

## Gigabit Ethernet and Line Scan Cameras - do they really fit?

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### The market for line scan cameras

To push line scan capabilities to a new level, Gigabit Ethernet (GigE) and line scan cameras have recently built a successful alliance. Despite this, a majority of applications on a unit-wise basis are still running older 1k and 2k line scan cameras. The line scan market has been and is now driven by extreme price pressure on these older cameras. Many of the designs have been on the market for five years or more, and they have been completely optimized in terms of camera capability and cost expectations.

Basler's Gigabit Ethernet based line scan cameras are total redesigns that use the newest components available and eliminate the typical bugs and restrictions found on older cameras. For example, our new runner line scan cameras have remarkably better noise characteristics compared even to recent Basler Camera Link cameras, along with a higher image data depth of 12 bits and improved camera features.

All in all, Basler sees an advantage in GigE line scan cameras because their use can result in an overall reduction in system cost when compared to Camera Link system layouts. In many cases, customers can see significant savings in terms of a total solution.

### The technical capability of Gigabit Ethernet in line scan applications

Our basic message is that GigE technology can effectively transmit around 100 megabytes of data per second. For cameras with 1k and 2k resolutions, this capacity will let you achieve line rates that are comparable to Camera Link based cameras. For cameras with 4k resolution, line rates for GigE will be slower compared to corresponding Camera Link models.

The following chart shows the theoretical line rate for typical line scan cameras with up to 4k resolution and the achievable line rates with cameras from Basler's runner line scan camera family.

	Theoretical Line Rate with a GigE Interface	Basler GigE Camera Line Rate	Basler GigE Camera Model
1k mono, 8 bit	80 - 100 kHz	56.3 kHz	runner ruL1024-57gm
2k mono, 8 bit	40 - 50 kHz	29.2 kHz	runner ruL2048-30gm
4k mono, 8 bit	20 - 25 kHz	---	Not available
2k color, 16 bit	Up to 20 kHz	9.2 kHz	Runner ruL2098-10gc

This table makes it clear that the GigE interface and line scan sensors are a good fit and can build strong, technically reasonable solutions which compete well with Camera Link.

### System layout gets larger and more flexible

Today's line scan systems normally use a Camera Link or Channel Link interface. Each camera in the system is connected via a Camera Link cable to a frame grabber in a host computer. The frame grabber is used to interpret the incoming data. This layout is typical, and systems that use it face a variety of problems. The 10 meter cable length restriction on Camera Link cables is frequently an obstacle in line scan applications that examine "infinite length materials" that are several meters wide. In these applications, typically a wide paper web, a steel ribbon, or a continuous wooden veneer, the material is inspected by several cameras spaced along a single bar located above the material. Processing of the images captured by the cameras is not normally done directly on the production floor. So cable length is always an issue and transmission of the image data to a remote processing unit is a major challenge.

With Gigabit Ethernet's maximum cable length of 100 meters, image data transmission over long distances is quite easy. In addition, Gigabit Ethernet offers layout possibilities that are a much better fit for wide-span systems. By adding Gigabit Ethernet switches, the system complexity can be greatly reduced and significant cost reductions can often be achieved. Gigabit Ethernet breaks the 10 meter cable length barrier that was set by Camera Link and allows systems to employ remote processing without the need for additional components such as repeaters or converter boxes.

### A system can be simpler and more cost effective by eliminating additional converter boxes

In the past, if an application required long cable distances, the only viable solution was the use of converter boxes. These boxes converted Camera Link signals into Gigabit Ethernet packets. Some customers were willing to design such boxes into their systems because they could eliminate their biggest problem, the need to cover long cable distances. The main drawback of this solution is an increased system price. Converter boxes can add several hundred euros to the cost of a system. In large systems in particular, these additional components were extremely critical because they often turned out to be the biggest cost driver in the image acquisition section of a machine.

In addition to the commercial aspects, a converter box is also technically questionable. The need for converter boxes adds technical complexity to the system and often requires changes to the system's application programs to accommodate the converter boxes. Because most older converter boxes are not totally compliant with the GigE Vision standard, this additional programming often results in a proprietary data transmission solution. That means additional effort is necessary to design-out the box when more cost effective solutions such as cameras with a GigE Vision interface become readily available.

### **The challenges posed by Gigabit Ethernet and line scan can be solved**

Because some well-understood hardware elements are eliminated and because their functionality must be taken over by other system components, the main challenges to be faced when changing from Camera Link to GigE line scan cameras are associated with system setup.

What is changing?

- The frame grabber is replaced with a network adapter card
- Encoder signals are input directly into the camera
- The cables are different and cable lengths can be longer
- The converter box is eliminated
- Programming for image data transmission is based on a new SDK
- The interface is GigE Vision and GenICam compliant

### **No framer grabber required**

As opposed to Camera Link, no frame grabber is required with a Gigabit Ethernet solution. Image transmission to the system's host computer is done via a common Gigabit Ethernet port that is present either directly on the computer's motherboard or a on a network adapter card that has been added to the computer. Generic GigE network cards are commercially available and widely used in consumer networks. Specifically recommended Gigabit Ethernet cards are also available from Intel. These recommended models allow the use of a higher performance device driver and are more reliable in terms of long-term availability.

High end network cards with pre-processing functionality are also available and can be used to easily replace Camera Link frame grabbers on a one-to-one basis. Most frame grabber companies who offer Camera Link grabbers now also offer equivalent products with a Gigabit Ethernet Interface so that no changes to existing processing applications need to be made.

### **Low cost cabling and enhanced cable lengths**

Gigabit Ethernet uses standard Ethernet cables. These cables are known as Category 6 (Cat 6) cables and can be obtained in different shielding classes. Because they are internally and externally protected against interference, Basler recommends using S/STP class cables, the highest off-the-shelf shielding class available. Even with the extra shielding, these cables are still very flexible and allow easy integration into a machine or a vision application.

In accordance with the Gigabit Ethernet standard, GigE cables are available in lengths up to 100 meters. This is a great enhancement in comparison to Camera Link's 10 meter limitation. To ensure tight connections, Basler runner line scan cameras are equipped with screw holes for horizontal, screwable GigE RJ-45 connectors. Naturally, standard RJ-45 connectors without the screw option can also be used.

