Industrial Camera Interface Guide

Choosing the Right Interface Comes Down to the Application

There are many types of cables and connectors used with today's industrial cameras. Determining what camera interface makes the most sense for a vision system comes down to several factors which will be explored in this guide. Additional factors such as bandwidth capacity, cable lengths, and additional hardware support will also be covered for each interface, as well as some examples of current camera models that are available today with these interfaces. The purpose of this guide is to explore and provide an understanding of the available interfaces within the industrial and scientific area scan camera market, along with each of their key features.

Camera Interfaces

Industrial cameras and scientific cameras are capable of incredible speed and resolution with a variety of image sensor (camera imager) options. Camera technology continues to evolve not just at the front end with sensor design, but also on the back end with camera interfaces. Introducing new connectors and new cables into vision systems continues to push the boundaries of imaging applications with higher bandwidths and more reliable data transfer.

USB3 Cameras

When it comes to the easiest digital interface to use, nothing really compares to USB (universal serial bus). This plug-and-play interface has been around since 1996 and in that time there have been some significant improvements. Mainly, the evolution to USB3 has changed the imaging industry with the push towards gigabit speeds. Now, USB3 has become a staple in the imaging industry and continues to evolve at an even faster rate.

The first iteration of USB3 was USB 3.0, but this name was changed several times to USB 3.1 Gen 1 and then USB 3.2 Gen 1. This pushed USB beyond the 480 Mbit/s speed limit of USB2 to up to five Gbit/s. USB3 connectors have been widespread in a variety of products, but not surprisingly, in the industrial and scientific imaging market the standard found a way to stick.

This supports cameras with compact sensors as small as 1/2.8" sensors found in the new Teledyne Lumenera Lt Series Board Level Cameras as seen in Figure 1, to large APS-C sensors that will be available in Teledyne Imaging cameras coming to market in the near future.

Figure 1: Lt Series Board Level Camera (left) And Lt Series Camera (with P-IRIS) (right).

There are a variety of connectors used with the USB3 standard. Connectors such as the standard USB3 Type-A are most commonly found on computers and other host devices used to capture images from a camera. USB3 Type-B and USB3 Micro-B are two of the most common connectors found on industrial camera bodies due to their locking connectors which help secure the cables that can reach up to 10 meters in length. Due to USB becoming the standard connector for computers and lots of other electronics, the hardware necessary to transfer image data from the camera is already available on most devices. Without a need to purchase frame grabbers, unique components, and cables, USB3 cameras provide a cost-effective set up and can be deployed in large numbers without adding unexpected costs to a vision system. To see a variety of USB3 camera options, visit the product page for Teledyne Lumenera's USB3 cameras.

As well as the physical interface, there is also software support through USB3 Vision® that is based on the GenICam™ generic programing interface. USB3 Vision allows many vision systems to use the same software platform after upgrading to a new camera. By using a camera such as the Lt-C/M4020B Board Level Camera that is supported by the same standardized USB3 Vision software, a designer can change the physical structure of a vision system without worrying about compatibility. There are many software packages that are based on the USB3 Vision platform. Depending on the manufacturer and features desired, the choice of software can be narrowed down. Examples of USB3 Vision software includes LuCam and Sapera offered by Teledyne Imaging.

GigE Cameras

Reliable high-speed image capturing has been possible since 2006 with GigE Vision®. By using Ethernet network cables such as Cat5 and Cat6, industrial cameras can use the GigE Vision standard to achieve a range of speeds. The most common speeds start from one Gbit/s and go up to five Gbit/s within the industrial imaging industry.

The GigE Vision standard is based on the Internet Protocol standard and is regulated by the AIA. By integrating network hardware into a vision system through GigE cameras, a user has the advantage of being able to control multiple cameras even from remote locations for 24 / 7 use. By having a full GigE Vision system, all the cameras being used can run on the same software platform. Without being physically present, cameras can function together with synchronized timestamps using Precision Time Protocol (PTP). This means multi-camera topology is a key benefit to developing a vision system with GigE in mind.

