6MB/s = 130.6	265.2	*Requires an external power supply. Otherwise no cameras are recognized. **Both cameras connected via a hub(1,2) to a port of the adapter. ***The cameras may hang up in case of lack of bandwidth or bus reset. The cameras may need to be powered off/on!

					2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 55.0MB/s = 55.0	324.2	*Requires an external power supply. Otherwise no cameras are recognized. **All 3 cameras connected directly to 3 ports of the adapter. ***The cameras may hang up in case of lack of bandwidth or bus reset. The cameras may need to be powered off/on!
		Built-in Renesas USB 3.0 Host Controller (1x port)	2.1.28.0	Gen.2	2x acA2500-14 -> 134.6MB/s x 2 = 269.2 1x acA1300-30 -> 23.8MB/s = 23.8	293.0	All 3 cameras connected via a hub(1,2) to the single built-in port.
DELL Precision T3600, Windows 7 Professional x64, Intel® Xeon® Quad Core CPU E5-1620 @ 3.6GHz, 3601MHz, RAM= 4GB	Intel C600/X79	**Texas Instruments** (**TUSB7320EVM**) xHCI Host Controller (2x ports, PCIe x1)	1.16.2.0	Gen.2/ Gen.3	2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA2500-14 -> 66.8MB/s = 66.8	347.0	*All 3 cameras connected via a hub(1,2) to a port of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.
					2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA2500-14 -> 66.8MB/s = 66.8 1x acA2500-14 -> 14.3MB/s = 14.3	**361.3**	*The first 3 cameras connected via a hub(1,2) to the one port of the adapter. The 4th camera connected directly to the 2nd port of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.
		Texas Instruments (**TUSB7340EVM**) xHCI Host Controller (4x ports, PCIe x1)	1.16.2.0	Gen.2/ Gen.3	2x acA640-90uc -> 93.4MB/s x 2 = 186.8 1x acA640-90uc -> 93.4MB/s x 1 = 93.4 1x acA640-90uc -> 66.8MB/s x 1 = 66.8	347	*The first 2 cameras connected via a hub(1,2) to the 1st port of the adapter. The other 2 cameras each connected directly to single ports of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.
					4x acA640-90uc -> 93.4MB/s x 4 = 373.6	**373.6**	*All 4 cameras connected each directly to single ports of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.
		Lycom UB-120Ti USB3.0 adapter with **TI** (**TUSB7340EVM**) xHCI Host Controller (4x ports, PCIe x1)	1.16.2.0	Gen.2/ Gen.3	2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA1600-20 -> 47.7MB/s = 47.7 1x acA1600-20 -> 42.9MB/s = 42.9	**370.8**	*All 4 cameras connected each directly to single ports of the adapter. **Does not require external power supply, but offers an optional connector for that.

DELL Precision T3600, Windows 7 Professional x64, Intel® Xeon® Quad Core CPU E5-1620 @ 3.6GHz, 3601MHz, RAM= 4GB	Intel C600/X79	**IOI** USB3.0 adapter with **4 x Renesas** (**D720202**) Host Controllers (4x ports, **PCIe x4**, U3X4-PCIE4XE101)	3.0.23.0	PCIe x4 Gen.2, 25W	3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 52.5MB/s = 52.5	332.7	*All 4 cameras connected via a hub[1,2] to a port of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.
					<u>Port 1 (via hub)</u>: 3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 47.7MB/s x 1 = 47.7 <u>Port 2 (via hub)</u>: 3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 47.7MB/s x 1 = 47.7 <u>Port 3 (via hub)</u>: 3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 47.7MB/s x 1 = 47.7 <u>Port 4 (via hub)</u>: 2x acA640-90uc -> 93.4MB/s x 2 = 186.8 1x acA2500-14uc ->71.0MB/s x 1= 71.0 1x acA2500-14uc ->70.1MB/s x 1= 70.1	**1311.6**	*A total number of 16 cameras connected via 4 hubs[1,2] each directly connected to a single port of the quad port adapter were tested. **Requires an external power supply. Otherwise no cameras are recognized.
		RocketU 1144C USB3.0 adapter with **4x ASMedia ASM1042A** XHCI 1.0 Controllers (4x ports, **PCIe x4**)	1.16.4.0	PCIe x4 Gen.2, 25W	2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA1600-20 -> 23.8MB/s = 23.8	304.0	*All 3 cameras connected via a hub[1,2] to a port of the adapter.
					<u>Port 1 (via hub)</u>: 2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA1600-20 -> 23.8MB/s = 23.8 <u>Port 4 (via hub)</u>: 2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA1300-30 -> 23.8MB/s = 23.8	608.0(*)	*A total number of 6 cameras connected via 2 hubs[1,2] each directly connected to a single port of the quad port adapter were tested. If all four adapter ports were used, a total bandwidth of 1216MB/s would be expected. This was not verified in practical tests though.

