

*"In this whitepaper we explore the technical reasons why certain camera interfaces are not appropriate for certain types of applications. Manufacturers of cameras with a specific interface (e.g., Firewire, CameraLink, USB2.0) would have you believe otherwise. What you might end up with is analogous to trying to hammer a square peg into a round hole!"*

# *GigE Cameras*

## *Myths & Facts*



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## **GigE: Facts & Myth -- An Unbiased White Paper**

Not every camera interface is correct for a specific application. Unfortunately, manufacturers of cameras with a specific interface (i.e. firewire, or camera link, etc.) would have you believe otherwise.

What you wind up with is analogous to trying to hammer a square peg into a round hole.

At 1stVision, we have the same sensors available in all the different camera interfaces; analog, camera link, firewire, USB2., and GigE.

From that perspective, we are writing this white paper on GigE interfaces.

### **Background**

Ethernet has been with us a long time. <http://en.wikipedia.org/wiki/Ethernet> What started out in computer networks at 3Mb/S then grew to 10 Base T, then 100 Base T, and now 1000 Base T or GigE, 1000Mbps/S.

The principle of the Ethernet is based on collision detect retry. Multiple devices are on a single wire. If 2 devices send information at the same time, there is a collision. Both try again at a random interval with the hope that the same interval isn't chosen by both. In this way, the receiver will always get their data, though when they get it cannot be determined exactly.

It wasn't until Gigabit Ethernet interfaces became available to the general public did GigE cameras become a reality.

The questions are: what are the pros and cons of GigE vs. other interfaces, and how do the GigE interfaces differ from manufacturer to manufacturer? We will try to answer these questions by providing answers to questions that we at 1stVision are asked every day!

Q1. Why didn't the camera industry come out with 100 Base T (fast Ethernet) interfaces?

A1. Myth. They did. If you are reading this white paper, chances are you are using video to solve some application. Most of those applications have at *least* VGA resolutions running at least at 30 frames per second (fps). This is a data rate of approximately, 10 Mbytes/S (MB/s). This is also assuming a pixel is 8 bits. If its 10 or 12 bits/pixel, you need to double the data rate.

10 MB/s = 100 Mb/s, so the 100 Base T has just enough capacity to barely run VGA cameras. Of course, with Ethernet, you normally don't get the entire capacity of the transport (try copying a large file to another computer when nothing else is going on, and you will see that normally you get about 50% at the very, very best), so vision vendors did not consider Ethernet for non compressed video transmission. (For most image processing applications in our market, such as determining what the bar code says, you need non compressed video, or lossless compressed video. Lossless compression typically gives you about a 25% reduction in data. Lossy algorithms can compress video by a factor of 10! If you use a lossy compression algorithm to gain size reduction, you might lose the information you need to determine the answer. )

For applications where compression is acceptable, you can get 100 Base T or even wireless 802.11g cameras. These cameras are available in the security markets.

Q2. Can I just plug a GigE camera into my Ethernet card? Will I see video?

A2. Myth. Physically, the connector on the GigE cameras is a standard RJ45 Ethernet connector, so you can plug the camera in. Then you must load a driver for the camera. If your application SW is GigEvision compliant (see Q9 on GigEvision), then you will see video. If not, you must use SW from the vendor supplying the camera. If the camera vendor's driver software has a DirectX component, then

any application SW that is DirectX compatible will work as well. If you do not have camera specific SW on the computer, you will NOT see video!

Q3. We have been told that there is PoE (power over ethernet).

A3. Fact. Most of the current cameras available right now do NOT support Power over Ethernet (POE) and therefore will require a separate power supply. Most of the vendors use a standard 12 pin Hirose connector with power and ground on pins 2,1. This ensures that any 12 pin Hirose power supply will work. Note, older 12 pin Hirose power supplies also supplied power on pins 11/12. Do NOT use this type of supply, as most GigE cameras have used those pins for other signals (typically I/O).

The next round of GigE cameras, showing up later this year and next year will probably have POE on many models. POE is at 48V, most cameras need a variety of voltages at 3.3,5, and 12 V , so a fair amount of power conversion circuitry is needed.

Note, most Ethernet cards do NOT supply power, so you would have to drive a POE camera via a powered switch or hub. Also, POE has limited power. So cameras with a large power draw will not be able to use POE.

Q4. I have been told that I need a high performance driver to use GigE. What is a filter driver? What is a high performance driver that I hear certain companies talk about?