Overall, GigE cabling offers a great potential for lowering costs. A standard 10 meter Camera Link cable can be priced up to ten times higher than a Cat 6 GigE cable. A user might save 100 euros or more in cabling per camera while gaining flexibility in system design.

### **A converter box is no longer required**

Compared to either Camera Link or a converter box, Gigabit Ethernet simplifies the camera to host computer interface. The frame grabber can be eliminated and a simple Gigabit Ethernet network card does the job. Tasks such as color conversion that have been performed on the frame grabber in the past are now directly embedded in the camera and can be activated via Basler's enhanced pylon API or pylon Viewer. Eliminating the Camera Link frame grabber represents a several hundred euro savings that can be achieved with a GigE Vision solution. And with a direct GigE connection, very expensive "Camera Link to Gigabit Ethernet converter boxes" are history, again saving several hundred euros.

### **Programming with the new SDK**

Basler's pylon driver package seamlessly supports GigE based systems. The pylon SDK enables straightforward integration via extensive documentation and code samples that can often be simply cut and pasted into existing applications. The pylon driver technology developed by Basler has been proven in several thousand camera installations over the last year and has gained a well deserved reputation for low CPU load, robustness, and ease of use. Thanks to pylon's GenICam compliance, customers can make use of any new features added in the future without making changes to their software.

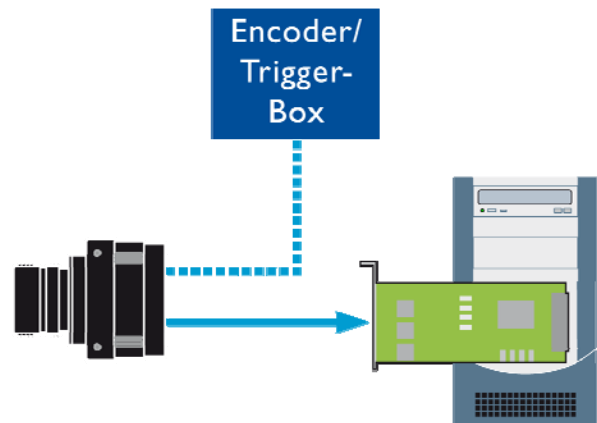
## The GigE Vision standard ensures compatibility, reliability, and robustness

The GigE Vision standard defines the methods used to transmit image data from a GigE camera to a host computer and to transmit control data from a host computer to a GigE camera. GigE Vision has established itself over the last few years as a highly capable industrial interface. During the last 18 months in particular, GigE Vision has been proven in a wide variety of applications and has justified the hype that preceded the availability of the first products in the marketplace. Due to its unique strengths in bandwidth, cable length, and cost, many applications have been moved from analog or Camera link technology to Gigabit Ethernet. Basler has continued its leadership role in GigE Vision based cameras by introducing several Gigabit Ethernet camera families, including the new runner line scan series. After an extremely successful introduction into the area scan market, Gigabit Ethernet has moved into the line scan arena and is playing out its benefits in this highly Camera Link dominated market place.

GigE's success is based on the effort of nearly all of the noteworthy companies in the machine vision industry to define a widely accepted standard for a GigE based interface. This was achieved in 2006 when the GigE Vision standard was established. The GigE Vision standard is a logical implementation built on top of the Gigabit Ethernet physical interface. It is by far the most important element in making Gigabit Ethernet viable in all kinds of vision systems. The main part of the logical implementation defines real-time capability, error handling procedures, and reliable image transfer (no image loss) methods.

### How Does Image Acquisition Work with a GigE line scan camera?

Image acquisition with a Gigabit Ethernet based line scan camera such as the Basler runner is similar to image acquisition with a Camera Link based camera. The camera receives the same type of triggering signals that have typically been used with Camera Link cameras. However, when an encoder is used with a GigE line scan camera, the encoder is directly attached to the camera and configuration must be done via the camera's API. This is a very easy, straightforward task. Once encoder setup is complete, image acquisition can be started. The camera can also be in used free-run mode where it triggers itself and no encoder or other trigger signal is required.



A typical system includes a camera that is driven by an encoder or a trigger box (a custom built box or PCB). The camera is connected with a Cat 6 cable to a network adapter card in a host computer.

### What is different when using Gigabit Ethernet?

As explained above, there are no major differences in triggering image acquisition. The main difference between GigE and Camera Link cameras is the way that data transmission is handled. Camera Link always transmits the data acquired by the camera directly through the Camera Link cable into the PC where a frame grabber stores each acquired line. The frame grabber stitches together a defined number of lines to create an image frame that can be processed.

When using a GigE line scan camera such as the Basler runner, the principle is a bit different. The camera transmits frames only. Each frame includes a number of lines that is defined by the user. The camera stores acquired lines internally until the defined number of lines for a frame has been reached. When a frame is complete, the camera transmits the data for the full frame to the host computer where it can be processed. The typical size of a frame is around 100 lines, but the size can be adjusted by the user according to their needs.

The concept of stitching a frame together inside of the camera rather than in a frame grabber is the main difference between GigE and Camera Link based solutions. In theory, this difference impacts the effective time needed to transfer a line to the host computer as compared to Camera Link. But in practice, the transmission speed of Gigabit Ethernet is more than sufficient. It compares well with Camera Link when you consider that in a Camera Link system the entire image must normally be built line-by-line inside of the frame grabber before image processing can begin.

## The Basler runner Series in Detail

The Basler runner series of line scan cameras was introduced at the VISION show in Stuttgart, Germany in 2007 and entered series production in March 2008. The cameras are direct successors to Basler's successful L100 and L300 series.

