eBook

Vision connectivity interfaces

Choosing between Camera Link, CoaXPress, GigE Vision, Camera Link HS, 10 GigE Vision, and USB3 Vision.

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Contents

EXECUTIVE SUMMARY

There are several video interface options currently available to connect various elements of imaging systems for machine vision, medical, outdoor and military applications. At the higher end of the performance range, standards such as Camera Link and GigE Vision have served their users well for the past decade, a period which ushered in an era of interface standardization in the industry. But new demands from systems makers, combined with improvements in camera performance and technical innovations in interface technology, are resulting in a second wave of high-speed connection options being developed. These include CoaxPress, Camera Link HS and 10 GigE Vision.

Given that cabling/connection media can account for up to 50% of a system's upgrade costs, the physical interface is extremely important. When considering a move to one of the emerging high-performance options, system developers must carefully weigh the tradeoffs across a range of criteria, including cost (initial and long-term), speed, ease of implementation and use, power, supplier support, and physical connection requirements in order to choose the best connectivity alternative for their specific application.

This paper looks at the current state of camera interface options, as well as the emerging interfaces coming to market in the next few years. Our conclusion is that each offers a unique approach to addressing the range of challenges present in modern imaging systems:

GigE Vision: Used in low- & mid-end vision systems with less critical speed and timing demands; cost effective solution when full speed is not required.
10 GigE Vision: Built on GigE Vision, faster physical layer and better timing accuracy with much higher power consumption; requires server grade equipment for implementation.

Camera Link: Industry default choice for higher speed connectivity where limited cable length and high cable costs are acceptable.
Camera Link HS: Originally designed to overcome the speed limitations of Camera Link for line scan cameras; first products may enter the market end of 2012.

CoaXPress: A new standard for applications that require higher speeds, longer cable lengths, and a single, flexible and inexpensive cable; frame grabber still required.

USB3 Vision: Based on existing, well defined USB 2.0 and 3.0 with machine vision specific features. 10x faster than USB 2.0 over shorter cable lengths; interesting step forward for USB 2.0 and FireWire based camera users

EVOLVING NEEDS OF VIDEO INTERFACES

The growing adoption of high resolution cameras – enabled by improved sensors and underlying silicon technology - in vision systems has resulted in new levels of performance and quality available to system developers. However, the large amount of data produced by these cameras has put a strain on the traditional interface techniques and technologies that link cameras and their host image processing systems.

Until recently, there were only 2 choices for demanding imaging applications: Camera Link for higher speeds but with short cable lengths or GigE Vision for longer cables but slower speeds. Essentially, a trade off always had to be made.

As a result, several initiatives are well underway that focus on improving camera interfaces to support the needed bandwidth, as well as provide cost-effective, scalable approaches. Each offer unique advantages and limitations. Developers of camera-dependent systems should evaluate their specific application requirements and understand the differences between the options available.

Important considerations -- beyond just raw performance -- are:

- Ability to easily integrate with existing system architecture
- Flexibility of the connection medium
- Scalability of solution to meet future requirements
- Physical infrastructure for application
- Transmission distance required
- Overall implementation cost
- Availability of products based on the interface

When considering an interface, it is important to understand both its current availability status, as well as the industry support behind it for future implementation in vision systems. The ability of the standard to grow with your product roadmap will eliminate costly changes.

The options for connecting various elements of an imaging system have come a long way in the past decade. After years of a chaotic lack of any standard interface in the 80s and 90s, the last ten years have seen dramatic improvements in establishing common interface protocols. As the industry has matured in this area, a handful of popular approaches have risen to the top, thanks mainly to either their backing by major suppliers or by leveraging existing infrastructure to better facilitate their adoption and implementation.

The most popular standards have been Camera Link, GigE Vision, USB 2.0, and IEEE1394b (FireWire). While USB 2.0 and FireWire are available in a large volume of products, their usefulness is limited to the 'low end' of the vision system markets (and largely consumer products for USB 2.0) because of both performance and connection constraints (mainly distance limit of connection). As mentioned before, developers of higher end image systems used to have two primary choices for interface options: Camera Link and GigE Vision.

By the late 2000s, it was clear that the interfaces described above were reaching their limits in terms of their ability to deliver on next-generations machine vision systems requirements. This is a result of the need for much higher bandwidths, as well as solutions that address evolving physical requirements of the system – cabling distance, flexibility, number of cameras required, and power needs. On top of this, as users transition to newer and more capable systems they are evaluating the total cost of implementation and maintenance of their system over the long run.

