Don't lose your connection

Why it makes sense to switch to USB 3.0 now

1 Why switch your interface?

In industrial environments, everything revolves around **reliability**, productivity and stability. Processes and equipment are subject to numerous **certifications**. Changes are planned and tested well in advance. No-one allows themselves to be dazzled by the limitless possibilities of technologies that are still in their infancy. And a healthy dose of skepticism towards new things is par for the course. In any case, the optimization of processes and workflows can best be planned using **known technologies**.

But how do you know when a technology is really ready to be deployed? At what point can you be sure there's **no risk** you may actually be sitting on a ticking technology time bomb? And, until that point arrives, is the best strategy to **sit back and wait?** But just think, where would we be today if we had never allowed ourselves to get on board with **new technologies?** How can we bring about a **fourth industrial revolution** by sticking to what's been tried and tested and resting on the incomplete knowledge of others?

2 Technology in transition

Since the first cameras with USB 3.0 technology were launched about five years ago, the new camera interface has had **sufficient time to mature**. The results of initial comparisons with tried and tested digital camera interfaces in industrial machine vision were clear and easily summed up. **USB 3.0** is:

- extremely **fast**
- **ideal for industrial applications**
- **easy** to use
- **suitable for universal use**

But the logical development of the USB interface had only revealed an inkling of its **enormous potential** at that point.

Since then, teething problems have been identified and have long since been eliminated. What remains is a sophisticated technology now capable of **conquering** the vision world. A complete system switchover won't happen overnight – after all, big changes require many small steps. Nevertheless, there are many arguments in favor of switching to USB 3.0 right now.

- **USB 2.0** is approaching the **end of its product life-cycle**. As a result, it is becoming increasingly difficult (and more expensive) to get the appropriate hardware and support.
- In 2012, Intel launched "Ivy Bridge" processors, thereby making **USB 3.0 a mainstream interface**.
- Current chipsets like Intel's "Sunrise Point" (Skylake architecture) represent another milestone. The USB 3.0 controller interface (xHCI) **unites all USB speed classes for the first time ever**
  - Low speed (1.5 MBit/s)
  - Full speed (12 MBit/s)
  - High speed (480 MBit/s)
  - SuperSpeed (5 GBit/s)
- As a result, a **USB 2.0 high speed controller** (eHCI) **is no longer integrated**. "New technology replaces old technology". New drivers have to bring old technology into the modern world.

In the same way, the consumer market inevitably also drives the new mainstream technology into the industrial environment.

3 Simply better – USB 3.0

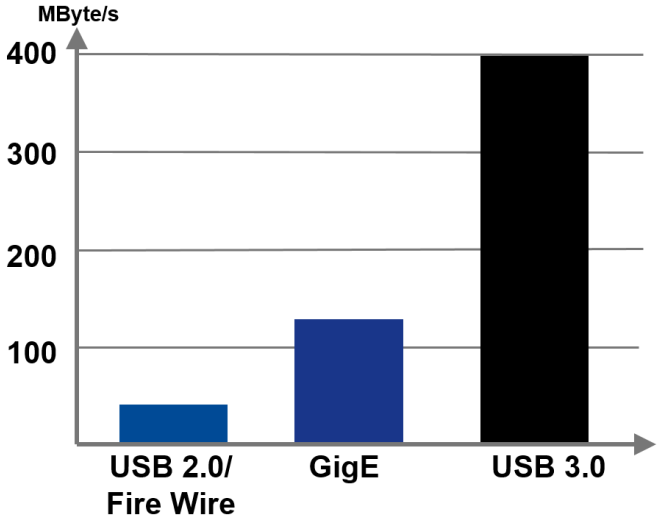

Figure 1 – Only USB 3.0 allows you to avail of all performance benefits offered by the latest CMOS sensors

USB 3.0 is still regarded as a newcomer in the area of camera interfaces. Despite this, it is already common knowledge that his technology offers much more than a **significantly higher throughput** (Figure 1).

Use of modern sensors

Table 1 provides an overview of the sensors currently used in IDS cameras. By limiting the maximum sensor pixel rate, **sensor capacity** can be **adjusted** to suit the bandwidth of the interface used. If the frame rate decreases too much, then it is no longer **useful** to work with the interface in question.