1GigE Cameras

As the name suggests, 1GigE cameras are capable of 1 Gbit/s speed. This type of bandwidth is transferred over a standard network cable, as shown in Figure 2, to either a host PC or a network switch. The value of using a network switch is the ability to easily synchronize many connected devices, such as with PTP. However, PTP is only used as a way of ensuring timestamps between cameras is synchronized, therefore additional unique features need to be implemented, such as those in Teledyne DALSA's GigE cameras, to fully synchronize the cameras in a GigE vision system to capture images at the same time. This means across many cameras, image acquisition can be tightly controlled to ensure there will be no mismatch as to when a camera is expected to take an image and when the image is captured.

Figure 2: Genie Nano 1GigE Camera connecting to a network cable.

Another important aspect of GigE cameras is that they can keep up these speeds reliably for constant use in applications such as factory automation and inspection, with cable lengths of up to 100 meters. To see a full list of Genie Nano 1GigE cameras like the ones featured in Figure 3, visit the [Teledyne DALSA product page.]

Figure 3: Genie Nano 1-GigE Cameras

5GigE Cameras

As the name suggests, the 5GigE cameras can reach up to five Gbits/s speeds. This means a five times improvement in bandwidth, but the costs associated with using a 5GigE camera and interface will most likely be much less, only slightly more than 1GigE. The real difference in price will come down to the sensor choice of the cameras. The increased speeds are achieved through 5GBASE-T link speed. Therefore, 5GigE vision systems can result in an increase in costs, but if the system can allow it, the increase in speed is far greater.

By having each camera use the GigE standard, the system can run on one simple software, such as the Teledyne Imaging Sapera platform which can help take full advantage of each camera for OEM type applications.

For applications that need maximum data throughput, [Teledyne DALSA offers the Genie Nano 5GigE camera line up.] A set of Genie Nano 5GigE cameras can be seen below in Figure 4, featuring the standard Genie Nano camera body, as well as the Genie Nano XL form factor.

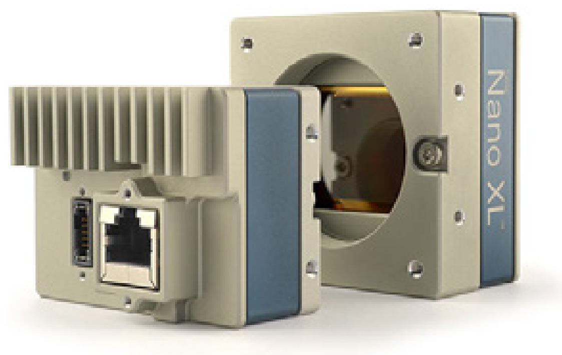

Figure 4: Genie Nano 5GigE Cameras

The speeds achieved by standard GigE cameras can be improved with TurboDrive™ to potentially double the standard data rate. This unique upgrade from Teledyne DALSA allows a typical 5GigE connection of 595 Mbytes/s to reach speeds almost double, up to 985 Mbytes/s. Instead of relying on completely different hardware, TurboDrive takes the existing GigE connection Teledyne DALSA cameras have and can increase speeds by 20-150%. This upgrade to performance does not put a vision system at risk of increased data loss, but instead a camera using TurboDrive can often run at frame rates twice as fast. This allows applications like assembly line imaging to run at double the speed because of increased framerate, efficiently doubling the speed of production. This technology is available within the various Genie Nano GigE products (including 1GigE and 5GigE) that range from 1/4" to APS-H sensor formats, as seen in Figure 5.

Figure 5: Teledyne DALSA Genie Nano Camera sizes.

Understanding the naming and the speeds can be quite confusing for interface standards such as USB and GigE. To help clarify, Teledyne Lumenera went ahead and went into depth on these two interfaces with the blog, ["USB And GigE: The Evolution Of Camera Interfaces For Imaging Systems."]