Several new interface standards that go beyond Camera Link and GigE Vision have been created in recent years including CoaXPress, Camera Link HS, 10 GigE Vision, and USB3 Vision.

Other emerging implementation alternatives include speed upgrades to FireWire, LightPeak and HD-SDI/3GSDI but, as with their predecessors, these are largely aimed at lower end /consumer systems or specialized applications. For the purposes of this discussion, we will concentrate on the interfaces that are best suited for leading-edge vision systems, and have advanced implementation initiatives and standardization well underway.

We will look at the relative strengths and weaknesses of Camera Link and GigE Vision as well as these next generation standards.

CAMERA LINK

Camera Link is a computer vision serial communication protocol. The standard is maintained and administered by the AIA (Automated Imaging Association). It was first launched in 2000, and should be acknowledged as the first true vision system interface standard.

Camera Link was initially developed to standardize connectors, reduce the number of wires in cables and offer scalability in terms of the number of outputs, bit depth, and speed. Its implementation is based on low cost components, which helps keep initial implementation costs lower, and no license or royalty fees are required. In the 2000s, Camera Link's greatest attraction was its performance and standard cables and connectors. It still offers benefits such as:

- Proven technology
- 6 Gbps (often acceptable)
- Low latency

But users have realized that Camera Link's performance is no longer sufficient for many higher end applications because:

- Its cabling length is limited, with a "best case" length of 10 meters
- The speed is limited to a maximum of 6 Gbps over 2 cables (2 Gbps over 1 cable)
- It requires a custom cable that is both more expensive and less capable compared to other more standard connection methods, such as coaxial cable or Ethernet
- The required cable is also bulky and inflexible
- There is no future roadmap to allow for higher speeds

As a result of these limitations, Camera Link's future will likely see its use migrate to mid- to lower-end applications and/or become obsolete by more robust emerging interface standard which we will discuss later on.

Camera Link facts:

Available since: 2000
Speed: 2Gbps(1 cable); 6Gbps(2 cables)
Cable length: 10 meter
Adapter: Frame Grabber ($ 400 and up)
Connection type: Point-to-point

GIGE VISION

The GigE Vision interface standard was launched in 2006 and is administered by the AIA. As its name implies, it is based on the internet protocol standard. Ethernet interfaces are either built into PC motherboards, delivered via standard network interface cards, or a via a frame grabber equipped with the GigE interface. To get the full performance with continuous 1 Gbps, a frame grabber is required.

The standard's main appeal is its use of existing network infrastructure – i.e. Cat-5 UTP Ethernet cable, resulting in the following benefits:

- Long-distance connections (100 meters)
- Low cost cables
- Well-suited for networked applications (which are in reality not that common in vision systems)
- Standard interface chips, switches and hubs for an additional cost and support benefit.

As with Camera Link, the use of GigE Vision has limitations as well which include

- Timing critical applications requiring 1 Gbps need a need a frame grabber to offload CPU and memory of PC – thus negating the full cost benefit of GigE Vision
- GigE Vision does not support real-time triggering, an important requirement in high-end systems
- Installation of software and drivers is more complicated and requires more technical support than other camera-specific interfaces when working without a frame grabber

In 2011 GigE Vision 2.0 was launched which included support of:

- 10 Gbps physical layer
- Multiple cables
- Compression techniques
- Small images
- Improved real-time triggering capabilities

GigE Vision Facts:

Available since: 2006

Speed: 1 Gbps

Cable length: 100 meter

Adapter: On PC, NIC ($25 and up)
Frame Grabber ($ 400 and up)

Connection type: Network

COAXPRESS

CoaXPress was designed in the beginning of 2007 to overcome all of the limitations of Camera Link. This provides the interface with many advantages in terms of bandwidth, infrastructure cost, ease of implementation, and scalability. With CoaXPress digital video, control, GPIO, triggering and power can be managed with just a single, flexible and cost- effective cable.

CoaXPress is a point-to-point serial interface connecting a camera to a frame grabber. The physical medium between the camera and the host is one (or more) 75 Ohm coaxial cables. Its use of coaxial cable enables automatic equalization of cable losses, which allows it to operate over greater distances. Thus, a fundamental benefit of CoaXPress is its ability to provide higher performance over longer distances than any other current or emerging standard.