### runner 1k monochrome models

Camera Model	ruL1024-19gm	ruL1024-36gm	ruL1024-57gm
Sensor Size	1024 pixels	1024 pixels	1024 pixel
Pixel Size (µm)	10 × 10	10 × 10	10 × 10
Max. Line Rate (kHz)	18.7	35.7	56.1
Min. Line Rate (kHz)	No minimum with external trigger 100 Hz without external trigger	No minimum with external trigger 100 Hz without external trigger	No minimum with external trigger 100 Hz without external trigger
Bit Depth	8, 12	8, 12	8, 12
Interface	GigE (GigE Vision)	GigE (GigE Vision)	GigE (GigE Vision)
Lens Mount Options	F-mount or C-mount	F-mount or C-mount	F-mount or C-mount

### runner 2k monochrome models

Camera Model	ruL2048-10gm	ruL2048-19gm	ruL2048-30gm
Sensor Size	2048 pixels	2048 pixels	2048 pixels
Pixel Size (µm)	10 × 10	10 × 10	10 × 10
Max. Line Rate (kHz)	9.5	18.7	29.2
Min. Line Rate (kHz)	No minimum with external trigger 100 Hz without external trigger	No minimum with external trigger 100 Hz without external trigger	No minimum with external trigger 100 Hz without external trigger
Bit Depth	8, 12	8, 12	8, 12
Interface	GigE (GigE Vision)	GigE (GigE Vision)	GigE (GigE Vision)
Lens Mount options	F-mount or C-mount	F-mount or C-mount	F-mount or C-mount

### runner 2k color models

Camera Model	ruL2098-10gc
Sensor Size	2098 pixels per line (3 lines)
Pixel Size (µm)	14 × 14
Max. Line Rate (kHz)	9.2
Min. Line Rate (kHz)	No minimum with external trigger 100 Hz without external trigger
Bit depth	8, 12
Interface	GigE (GigE Vision)
Lens Mount options	F-mount or V-mount

## runner Camera Features

### Input/output functionality

The Basler runner line scan camera family is equipped with 3 inputs and 2 outputs. These inputs and outputs can accommodate a variety of the methods commonly used for signaling industrial cameras, such as RS-422, RS-644, and LVTTTL. In addition, the cameras can be directly attached to an incremental encoder. Some details of these I/O signaling methods include:

#### RS-422

RS-422 is a serial interface standard that defines the electrical properties of the interface, but does not define the connector, pin-out, or communications protocol. Due to its symmetrical signal transmission characteristics, RS-422 is considered to be a very robust transmission technique. Devices with RS-422 I/O can be used in a bus structure and can be daisy chained. This capability supports, for example, the use of a single trigger signal to trigger several cameras or the use of a camera output signal to trigger other cameras.

#### RS-644 LVDS (Low Voltage Differential Signaling)

RS-644 is a high-speed interface standard for data transmission. As with RS-422, it defines the physical layer only and no protocols. Its characteristics include a relatively low voltage level and a differential signaling scheme. The runner can accept and work with RS-644 signals. This is especially beneficial in systems with a layout that is a bit older and where the user only wants to make small changes to the system.

#### LVTTTL

Low Voltage TTL signals can also be handled by the runner inputs and can be used for triggering the camera.

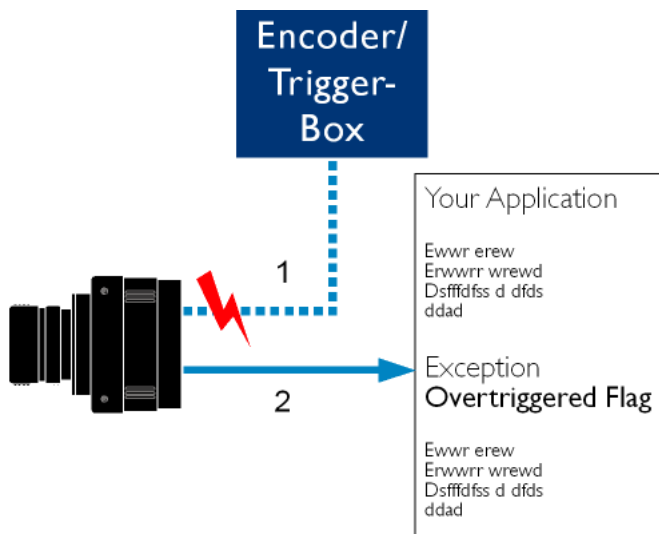
### Over trigger detection eliminates missed triggers

All runner cameras are equipped with an internal over trigger detection feature. The detection feature prevents "missed" triggers from going unnoticed. In normal operating mode, line scan cameras are triggered externally. Ideally, each trigger signal should yield a line acquisition. But in reality, some trigger signals may not be processed because they are received by the camera while it is still working on the previous line acquisition. In this situation, the trigger signal is normally just ignored, and the user gets no notification. This situation is commonly called "over triggering" because trigger signals are being received by the camera faster than they can be executed.

In the real world, the user often is not aware that over triggering is happening, assumes that every trigger will be successful, and thinks that everything is operating normally. This is especially true when inspecting continuous material

such as paper. In this case, it is very hard to be aware of over triggering because the material is homogeneous in color and even if some line acquisitions are missed, the resulting image looks OK.

But it is precisely in this type of application where it is essential to get all of the image data so that minute defects can be detected.



Basler has implemented a feature in the runner that informs the user if over triggering occurs. As illustrated in the drawing, the camera has been over triggered. The camera creates an "event" message that is sent to the host computer. If the user has activated event message generation and is listening for event messages within their application, an exception is created that can be used for information, debugging, or stopping the acquisition. In addition, the affected frame is tagged so that it can be detected by the application as well.

<input type="checkbox"/>	Line 1	Trigger 1	Status	ok
<input type="checkbox"/>	Line 2	Trigger 2	Status	ok
<input type="checkbox"/>	Line 3	Trigger 3	Status	ok
<input type="checkbox"/>	Line 4	Trigger 4	Status	ok
<input type="checkbox"/>	Line 5	Trigger 5	Status	ok
<b>Frame Status Chunk</b>		Trigger: 5	Lines: 5	

When the runner was placed in some existing applications, this new feature detected over triggering that was causing lines to be missed and that the users were not aware of. This new knowledge allowed the users to tweak their applications and to obtain better performance.

### Debouncer - safe triggering and no "ghost triggers"

The debouncer feature discriminates between a valid and an invalid signal on the camera's digital inputs. The debouncer feature specifies a minimum time that an input signal must remain high or remain low in order to be sensed by the camera as valid. The fact that the minimum time is adjustable makes this feature exceptionally flexible. The debouncer feature is especially useful in eliminating the "ghost triggering" problems often encountered in tough industrial environments.

