Point Grey USB 3.0 FAQ & Practical Guide

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POINT GREY Innovation in Imaging

USB 3.0

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Part 1: SuperSpeed USB 3.0 Technology Overview

What is SuperSpeed USB (aka USB 3.0)?

SuperSpeed USB, also known as USB 3.0, is the next generation of the popular plug and play Universal Serial Bus serial communication specification. It is managed by the USB Implementers Forum (USB-IF), and is designed to build on the strengths of USB 2.0 while addressing many of its limitations.

What is the bandwidth of USB 3.0?

The effective bandwidth available via the bulk transfer method is around 440 MByte/s. This is approximately 10 times the bandwidth available with USB 2.0, and 5 times that of 1394b. The practical bandwidth is a function of the USB 3.0 chipset and the motherboard chipset. For example, some Intel motherboards limit the PCIe Gen 2.0 x1 interface to Gen 1.0 speeds (2.5 Gb/s instead of 5Gb/s). Click here for a summary of Point Grey recommended hardware configurations. In 2013, the USB 3.0 Promoter Group announced plans to enhance existing USB 3.0 performance by introducing a 10 Gbps USB 3.0 specifcation. The new specificationwill double the existing USB 3.0 data rate while maintaining backward compatibility.

In one streaming test, two Flea3 cameras (1328x1048 camera at 120fps) connected to a single $60 USB 3.0 interface card successfully generated a total 340 MByte/s of image data with no dropped data.

How does its architecture differ from USB 2.0?

USB 2.0 employs a host-directed (aka master-slave) architecture where every transaction either goes to or comes from the master (the host computer). Communication is half-duplex, allowing data to flow in only a single direction at a time. USB 3.0 adds five wires for a total of nine wires in the connectors and cabling and utilizes a unicast dual-simplex data interface that allows data to flow in two directions at the same time; an improvement over USB 2.0's unidirectional communication model.

USB 3.0 is still a hosted device protocol, but uses asynchronous signaling, which allows a device to notify the host when it is ready for data transfer. This significantly reduces system overhead and CPU usage compared to the polling mechanism in USB 2.0. A variety of other protocol improvements, such as streaming support for bulk transfers and a more efficient token/data/handshake sequence, improve system efficiency and reduce power consumption.

Are USB 3.0 devices available now? Will most computers support USB 3.0 in the future?

Yes. A wide variety of products have passed SuperSpeed USB certification testing, including motherboards, notebook and netbook computers, add-in cards, and the device-enabling xHCI and physical layer (PHY) chips. Peripherals (cards, cables, motherboards, etc.) are readily available, and virtually all major computer system manufacturers provide systems with USB 3.0 on the mother board. Both AMD and Intel are both shipping certified USB 3.0 chipsets and forecasts are for USB 3.0 to be on every PC by 2015.

Is USB 3.0 backward-compatible with USB 2.0?

Yes. Although the USB 3.0 cable contains five new wires, it is still backward-compatible with USB 2.0, allowing consumers to continue to utilize their existing USB 2.0 peripherals with a USB 3.0-enabled computer, or USB 3.0 devices with a legacy computer. USB 3.0 Standard-A receptacles are backward-compatible with USB 2.0 but add new pins for USB 3.0 signals. The new Standard-B and Micro-AB female receptacles are also backward-compatible. USB 3.0 introduces new Micro-B and Micro-A plugs and receptacles.

Are there EMC (Electromagnetic Compatibility) improvements with USB 3.0?

Yes. All USB 3.0 devices must include spread spectrum clocking (SSC), which modulates the signal and spreads the energy over a wider frequency band. SSC is used to lower electromagnetic emissions for emissions compliance.

How does Thunderbolt fit in?

Thunderbolt is a new high speed interface technology that offers approximately 10Gbit/s of bandwidth, and combines DisplayPort and PCI Express (PCIe) interfaces. It is not clear if there is a future for Thunderbolt as a digital interface technology for industrial cameras. It is clear that USB 3.0 is rapidly becoming ubiquitous in the consumer space and will become one of the predominant interfaces in the vision industry. Click here for an in-depth examination of Thunderbolt and how it compares to USB 3.0.

Part 2: USB 3.0 Benefits For Machine Vision Applications

How do FireWire, GigE, Camera Link, USB 2.0, and USB 3.0 compare to each other in terms of bandwidth, cable length, and usability?