CoaXPress is a public, royalty-free standard, originally hosted by the Japan Industrial Imaging Association (JIIA). Version 1.0 of the CoaXPress standard was released in December 2010 and global approval of the standard by AIA and EMVA was received in March 2011. Several companies in the machine vision supply chain, including suppliers of cameras, frame grabbers, cable solutions and drivers, have implemented it.

CoaXPress

Benefits

- Digital video, control, GPIO, triggering and power over one cable
- Coax ease of use, flexibility,reliability, and low costs
- Camera Link timing accuracy
- Camera Link speed and higher
- GigE cable length
- Support of legacy coax cables (analog systems)
- Plug and Play

Limitations

- Requires a frame grabber/interface card

Bottom line

No trade off between higher speed and long, flexible cable

As stated, the standard's use of coaxial as its connectivity medium offers many advantages over other media (e.g. twisted pair), in addition to inherent performance capabilities (CoaXPress offers up to 6.25 Gpbs over a single cable and is scalable to an unlimited number of cables). Coaxial cables are already in use in many legacy systems, including analog cameras that need to be upgraded to high-resolution digital cameras. There are hundreds of different coaxial cables to choose from, depending on the application: standard RG59/RG6 type, thin and flexible cable for moving cameras, higher quality cables for extra length or a noisy environment, etc. Considering that up to 50% of a system upgrade cost can be in cabling, the use of coax is a very important advantage (one report indicated that the cost to upgrade a state-of-the-art military aircraft from analog to digital connectivity is $150,000 per plane).

In addition to cost-effectiveness, coaxial cables can be very long (CoaXPress supports transmission of up to 130 meters). Also, field installation of BNC connectors is easy and efficient. Coaxial cables also don't have skew problems that are common with cables that use differential and/or multiple wires.

Power over cable is another important consideration for systems developers. CoaXPress enables power-over-cable capable of most systems' needs (13W per cable), eliminating the need for separate power supplies. This is especially critical in many outdoor applications.

Because GenICam™ (abbreviated for Generic Interface for Cameras) is part of the CoaXPress standard, the specific interface technology is decoupled from the user application programming interface (API). This allows for standard software development independent of the specific physical layer of the interface and the camera.

This standard also includes real-time trigger support, making it well suited for timing critical applications like fast area scan and line scan.

CAMERA LINK HS

Camera Link HS is a standard administered by the AIA (Automated Imaging Association). The interface is based on a single company initiative originally called HS Link, which was designed to overcome the speed limitations of Camera Link. As of May 2012, Camera Link HS is a global standard.

It is not, however “Camera Link 2.0” and is in fact a new standard of its own. While it does offer increased bandwidth, extended transmission distances and reduced cabling complexity over Camera Link, it is not a plug-in replacement for the previous standard.

The most significant improvements in Camera Link HS over Camera Link are in the area of speed performance. It is capable of 3.125 Gbps speeds on two cables, and scaling performance upward requires multiple cables, which can introduce system implementation issues. Camera Link HS also uses the GenICam™ standard communication protocol.

The CX-4 Infiniband cables required are best for stationary applications and introduce reliability issues if bent. The cabling is relatively expensive compared to other alternatives. The needed connectors are expensive, too, and not installable in the field. Alternate cables are possible, including coax.

Camera Link HS is a very capable approach but is expensive to implement and maintain if its full benefits are to be realized. It has also yet to penetrate a broad range of applications, which has narrowed the input that has gone into its evolution. As a result it has limited appeal to many applications outside its primary foothold in high end line scan camera-based machine vision systems.

Benefits
- Standard cables
- Solves speed bottleneck of Camera Link

Limitations
- Not an evolutionary upgrade from Camera Link
- Multiple cables required for full speed
- Infrastructure cost: cable and connectors
- Non-Flexibility of cabling.
- Products not available until 2012

Bottom Line

Solid solution for very niche applications.

10 GIGE VISION

GigE Vision over 10 GigE, often called 10 GigE Vision, is the next generation of the GigE Vision interface standard which was launched in 2006 and is administered by the AIA. It offers higher speed data rate transfer (10 Gbps per single cable and up to 40 Gbps on 4 cables). Like GigE Vision, 10 GigE Vision uses Ethernet-based connection infrastructure and supports long cable lengths. Real-time triggering is planned to be included.