CoaXPress

Unlike USB3 or GigE cameras, CoaXPress (CXP) uses coax cables that need to be connected to a frame grabber. Another name for a frame grabber is a capture card. These are found in the host computer where they help process the image data coming from a camera. Even though there is a need for a frame grabber to capture images with a CXP camera, the benefit is having a significant boost in performance. The frame grabber acts as a physical upgrade to the host computer giving the overall vision system more capacity to process image data and increase the overall bandwidth of the system. The bandwidth of an individual CXP camera can be increased by leveraging the multiple connectors on the back of the camera and the frame grabber to open up more channels for data to flow through. An example of a Teledyne DALSA Xtium series frame grabber can be seen in Figure 6 with four coax connectors located on the panel that would be positioned on the back of a computer.

Figure 6: A Xtium2 CXP PX8 Series frame grabber.

CXP cameras can have up to four connectors on the rear of the camera, as seen in Figure 7. This interface is capable of 6.25 Gbit/s speeds over each channel. When all these channels are plugged into one frame grabber the vision system can maximize its bandwidth. Multiplying single channel speed by four and a vision system equipped with a Genie Nano CXP camera can reach speeds up to 25 Gbit/s. These speeds are part of the CXP6 standard and can be achieved with coax cables up to 35 meters in length.

Figure 7: Backside of a Genie Nano XL CXP Camera.

To see the full selection of CXP cameras, visit the [Teledyne DALSA Genie Nano CXP Cameras product page] and for information on frame grabbers for CXP cameras, check out the [frame grabber product page.]

Camera Link

For a standardized camera interface, Camera Link, seen in Figure 8, offers a reliable and simple design to improve the connection between cameras and frame grabbers. Camera Link was first developed in the year 2000 with a significant update to Camera Link 2.0, new options such as Mini Camera Link connectors for smaller cameras, Power over Camera Link (PoCL), and PoCL-Lite (an even smaller PoCL cable).

Figure 8: Genie Nano Camera Link Cameras

With Camera Link, cables can reach up to 10 meters in length and while under Full / 80-bit capacity, lengths up to seven meters are supported. With both Full and 80-bit output, a Camera Link camera will need two cables connected to a frame grabber to take full advantage of the maximum image data throughput.

Speeds with Camera Link cameras can reach 255 Mbyte/s with a single cable in base configuration and up to 850 Mbyte/s with two cables in Deca configuration. Also, instead of connecting one camera with two cables, a vision system can also connect two cameras in a double base configuration to one frame grabber. This allows the host PC to control multiple cameras through one interface.

Teledyne DALSA offers software support for Camera Link cameras through Sapera LT featuring CamExpert and GenICam compliance. With updated software, visions systems that use Camera Link can upgrade to new models as better sensor technology continues to evolve. Visit [the Genie Nano Camera Link product page] to learn more about the different models available.

Camera Link HS

Building on the foundation developed by Camera Link, as of 2012 Camera Link HS (CLHS) has been using standard cabling solutions such as SFP, SFP+, CX4, and fiber optic cables to maximize length and speed. With these options, CLHS cameras can connect over a range of up to 15 meters with copper cabling and as long as 5000 meters with fiber cabling with throughput up to 8.4 Gbit/s per lane and up to 7 lanes on a single cable. An example of a CLHS camera can be seen below in Figure 9, featuring a medium format Falcon4 86M camera.

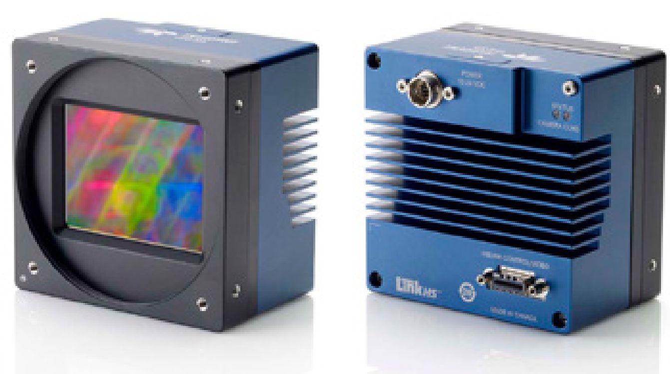

Figure 9: Falcon4 86M Camera Link HS front and back view.

