

# Long-Haul Camera Connections

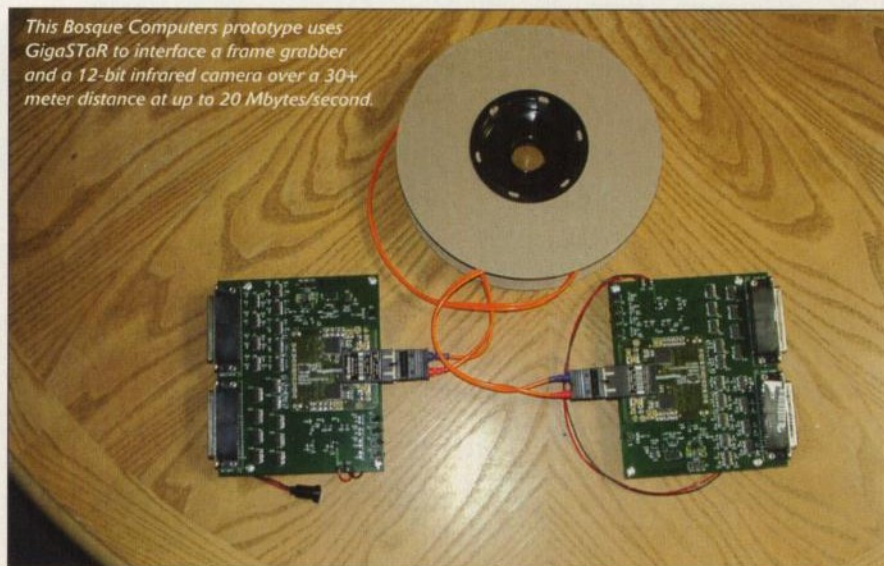
For years, there were no off-the-shelf solutions for carrying camera data over long distances, and ad hoc solutions were clumsy at best. At last, an alternative may be just around the corner...

by Tom Morgan  
and Jack Okabayashi

There are many scientific applications where it isn't practical to place a company's computer system at the same physical location as cameras or other sensor sources, astronomy being an extreme example. In industrial applications such as machine vision, the point of data capture frequently resides in an electrically noisy environment, so it's highly desirable to ship camera output to a remote computer for processing and storage.

There are, in fact, many situations where it's advantageous to move sensor data 100, 200 or 300 feet from the work area to a computer stashed on the other end of a production line. The problem is that there has been no off-the-shelf interface solution for handling the long haul. Standard camera interfaces, both legacy interfaces such as RS-422 and the new Camera Link interface, have severe distance limitations of well below 100 feet.

With that in mind, Bosque Computers is working with a new general-purpose digital interface from Inova Semiconductors, Inc., called GigaSTaR, in



order to build systems capable of transmitting camera outputs over distances of 500 feet and beyond.

The Bosque digital video recorder is a 6-slot PCI system with 100 BaseT Ethernet, a frame grabber card, timing card, display card and RAID controller card, with a vacant slot for other off-the-shelf or custom cards customers might wish to add. The standard system also includes between 60 and 140 Gbytes or so of mass storage and a high-capacity tape backup. It's capable of capturing up to 500 frames/s of uncompressed data at 60 Mbytes/s, with custom versions capable of operating considerably faster. Although compressing sensor data can greatly minimize the transmission and storage burden on a system, uncompressed data provides the greatest fidelity and the best basis for subsequent image processing.

## LOOKING FOR ALTERNATIVES

Before settling on GigaSTaR, Bosque made an extensive investigation into transmission alternatives for its remote data recorder but discovered a lack of elegant interface solutions for its needs. Of specific

concern among the interfaces between cameras and frame grabbers were issues of cable length, cable size and drive capability.

Although the Camera Link interface has gone a long way towards providing a viable interface standard for cameras, it is far from pervasive, and the great variability in non-standard camera types will continue to support a diversity of interfaces in the market. Camera Link is a very flexible interconnect—supporting a range of clock rates and carrying 8, 12, 16 or 24 bits of data on a single channel in what's known as its "base" configuration. It's also quite scalable, offering a two-channel, 48-bit mode known as the "medium" configuration and a 3-channel, 64-bit mode known as the "full" configuration. At a 66 MHz clock rate, the base configuration can provide transfer rates up to about 1.6 Gbits/s on a single cable and connector. The medium and full configurations each need two cables and connectors.

For handling systems with multiple cameras or multi-tap cameras, however, Camera Link can quickly run out of bits. For a multi-tap camera with 4 taps at 4 bits each, the result for a two-wire differ-

ential connection is over 30 wire connections just for data, without taking syncs, controls and other housekeeping items into account. That's beyond the capability of a Camera Link base configuration. For a camera with 12 taps at 12 bits each, the result is 288 wires minimum, well beyond Camera Link's range.