### Gamma correction - for a better visual impression

This feature modifies the brightness of the images by calculating a correction value for each pixel in the image. The correction improves the perception of the image by the human eye. By activating and adjusting the Gamma feature, a user can make the image appear brighter or darker. The result is usually perceived by the human eye as more detailed and sensitive. This feature is especially helpful when image analysis or monitoring is done by an operator.

### Color interpolation inside the camera – less processing in the PC

The runner ruL2098-10gc color camera performs color interpolation inside of the camera and delivers color images in YUV format directly to the host computer. This dramatically reduces the bandwidth needed to transmit images and does not require further processing in the PC. So image data can be directly processed by the user's application.

### Higher pixel bit depths for greater detail in the images

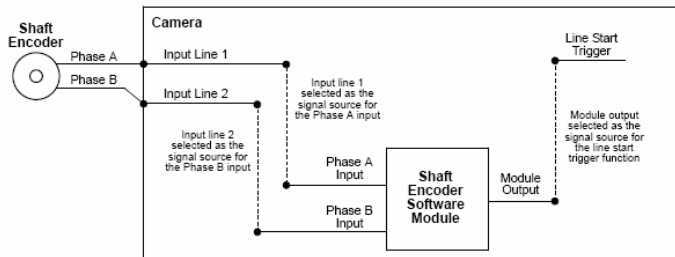
All runner camera models feature 12 bit imaging. This means that the bit depth of each pixel can be up to 12 bits. This advantage was realized by using the newest electronic components in the cameras and by repeatedly checking the image quality during development against the EMVA 1288 standard. Most of the current cameras on the market feature 8 or 10 bit depth.

### Basler runner cameras accept direct encoder input

Basler runner cameras can handle the direct input of encoder signals. In the past, shaft encoder signals were typically input into a frame grabber. But because frame grabbers are often eliminated when using a GigE line scan camera, the ability to directly accept encoder input was implemented on the runner. A runner can accept incremental encoder signals using two of the input lines accessible via the Hirose connector on the back of the camera. This capability allows faster restructuring of an existing system layout because the user can directly replace a frame grabber based camera without the need to build a custom box or PCB to trigger the camera with an encoder. The switch to a Gigabit Ethernet based solution from a Camera Link layout is fast, easy, and straightforward.

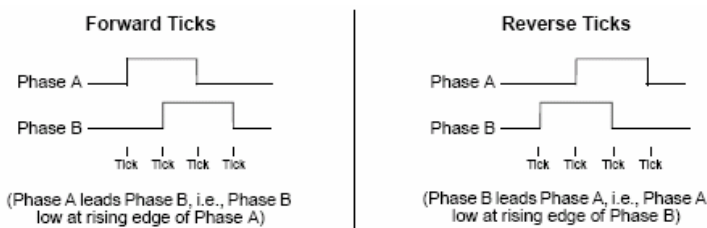
## The internal shaft encoder module

Basler runner cameras are equipped internally with a shaft encoder software module. The module can accept input from a two channel shaft encoder (Phase A, Phase B). The module outputs a signal that can be used, for example, as a source signal for the camera's line start trigger function or frame start trigger function. The drawing shows a typical implementation of the camera's shaft encoder software module.



To use the shaft encoder module, selection of a source signal for the module's Phase A input and a source signal for the module's Phase B input must be done. So, for example, you could apply the Phase A signal from a shaft encoder to physical input line 1 of the camera and select input line 1 as the source signal for the Phase A input to the module. And you could apply the Phase B signal from a shaft encoder to physical input line 2 of the camera and select input line 2 as the source signal for the Phase B input to the module.

The camera can also interpret the direction of the encoder as shown in the drawing.



The camera is equipped with several counters for counting the number of ticks generated by the encoder. The counters can be read via the pylon API. They deliver valuable information that can be used within an application for things such as error detection or for tracking the material being inspected. Some cases that describe the functionality of the camera's "reverse counter" appear below.

### The reverse counter

The main purpose of the camera's reverse counter is to compensate for mechanical "jitter" in a conveyor used to move objects past the camera. This jitter usually manifests itself as a momentary change in the direction of the conveyor.

The rules that govern the operation of the reverse counter are as follows:

- If the conveyor is running in the reverse direction and the current reverse counter count is less than the maximum (i.e., less than the current setting of the Reverse Counter Max parameter), the reverse counter will increment once for each reverse tick received.
- If the conveyor is running in the forward direction and the current reverse counter count is greater than zero, the reverse counter will decrement once for each forward tick received
- When the Shaft Encoder Mode is set to Forward Only:
  - If the reverse counter is not incrementing or decrementing, the software module will output a trigger signal for each forward tick received from the shaft encoder.

If the reverse counter is incrementing or decrementing, trigger signal output will be suppressed.

- When the Shaft Encoder Mode is set to Any Direction:
  - If the reverse counter is not incrementing or decrementing, the software module will output a trigger signal for each forward tick or reverse tick received from the shaft encoder.

If the reverse counter is incrementing or decrementing, trigger signal output will be suppressed.

To understand how these rules affect the operation of the encoder software module, consider the following cases:

### Case I

This is the simplest case, i.e., the Shaft Encoder Reverse Counter Max is set to zero. In this situation, the reverse counter never increments or decrements and it will have no effect on the operation of the encoder software module.

When the Shaft Encoder Reverse Counter Max is set to zero:

- If the Shaft Encoder Module Mode is set to Forward Only, the software module will output a trigger signal whenever it receives a forward tick from the shaft encoder, but not when it receives a reverse tick.
- If the Shaft Encoder Module Mode is set to Any Direction, the software module will output a trigger signal whenever it receives either a forward tick or a reverse tick from the shaft encoder.

