USB 3.0 (USB3 Vision) Instead of FireWire — Better Performance and Lower Costs when Switching Camera Interfaces

Owners of FireWire cameras around the world over are all asking themselves the same question: how long will my camera system continue working, when is it time to make a switch, and when that time comes, which other camera interface is right for me? One thing is certain: FireWire is slowly but surely losing the support of the PC world, and will eventually disappear off the market. The new USB 3.0 interface and the USB3 Vision standard associated with it are considered an ideal successor. After all, the interface features technology similar to that found in FireWire, comes at an affordable cost and is built around mature technology that will be in use for many years to come. The one-time cost of switching is more than justified.

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1. Main topic: The End of FireWire

Since the introduction of USB 3.0 and the related USB3 Vision standard as a new camera interface for the vision market, more and more users are pondering the switch from their old FireWire[1] cameras to new USB 3.0 cameras. The cameras are used in a broad range of applications, so each customer's considerations must be filtered through the specific needs of their given industry, be it microscopic, medical technology, measurement engineering or classic inspection systems used in factory automation.

This white paper describes in detail why it is necessary and advisable to switch from the FireWire camera interface to USB 3.0, as well as which factors should be taken into consideration.

When making a switch, users always have a choice between different interfaces. The most significant interfaces involved here are USB 3.0, Gigabit Ethernet and Camera Link. For those interested in extensive details on the characteristics and benefits of each interface, please see Basler's white paper „Comparison of the Most Common Digital Interface Technologies in Machine Vision." That white paper also explores the USB3 Vision standard that is associated with the USB 3.0 interface, ensuring clear definitions of all relevant issues ranging from data transfer between camera and PC to cables, drilling diagrams and other central issues. Basler played a leading role in the development of that standard, which means of course that Basler USB 3.0 cameras are 100% compliant with the USB3 Vision standard. Because it works with technical characteristics highly similar to FireWire, USB3 Vision can be considered the closest and thus best fundamental recommendation when switching.

In summary, the following reasons speak to making a switch away from FireWire:

- The hardware is getting more expensive and difficult to find. This is because FireWire no longer plays a role for PC hardware on the consumer market.
- Modifications in the software or migration to a new operating system necessitate a change. Windows 8 for example offers no natural support for FireWire, while USB 3.0 host controllers can be used immediately, without any driver installation.
- The bandwidth is no longer sufficient to cover current requirements for vision systems — let alone future ones — such as higher frame rates, resolutions and new pixel formats.
- The savings for the overall system justify the one time integration costs through the lower production costs. A sample calculation is included in section 4.

[1] *Throughout this white paper, the term "FireWire" is used synonymously with IEEE 1394a and IEEE 1394b.*

2. Detailed comparison of FireWire and USB3 Vision

The following table summarizes the key technical characteristics of the two interfaces. It makes clear that USB 3.0 and the USB3 Vision Standard offer several benefits that FireWire can't match. This includes for example a data packet resend mechanism that enables the resending of lost packets if even the minutest errors are discovered in the image data. The large bandwidth helps with this, naturally. This mechanism is stable and beneficial especially if the camera has an internal frame buffer (such as the 56 MB in the Basler ace USB 3.0) capable of buffering the data for a certain period.

	IEEE 1394b	USB3 Vision
Connectors	Defined connectors	Defined screw lock connectors
Cables	Max. 4.5m by specification	No maximum cable length defined*
Hubs	Not industrial applicable	Mechanically defined industrial hubs (screw lock)
Camera control	Via DCAM**	Via GenICam
Transaction type	Isochronous (without resends)	Bulk (guaranteed delivery, incl. resends)
Bandwidth	64MB/s (single camera)	350MB/s (above 400MB/s possible)***
Power	8–33V; 1.5A	5 V; 900mA
Latency & Jitter	See graph	See graph

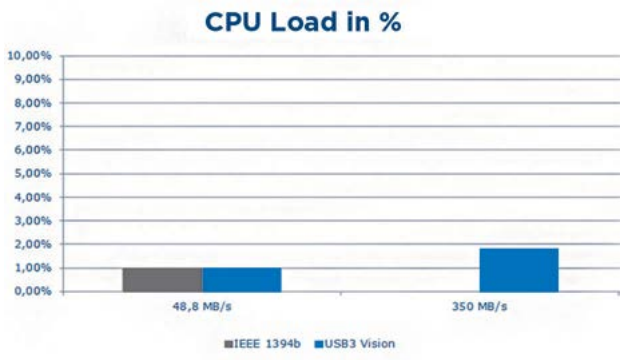
* The standard defines a cable's signal quality and voltage specifications. As such, cables should always be tested for conformity to the applicable standards.