Obviously if one interface could cover all requirements, ranging from bandwidth, cable length, price, and so on, it would be the clear technical winner. But in reality customer requirements are too diverse to be met by just one interface.

Following is a general comparison of the key digital interfaces that are commonly available in today's industrial cameras. Please note that some of the information presented in this table is subjective and that the performance of each interface will depend on the exact system configuration it is used in.

	FireWire-b	Gigabit Ethernet	USB 2.0	USB 3.0	Camera Link	Winner	Second Place
Bandwidth	80 MByte/s	100 MByte/s	40 MByte/s	440 MByte/s	680 MByte/s (8-tap)	Camera Link	USB 3.0
Cable length	10 meters	100 meters	5 meters	3 meters	10 meters	GigE	1394b
Power + data over one cable	Yes (45 W)	Yes with POE (15 W)	Yes (2.5 W)	Yes (4.5 - 7.5 W)	Yes with POCL (4 W)	1394b	GigE
Consumer acceptance	Good	Good	Excellent	Excellent	None	USB 2.0	USB 3.0
Multiple cameras	Excellent	Good	Fair	Excellent	Fair	1394b	USB 3.0
Camera control standard	Yes - IIDC	Yes - GigE Vision	No	Yes - USB3 Vision	Yes - Camera Link	Not USB 2.0…	
CPU usage	Low	Medium	High	Low	Medium	1394b	USB 3.0
Total cost*	Medium	Medium	Low	Low	High	USB 2.0	USB 3.0
*Framegrabber + cables + power spuply							

Beyond the obvious, why is higher bandwidth important? How does it help 'future proof' my systems?

At 440 Mbytes/s, USB 3.0 supports the ability to run faster and/or higher resolution image sensors. As shown from the table below, many new sensors require over 100 Mbytes/s support. At these rates, both GigE and FireWire are no longer viable; USB 3.0 or Camera Link are the two most mature and readily usable interfaces available.

Higher bandwidth also supports more cameras on the same bus and higher bit depth from existing sensors, allowing more data to be transferred per readout cycle.

	Sony ICX674	Sony ICX694	Sony IMX136	E2v EV76C570	On Semi Vita1300
Type	CCD		CMOS		
Size	2/3"	1"	1/2.8"	1/1.8"	1/2"
Pixels	2.8 MP	6 MP	2.3 MP	2 MP	1.3 MP
Max FPS	50 FPS	25 FPS	108 FPS	60 FPS	150 FPS
Data Rate	140 MB/s	150 MB/s	248 MB/s	120 MB/s	195 MB/s

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Does USB 3.0 really lower system cost?

Yes! This table gives a quick price comparison between interfaces for a single and a 4-camera system. All prices are publically available and as much as possible, obtained from a single source. Note: the camera cost is not included in this comparison.

Clearly, USB 3.0 requires the lowest cost support in both a single and multi-camera configuration.

	FireWire-b	GigE	USB 3.0	Camera Link
Frame grabber	$95[1]	$60[1]	$60[1]	$895[2]
Cable (3m)	$25[1]	$35[1]	$10[1]	$160[2]
Power supply	N/A	$40[1]	N/A	$75[2]
Total cost for single camera solution	$120	$160	$70	$1130
4-port frame grabber	$300	$300[3]	$70[3]	$1K+
Total cost for 4-camera solution[4]	$400	$700	$110	$2K+

[1] List price from Point Grey online store

[2] List price from Edmund Optics online store

[3] List price from StarTech online store

[4] Including extra cables and power supplies

How does USB 3.0 ensure a more reliable imaging pipeline?

A number of factors contribute to USB 3.0's reliability:

- It is more common for USB 3.0 cameras and cables with screw lock connectors
- Increased power delivery reduces power-related problems.
- USB 3.0 xHCI host controllers support a packet resend mechanism to address issues with data corruption.
- The SuperSpeed USB Compliance process ensures proper operation of USB 3.0 peripherals.
- Cameras with on-camera data buffer help minimize the chance of dropped or corrupt data.

How has power delivery improved?

USB 3.0 provides more efficient power management and increased power delivery over USB 2.0. The amount of current draw for USB 3.0 devices operating in SuperSpeed mode is now 900 mA, resulting in an increase in total power delivery from 2.5 W to 4.5 W (at 5 V). The USB Battery Charging 1.2 specification allows up to 7.5 W. USB 3.0 also offers an improved mechanism for entering and exiting low-power states, depending on whether a device is active or not, and eliminates power-consuming polling.