## Case 2

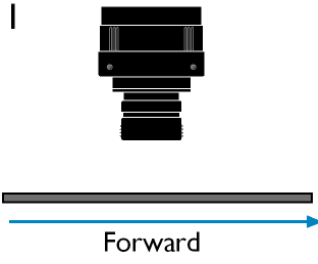
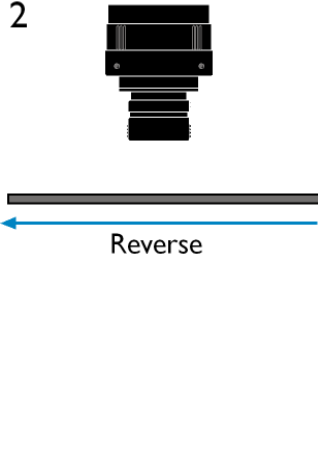
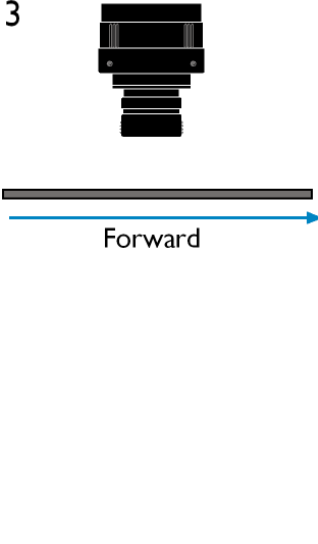
In this case, assume that:

- a shaft encoder is attached to a conveyor belt that normally moves continuously in the forward direction past a camera.
- the conveyor occasionally "jitters" and when it jitters, it moves in reverse for 4 or 5 ticks.

For this case, the Shaft Encoder Module Mode parameter should be set to Forward Only. The Shaft Encoder Module Reverse Counter Max should be set to a value that is higher than the jitter we expect to see. We decide to set the value to 10.

Given this situation and these settings, the series of diagrams below explains how the encoder software module will act:

By suppressing trigger signals when the conveyor was moving in reverse and then suppressing an equal number of trigger signals when forward motion is resumed, we ensure that the conveyor is in its "pre-jitter" position when the module begins generating trigger signals again. Note in step two that if the conveyor runs in reverse for a long period and the reverse counter reaches the max setting, the counter simply stops incrementing. If the conveyor continues in reverse, no output triggers will be generated because the Shaft Encoder Mode is set to Forward only.

<p>1</p> 	<p>The conveyor is moving forward and the encoder is generating forward ticks. Whenever the module receives a forward tick, it outputs a trigger signal.</p> <p>The reverse counter is at 0.</p>
<p>2</p> 	<p>The conveyor jitters and moves briefly in reverse. During this reverse movement, the shaft encoder generates 5 reverse ticks.</p> <p>The reverse counter will increment by 1 for each reverse tick and when the reverse motion stops, the reverse counter count will be 5.</p> <p>While the reverse counter is incrementing, the output of trigger signals from the module is suppressed.</p>
<p>3</p> 	<p>The conveyor resumes forward motion and the shaft encoder module begins generating forward ticks.</p> <p>The reverse counter will decrement by 1 for each forward tick. While the reverse counter is decrementing, the output of trigger signals from the module is suppressed.</p> <p>When the reverse counter decrements to 0, decrementing stops and suppression of the trigger signals stops. The module will begin outputting a trigger signal for each forward tick received.</p>

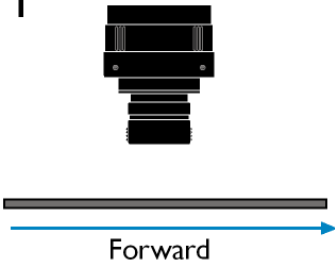

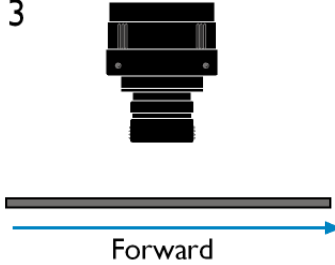
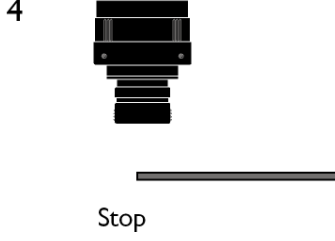
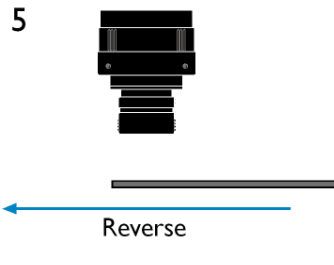
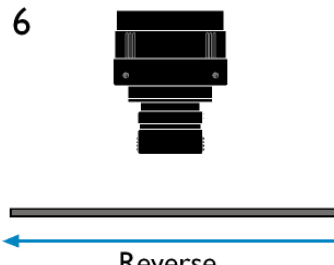
### Case 3

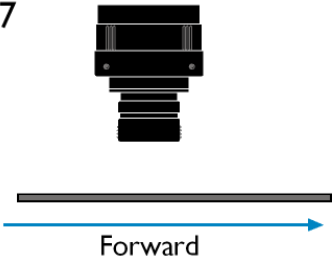
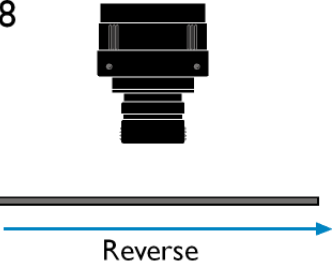
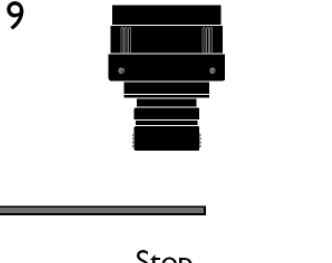
In this case, assume that:

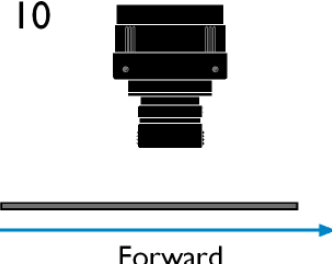
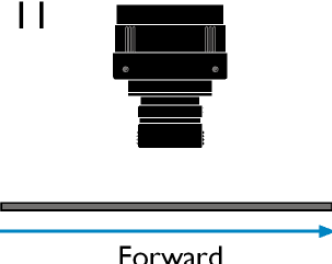
- we are working with a small conveyor that moves back and forth in front of a camera.
- a shaft encoder is attached to the conveyor.
- the conveyor moves in the forward direction past the camera through its complete range of motion, stops, and then begins moving in reverse.
- the conveyor moves in the reverse direction past the camera through its complete range of motion, stops, and then begins moving forward.
- this back and forth motion repeats.
- the conveyor occasionally "jitters". When it jitters, it moves 4 or 5 ticks in a direction of travel opposite to the current normal direction.