DELL Precision T3600, Windows 7 Professional x64, Intel® Xeon® Quad Core CPU E5-1620 @ 3.6GHz, 3601MHz, RAM= 4GB	Intel C600/X79	**Forcom** USB3.0 adapter with **4 x Renesas** (**D720202**) Host Controllers (4x ports, **PCIe x4**, PEU3P44)	3.0.23.0	PCIe x4 Gen.2, 25W	Port 1 (direct): 1x acA2500-14 -> 140.1MB/s x 1 = 140.1 Port 2 (direct): 1x acA2500-14 -> 140.1MB/s x 1 = 140.1 Port 3 (direct): 1x acA2500-14 -> 140.1MB/s x 1 = 140.1 Port 4 (direct): 1x acA2500-14 -> 140.1MB/s x 1 = 140.1	560.4	*The adapter showed stable performance only if cameras were directly connected to single ports. **If multiple cameras were run via a hub, cameras hung up eventually and needed to be reset. Because of that it is not recommend-able to use this adapter in combination with hubs.
		VIA Labs VL805 USB eXtensible Host Controller (2x ports, PCIe x1)	6.1.7600.4201	PCIe2 x1, PCIe2 x4, PCIe3 x4, 25W	Port 1 (via a hub): 2x acA2500-14 -> 140.1MB/s x 2 = 280.2 1x acA1600-20 -> 81.1MB/s x 1 = 81.1	361.3	*Requires an external power supply. Otherwise no cameras are recognized. **Only supports a Maximum Transfer Size (USB Request Block size) <= 1MB. ***Might not work properly if plugged into a PCIe3x16, 75W slot. In this case any USB3 Vision cameras will be recognized as Low Speed devices and will not work at all.
					Port 1 (via a hub): 2x aca2500-14 -> 140.1MB/s x 2 = 280.2 1x aca1600-20 -> 66.8MB/s x 1 = 66.8 Port 2 (direct connection): 1x aca2500-14 -> 14.3MB/s x 1 = 14.3	361.3	
		Best connectivity USB 3.0 adapter with **Renesas** (**D720202**) Host Controller (2x ports, PCIe x1)	3.0.23.0	Gen.2/ Gen.3	3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 52.5MB/s = 52.5	332.7	*The first 3 cameras connected via a hub(1,2) to the 1st port of the adapter. The 4th camera connected directly to the 2nd port of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.
		Syba USB 3.0 adapter with **Renesas** (**D720201**) Host Controller (3x external ports + 1x internal port, PCIe x1)	3.0.23.0	Gen.2/ Gen.3	2x acA640-90uc -> 93.4MB/s x 2 = 186.8 1x acA640-90uc -> 93.4MB/s x 1 = 93.4 1x acA640-90uc -> 66.8MB/s x 1 = 66.8	347	* The first 2 cameras connected via a hub(1,2) to the 1st port of the adapter. The other 2 cameras each connected directly to single ports of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.
					3x acA640-90uc -> 93.4MB/s x 3 = 280.2 1x acA640-90uc -> 52.5MB/s = 52.5	332.7	* All 4 cameras connected via a hub(1,2) to a port of the adapter. **Requires an external power supply. Otherwise no cameras are recognized.