On the surface 10 GigE seems to solve the limitations in speed and triggering that are present with GigE Vision, but power consumption and cost increases are introduced. The power requirement for 10 GigE Vision is very high, up to 6 or 7 Watts. The cost benefits of GigE Vision are gone in that expensive, high-end server components are the backbone of the interface. Frame grabbers are also always required.

The performance capabilities of 10 GigE are clear but because of cost and implementation issues it is not as clear the overall value it offers as a practical solution to many image systems.

GiGE VISION

Benefits
- High-speed data rates
- Uses existing Ethernet infrastructure
- Long cable lengths

Limitations
- High power consumption (6 or 7 W)
- Complex and expensive implementation
- Quality/reliability of cabling.
- Requires expensive server grade components for implementation
- Frame Grabber required for full performance

Bottom Line

Higher performance than GigE Vision at higher costs and power

USB3 VISION

The USB3 Vision interface is based on the standard USB 3.0 interface and uses USB 3.0 ports that will soon be standard on most PCs (with Windows 7 service pack and Windows 8 native support expected soon). The standard was released in January 2013. This means that products that officially comply with the standard will not be available until later this year.

USB3 Vision offers a maximum bandwidth of 5 GB/s. Power and data are transmitted over the same cable and it uses the GenICam™ generic programming interface.

As with USB 2.0, the maximum cable length is relatively short. The official specification is 3m, although it is possible to operate up to around 10m with special cables. While USB3 Vision is 10 times faster than USB 2.0, it is only slightly faster than Camera Link Base and does not enable full frame rates of latest generation sensors.

There isn't a USB hub available with more than six ports on it, so USB doesn't scale to those high camera-count applications as easily as GigE Vision. While no frame grabber is required, a high end CPU may be necessary depending upon the amount of processing.

USB3 VISION

Benefits
- Standard connectors
- No frame grabber required
- 10x faster than USB 2.0

Limitations
- Cable length is very short
- Speed is not much faster than Camera Link base
- Need a powerful CPU to handle data and image processing

Bottom Line

USB3 Vision will take some of the market share from Camera Link at the lower end or provide a step forward for FireWire camera users

SUMMARY

The diverse requirements of a modern imaging system require a multi-faceted approach to connectivity and interfaces. While performance is critical and will always be at the top of the list for high-end applications, it is also necessary to evaluate other needs in parallel, such as connection distance, ease and cost of implementation, power supply, timing and long-term vendor support.

Camera Link HS and 10 GigE Vision both overcome the speed limitations of previous generation interfaces and can be good options when either very long cable lengths or very fast speeds are not required. USB3 Vision does not overcome the speed limitations or cable lengths limitations of Camera Link. Only CoaXPress eliminates all of the inadequacies of the previous generation. It has the very high speed performance with a physical connection medium that addresses the complete range of requirements for the broadest variety of systems. It allows the use of longer, more flexible, and easier to maintain cables, while delivering higher speeds in a solution that is plug-and-play with existing infrastructure.

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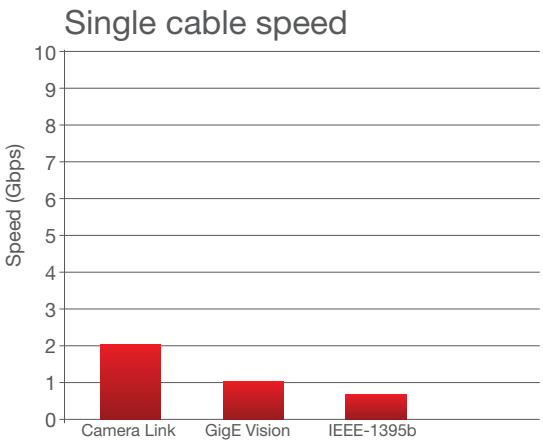
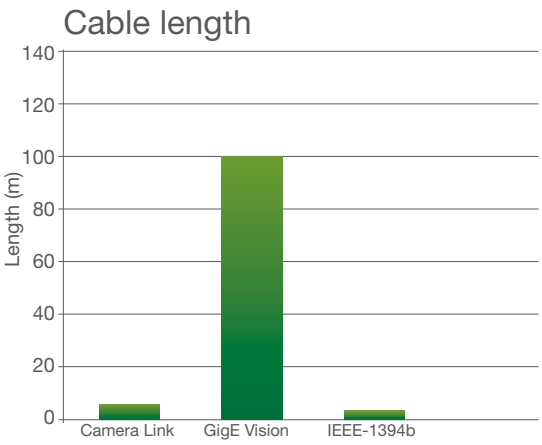
APPENDIX

