The Future of Machine Vision

Tackling the Demands of High-Speed Digital Imaging with CoaXPress® Technology

In the digital imaging world, standards such as Camera Link®, FireWire® and USB 2.0 have admirably served their intended purpose, but machine vision has changed dramatically since they were developed. While they all remain serviceable for some systems, they have reached the end of the road for the most demanding applications. Consequently, GigE Vision®, USB3 Vision™ and CoaXPress, are competing to take their place. Each one has its strengths and weaknesses but it is CoaXPress that will be the "likely winner", as it has the ability to meet today's most stringent requirements—all at lower cost per bit and with greater flexibility than the alternatives.

To defend this admittedly bold statement, it helps to start with a discussion of how the potential successors to Camera Link, USB 2.0 and FireWire are utilized and the unique demands placed on any potential vision system. A good place to start is the ever-increasing need for faster and higher manufacturing throughput in factories. The vision inspection system has previously been the limitation on factory output. In order to achieve higher throughput, vision systems must capture very-high-resolution (uncompressed) images much faster while processing at a much greater speed.

In addition, image processing systems must be able to process a moving or still image and make a go/no-go decision within milliseconds of image capture. Advancements in Complementary Metal-Oxide Semiconductor (CMOS) image sensors are occurring rapidly and these devices are now capable of much higher sensitivity and speed, dynamic range, and resolution. Image sensors which support 4K resolution are becoming common. In fact, at least one manufacturer is producing sensors with a resolution up to 250 megapixels. Consequently, the communications bus linking the camera to its processing resources must have significantly greater bandwidth and throughput, so Camera Link, USB 2.0 and FireWire simply won't be fast enough.

These requirements aren't limited to only traditional machine vision applications such as manufacturing and production either. For example, traffic and license plate monitoring and autonomous vehicles will require cameras that can produce extraordinary detail and color accuracy. Additional uses are medical imaging and telesurgery systems, which demand precise imaging with virtually no latency. Other challenging applications include video surveillance, aircraft infotainment,

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and high-speed board-to-board communications, as well as defense and aerospace systems.

All of these applications will push the boundaries further than ever before. To meet their requirements, higher bandwidths throughout the signal path up to 1200 megabytes per second (MByte/s) will initially be needed with gradually increasing data rates in the future. Systems that require longer cable runs must be able handle these higher speeds with the least expensive cable and connector solutions as well.

The number of manufacturers of camera and frame-grabber equipment adopting CoaXPress continues to grow, as it offers them the easiest way to transition to high-speed digital imaging while minimizing deployment costs with speeds four times faster and ranges 10 times longer than competing solutions.

To be truly effective, a communications bus must combine simplicity (ideally plug-and-play), the capability for customization, the lowest possible cost per bit, as well as the ability to scale in performance with little or no additional hardware. Bearing all of this in mind, examining each candidate standard demonstrates its viability in these environments.

Name	Data Rate (MByte/s)	Number of Cables Required	Maximum Distance	Cable Type
Camera® Link				
Base	255	1	10m	Proprietary
Medium	510	2	10m	Proprietary
Full	680	2	5m	Proprietary
80 Bit	850	2	4m	Proprietary
GigE Vision®				
Gigabit Ethernet	115	1	100m	Off the Shelf Cat 5/6
USB3 Vision®				
USB 3.0	400	1	3m	Off the Shelf USB
CoaXPress®				
CXP-1	120	1	140m	Off the Shelf Coax
CXP-2	240	1	110m	Off the Shelf Coax
CXP-3	300	1	100m	Off the Shelf Coax
CXP-5	480	1	60m	Off the Shelf Coax
CXP-6	600	1	40m	Off the Shelf Coax
2X CXP-6	1200	2	40m	Off the Shelf Coax
4X CXP-6	2400	4	40m	Off the Shelf Coax

Table 1 – Next-Generation Machine Vision Bus Standards Compared

Camera Link

Camera Link is the mature standard; it is widely used, but requires bulky and expensive cables with limited cable lengths in the 4–10m range. Camera Link delivers data rates of 255 MByte/s (Base) to 850 MByte/s (80 bit), and some recent products support GenICam™. Connectors cannot be installed in the field, which is a major issue in some environments.

GigE Vision

GigE Vision delivers data rates up to 115 MByte/s using Cat 5 or Cat 6 cable. As it rides on the back of the ubiquitous Ethernet—which is in millions of applications worldwide—it can be part of an existing network. It supports cable runs up to 100m and multi-camera applications, and it enables triggering.