** Basler IEEE 1394 camera control was already based on GenICam.

*** Test setup with Basler camera (acA2500-14uc) and Intel Ivy bridge host controller.

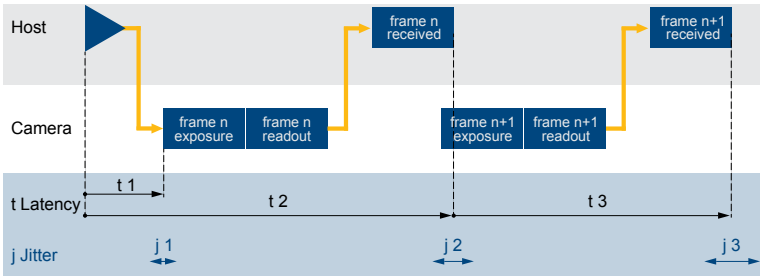
Two important characteristics require extra consideration here: CPU load and real-time capability.

Comparison of CPU load: USB 3.0 shines when it comes to the involvement of the CPU as well: the CPU is barely utilized even at data rates over 350MB/s. This comes thanks to the direct memory access in USB 3.0 on the host computer. It reserves blocks even before the images are transmitted so that the mechanism can forgo the copy process. The overhead levels remain very low. In more technical terms, the differential between the gross and net data rates is very low. The following CPU load comparison on a test computer highlights this very strong performance:



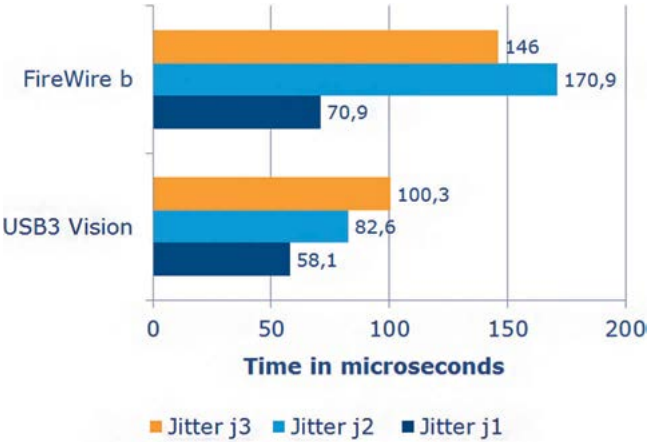
Real-time capability: When talking about vision systems, real-time capability refers to various points in the system where latency and jitter can occur. Latency involves a measurement of absolute time, while jitter refers to the variation in times between one identical process step and the next identical process step. The jitter time value is also the most important for deterministic predictions of when the next process step can transpire, since it absolutely relies on the one before it.

The following diagram illuminates jitter by splitting up the camera and PC sides. Three different points are defined here.



Software Trigger

Now measurements of the real-time capability are performed on a test computer[2]. These are average values over 10,000 cycles. They show that USB 3.0 is the better interface when it comes to real-time capability[3].



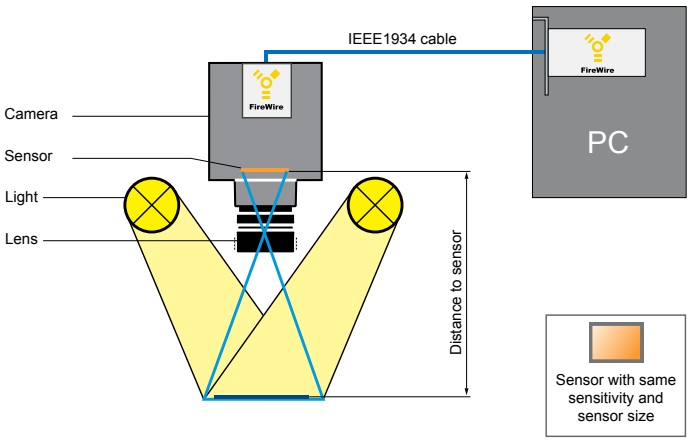
[2] *Working with the following specifications: HPZ200, Win7, I5 650@3.2GHz, 4GB RAM*