Camera manufacturers therefore need to decide which interface to combine with new sensors. And, in doing so, they naturally look to what the market requires. A camera application decides which camera system you use – not the other way round. This is true of the **image sensor** in particular, which must offer options that fit the application. The data interface needed is then automatically determined by the requirements that apply to the necessary data transfer. Therefore, **modern sensors** simply **don't belong** in cameras with an "old" interface like **USB 2.0**.

"The application decides which camera system you use – not the other way round!"

And anything that ultimately motivates users to make the change is also part of the transformation. The deployment of a new technology always involves a learning curve. **Direct experience** is an **invaluable advantage**. At the latest when the technology you've been using breaks down and you need to find alternatives.

Maximizing sensor performance

A direct comparison of two cameras with an identical megapixel sensor (such as e2v EV76C560) but with different interfaces reveals **clear differences in the maximum data rate**. IDS has been selling this sensor for a long time in the USB 2.0 camera UI-1240 with various housing variants. By **switching the interface** to the **USB 3.0** camera family, this same sensor can finally show just what it is capable of. When the maximum pixel rate is used, **the sensor bandwidth increases** to 86 megapixels per second. Thanks to USB 3.0, the sensor's maximum frame rate (60 images per second) can be fully implemented in your application.

Sensor	**e2v EV76C560**			**ON Semiconductor MT9P006STC**			**CMOSIS CMV4000-3E5C1PP**			**Sony IMX174LQJ-C**		
Resolution	SXGA			QSXGA			4MP			2MP		
Interface	USB2	GigE	USB3	USB2	GigE	USB3	USB2	GigE	USB3	USB2	GigE	USB3
Sensor bandwidth (Mpixel/s)	35	71	86	43	96	104	-	84	344	-	-	480
Frame rate (1/s)	25.8	50	60	6.3	14.1	15.2	-	19	80	-	-	166

Table 1 – The maximum data rate of modern high-performance sensors can only be exploited using USB 3.0. USB 2.0 and GigE only work with a reduced sensor bandwidth or are not used.

Reducing CPU usage

The host controller doesn't need to constantly query new data, thanks to the **asynchronous communication** of USB 3.0, which contrasts with the tried and tested "polling" used in USB 2.0. This is also evident in the **much smaller CPU load** on the host PC. In a test with the e2v sensor, the CPU load was three times higher with the USB 2.0 camera than with the USB 3.0 variant with an identical configuration of camera parameters. This means **more CPU "free time"**, which your application can use for other tasks.

4 USB 3.0 system – how it works

USB 3.0 multiplies the volume of image data that can be supplied to your application. However, the transmission of data in the gigahertz range requires all relevant system components to have been certified and quality approved.

A USB 3.0 camera can be compared to a Formula 1 racecar. It won't run smoothly or reach maximum speed (SuperSpeed) on regular lead-free fuel. USB 2.0, on the other hand, is like a mid-range car. Every cable effortlessly transmits USB data at high speed. The quality and tolerance of system components is virtually irrelevant when the target bandwidths are so low. **USB 2.0** itself is the **bottleneck**.

"Your USB 3.0 system is only as good as its weakest link!"

Therefore, the performance of a USB 3.0 SuperSpeed system is not the result of using a specific camera and the corresponding driver package in any PC system. The saying "The system is only as good as its weakest link" really hits the nail on the head in this case. USB 3.0 strives to attain a data speed that must be supported by all components in the transmission chain. Due to the large **leap in performance made by USB technology**, all system components are required to work at full capacity all the time without large tolerances.

IDS provides you with **support** in **choosing the right accessories** and helps you to identify and eliminate any weak spots. That's why IDS only recommends and distributes top-quality USB 3.0 accessories to enable **smooth operation** with high data rates.

High-quality cables are essential

What exactly does "high-quality" mean and why is it so important for USB 3.0? To answer these questions, you need to imagine for a moment which **tasks** a cable performs and which **requirements** it must meet.

A cable creates a pluggable, flexible and sufficiently long connection between two devices to enable the transmission of electrical signals or power without any losses.

This means that both **mechanical** and **electrical factors** may interfere with the working of a cable – loose plugs, kinks or tears in the copper wire or poor signal strength to name but a few.