As in all image capture applications, uncompressed image files represent the highest possible resolution but are far greater in size than typical files. Because systems based on GigE Vision require that an image be compressed before sending it and later decompressed, this adds latency that is intolerable in some applications. GigE Vision is also capable of sending uncompressed data; however, since it is only 115 MByte/s in bandwidth, this presents a challenge.

USB3 Vision

USB3 Vision uses the USB 3.0 standard and has the advantage of universal use in many applications. It does not require a frame grabber card and uses the GenICam programming interface. However, the lack of a frame grabber requires higher CPU usage. At 400 MByte/s, its highest data rate is not much greater than that of base Camera Link, so full support for some current and probably all next-generation sensors is unlikely. As with all USB variants, cable lengths are extremely short—about 3m.

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CoaXPress

One of the newer machine vision standards in this mix, CoaXPress, has the advantage of being designed from its inception to be a successor to Camera Link by addressing all of its shortcomings, which it has achieved. For example, it is the only one of these four options that allows video, camera control for triggering, and up to 13W of power to be delivered via a single, off-the-shelf 75Ω coaxial cable up to 100m with standard BNC or DIN1.0/2.3 connectors. It is an asymmetric, high-speed, point-to-point open serial communication standard that is royalty-free and supports GenICam, with a roadmap that extends to 1200 MByte/s over a single cable.

There is a misconception that CoaXPress can only be used in high-end applications. For lower end applications, CoaXPress sends uncompressed files, which results in near zero latency. That may not be necessary in systems where the bandwidth requirement is less than 115 MByte/s, cable distance is less than 150m and no power over cable is required. In this case CoaXPress may not be needed. Even though coax cable is inexpensive, its shielding makes it more resistant to EMI than other types of cable and enables automatic cable-loss equalization to increase achievable distance. In addition, BNC and DIN1.0/2.3 connectors are easily field-installable. The maximum data rate over a single cable is 600 MByte/s, and scalability is essentially infinite, limited only by the number of cables that can be accommodated. For example, the maximum range can still be maintained with a data rate to 2400 MByte/s when four cables are used. When simultaneously using additional cables for up to six lanes (see Table 2) a downlink speed of up to 3600 MByte/s is attainable over a distance of 40m with RG6 coaxial cable.

Configuration	Data Rate (MByte/s)	Maximum Range RG-6 (m)
CXP-1	120	140
CXP-2	240	110
CXP-3	300	100
CXP-5	480	60
CXP-6	600	40
4x CXP-6	2400	40
6x CXP-6	3600	40

Table 2 - CoaXPress® Configurations

The use of coax has other benefits as well. For example, it is still used in many older analog systems, making upgrades to higher-resolution digital cameras far easier and less expensive than the alternatives. In addition, there are hundreds of different variants of 75Ω cable designed to accommodate abuse, extensive flexing, resistance to chemicals and other contaminants, and other environmental factors. These cables also don't suffer from skew that can be a factor with differential or multiple wires.

Although CoaXPress is designed to meet future imaging challenges, its scalability works both ways, making it usable in a vast number of applications other than those considered to be "high end". When the highest performance is not required, CoaXPress systems can be built using less expensive components. This is just one of the reasons why the standard is gaining popularity in a broad spectrum of applications and markets.

Three of the contenders to become the "gold standard" for next-generation machine vision—GigE Vision, USB3 Vision, and CoaXPress—have attributes that make them appealing in certain circumstances. However, for the majority of applications, CoaXPress has the broadest appeal. It was created from its inception to not only perform all of the functions that gave Camera Link its near-universal acceptance but also eliminates its weaknesses, while providing a cost-effective roadmap for satisfying tomorrow's machine vision demands. As a result, of the competing standards, 600 MByte/s CoaXPress offers the lowest cost, highest performance, and least power consumption.

An Enthusiastic Response

Active Silicon and Adimec are two of the key companies driving the development of the standard that became CoaXPress, which was officially launched in November 2009. "We were well aware that Camera Link was running out of bandwidth, and knew of the considerable benefits of coax cable from the SDI broadcast standards," said Chris Beynon, Active Silicon's chief technology officer. "So a high-speed, coax-based imaging

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standard seemed a great solution for the industry. Now seven years later, that initial optimism has been proved justified, with CoaXPress being the dominant standard for very-high-speed imaging into computers."