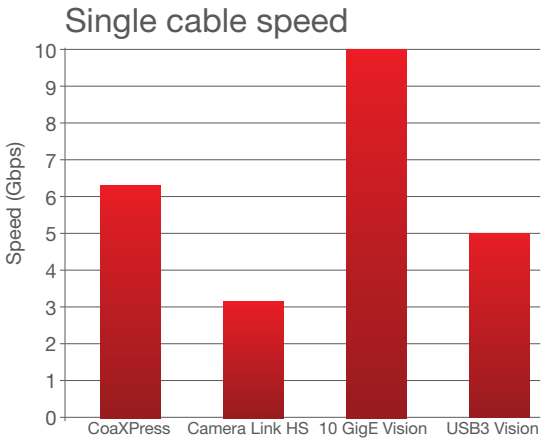
TECHNICAL COMPARISON OF ORIGINAL STANDARDS

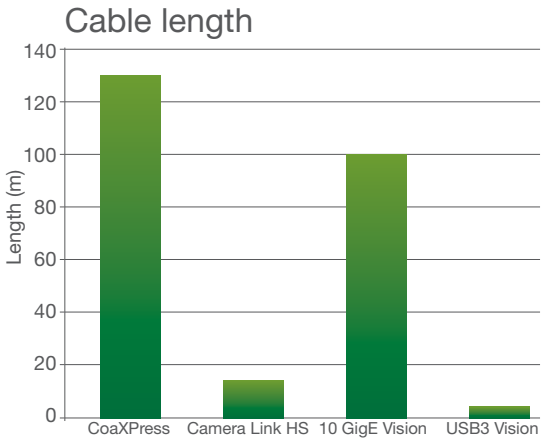




	Camera Link	GigE Vision	IEEE-1394b
Single Speed	2 Gbps (Base, 1 cable)	1 Gbps	768 Mbps (S800)
Maximum Speed	6 Gbps (Full, 2 cables)	2 Gbps (2 cables)	1.6 Gbps (S1600 - 2 cables)
Link Cost	Medium	Medium/High	Low
Complexity	Low	High	Low
Cabling	Custom multi-core	Cat-6	Complex, mass produced
Maximum Length	10m / 7m	100m	4.5m
Data Integrity	None	CRC/Resend	CRC
Real Time Trigger	Yes	No / Future	No
Power over Cable	PoCL: 4W	PoE: 13W PoE+: 25W	45W

TECHNICAL COMPARISON OF NEXT GENERATION STANDARDS





	CoaXPress	Camera Link HS	10 GigE Vision	USB3 Vision
Single Speed	1.25 Gbps - 6.25 Gbps	3.125 Gbps	10 Gbps (future)	5 Gbps
Maximum Speed	N x 6.25 Gbps (N cables)	2N x 3.125 Gbp (N cables)	40 Gbps (4 cables)	5 Gbps
Link Cost	Medium	Medium	High	Low
Complexity	Medium	Medium	High	Low
Cabling	Coax	CX-4	Cat-6, Cat-6a, Cat-7	Complex, mass produced
Maximum Length	130m / 40m	15m	37m, 55m, 100m	3m (greater with extender)
Data Integrity	CRC	CRC/Resend	CRC/Resend	CRC
Real Time Trigger	Yes	Yes	Planned	No
Power over Cable	13W per cable	Planned	PoE: 13W PoE+: 25W	4.5W
Standardization Status	Global standard	Global standard	Global standard	Global standard
Available Standard Products	Yes	No	Some	Some

ABOUT ADIMEC

Adimec specializes in the development and manufacturing of high-performance cameras that meet the application-specific requirements of key market segments, including machine vision, medical imaging, and outdoor imaging. Founded in 1992, the company partners with major OEMs around the world to facilitate the creation of industry-leading cameras. The unique Adimec True Accurate Imaging® technology provides new levels of precision and accuracy to vision systems. Its diverse line of camera products meet a wide range of performance, size, cost, interface and application requirements. Adimec has offices around the world focused on creating customer value and satisfaction through local, personalized support.

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