A4. Myth. Processing Ethernet packets requires a fair amount of CPU muscle. Ethernet data being sent does not have to be in order, and it might be coming from various sources, so it might not arrive at the destination in order. To address this issue, not only is the data sent, but information about the data is sent. (How big is the file, where it is coming from, what file the data belongs to, etc.) So on the receiving end, a processor takes this information and puts the data back together so it looks like what was on the sending side. For regular networking data, the OS normally has SW to do this for the user. Network card drivers, protocol stacks, etc., all exist in Windows or Linux, etc.

There are some differences between regular network data, and streaming uncompressed video data. Regular Internet data or network data are usually transferring small files. A web page is maybe 10KB of data. The document I am writing here is small, and I only save to the network every 10 minutes. Streaming video data, as discussed above is coming in at very high speed, continuously.

If we were to ask the regular OS SW to decode streaming video data, it would get overwhelmed by it. The driver wasn't built for this! Tests showed that on a 2.5GHz P4 processor, 50+% of the processor is used to decode monochrome VGA 30 fps video. So even though we have 100 MB/s of channel capacity in GigE, moving 10MB/s of data used 50% of the processor! Not a very good scenario.

However, as we said, streaming video data is NOT like regular network data, and we can take advantage of that. We know exactly what the data looks like, so we can optimize for this. Also, there are some network cards that have some processing on them that will offload the host CPU of decoding the data. Coupling these together, we get a high performance driver. The network card that is used is the Intel Pro 1000 card. When using the high performance driver, the camera is coupled directly to the Intel card. Using this combination brings the host CPU load down to just a few percent. What we have essentially done is made the network card into a frame grabber! It is a direct connect from the camera to the computer. Realize that you can ONLY use this card now to connect to a GigE camera! If you want to do networking or get on the Internet, you must have a second networking card in your computer. The high performance driver replaces the standard SW for the network card with SW specifically to make the card act like a framegrabber for GigE cameras. It now does not know what to do with networking data.

What happens if you don't have an Intel Pro 1000 card? For instance, no laptops currently use this chipset for their networking. This is where the FILTER driver comes in. It is smart enough to know

about streaming video and it FILTERS out that data from network data. In this situation, you can put the internet data and camera data into a switch, and take the output of the switch and put it into your network card. The filter driver sits on top of this hardware and will accept both camera data and network data. The performance you get from this configuration depends mostly on how well the filter driver was written. For instance, the Dalsa Genie driver was written so well that Dalsa does not even offer a high performance driver. They say their filter driver is within 1 or 2% of the high performance driver, and you can use their driver on any network card! Other manufacturer's say that their filter drivers are about half as efficient as the high performance driver.

Q5. I have been told that Ethernet is non deterministic, and therefore it is no good for vision processing.

A5. Myth. Actually, when we discuss determinism, we also need to discuss latency and repeatability. What we want to know is what happens when we send data from the source to the destination. How long will it take to arrive, and will it always arrive in the same amount of time.

With frame grabbers, it always took the data the same exact amount of time to get from the camera to the grabber's memory, with essentially no extra delay. Assuming a DMA mechanism on the grabber, the data showed up in host memory in pretty much the same amount of time every time.

Of all the digital camera interfaces, only 2 of them will mimic the above situation. The first of course is camera link, which involves a frame grabber. The second is firewire, since built into the firewire protocol is an isochronous transfer mechanism. Essentially, firewire has time slots for moving the data. Firewire A guarantees 32 MB/s of data, Firewire B, 64 MB/s. If you are not using 'other' parts of the protocol you can get more bandwidth, but it is not guaranteed!

USB and GigE offer no such protocol. Shake the mouse rapidly while doing a USB transfer, and you will see the data rate vary as the CPU gets overloaded with 1000 interrupts/s!

So how can GigE be used for vision processing? Simply put, you must look at how much data you have, versus the capacity of the bus, versus how critical it is to get the data on time. For example, say you are looking at boxes coming down a line. The data rate of the camera is 22 MB/s, the capacity of GigE is 100 MB/s and you have 4 cameras. In this case, you are using 88 MB/s out of 100MB/s, and the consequence of missing a box is pretty high. I would be a bit leery of being that close to the max capacity. However, if you change this scenario to using 2 cameras, there should be no problem to use this arrangement.

Q6. Many different camera manufacturers have cameras with the same sensors. They say there are no differences between GigE cameras with the same sensors from different companies?

A6. Myth. We have been telling clients for years that if you were to point a variety of manufacturers cameras using the same sensor out the window looking at the landscape on a nice sunny summer day that we don't believe that you would be able to distinguish one picture from another. However, there are a lot of differences in using the cameras, features of the cameras, setting up the cameras, size of the cameras, how they work at the edge of the picture envelope (low/high light, low/high gain, etc.), and with digital cameras, most importantly, the software the cameras have that is needed to actually get pictures from the camera.