Having to use multiple channels for a camera-to-frame-grabber interface increases the physical size of the cabling and connector(s). The trend in cameras is clearly towards miniaturization, however, and it's becoming increasingly difficult to fit I/O connectors into the available camera real estate. Extra channels have a serious impact on cable size and cost to the point that copper begins to lose its cost advantage over optical fiber. Moreover, even when cost and connector real estate are not necessarily major issues, the physical inflexibility of a big cable can create problems for placing and routing the interconnect where it needs to go.

### GOING THE DISTANCE

A Camera Link channel takes up to 28 TTL-level signals (24 data, 4 timing) and splits them among five sets of differential twisted-wire pairs: four pairs for data and one pair for a clock. Based on the ANSI/TIA/EIA-644 LVDS (Low-Voltage Differential Signaling) standard, it is a pseu-

other perturbations threatening to corrupt data beyond a short haul.

The separate clock line of Camera Link also introduces limitations, as it does with any pseudo-serial interface, with the clock signal degrading over distance. GigaStAR avoids this problem by relying on an embedded clock. The upshot is that while Camera Link provides high noise immunity and signal integrity, it does so only at distances up to about 10 meters. At that point, additional hardware—signal repeaters or fiber-optic converters—must be added to a system to extend the range of a Camera Link connection.

The downside of repeaters and converters is that they increase overall expense and require extra hardware to be added to the system. The fiber-optic converters add extra complexity to the system in terms of requiring a double conversion, from Camera Link to fiber optic and back again. The repeaters and converters are also typically limited in the bit width of the Camera Link configurations they can handle and, of course, real-time delivery of data is severely undercut. The degradation of the clock signal multiplies with each repeater, severely limiting the ultimate distance of a pseudo-serial link.

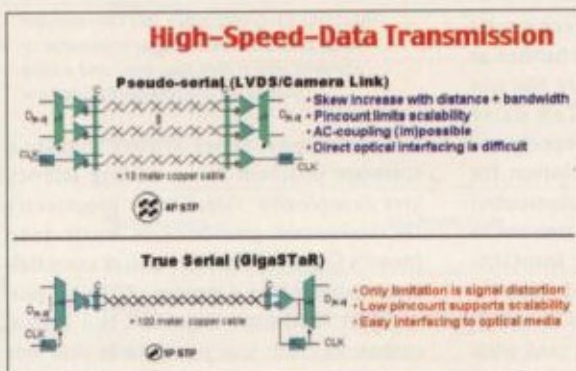
In contrast to Camera Link, GigaStAR is designed from the ground up as a long-

haul interconnect, able to handle 35-meter links over standard CAT 7 flexible shielded twisted-pair cabling, 50 meters with a solid CAT 7 and up to 100 meters with W.L. Gore and Associates' special "EyeOpenPlus" STP-cable. It is also medium agnostic and can be deployed on fiber optic cable to achieve distances to 500 meters using multimode fiber and even

farther with single-mode fiber.

In the current generation of Inova's GigaStAR transmitters and receivers, the interconnect accepts up to 36 bits of data on a single channel and, running at 33 MHz, provides a sustained 1.18 Gbit/s transfer rate on a single twisted pair. A second generation of transmitters and receivers, the GigaStAR Digital Display Link with a dedicated multimedia-interface, expected to be announced soon, is doubling that rate.

As with Camera Link, multiple GigaStAR channels can be operated in parallel to boost channel count and/or



*Both serial and pseudo-serial interfaces can supply high speeds, but the distance capabilities of the latter tap out at about 10 meters.*

do-serial interface, not a true serial interface like GigaStAR, which requires just a single twisted pair. The result is a vast difference in distance capabilities.

Pseudo-serial interconnects offer a clear bandwidth and distance advantage over parallel interconnects, which quickly run into crosstalk and other signal integrity problems as cable length grows. But the pseudo-serial approach has its own signal integrity issues, with signal skew, distortions, reflections and

# A Call for Modular Interfacing

Line-scan cameras, area-scan cameras, single and multitap cameras, small- and large-format cameras, slow and fast cameras, monochrome and color cameras, infrared cameras—there's no end to the diversity of industrial cameras in use today and more than a few different interfaces. No single interface addresses all the different connections out there today. And it seems that every time a camera vendor comes out with a new high-end model, it contains some special interface or data format, with total disregard for the interface dilemma.

Bosque is currently considering different ways of providing a GigaSTAR interface for those cameras that will ultimately be hooked into its production digital video recorder system, in search of the most cost-efficient approach. Ultimately, we would hope that camera makers and frame grabber makers integrate GigaSTAR directly into their products. This would avoid the need to perform a double conversion in the interconnect—such as from Camera Link to GigaSTAR and back again. GigaSTAR is flexible enough, however, to be used as an extension medium for LVDS/Camera Link and other digital interfaces. In the short term, we are making demo converter boards that interface whatever comes off a camera to a small GigaSTAR module on a frame grabber.

