Baumer

User´s Guide

SXG cameras (Gigabit Ethernet)

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1. General Information

Thanks for purchasing a camera of the Baumer family. This User´s Guide describes how to connect, set up and use the camera.

Read this manual carefully and observe the notes and safety instructions!

Target group for this User´s Guide

This User's Guide is aimed at experienced users, which want to integrate camera(s) into a vision system.

Copyright

Classification of the safety instructions

In the User´s Guide, the safety instructions are classified as follows:

Notice
Gives helpful notes on operation or other general recommendations.

	Caution
Pictogram	Indicates a possibly dangerous situation. If the situation is not avoided, slight or minor injury could result or the device may be damaged.

2. General safety instructions

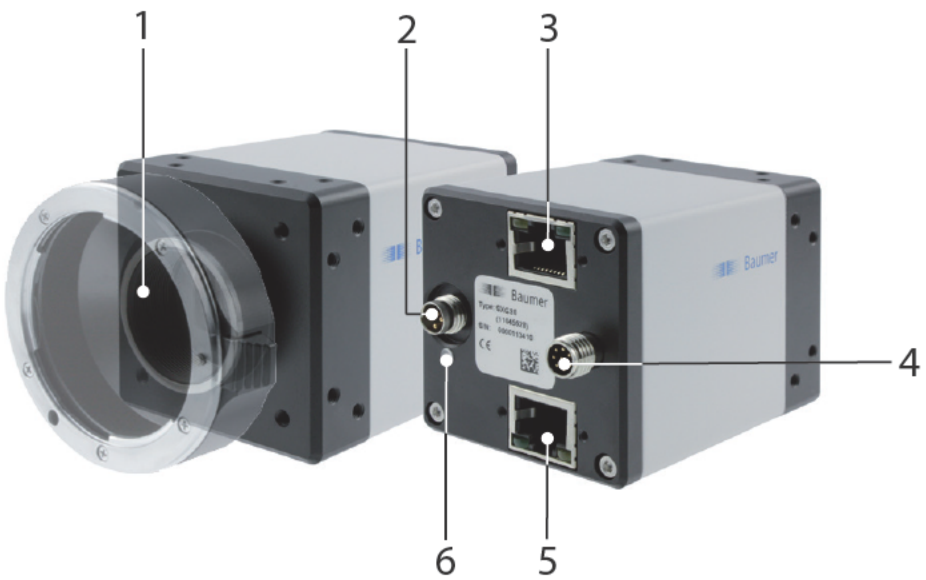
Observe the following safety instruction when using the camera to avoid any damage or injuries.

⚠	Caution
	Provide adequate dissipation of heat, to ensure that the temperature does not exceed +60°C (+140°F). The surface of the camera may be hot during operation and immediately after use. Be careful when handling the camera and avoid contact over a longer period.

3. Intended Use

The camera is used to capture images that can be transferred over two GigE interfaces to a PC.

4. General Description



Nr.	Description	Nr.	Description
1	(respective) lens mount	**4**	Digial-IO supply
2	Power supply	**5**	GigE Port 1
3	GigE Port 0 (PoE)	**6**	Signaling-LED

5. Camera Models

5.1 SXG – Cameras with C-Mount

Figure 1 ▶
Front view of a Baumer SXG C-Mount camera.

Camera Type	Sensor Size	Resolution	Full Frames [max. fps]
Monochrome			
SXG10	1/2"	1024 x 1024	120
SXG20	2/3"	1600 x 1200	68
SXG21	2/3"	1920 x 1080	64
SXG40	1"	2336 x 1752	32
SXG80	4/3"	3296 x 2472	16
Color			
SXG10c	1/2"	1024 x 1024	120
SXG20c	2/3"	1600 x 1200	68
SXG21c	2/3"	1920 x 1080	64
SXG40c	1"	2336 x 1752	32
SXG80c	4/3"	3296 x 2472	16