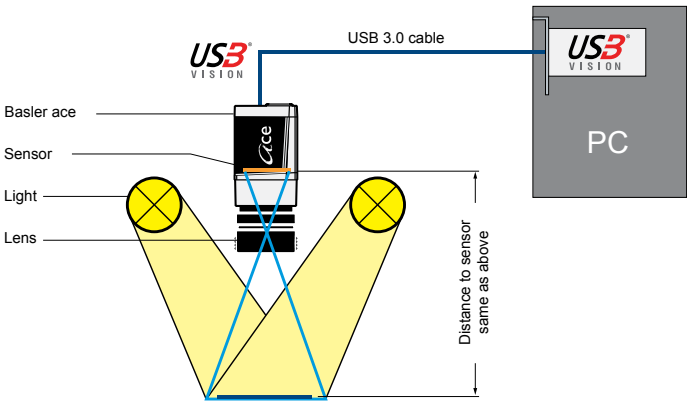
[3] *Values depict the jitter in a positive and negative direction through average latency.*

3. What must be taken into account during the switchover: Hardware and software

This chapter takes a closer look at the installation costs associated with the switch from FireWire to USB 3.0. This is intended to provide a rough basis from which to evaluate the time and costs involved with adaptation of the hardware and software integration.

Adaptation of the hardware:
For demonstration purposes, we'll examine a one-camera system being used for object inspection. The entire mechanism is oriented toward this object. The distances are already calculated and the lens has been selected appropriately for the sensor format and resolution. A highly specialized lighting system may also be included. An appropriate camera bracket is selected based on the lens. In some cases the camera size is an issue. The rear part of the setup is typically of a simple configuration: the camera is connected via FireWire cable to the PC, either through a PCIexpress card or directly into a motherboard with connections for the FireWire cable. For a precise triggering, a cable is used to connect the hardware trigger with the camera.





Switching over this same setup to USB 3.0 involves minimal time and cost, as the same sensor could also be selected for use on a USB 3.0 camera. The major benefit is that the entire optical setup can remain in place. This is especially important in situations where frequently used, high-quality CCD sensors are used — although they too will achieve better performance when paired with the faster speeds of USB 3.0. If the identical sensors can't be found, then it is a benefit to have equivalent or similar sensor sizes and sensitivity. Basler offers a broad selection of sensors for its USB 3.0 cameras to improve the chances of finding a compatible fit.

The size of the housing on the USB 3.0 camera should be similar to, and certainly no larger, than the current generation of FireWire cameras, and where possible are designed to fit on the same mounting scheme. This keeps the adjustment time and cost on the mechanical side very low. Naturally, on the PC side the cable and either the entire PC hardware (which, given the sinking purchase prices is not necessarily a negative) or just the PCIexpress card need replacement[4].

Taken as a whole, one-time costs for all hardware requirements remain entirely reasonable. In the long term, new PC hardware is probably more cost-efficient anyways for the material costs per system.

Software adjustments:
The cost and effort involved with integrating the software can vary greatly. Two examples illustrate the potential extremes.