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Part 3: Practical Considerations

What are the system requirements?

There are many components of a USB 3.0-enabled vision system, ranging from cameras, cables, hubs, cards, PCs, and software. Please see Recommended USB 3.0 System Components App Note. With the aim of providing optimal processing performance and full x1 PCIe 2.0 speed for USB 3.0 imaging, this note lists and compares: cables; hubs; operating systems; motherboard, CPU and chipset combinations; as well as USB 3.0 xHCI host controller and driver combinations.

When choosing components, remember that USB 3.0 technology is still relatively new, thus the ability to upgrade (or downgrade) firmware and software of various system components is important. Many components have this ability on the device.

What operating systems support USB 3.0 camera video streaming?

Point Grey's latest version of the FlyCapture Image Acquisition Software supports USB 3.0 cameras under Microsoft Windows XP, Windows 7, Windows 8 and Ubuntu 12.04.

Support for Microsoft operating systems is achieved in one of two ways. First, Point Grey has developed its own xHCI driver, PGRxHCI, which allows users to operate Point Grey USB 3.0 cameras on both 32- and 64-bit versions of Windows. Alternatively, users can use the driver from the USB 3.0 host controller chipset manufacturer together with Point Grey's camera-level PGRUSBCAM driver to run their Point Grey USB 3.0 camera.

Are USB 3.0 cameras currently available and what are they like?

USB 3.0 machine vision cameras are now readily available from many key vendors. Most of these are of the compact 'ice cube' form factor as USB 3.0 connectors and low-power technology enable small camera designs. Generally they are CMOS-based due to higher data rates, lower power requirements, and ease of implementation. Many rely on the Cypress EZ-USB FX3™ general purpose USB 3.0 device controller, for USB 3.0 connectivity. Point Grey does not – we have created our own USB 3.0 link layer which we load into an FPGA – but we have worked extensively with the FX3. A common implementation consists of a CMOS sensor connected to the FX3 + a small FPGA, and according to Cypress, the FX3 can sustain performance of up to 320 MB/s. Some cameras feature a large data (frame) buffer; this is key for maximizing reliability.

What is a data (frame) buffer and why is it important on a USB 3.0 camera?

If a host system is busy, it may not be able to keep up with the data traffic coming from the camera in which case data throughput drops. Point Grey USB 3.0 cameras have a data buffer that allows images to be temporarily queued in the camera after readout. The main advantage of the data buffer is that it allows the system to handle momentary slowdowns on the bus without dropping data. If the overall data throughput drops below requested data rate for an extended period of time, the camera can send entire un-corrupted frames out slower, and drop entire frames cleanly, rather than drop partial frames and cause image data errors.

Is there a standardized camera control protocol for USB 3.0 cameras?

Yes, the USB3 Vision standard is being developed specifically to provide a common camera control interface for USB 3.0 cameras. It will be an interoperability standard for devices based on the USB 3.0 electrical specification, in the same way IIDC and GigE Vision are standards for FireWire and Gigabit Ethernet devices. It will allow for easy interfacing between the USB3 Vision device and a computer using standard USB 3.0 hardware. Hosted by the Automated Imaging Association (AIA), the global trade association for the vision and imaging industry, the standard has been finalized in January 2013. Currently, Point Grey cameras implement the IIDC specification. All Point Grey USB 3.0 single lens cameras will have USB3 Vision support via firmware upgrades.

What does USB3 Vision define and how is it structured?

USB3 Vision defines USB 3.0 related requirements, device identification and control interfaces, data streaming mechanisms, mechanical requirements and testing frameworks. USB3 Vision draws many of its specifications from the GigE Vision and GenICam standards, for example cameras will have an XML file that defines supported features.

The specification requires the transfer mechanism to be bulk; future versions may add isochronous as an option. Backward compatibility with USB 2.0 is not a requirement, but this may be supported by the camera itself. Also, the standard is designed to support "zero copy", unlike GigE which copies every packet.

What software packages support USB 3.0?

Most vendors, like Point Grey, provide their own SDK for interfacing with cameras and the SDK can even allow for seamless connection of all their cameras, regardless of interface. Point Grey's FlyCapture SDK will support USB3 Vision in future releases. Key software providers such as Cognex, Mathworks, Matrox, MVTec, NI, and Stemmer are part of the USB3 Vision Committee and their support of the standard will be key to ensuring USB3 Vision-compliant cameras run seamlessly with USB3 Vision-compliant software.