For this case, the Shaft Encoder Module Mode parameter should be set to Any Direction. The Shaft Encoder Module Reverse Counter Max should be set to a value that is higher than the jitter we expect to see. We decide to set the value to 10.

Given this situation and these settings, this series of diagrams explains how the encoder software module will act during conveyor travel:

<p>1</p> 	<p>The conveyor is moving forward and the encoder is generating forward ticks. Whenever the module receives a forward tick, it outputs a trigger signal. The reverse counter is at 0.</p>
<p>2</p> 	<p>The conveyor jitters and moves briefly in reverse. During this reverse movement, the shaft encoder generates 5 reverse ticks. The reverse counter will increment by 1 for each reverse tick and when the reverse motion stops, the reverse counter count will be 5. While the reverse counter is incrementing, the output of trigger signals from the module is suppressed.</p>
<p>3</p> 	<p>The conveyor resumes forward motion and the shaft encoder module begins generating forward ticks. The reverse counter will decrement by 1 for each forward tick. While the reverse counter is decrementing, the output of trigger signals from the module is suppressed. When the reverse counter decrements to 0, decrementing stops and suppression of the trigger signals stops. The module will begin outputting a trigger signal for each forward tick received.</p>
<p>4</p> 	<p>The conveyor reaches the end of its forward travel and it stops.</p>
<p>5</p> 	<p>The conveyor begins moving in reverse and the shaft encoder starts generating reverse ticks. The reverse counter will increment by 1 for each reverse tick. While the reverse counter is incrementing and the reverse count is below the max (10 in this case), the output of trigger signals from the module is suppressed.</p>
<p>6</p> 	<p>The reverse counter reaches the max (10 in this case) and stops incrementing. Suppression of trigger signals is ended. Because the shaft encoder mode is set to any direction, the module begins generating one trigger signal for each reverse tick received. The reverse counter remains at 10.</p>

<p>7</p> 	<p>The conveyor jitters and moves forward briefly. During this forward movement, the shaft encoder generates 4 forward ticks.</p> <p>The reverse counter will decrement by 1 for each forward tick. When the forward motion stops, the reverse counter count will be 6.</p> <p>While the reverse counter is decrementing, the output of trigger signals from the module is suppressed.</p>
<p>8</p> 	<p>The conveyor resumes reverse motion and the shaft encoder module begins generating reverse ticks.</p> <p>The reverse counter will increment by 1 for each reverse tick. While the reverse counter is incrementing, the output of trigger signals from the module is suppressed.</p> <p>When the reverse counter reaches the max (10 in this case) it stops incrementing and suppression of the trigger signals stops. The module will resume outputting a trigger signal for each reverse tick received.</p> <p>The reverse counter count is now 10.</p>
<p>9</p> 	<p>The conveyor reaches the end of its reverse travel and it stops.</p>

<p>10</p> 	<p>The conveyor begins moving forward and the shaft encoder starts generating forward ticks.</p> <p>The reverse counter is at 10 and will now begin decrementing by 1 for each forward tick. While the reverse counter is decrementing and the reverse count is greater than 0, the output of trigger signals from the module is suppressed.</p>
<p>11</p> 	<p>The reverse counter reaches 0.</p> <p>Suppression of trigger signals is ended. Because the shaft encoder mode is set to any direction, the module begins generating one trigger signal for each forward tick received.</p> <p>The reverse counter remains at 0.</p>

There are two main things to notice about case three. First, because the encoder mode is set to any direction, ticks from the shaft encoder will cause the module to output trigger signals regardless of the conveyor direction, as long as the reverse counter is not incrementing or decrementing. Second, the reverse counter will compensate for conveyor jitter regardless of the conveyor direction.

**Note:** It is important to reset the reverse counter before the first traverse in the forward direction. This resets the counter to 0 and synchronizes the counter software with the conveyor direction. (The software assumes that the conveyor will move in the forward direction after a counter reset.)

## Additional features in the runner

In comparison to Camera Link cameras, GigE Vision based cameras such as the runner include more built-in features, and the features can be more easily accessed and used. Some additional features especially worth mentioning are:

- A Lookup Table for defining customer specific grey value interpretations
- Digital Shift for specifying different interpretations of the acquired pixel data
- A CRC Checksum to ensure reliable communication and allow corrupt image detection
- Chunk Data for tracking camera functions, for example, the status of the camera's inputs and outputs

## System Possibilities

### A simple setup with one camera and one computer

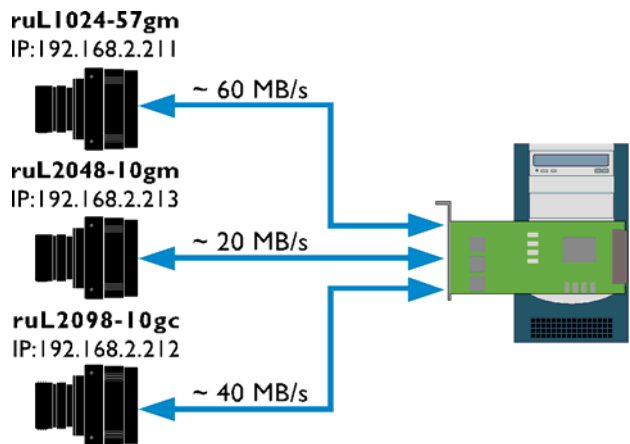
The connection of one camera to a single host computer is the easiest available setup. In this scheme, the computer is normally equipped with a network adapter card, and the camera is connected directly to the card. Getting started using the camera is straightforward as well. Basler's pylon driver package includes camera drivers, a camera API, a viewer tool, and a camera finder tool. With the pylon package installed, the camera can be configured within minutes. The first images can be acquired very quickly, and depending on the complexity of your application, you can begin full operation in short order.

The following table makes a direct cost comparison between a GigE and a Camera Link solution.