With 3.125 Gbit/s per lane using M protocol and up to 10.3 Gbit/s using X protocol, CLHS can provide images from a sensor as large as the Falcon4's 86-megapixel sensor much quicker than other interfaces. This medium format sensor size can be visualized in Figure 10 when compared to the smaller Genie Nano 1GigE camera. The increase in effective bandwidth 60 times greater than a 1GigE connection.

Figure 10: Size contrast between a smaller Genie Nano 1GigE camera and a Falcon4 86M.

The Falcon4 product line features both the high resolution 86M model and the Falcon4-CLHS M4480, shown in Figure 11, that can transfer an exceptional number of images with a frame rate as high as 609 frames per second using the Teledyne e2v Lince11M sensor. A frame grabber can help minimize the workload on the host CPU and focus the image acquisition with the on-board Data Transfer Engine (DTE). The Xtium also comes with Teledyne DALSA's Trigger to Image Reliability framework to ensure that at no point does image data have a chance to be compromised through, triggering, image capturing, and data transfer.

Overhead and Encoding

Each interface has a potential to reach a theoretical maximum bandwidth. This number, however, disregards a lot of the actual overhead involved with transmitting data to a host device from the camera. Each interface will have some form of encoding and this can be different between two similar cameras. For example, if two cameras have the same sensor but one uses 1 GigE and another uses 5 GigE, the encoding will be different. Encoding is a measure of how efficiently a device packages data before sending it off to the host, such as a computer collecting image data from a camera. USB3, 1GigE, and CXP use 8 / 10 encoding which means about 20 percent of the bandwidth is lost to the encoding process. The 5GigE interface uses a 64 / 66 encoding which is far more efficient, with only about a three percent overhead. Camera Link is an interface that does not use the same sort of overhead, but instead has about a five percent loss in bandwidth. This limitation is due to the gaps between image frames that are the result of sets of image data (referred to as data lines) synchronizing with the camera clock. The successor, CLHS, also uses 64 / 66 encoding. However, the more pressing issue with maximizing bandwidth for CLHS comes from frame grabber bandwidth limitations. The design of most frame grabbers still cannot fully take advantage of the theoretical speeds from an interface as fast as Camera Link HS. Additionally, the 8 lane PCI express (PCIe) 3.0 interface that many frame grabbers use to communicate with a host computer is not yet on the same bandwidth potential as some industrial interfaces. This limitation will begin to fade as PCIe 4.0, and future updates becomes more commonly adapted in frame grabber technology.

Figure 11: Falcon4-CLHS M4480

The complexity of how many parts of a vision system impact the actual bandwidth potential goes far beyond just the interface. The camera sensor is even more significant than the interface when it comes to the potential bandwidth the vision system can output. Depending on specifications, including but not limited to, the clock speed of the sensor and the sensor interface that communicates to the rest of the vision system, the amount of data a camera can output can vary greatly beyond just the physical interface such as GigE, USB, CXP, or CLHS.

Conclusion

With all the various camera interfaces available, it can be challenging to decide just which one best suits a particular imaging application. However, by understanding the bandwidth, synchronization, ease of deployment, and cable length that each interface offers, it becomes much easier to make a decision. By comparing the bandwidth of each interface, as shown in Figure 12, the difference in how much image data can be collected becomes clear. Using a CXP or CLHS camera will provide much higher bandwidth for a vision system, but in applications where a frame grabber is not necessary or not possible, options such as USB and GigE become a good choice. Deciding which interface best suits a particular system comes down to the needs of the application. For more information on selecting the right camera and interface to support your imaging application, reach out to our imaging experts who would be happy to discuss. You can contact them at lumenera.info@teledyne.com.