What is the maximum USB 3.0 cable length?

The maximum length is not explicitly specified in the USB 3.0 standard. However, the standard does describe the relationship between wire gauge and maximum length in order to achieve USB 3.0 voltage drop and attenuation requirements. For example, a cable can be up to 3.0 meters long and still adhere to the USB 3.0 specification.

A screw-locking Micro-B connector is specified by the USB3 Vision committee. Point Grey USB 3.0 cameras adhere to the USB3 Vision screw locking specification. Click here to see Point Grey's USB 3.0 cable offering. USB 3.0 hubs and repeaters already are in production and available from companies like Diamond and IOI, and work is in progress on signal-corrected long-distance cables and optical solutions from companies like Alysium-Tech, CEI and Newnex.

For more information on extending the working distance of a USB 3.0 camera, please refer to this application note.

What is the CPU usage like compared to other interfaces like FireWire, GigE, and USB 2.0?

In general, CPU resource usage will be less than USB 2.0 and GigE, and more similar to FireWire.

In one streaming test, two Flea3 cameras connected to a single Point Grey U3-PCIE2-2P01 Gen 2.0 PCIe card successfully generated a total of more than 280 MByte/s of image data. Images were processed and displayed on a monitor. The Intel i7 PC used for the test was running Windows 7, and CPU usage was between 1 and 2%.

There are a number of factors that help streamline USB 3.0's power usage:

- USB 3.0 also uses asynchronous signaling, rather than constant polling, which allows a device to notify the host when it is ready for data transfer. A variety of other protocol improvements, such as streaming support for bulk transfers and a more efficient token/data/handshake sequence, improve system efficiency and reduce power consumption.
- USB 3.0 also supports direct memory access (DMA), which allows data to be read from / written to main memory without going through the CPU.
- Increased bandwidth allows more data to be transmitted, such as full color processed images e.g. 1.3 MP 60 FPS RGB24 = 180 MB/s. This removes the requirement for the host system to perform this processing

What is the maximum number of cameras I can connect to a single USB 3.0 bus?

The theoretical number of devices on a network is 255 units, but in practice the number of devices is determined by the host controller and by host system processing speed. Host controllers available today support up to ~30 devices (hubs are counted as a device). Click here to learn what motherboard, CPU and chipset configurations Point Grey recommends for optimal processing performance. Point Grey performs long term tests with 24 cameras on one PC using 3 host adapters and six 4-port hubs. Click here to read "Setting up Multiple USB 3.0 Cameras "

What hubs are available?

Hub chipsets are available from VIA, TI, Genesys Logic, and SMSC . All claim to be USB 3.0 compliant, but none are officially certified

since USB 3.0 compliance tests are still not defined. Hubs range in price from $50 to $199 depending on the type of enclosure; consumer grade, industrial grade with screw-locking or board level with reference design.

Hubs can limit data rates. In one test, Point Grey observed at 20% drop – from 340 to 272 MB/s. For more information see Recommended USB 3.0 System Components App Note.

Part 4: Point Grey USB 3.0 Cameras

Why should I choose Point Grey USB 3.0 cameras for my application?

Point Grey's USB 3.0 product lines offer industry-leading innovation and price-performance; fast, easy, and reliable end-to-end imaging; and superior imaging performance. Interested in learning more? Read the rest of these FAQs!

What makes Point Grey's USB 3.0 products innovative and reliable?

The ultra-compact Flea3 FL3-U3 measures just 29 x 29 x 30mm and offers a variety of low-cost, high-speed, CMOS image sensors, ranging from 1.3 to 8.8 megapixels. The high performance Grasshopper3 GS3-U3 features large resolution CCDs ideal for industrial and scientific applications. Unlike most other manufacturers, we have developed our own USB 3.0 link layer IP, which has been implemented in an FPGA. With complete control over the core technology, we have the flexibility to choose what features are developed and the timing of firmware releases without relying on third-party chip vendors.

All Point Grey USB 3.0 cameras provide a screw-lock connection that minimizes the chance of disconnects. Other unique features dedicated to maximizing USB 3.0 reliability include a data buffer for image retransmission; on-camera power, temperature, and status monitoring; and in-field updatable firmware.