Component	Basler runner GigE Line Scan Camera	Cost (list price)	Conventional Camera Link Line Scan Camera	Cost (list price)
Camera	Depends on the model	Similar to Camera Link	Depends on the model	Similar to GigE
Cables	Ten meter GigE Cat 6 cable	25 €	Ten meter Camera Link cable	230 €
Frame Grabber/ Network Card	Intel Pro 1000 GT Network Card	45 €	Standard Base Configuration Camera Link Frame Grabber	650 €
Total		70 €		880 €

## Advanced setup one - multiple cameras and one computer with a multiport GigE card

In this scenario, several cameras are connected to a single host computer. The computer could contain several single-port GigE network adapters with each camera connected to an individual adapter, or it could contain a multiport GigE network adapter with several cameras connected to the single adapter. The drawing illustrates one possible setup where three cameras are attached to a four port network adapter card. Because it is a PCI Express device, the adapter card can transfer up to 250 MB/s to the PC. All of the cameras are using Basler's pylon driver and they operate simultaneously.



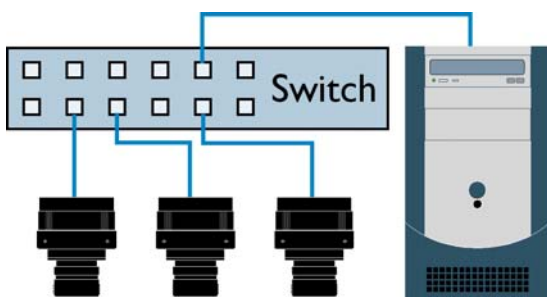
Because it is very easy to attach up to four cameras to the PC with this system layout, the advantages of using Gigabit Ethernet as opposed to Camera Link are quite obvious in this case. From a technical standpoint, Gigabit Ethernet and GigE Vision can handle this configuration well. The IP addressing protocol of GigE and the multi-camera handling capabilities of GigE Vision and Basler's pylon driver also make managing this application an easy task.

The following table clearly demonstrates the commercial advantages of this GigE solution using the runner.

Component	Basler runner GigE Line Scan Camera	Cost (list price)	Conventional Camera Link Line Scan Camera	Cost (list price)
Camera	Depends on the model	Similar to Camera Link	Depends on the model	Similar to GigE
Cables	Ten meter GigE Cat 6 cable	75€ (25 €/ each)	Ten meter Camera Link cable	690 € (230 €/ each)
Frame Grabber/ Network Card	Intel Pro 1000 GT Quadport Network Card	280 €	Standard Base Configuration Camera Link Frame Grabber	1300 € (650€/ each)
Total		355 €		1990 €

## Advanced setup two - multiple cameras and one computer with a network switch

In this scenario, several cameras are connected to a host computer that has one single-port GigE network adaptor. As shown in the drawing, the cameras are connected to a standard Gigabit Ethernet network switch and the switch is connected to the GigE network adaptor card in the computer. This scenario reflects a multi-camera system where simultaneous grabbing of images on all of the attached cameras is not required. This can be useful in applications where not all cameras are used at the same time or the cameras are used at different stations. From a technical standpoint, Gigabit Ethernet and GigE Vision can handle this configuration well. The IP addressing protocol of GigE and the multi-camera handling capabilities of GigE Vision and Basler's pylon driver also make managing this application an easy task.



Since the switch employs the common IP protocol and the Gigabit Ethernet implementation, it works seamlessly with GigE Vision devices like the runner cameras. Up to 100 MB per second of image data can be transferred from the cameras. This would allow up to five runner ruL1024-19gm cameras to be running at the same time. Thanks to a time delayed data transmission feature inside the camera, image data can be transmitted even more efficiently to save bandwidth and CPU load. This feature has proven itself in a 16 camera system that does explosion analysis. In that system, 16 cameras capture an image and transmit the image data in a time delayed, sequential fashion. That is an easy task with Basler's runner cameras and pylon software and is unique in comparison to other camera vendors.

The following table clearly demonstrates the commercial advantages of this GigE solution using runner.

Component	Basler runner GigE Line Scan Camera	Cost (list price)	Conventional Camera Link Line Scan Camera	Cost (list price)
Camera	Depends on the model	Similar to Camera Link	Depends on the model	Similar to GigE
Cables	Ten meter GigE Cat 6 cable	75€ (25 €/ each)	Ten meter Camera Link cable	690 € (230 €/ each)
Frame Grabber/ Network Card	Intel Pro 1000 GT Network Card	45 €	Standard Base Configuration Camera Link Frame Grabber	1300 € (650€/ each)
Other Hardware	GigE Switch, e.g., Netgear GS116	150 €		
Total		270 €		1990 €

## Target Applications for the runner

The runner is a recently designed, mainstream camera intended for typical 1k and 2k line scan applications. One big advantage of this camera series is that it was a totally new camera design, done in 2007 and implementing the newest electronic components. In addition, Basler's ten years of line scan camera design experience was a constant influence and had a major impact on the runner. For example, we concentrated our efforts on image quality, low speed and acceleration optimization, and ease of use. The result is the runner's exceptional performance in the low speed and acceleration situations that are present in many line scan applications.

The first runner customers successfully tested the camera in the following industries or applications:

- Textile inspection
- Wood and parquet inspection
- Under-car surveillance
- Tile inspection

Customers praised the performance of the camera even at speeds of just several lines per second. This performance is made possible by the "sensor clearing" feature embedded in all runner models.

The runner has also proven to be an ideal fit for all standard 1k and 2k applications including:

- Web inspection (wood, paper, foil, etc.)
- Surface inspection (PCBs, flat panels and displays, semiconductors, etc.)
- Document scanning and postal sorting
- Food inspection

# Questions & Answers

## 1.) What about CPU load?

Basler offers the new pylon driver package for use with our Gigabit Ethernet cameras. This package includes drivers, a camera API, an advanced viewer, and extensive documentation and sample programs. Basler has created this new driver package using the competencies acquired during our more than six years of FireWire driver development experience.

The most challenging task for Gigabit Ethernet camera driver development was to achieve a machine vision specific implementation. This was largely done by defining the GigE Vision standard and designing the GigE Vision certification process. The way that the Basler drivers perform shows that a deep knowledge and key customer feedback were used to design the core of our GigE Vision based imaging capabilities.