ASUS X53S, Windows 7 Home Premium x64, Intel® Core™ i5-2410M CPU @ 2.3GHz, RAM= 6GB	Intel 6 Series/C200 (HM65) Express Chipset	**Built-in ASMedia** ASM1042 Super Speed xHCI Host Controller (1x port)	1.12.5, 1.16.2, 1.16.4	Gen.2	1x acA2500-14 -> ✘ = ✘	✘	*No SuperSpeed bandwidth supported. **Regular transmission errors even at HighSpeed bandwidths (< 35MB/s) were observed.
Customized, Windows 7 Professional x64, Intel® Core™ i7-3770 @ 3.4GHz, RAM= 16GB	Intel 7 Series/C216 (Z77) chipset, Mother-board: ASRock Z77 Extreme9	**Built-in Etron (EJ188)** USB 3.0 Extensible Host Controller (4x ports; 2x ports)	1.0.0.111, 1.0.0.115	Gen.2	1x acA2500-14 -> ✘ = ✘	✘	*The camera cannot be operated at all, because the Etron driver delivers wrong information about the camera USB configuration descriptors, which in turn causes the device discovery to fail.
HP Z200, Windows 7 Professional x86, Intel(R) Core(TM) i5 CPU 650 @ 3.2GHz, RAM= 4GB	Intel 5 Series/3400 (3450) Chipset	**ASUS** USB3.0 adapter with **Renesas** (**D720200**) Host Controller (2x ports, PCIe x1)	2.1.28.0 / 2.1.39.0	Gen.1	1x acA2500-14 -> 134.6MB/s = 134.6 1x acA1300-30 -> 26.4MB/s = 26.4	161.0	2 cameras connected via a hub(1,2) to a single port of the adapter.
					1x acA2500-14 -> 134.6MB/s = 134.6 1x acA1300-30 -> 32.1MB/s = 32.1	166.7	2 cameras connected each directly to a port of the adapter.
DELL OptiPlex 745, Windows 7 Professional x86, Intel® Pentium(R) D CPU 3.00GHz, RAM= 1GB	Intel® Q965 (ICH8) Express Chipset	**ASUS** USB3.0 adapter with **Renesas** (**D720200**) Host Controller (2x ports, PCIe x1)	2.1.28.0 / 2.1.39.0	Gen.1	1x acA2500-14 -> 134.6MB/s = 134.6 1x acA2500-14 -> 22.1MB/s = 22.1	156.7	2 cameras connected via a hub(1,2) to a single port of the adapter.
					1x acA2500-14 -> 134.6MB/s = 134.6 1x acA2500-14 -> 28.8MB/s = 28.8	163.4	2 cameras connected each directly to a port of the adapter.

1) For the tests an **IOI** and **Exsys** USB 3.0 hubs with 4 ports were used. The maximum bandwidth supported by the hubs is < 350 MB/s.

2) The documented above test results were gained in the course of short term tests (20-30min for each). For this time frame the given setup showed to be stable and no image loss was observed. However, the Basler technical support recommends running cameras with around 10MB/s less total bandwidth than the maximum possible bandwidth listed above.

3) A total bandwidth of 580MB/s was reached by using 5 acA2500-14um/uc cameras and a hub. Since USB3.0 specification does not support such bandwidth ranges, Basler assumes that Intel is using some “hardware tweaking” internally in order to reach 580MB/s in practice.