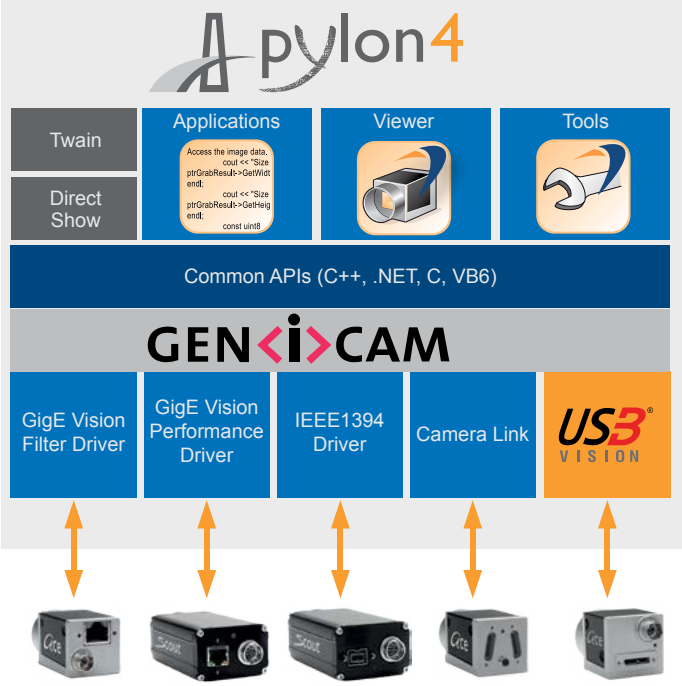
Variant 1: A proprietary system based on DCAM is used. This proprietary software supports only DCAM-compatible cameras and cannot be used with cameras working with new interface standards, including USB3 Vision without time-intensive modifications. The software interface must be reprogrammed to fit the GenICam standard. Basler pylon Camera Software Suite offers an extensive, no-cost software complete packet with a high-powered Software Development Kit (SDK) that even relatively inexperienced software developers can use to port DCAM to GenICam without problem. The good news: once successfully ported to GenICam, the equipment is then also ready for other current and future machine vision software interfaces, since GenICam is the standard that all interface technology must comply with!

Variant 2: A GenICam-based software environment is in use, requiring only minor adjustments. Ideally the software environment would include an update of all drivers for USB3 Vision and the camera controller. This

[4] *Care must be taken that the PCIexpress bus is capable of handling the greater bandwidth. A USB 3.0 PCIexpress card with 1 lane, for example, would be limited to 250MB/s if inserted into a PCIexpress version 1.0/1.1 slot.*

is for example on hand in the Basler pylon Camera Software Suite or for many image library manufacturers.

The following diagram illustrates the setup and contents of the **pylon Camera Software Suite.**



4. Cost/benefit analysis: When does a switch pay for itself?

The following budget calculation depicts how a switch to USB 3.0 can pay for itself from a budgetary standpoint. This example is based on a camera model from another camera maker[5]. The switch is being made from that camera maker to a Basler USB 3.0 model with the same sensor. The primary costs will come in the area of software, namely in adjusting the software interface to the new camera interface. A small portion falls on the hardware side, namely mounting the camera and installing USB 3.0 with cables and ports. The use of identical sensors means that no adjustments are required for the optics, machine mechanics or illumination system.

The comparison shows that the break-even point is reached before the first year is even finished. From year two the savings are in the high five-digit range.

The example is based on a system of 100 installed cameras. The break-even point could potentially be reached within the first year. The costs for cables and hardware were not examined here, although here too savings can be expected (USB 3.0 hardware setups tend to be roughly 20% cheaper).

Sample calculation in €	FireWire camera with ICX 274 sensor	ace USB 3.0 camera with ICX 274 sensor
One-time costs for software adjustments (2 worker-months)	0	18,000
One-time costs for hardware adaptation (4 worker-weeks)	0	9,000
One-time costs for logistics/parts lists adaptation and similar	0	5,000
List price for camera	1,099	729
Purchasing costs for cameras per year	109,990	72,900
Savings year 1:	0	5,000
Savings year 2:	0	37,000
Savings year 3:	0	37,000

[5] *Note: a switch from a Basler FireWire camera to a Basler USB 3.0 is even simpler, especially if Basler pylon software is already in use — for more on this, see point 3. In that case, the software integration cost would be very low.*

Author

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Before joining Basler, René worked in sales and marketing of a well-known German medical technology company for eight years.

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About Basler

Basler is a leading global manufacturer of digital cameras for industrial and video surveillance applications, medical devices, and traffic systems. Product designs are driven by industry requirements and offer easy integration, compact size, excellent image quality, and a very strong price/performance ratio. Founded in 1988, Basler has 25 years of experience in vision technologies and has designed and manufactured high quality digital cameras for 15 years. The company employs more than 350 people at its headquarters in Ahrensburg, Germany, as well as at international subsidiaries and offices in the U.S., Singapore, Taiwan, China, and Korea.

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