CPU usage is one of the most interesting topics discussed whenever Gigabit Ethernet is considered in connection with machine vision. Each player in the machine vision industry must convince the customer that CPU usage with GigE is reasonable. The main difference compared to FireWire and Camera Link is that GigE has no CPU-independent incoming data management. This means that every data package must be inspected when arriving in the PC and copied afterwards. Without doubt, this process involves the CPU. To keep the CPU usage as low as possible, Basler offers two different GigE Vision drivers, a filter driver and a performance driver.

### The Filter Driver

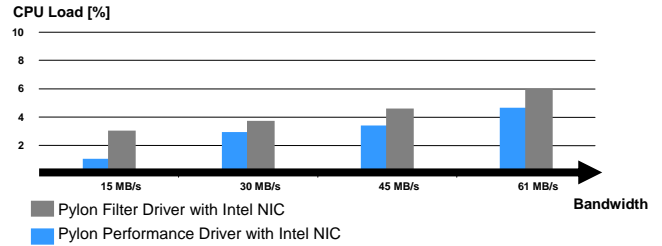
The filter driver quickly separates incoming data packages and transfers the packets in them directly to the application. The Filter Driver can be used with any network interface card available on the market. The CPU load seen with this driver is generally attributable to the fact that the packets normally must be copied two times. The Basler Filter driver is located below the Windows IP Stack.

### The Performance Driver

This driver separates incoming packages and transfers the packets in them directly to the application. The CPU load seen with this driver is generally attributable to the fact that the packets must normally be copied at least once.

The Basler performance driver is a hardware specific GigE Vision network driver compatible with network adapters that use specific Intel chipsets. The main advantage of the performance driver is that it lowers the CPU load needed to service the network traffic between the host computer and the camera(s).

The following graph reflects a typical result for a medium performance PC and bandwidth usage similar to an IEEE 1394b based system. The machine is equipped with a Pentium D 2.7 GHz processor and an Intel Pro 1000GT network adapter card and is using the Basler pylon SDK. The measurements were performed with one camera that was set for a 4000 byte packet size.



### runner 1k monochrome models

Camera Model	ruL1024-19gm	ruL1024-36gm	ruL1024-57gm
Sensor Size	1024 pixels	1024 pixels	1024 pixel
Pixel Size (µm)	10 x 10	10 x 10	10 x 10
Max. Line Rate (kHz)	18.7	35.7	56.1
Bandwidth Used (8 bits)	~ 19 MB/s	~ 36 MB/s	~ 58 MB/s
Bandwidth Used (12 bits)	~ 38 MB/s	~ 72 MB/s	~ 97 MB/s (Mono12 packed)

### runner 2k monochrome models

Camera Model	ruL2048-10gm	ruL2048-19gm	ruL2048-30gm
Sensor Size	2048 pixels	2048 pixels	2048 pixels
Pixel Size (µm)	10 x 10	10 x 10	10 x 10
Max. Line Rate (kHz)	9.5	18.7	29.2
Bandwidth Used (8 bits)	~ 20 MB/s	~ 39 MB/s	~ 60 MB/s
Bandwidth Used (12 bits)	~ 40 MB/s	~ 78 MB/s	~ 96 MB/s (Mono12 packed)

### runner 2k color models

Camera Model	ruL2098-10gc
Sensor Size	2098 pixels
Pixel Size (µm)	14 x 14
Max. Line Rate (kHz)	9.2
Bandwidth Used (8 bits)	~ 40 MB/s (YUV)
Bandwidth Used (12 bits)	~ 89 MB/s (RGB 12 VI packed)

## 2.) How reliable is the data integrity on a GigE connection?

A variety of mechanisms make the integrity of the data transmitted over Gigabit Ethernet extremely reliable. The basic mechanism is part of the Ethernet implementation itself. This implementation's CSMA/CD procedure handles access to the physical medium and defines rules for traffic on the bus.

A GigE network's IP protocol controls the flow of the data, and packets are counted and can be identified. In addition, the GigE Vision protocol enhances end-to-end data transmission reliability by tracking all packets and requesting missed packets. So packet losses, which mean image data loss, can be prevented. As a final data integrity mechanism, Basler offers CRC checksums for each frame. The checksums cover all of the imaging data included in a frame and can be used to detect data corruption in the image itself.

## 3.) Can cables be screw locked?



Runner cameras are equipped with a horizontal screw lock mounting capability. As the image shows, standard RJ-45 connectors can be used with a runner as well as horizontally orientated screw connectors. Basler offers a wide variety of cables equipped with standard or with screw lock connectors. The screw lock layout on the runner follows the de-facto industry standard, so cables can also be obtained from other suppliers.

## 4.) Can the runner work with third party software libraries?

The answer is a clear "Yes". Basler has designed the runner to comply with both the GigE Vision standard and the GenICam standard. Our compliance with these standards has been verified and accepted, and the runner is listed by the AIA as a compatible camera.

In addition, Basler routinely performs in-house compatibility tests with all common machine vision imaging libraries as well as some medical imaging libraries. These third party companies also receive the first production units of each new camera model and the newest firmware updates so that they can ensure compatibility.

A detailed list of supported libraries can be obtained from the Basler Components support team.

## 5.) Can the runner master low speed situations?

Due to its high image quality and ease of integration, Basler's newest camera series, the Basler runner, has been impressive in a range of customer applications. And in several applications with minimum line rates of 1 Hz up to 100 Hz, Basler runner cameras have displayed exceptionally good performance while running at these unusually slow speeds. The Basler ruL2098-10gc tri-linear color runner camera can deliver superb images under these conditions, which are normally quite challenging for a color line scan camera. Thanks to a built-in "sensor clearing" feature, the sensor's readout at slow speeds is greatly improved. Noise and artifacts are limited, resulting in better images and better image processing results.

In one particular application, the Basler runner inspects wood shelves for knotholes and other defects that can limit the quality of the product. Line scan cameras from several competitors were tested for this application. But due to the machine's speed variations while examining the wood, the application pushed most of the competitors beyond their limits.

Very positive results have also been reported from evaluations in security applications that use the Basler runner to inspect vehicles. These under-car surveillance systems scan for bombs and other suspect items attached to the bottom of a car or truck. Typically, the camera is embedded in the street inside of a large box and must adapt to the speed of the slow moving vehicles.

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