acA2000-165u and the acA2040-90u Only

USB 3.0 Host Controllers' Maximum Bandwidth Measurements							
PC	**Chipset**	**Host Controller**	**Driver Version**	**PCIe Bus Generation (PC)**	**Camera Setup**	**Maximum Possible Bandwidth, [MB/s]**	**Comments**
DELL OptiPlex 7010, Windows 7 Professional x64, Intel Quad Core i7-3770 @ 3.4GHz (**Ivy Bridge**), RAM= 16GB	Intel® Q77 Express Chipset	Built-in **Intel** USB3.0 adapter (4x ports) with **Intel** USB 3.0 eXtensible-Host Controller	1.0.9.254	Direct chipset integration	1x acA2040-90um[3]	**361**[2]	* 1 camera connected directly to a single port of the adapter.
		IOI USB3.0 adapter with **4 x Renesas** (**D720202**) Host Controllers (4x ports, **PCIe x4**, U3X4-PCIE4XE101)	3.0.23.0	PCIe x4 Gen.2, 25W	1x acA2040-90um[3]	**355-361**[2]	* 1 camera connected directly to a single port of the adapter. ** Renesas Gen.2 Host Controllers reach stable bandwidth rates at about 355MB/s to 361MB/s depending on the PC and the motherboard implementation.
		ASUS USB3.0 adapter with **Renesas** (**D720200**) Host Controller (2x ports, PCIe x1)	2.1.39.0	PCIe x4 Gen.2, 25W	1x acA2040-90um[3]	310	* 1 camera connected directly to a single port of the adapter. ** Renesas Gen.1 Host Controllers seem not to support the maximum camera bandwidth of 361MB/s.
		Texas Instruments (**TUSB7340EVM / TUSB7320EVM**) xHCI Host Controller (4x ports, PCIe x1)	1.16.2.0	PCIe x4 Gen.2, 25W	1x acA2040-90um[3]	310	* 1 camera connected directly to a single port of the adapter. ** TI Host Controllers seem not to support the maximum camera bandwidth of 361MB/s.

		RocketU 1144C USB3.0 adapter with **4x ASMedia ASM1042A** XHCI 1.0 Controllers (4x ports, **PCIe x4**)	1.16.4.0	PCIe x4 Gen.2, 25W	1x acA2040-90um[3]	295-345	* 1 camera connected directly to a single port of the adapter. ** For Maximum Transfer Size (Default)= 1MB a stable image transmission was reached at about 295MB/s. *** For Maximum Transfer Size= 4MB a stable image transmission was reached at about 345MB/s. **** ASMedia Host Controllers seem not to support the maximum camera bandwidth of 361MB/s.
		VIA Labs VL805 USB eXtensible Host Controller (2x ports, PCIe x1)	6.1.7600.4201	PCIe x4 Gen.2, 25W	1x acA2040-90um[3]	361	* 1 camera connected directly to a single port of the adapter. ** VIA Labs Host Controllers only support a Maximum Transfer Size (USB Request Block size) <= 1MB.

1) The documented above test results were gained in the course of acquiring 100.000 test images. For this time frame the given setup showed stable operation and no image loss was observed. However, under circumstances it might be necessary to decrease the resulting camera bandwidth by using the camera parameter called “Device Link Throughput Limit”.

2) It is recommended to use Intel Ivy Bridge and Renesas Gen.2 host controllers with acA2000-165u and acA2040-90u cameras.

3) acA2000-165u and acA2040-90u cameras will always “wake up” with a decreased frame rate that results in about 200MB/s bandwidth. This is required due to the limited performance of some USB3.0 host controllers. In order to increase the camera frame rate and bandwidth you have to use the camera parameter called “Device Link Throughput Limit”.

4 USB 3.0 Host Controller Recommendations

So far, Basler has found the **Renesas** USB 3.0 host controller chipsets (driver versions for Windows XP/7: 2.1.39.0 for *uPD720200* or *uPD70200A* chipsets or 3.0.23.0 for *uPD720201* or *uPD720202* chipsets) and the **Intel Ivy Bridge** chipset (no driver support for Windows XP and Windows Vista) to work well with Basler ace USB 3.0 cameras.

The Renesas chipsets are e.g. used on ASUS and IOI PCIE USB3 host adapter cards, which can be purchased from Basler (Basler- part no. 2000033279, 2000034476).

It is recommended to use the IOI PCIE USB3 host adapter card (Basler- part no. 2000034476) in combination with acA2000-165u and acA2040-90u cameras.