Conventional copper-based, passive cables are bound by a set of **basic physical rules**. Often, these make it difficult for cable manufacturers to produce suitable cables that fulfill all requirements. **Compromises** have to be made!

A high-frequency data signal like USB 3.0 (5 GHz) is weakened by physical **line resistance**. The stronger this is, the longer the copper wire and the smaller the wire diameter must be. The resulting signal loss is referred to as **insertion loss**.

Line resistance can be reduced by **increasing the wire diameter**. In other words, the thicker the copper wire within a USB 3.0 cable, the better the transmission properties in the high frequency (HF range). The AWG value (American Wire Gauge) indicates the diameter of an electrical wire. A low AWG value means a larger diameter, and thus lower line resistance. However, the **total thickness** of the USB 3.0 cable increases as a result, making it **less flexible** and complicating the mounting of a connector.

In a nutshell, lots of things can go wrong with USB 3.0 **cable production**. In particular, cables that are produced **cheaply** and easily for the consumer market frequently do not meet the standard of **build quality** required to satisfy the rigors of the industrial environment. This leads to increased numbers of USB transmission errors or drops in connection. The result is reduced transmission performance (bandwidth) or **an unstable connection**.

Decreased transmission quality may cause a camera with USB 3.0 hardware to be registered as a USB 2.0 high speed device when **establishing a connection** with the camera driver. The USB port used and its internal cabling may be to blame. For more information, see the section **The "right" USB 3.0 connection**

Cable length

The USB 3.0 specification is **not** limited to a **maximum** cable length. This is explained by the relationship or rather the **compromise** between the cable length and the relevant high-frequency properties (insertion loss) or voltage drops. If these factors can be minimized, then a **longer, correctly functioning cable** can be manufactured.

IDS works in close **collaboration** with experienced USB cable manufacturers to support them in the development of high-quality, efficient cables. IDS also strives to offer **longer passive** cables for many different applications. To preserve **line quality**, the 5 m and 8 m cables have a **larger wire diameter** as required by the technology. With strong partners at our side, we can thus guarantee a **stable connection** between the cable and the plug.

As a result, you don't need to switch to a different camera interface if you require a **longer cable connection** in excess of 8 m for your application. **Active fiber optic cables** also transmit USB 3.0 data over long distances with a consistently high data rate.

Figure 2 – Active USB 3.0 hybrid cables from IDS enable USB 3.0 connections up to 50 m

IDS sells ready-made USB fiber optic cables (Active Optical Cable – AOC) up to a **length of 50 m**. If necessary, you can directly swap a longer cable length for a passive cable. The electronics required for signal processing and amplification is integrated directly into the connector. Despite this, the **connectors are only slightly longer and thicker than their** passive counterparts.

In addition to the fiber optic cable, a copper-based **power supply line** is also integrated. This is known as a "hybrid" cable. This means that a camera can also be supplied with power by the host PC **directly** by means of an AOC cable. The supply voltage is provided via the USB port on the host PC, and feeds both the camera and the cable electronics. An optional Y-USB cable can be used to connect a second USB port to supplement the power from the first port and guarantee a **power supply for energy-intensive devices**.

The "right" USB 3.0 connection

Caution: Even if ports are explicitly identified as SuperSpeed USB ports, there are some "rotten apples" in the USB 3.0 barrel that may leave you with a very bad taste in your mouth!

Front ports are connected to the motherboard by cable bridges inside the PC. As a result, they are governed by the same rules that apply to cable connections between a PC and camera. Nevertheless, most cable assemblies you will come across are **particularly incompatible with USB 3.0**:

- Very **poor shielding** on the plug connections or exposed cable strands.
- **Additional plug connections** between the camera and USB controller via these "cable extensions" have a negative impact on signal quality.
- It is doubtful that these ports will have a sufficient and **stable power supply**.

Furthermore, several front ports are often connected via the same USB controller. These then **share** the maximum permitted USB 3.0 **bandwidth** between them. Therefore, if you want maximum throughput, avoid operating several cameras at once.

Back ports on a PC are securely soldered to the motherboard. No problems due to cables or connectors are to be expected with these ports. However, experience indicates that their **properties vary** very significantly depending on the number of motherboards and on the operating systems used. As a result, their general suitability for high-performance USB 3.0 data transmission cannot be assumed.