Point Grey has performed countless tests to maximize the speed and reliability of the imaging pipeline, including:

- Long term streaming tests running 24 hours a day, 7 days a week in order to uncover hard-to-reproduce problems.
- Design revision tests, e.g. 2 cameras 1920x1080@60fps, running a minimum of 3 days producing over 31 million images per test.
- Thousands of camera arrival/removal tests.
- Cable testing using the Quantum Parametrics High Speed Interconnect Tester.

Does Point Grey offer any USB 3.0 accessories? What are the benefits?

Point Grey offers a low-profile PCI Express Gen 2.0 USB 3.0 card. The benefits of the Point Grey card include:

- Two SuperSpeed USB ports
- Internal power connector
- Both standard and low profile PCIe mounting brackets
- Data transfer speeds of 5 Gbit/s

The card is built with a Fresco Logic FL1009 Extensible Host Controller Interface (xHCI) chip which provides distinct performance improvements over other available chipsets. It can be optionally used with Point Grey's low-level USB 3.0 xHCI driver to improve streaming performance and provide enhanced bus diagnostics. In scenarios where frame rate is being limited, our card achieves a higher processed frame rate than other available cards. Point Grey minimizes reliance on chipset or OS vendors to resolve issues or provide driver support. We manufacture the cards and test each one before they ship.

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What are the general hardware requirements (e.g. laptop, desktop, CPU) for running Point Grey USB 3.0 cameras?

Click here for a summary of Point Grey recommended hardware configurations. Point Grey provides a range of qualified USB 3.0 accessories.

Are Point Grey USB 3.0 cameras backward-compatible with USB 2.0?

Yes, a Point Grey USB 3.0 camera can be plugged into a USB 2.0 bus and operate at USB 2.0 speeds. The camera must use the PGRUSBCAM camera driver, which is distributed with Point Grey's free FlyCapture SDK. Point Grey's low-level PGRxHCI driver does not currently support USB 2.0.

Is it easy to switch from using Point Grey FireWire or USB 2.0 cameras to Point Grey USB 3.0 cameras?

Users who have developed custom applications for their Point Grey FireWire or USB 2.0 cameras using our FlyCapture SDK will find migrating to USB 3.0 relatively easy. The FlyCapture SDK is a free software package for image acquisition and control of Point Grey digital cameras. The SDK's simplified object-oriented interface is designed to make application development faster and easier for software developers, and the hardware abstraction layer (HAL) enables the seamless connection of any Point Grey FireWire, USB 2.0, USB 3.0, or GigE Vision cameras FireWire or USB 2.0 camera product to the host system. A common application programming interface (API) allows existing Point Grey camera users to connect a USB 3.0 camera to their system and run their custom applications with minimal reconfiguration.

How can I synchronize multiple cameras on the same bus? Do they automatically synchronize like Point Grey FireWire cameras?

Currently, Point Grey cameras do not automatically synchronize their image exposure with other cameras on the same USB 3.0 bus like Point Grey FireWire cameras. To achieve synchronization, you must use the camera's external trigger capability. The camera supports both hardware (an external electrical signal) and software (a software command to the camera) triggering. Note that the maximum rate at which the camera can be triggered may be less than the maximum frame rate of the camera when free-running.

Do Point Grey USB 3.0 cameras use bulk or isochronous transfers for image streaming?

Point Grey's Flea3 cameras will use bulk (guaranteed delivery) rather than isochronous (guaranteed bandwidth).

Do Point Grey USB 3.0 cameras use the USB Video Class (UVC) camera control protocol?

No, the Flea3 uses the same IIDC v1.32 camera control protocol used by all other Point Grey FireWire and USB cameras.

About Point Grey

Point Grey Research, Inc. is one of the world's largest and most innovative manufacturers of high performance digital cameras for industrial, bioscience, traffic, and GIS applications. We offer a unique and comprehensive portfolio of USB 3.0, GigE, FireWire, USB 2.0 and Camera Link products known for their outstanding quality, ease of use, and unbeatable price-performance.

After demonstrating the world's first USB 3.0 camera in 2009, Point Grey continues to push the boundaries of USB 3.0 imaging technology with an ever growing portfolio of high quality USB 3.0 cameras. Click here to explore Point Grey's USB 3.0 offering including cameras, cards, cables and drivers.

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