Products based on the Intel Ivy Bridge architecture can be found under this link:

http://ark.intel.com/products/codename/29902/Ivy-Bridge

5 CPU Load Measurements

The Basler technical support department has conducted some CPU load measurements in order to prove the advantage of the “zero-copy” mechanism (DMA) used by the Basler ace USB3 Vision compliant cameras and pylon software.

NOTICE	
	The presented test results are not intended to be absolutely precise and should be treated instead as strictly informative and without any warranty.

5.1 Prerequisites

For the CPU load caused by Basler ace USB3 Vision compliant cameras to be measured the following hardware components and software tools were used:

- Lenovo T430, Windows 7 Enterprise x86, Intel(R) Core i5-3320M CPU @ 2.6GHz (Ivy Bridge), RAM= 8GB
- Built-in Intel USB3.0 adapter (2 x ports) with Intel(R) USB 3.0 eXtensible-Hostcontroller, Driver version: 1.0.4.225
- Exsys USB 3.0 hub
- Camera setup :
    - 3 x acA2500-14um/uc and 1 x acA1300-30uc
    - 3 cameras connected via the hub to the first port of the adapter, the 4th camera (acA2500-14) connected directly to the second port
    - Total Resulting Bandwidth= 430.5MB/s
- A standard pylon SDK C++ sample e.g. “Grab.cpp” was used for image acquisition. That is, in this use case only the CPU load caused by the image acquisition was measured, i.e. no image processing was involved.
- Software tools used for measuring the CPU load:
    - “xPerf” which is part of the Windows Performance Toolkit (WPT), download under : http://msdn.microsoft.com/en-us/performance/cc825801.aspx
    - “perfmon” (Performance Monitor) which is a standard tool available on Windows 7 OS

5.2 Results

For the above described setup the CPU load measured with “xPerf” and “perfmon” at total resulting bandwidth of 430.5MB/s was below **2%**.

6 Revision History

Document Number	Date	Changes
AW001260	24 April 2013	Initial release version of this document.
AW001260	04 June 2013	▪ Added one new test result for DELL OptiPlex 7010 (Intel USB 3.0 xHCI host controller) on page 4 ▪ Added an additional comment for the missing driver support for Intel Ivy Bridge on Windows XP and Vista on page 10.
AW001260	02 July 2013	▪ Added new test results for Texas Instruments TUSB7320EVM/ TUSB7340EVM host controllers on page 8.
AW001260	01 November 2013	▪ Updated the list of hardware components used for the tests on page 3. ▪ Updated the test results and the comments for IOI USB3.0 adapter with Renesas (D720202) Host Controller (2x ports, PCIe x1, U3-PCIE1XG202-10) on page 5. ▪ Updated the test results and the comments for Texas Instruments TUSB7320EVM/ TUSB7340EVM host controllers on page 8 ▪ Added new test results for IOI USB3.0 adapter with 4 x Renesas (D720202) Host Controllers (4x ports, PCIe x4, U3X4-PCIE4XE101) on page 9. ▪ Added new test results for “Best connectivity” and “Syba” USB 3.0 adapters with Renesas Gen.2 host controllers on page 9.
AW001260	02 December 2013	▪ Added new test results for Lycom UB-120Ti USB3.0 adapter with TI (TUSB7340EVM) xHCI Host Controller (4x ports, PCIe x1) on page 8. ▪ Added new test results for RocketU 1144C USB3.0 adapter with 4x ASMedia ASM1042A XHCI 1.0 Controllers (4x ports, PCIe x4) on page 9. ▪ Added new test results for Forcom USB3.0 adapter with 4 x Renesas (D720202) Host Controllers (4x ports, PCIe x4) on page 10. ▪ Added new test results for VIA Labs VL805 USB eXtensible Host Controller (2x ports, PCIe x1) on page 10.

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AW001260	28 May 2014	▪ Added new test results for acA2000-165u and acA2040-90u cameras on page 12 and page 13. ▪ Added new information about the IOI PCIE USB3 host adapter card on page 14.

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