Chipset drivers also have a role to play. As these are responsible for many hardware components in addition to USB controllers, they need to be maintained and enhanced for each new generation of processors. Therefore, drivers must remain maintainable and manageable in order to avoid systematic software errors. Obviously, older operating systems are not supplied with unlimited **updates** for new hardware. Just recently, Microsoft announced that it was to **discontinue** its **Window 7** support for Intel's current **Skylake** processor architecture.

For you, as a user of USB camera hardware, this may have **inexplicable effects** under certain circumstances in this time of technological change. Large manufacturers like Microsoft, Intel or AMD push their products into the market, thereby forcing the hands of consumer customers and business customers alike.

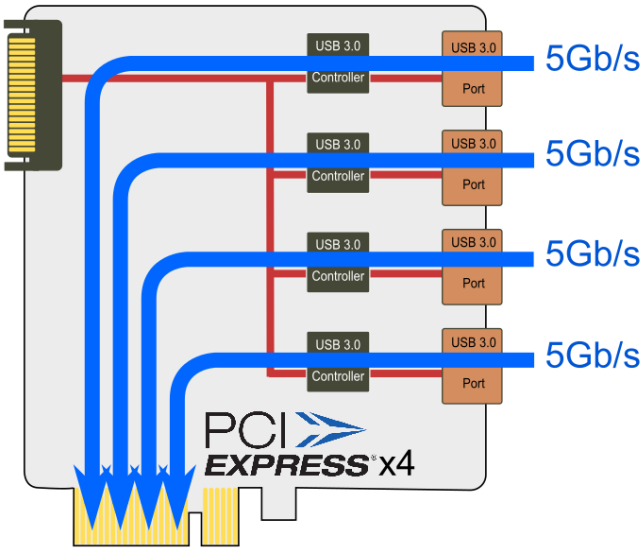

Figure 3 – With PCIe x4 Rev.2 cards, you can transmit parallel data streams from 4 USB cameras, each with the maximum USB 3.0 bandwidth, via 4 separate USB host controllers

The **solution**: By using **USB 3.0 PCI Express plug-in cards** (Figure 3), you can exert a direct influence on the properties of your USB 3.0 ports. The internal PCI Express bus allows you to equip each of your PC systems with everything they need:

- **Identical** USB 3.0 hardware for all systems
- **Independent** of changing PC hardware
- **Stable** driver software **directly** from the manufacturer
- Established, **long-term** hardware quality
- **Adequate** power supply directly from the PC power supply unit
- **Maximum** data bandwidth thanks to a dedicated USB controller for each USB port

That's why IDS tests and distributes USB 3.0 PCI Express plug-in cards that meet these requirements. Using these plug-in cards **reduces** possible **weaknesses** and incompatibilities to a minimum and offers you **greater system reliability** thanks to the reference hardware.

In conjunction with our own uEye camera, the plug-in cards provide you with an optimized, high-performance foundation for a **stable** USB 3.0 camera system.

5 USB 3.0 multi-camera – it's so easy!

A multi-camera system works with a small number of cameras and a large data throughput, or with a large number of cameras and a smaller throughput per camera. Here, too, the type of applications you use will determine the number of cameras that are to be operated on a host system, as well as the data bandwidth and the cable length.

When building a multi-camera system, the **same rules** that apply for a stable USB 3.0 system apply here too. And if you abide by these rules, there should be no nasty surprises in store.

With the system components offered by IDS, it's very easy to build a stable USB 3.0 multi-camera system. Even active cables with a length of 50 m should pose no problem for multi-camera operation.

Two essential points should always be borne in mind when **building a multi-camera system**:

- You require a sufficient number of **high-performance** USB 3.0 ports in the host system in order to guarantee the required data bandwidth for all cameras.
- You also require an adequate **power supply** to all connected cameras in order to guarantee reliable operation.

USB controllers establish a connection between the USB data and the virtually unlimited data highway inside the PC. Each SuperSpeed controller uses a small part of this highway for your application. If only one USB port is connected to a controller, this means that the entire USB 3.0 bandwidth is available to a single consumer device.