Many of the camera manufacturers are using the same components to drive the sensor; they are using the same A/D converter, the same clocks, etc. So for mainstream video, it would be very hard to differentiate. However, when you have a situation that is using the camera at the design edges, then you will see some difference depending upon how skillful the engineers have been in signal routing, electronic noise rejection, etc.

Regarding features, some manufacturers have added both hardware and software that allows for

certain functionality. For example, Dalsa Genie cameras have brought their framegrabber past with them. Large on board memory, LUTs, onboard processing for DeBayering color images, line by line correction, etc. are all part of the camera. (So we don't seem biased, Dalsa is not unique with these features) Whether or not you need this functionality depends upon your application. Also, check the prices. It might be that cameras with extra functionality that you do not need do not cost more, so you might want to consider them anyway, or they might cost more in which case you might not want to pay for functionality you won't use.

Software is a critical component with digital cameras. Unlike the old analog cameras, where all you had to do was plug them into a monitor to see if they were working. Without the software, you get no video from a GigE camera! Software usually comes in a few different parts. You need a driver, you need a setup/viewing program, and you might need a SDK. Most manufacturers allow you to download their SW or their manuals, so you can check out how hard or easy it will be to program.

Q7. I have been told that I can use multiple GigE cameras in my application? If this is true, how do I do this?

A7. Fact. One thing we try to tell all of our clients is that unless absolutely positively necessary, you should never be using a switch with a GigE camera on time critical application! Yes, you can hook up as many GigE cameras as you want in your application. Via a switch(s), you can put as many cameras on the system as necessary. Realize to get the performance you need, you should calculate the output data rate of the camera ( $H \text{ pixels} \times V \text{ pixels} \times \text{fps} \times \# \text{ of bytes}$ ) in MBytes/S. One GigE port can handle 100 MBytes/S. So if you have a card with 2 ports, and you have 2 cameras each outputting 45MBytes/S, no problems. However, if you have a card with 4 PHYS, and 4 of these cameras, you are putting out more data than the card can accept. This is analogous to trying to drink from a firehose! The solution here would be to get another 2 port card, and use 2 2 port cards for the 4 cameras.

Q8. I have heard that I can't get good performance on GigE. What kind of performance can I expect with GigE? How about vs. other interfaces?

A8. Fiction. If you are using a GigE camera connected directly to a GigE network card, we have seen continuous data transfer rates of 90MB/s. This assumes good efficient software from the camera manufacturer, and a fairly high end computer. You will not see this type of performance if you have a switch/router rather than a direct connection. GigE has the highest bandwidth of all standard digital interfaces (Firewire, USB, GigE) except for camera link.

Q9. I have heard that is GigeVision is a specification.

A9. Fact. GigeVision has been ratified by the AIA (see [www.machinevisiononline.org](http://www.machinevisiononline.org)). Both cameras and Software can be Gigevision certified. This specification is a baseline, a least common denominator. Please realize that there might be specific camera functionality that is not currently part of the GigeVision specification, even though the camera is Gigevision certified. (The camera's functionality is a super set of the GigeVision specification).

Also realize a GigeVision camera will not work with all software, but only with GigeVision software. GigeVision software will not work on any gigabit ethernet camera, but only GigeVision cameras. As an example, many camera vendors have ported over existing software from previous generation hardware (maybe frame grabbers, or cameras with other interfaces). This software is specific to the GigeVision camera from that vendor. It is not GigeVision compliant. It will not work with other GigeVision cameras! Many of these vendors also have GigeVision software that is a subset of their entire library. With this software, you can use any GigeVision vendors's camera, but you may not get all specific functionality of that particular camera.

Q10. Can I see the camera over a network? Can I see video over WiFi?

A10. Fact! This depends upon the software from the manufacturer, and how you connect the camera.. For instance, both Dalsa and JAI GigE cameras can be seen over the network if you install the software that comes with them. When you plug in a camera to the network (not directly connected to the computer), if you have it set to get an address via LLA/DHCP, the cameras gets it's IP address from a router that knows all the addresses of the devices on the network. In this manner, if you are sitting on any computer on the network, and it has the camera SW package installed (this usually has a device driver, a network package, a viewer, and sometimes a SDK), the camera's network package will search out any cameras on the network. You can then use the camera from any computer, even though the camera is connected to a switch or a router. The computer you are on can be connected to the network via a wire or WiFi! However, if the camera is connected directly to a computer, it is getting its network address from that computer, and other computers on the network do not know about it. You will NOT be able to use this camera from another computer with this configuration.