This opinion was seconded by Dr. Joost van Kuijk, CEO/CMO of Adimec. "We anticipated a need for industrial vision cameras with increased data rates based on the capabilities of CMOS image sensors and the way companies wanted to exploit them. This is why we adopted CoaXPress early on," said van Kuijk. "We also took advantage of CoaXPress being a completely new interface standard to introduce features that would make integration and adoption simpler, such as using longer, flexible cables, that also handle power and control over a single cable."

Manufacturers of frame grabbers have seen the benefits as they integrate CoaXPress into their product lines. "For our frame grabbers, the megabyte-per-second cost has dropped significantly," said Donal Waide, director of sales at Bitflow. "On average, the cost is about one third of moving data on Camera Link, and we've seen an enthusiastic response from customers who compare costs between Camera Link and CoaXPress cameras that are sometimes twice and even four times faster."

"The adoption of CoaXPress allows Matrox Imaging to offer leading-edge image capture boards with technological features and benefits previously unavailable with existing camera interface standards," said Michael Chee, product manager at Matrox. "As a result, users have better tools to develop a high-performance, cost-effective imaging applications, and with additional advances from Microchip, Matrox Imaging will be able to deliver further innovative image capture solutions to the industry."

Optimizing CoaXPress Performance

As noted earlier, equalization technology is a key determinant of the distance a CoaXPress cable can achieve while maintaining a given data rate. To optimize this parameter, Microchip's 600 MByte/s CoaXPress chipset uses a proprietary auto-adaptive equalization algorithm that overcomes the degradation of digital signals from cable attenuation. The equalizer estimates the frequency-dependent losses introduced by the cable and compensates for them (see Figure 1).

The chipset includes two devices in QFN-packages: the **EQCO62T20** transmitter and the **EQCO62R20** receiver. These devices support cable runs up to 40m at 600 MByte/s with a very low power consumption of 140 mW from a single 1.2-VDC supply. A lower-speed, lower-cost version of the chipset is also available, comprised of the **EQCO31T20** and **EQCO31R20**, that can operate at up to 100m at 300 MByte/s. Both chipsets can be used as repeaters to achieve multiples of these distances. Camera control is managed through a full-duplex 20-Mbps uplink channel on the coax cable. The transmitter ICs are integrated in the camera and the receivers are integrated in the frame grabber or in the system head end to provide bidirectional signaling. Support for the current products includes a receiver (host) evaluation board and transmitter (camera) evaluation board.

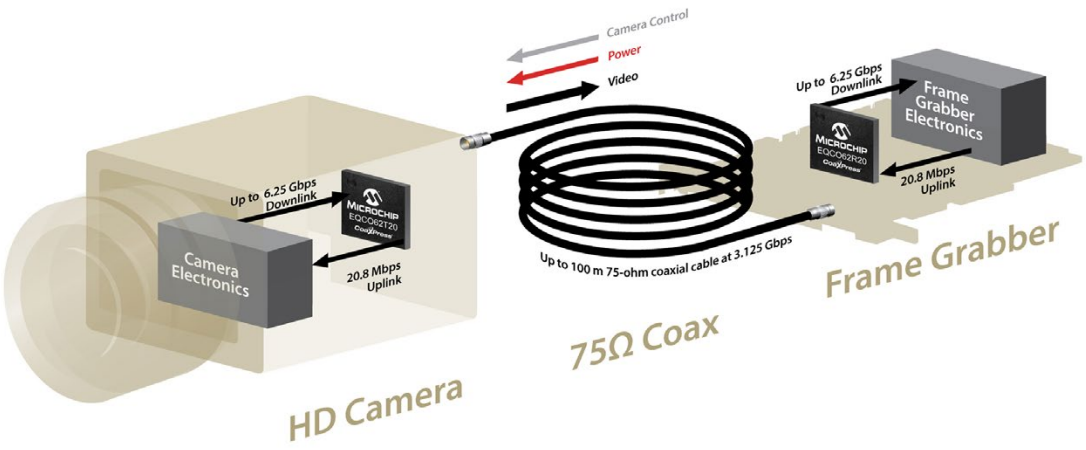

Figure 1 - Typical CoaXPress® Implementation

Our CoaXPress product roadmap includes a second generation product. The CXP-12 will deliver data rates up to 1200 MByte/s downlink, simultaneous uplink speeds up to 42 Mbps, and power over a single coax cable.

Visit our **CoaXPress page** to learn more about this standard and to get more information about our latest. products.

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