This **1:1 connection** represents the **most powerful configuration** for a camera. The more single-controller ports are available in the system, the more a multi-camera system can **benefit** from the performance of internal data interfaces such as PCI Express. You can use the USB 3.0 PCI Express cards described above to ensure the most effective use of these controller ports.

If you don't require the full USB 3.0 bandwidth for a camera, several data providers can **share** this bandwidth among themselves.

You can create **1:n connections** with **USB hubs**. Ensure that a sufficient power supply is available for all connected cameras at each distribution point. **Active** USB hubs guarantee this additional power supply by means of separate power supply units.

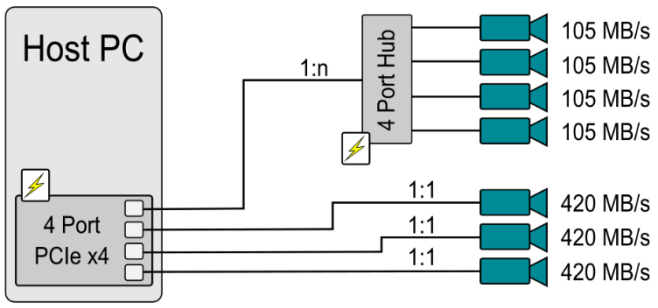

Figure 4 – Possible throughput in a USB 3.0 multi-camera system with direct and distributed use

Yet this is also precisely where the potential **pitfalls** for a multi-camera application lie. If manufacturers **cut costs** in the wrong places to bring prices down, the built-in hardware will have the **wrong dimensions** for a SuperSpeed camera application. This results in voltage drops or even power outages. In all such cases, stable operation of the cameras cannot be guaranteed.

For this reason, IDS has only included flawless USB hubs in its portfolio, which work under all load conditions. In other words, IDS only provides you with **suitable components** that ensure a stable, high-performance multi-camera system.

To ensure that each camera's **transmission performance** is as required, the connection path and bandwidth sharing with other cameras must be monitored. The IDS Software Suite also includes **useful tools** for support.

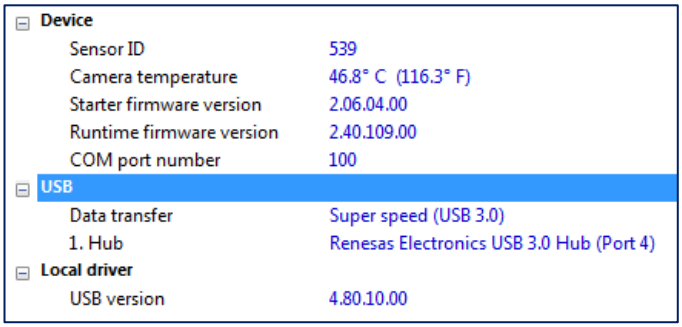

Figure 5 – IDS Camera Manager shows the USB connection parameters for a camera

IDS Camera Manager shows the **transmission speed** and the connections via hubs for each USB 3.0 camera (Figure 5). This give you a very detailed picture of the camera's USB connection topology.

Meanwhile, the **performance overview** in the uEye Cockpit allows you to ensure ideal synchronization of the cameras' data rates without overloading the system.

6 Summary

The transition of camera interface technology to USB 3.0 is inevitable. USB 3.0 is by now a **mature** technology, and its use is spreading incredibly rapidly. It is the **ideal** data interface for new applications with **modern** sensors.

A wealth of **knowledge** and **experience** has by now been **acquired** in relation to USB 3.0 technology, and this is reflected in the way in which cameras and accessories are evolving. IDS has been developing and selling industrial cameras with USB technology for around 12 years now, and, for the past five years, has also been pioneering USB 3.0 cameras and accessories. A **new and improved second generation** of many of the cameras has already been released. The IDS Software Suite is **enhanced** and continually **improved** with each new sensor.

This makes IDS a strong partner for USB cameras, which has acquired a wealth of experience since USB high speed was first introduced as a camera interface. “Now is the time to **get on board with USB 3.0!**”

The next evolutionary stage in the form of USB 3.1 with 10 GBit/s and even more innovations is just around the corner. The “USB 3.1 Type C” universal cable opens the door and is already used in our uEye LE series with USB 3.0 bandwidth. **“Don't lose your connection.”**

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