Perhaps a small terminal box at the end of the link would be appropriate for interfacing a camera to Bosque's system. Or perhaps the best route is to provide just raw cable and let the customer put his own connector on. Most industrial cameras have internal TTL-level outputs, and it would make an integrator's job much easier to interface directly to them, rather than having to provide special terminations for different cameras. It's not the wiring of cameras but their connectors that are so diverse: one vendor's connector has 44 pins, while another's has 62, still another's has 68 and so on.

But perhaps the best approach to simplifying making connections between cameras and frame grabbers would be a modular one. This concept has, in fact, gained some advocates, though it's not as yet robust or widespread. A few camera makers are starting to offer cameras with different output modules for different interfaces. And a few frame grabbers likewise accept different daughterboards for different camera interfaces. There will always be "special" cameras out there, and a modular approach would go a long way towards coping with that headache.

—Tom Morgan

aggregate data rate. One hallmark of GigaSTAR is EMI immunity so that less expensive copper cabling can be used in environments that previously required optical fiber, making it attractive for cost-sensitive applications such as machine vision.

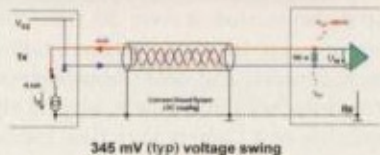
## SUBTLE ADVANTAGES

GigaSTAR also has a few more subtle advantages over other camera interconnects. While Camera Link is DC-coupled, GigaSTAR is AC-coupled, which enables it to daisy-chain a large number of cameras using repeaters without introducing concerns with ground bounce and other power perturbations. The fact that a GigaSTAR repeater provides a completed regenerated signal, rather than the repeated/re-amplified signal of LVDS/Camera Link, effectively eliminates any jitter arising from the cable and signal sources. As such, an almost infinite number of repeaters can be daisy-chained without deteriorating the signal's quality.

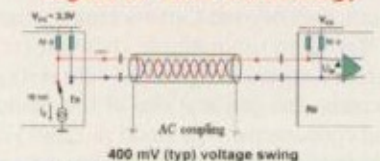
Camera Link is also constrained in the number of repeaters that can be used to incorporate multiple cameras onto one channel because its separate clock signal degrades further at every step of the chain. Bosque has not implemented such a GigaSTAR daisy chain of cameras, but such a configuration would be an excellent solution for security systems. Not yet implemented for cameras, GigaSTAR daisy chains are in widespread use for passenger infotainment systems in public transportation applications where up to 30 LCD monitors are linked to one graphic card with no quality degradation from the first one in the chain to the last.

Further, the National Semiconductor ChannelLink devices commonly used for Camera Link have a 20 MHz minimum clock requirement, which introduces complexities when slower cameras are needed. Workarounds include adding null data to the data stream or moving data in on the strobe instead of the clock and then out on a surrogate clock. GigaSTAR, in contrast, has no such requirement: it automatically sends header pattern information to the receiver and maintains link synchronization while the user applies synchronous/

## Low Voltage Differential Signaling (LVDS)



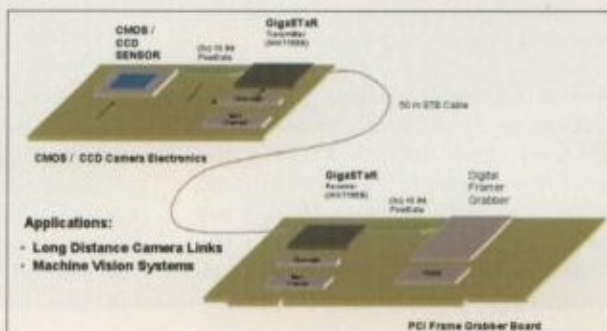
## GigaSTAR® Link Technology



Both LVDS and GigaSTAR can be daisy-chained through repeaters, but DC coupling and other factors severely limit this capability for LVDS.

asynchronous data at a data rate from zero up to the maximum 1.118 Gbits/s.

Bosque also investigated using network technology for remote data transmission. Fibre Channel, for example, could have easily handled the required data rates,



GigaSTAR integrates easily into cameras and frame grabbers with a single transmitter or receiver, plus a little glue logic and a back channel for housekeeping functions.

but such approaches always require a software protocol layer, adding latency and complexity. GigaSTAR's proprietary DC-balanced protocol is built into Inova's GigaSTAR devices and is essentially transparent to a system. With its protocol in hardware, GigaSTAR is a logical extension cord: you put data in one side and it squirts out the other end. ♦

(Photos: Bosque Computers and Inova Semiconductors)

Tom Morgan founded Bosque Computers (Albuquerque, NM) ten years ago and serves as its Chief Engineer. Bosque specializes in equipment that provides non-compressed video recording from non-standard camera sources, primarily for the scientific community. Jack Okabayashi is the North American Sales and Marketing Director for Inova Semiconductors, Inc. (Phoenix, AZ). To reach the authors, contact David Lieberman by phone at (978) 597-2564 or via e-mail at davidlieberm@earthlink.net.