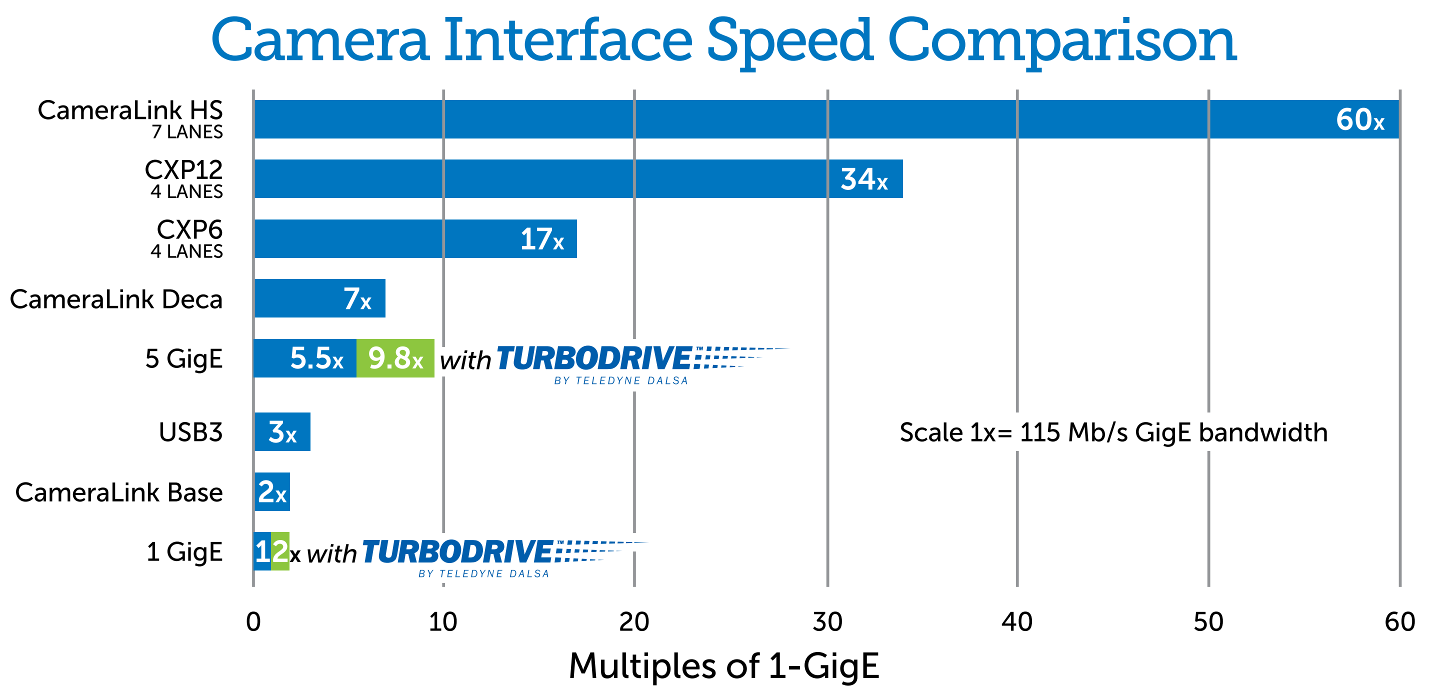

Figure 12: Comparison between different camera interfaces and their bandwidth.

Americas
Boston, USA
+1 978-670-2000
sales.americas@teledynedalsa.com

Europe
Krailling, Germany
+49 89-89-54-57-3-80
sales.europe@teledynedalsa.com

Asia Pacific
Tokyo, Japan
+81 3-5960-6353
sales.asia@teledynedalsa.com

Shanghai, China
+86 21-3368-0027
sales.asia@teledynedalsa.com