Dimensions

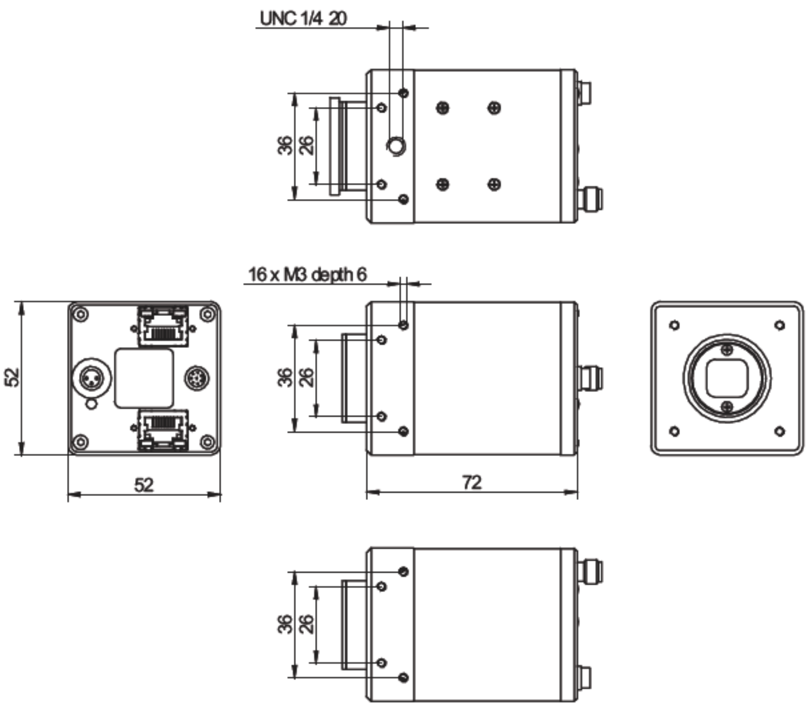


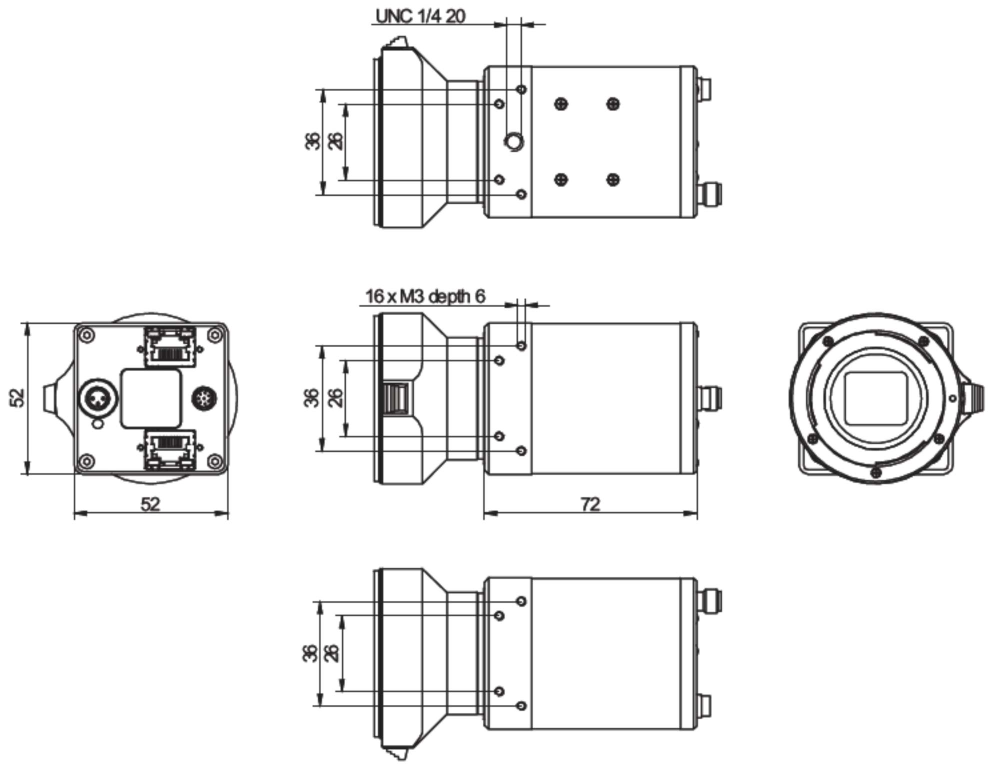
Figure 2 ▶
Dimensions of a Baumer SXG camera.

5.2 SXG-F – Cameras with F-Mount

◄ **Figure 3**
Front view of a Baumer SXG-F camera.

Camera Type	Sensor Size	Resolution	Full Frames [max. fps]
Monochrome			
SXG21-F	2/3"	1920 x 1080	64
SXG40-F	1"	2336 x 1752	32
SXG80-F	4/3"	3296 x 2472	16
Color			
SXG21c-F	2/3"	1920 x 1080	64
SXG40c-F	1"	2336 x 1752	32
SXG80c-F	4/3"	3296 x 2472	16

Dimensions



◄ **Figure 4**
Dimensions of a Baumer SXG-F camera.

6. Product Specifications

6.1 Sensor Specifications

6.1.1 Quantum Efficiency for Baumer SXG Cameras

The quantum efficiency characteristics of monochrome and color matrix sensors for Baumer SXG cameras are displayed in the following graphs. The characteristic curves for the sensors do not take the characteristics of lenses and light sources without filters into consideration, but are measured with an AR coated cover glass.

Values relating to the respective technical data sheets of the sensors manufacturer.

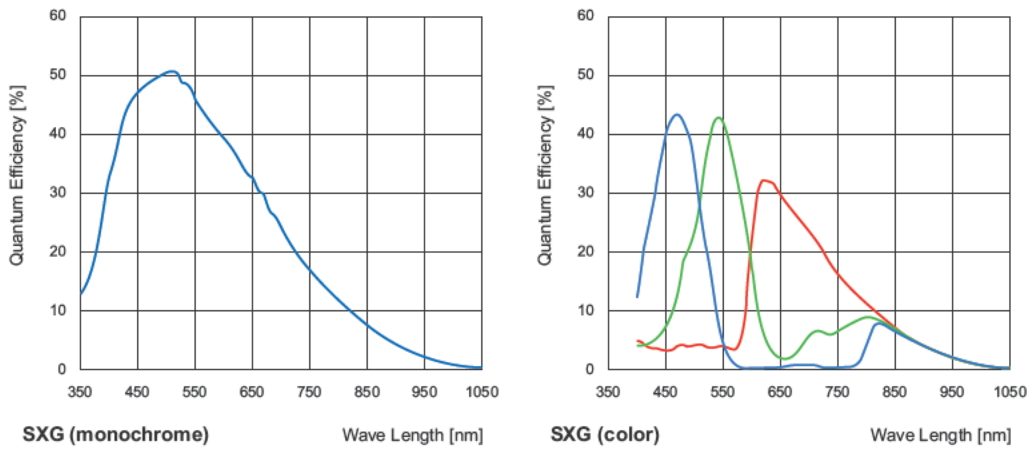


Figure 5 ►
Quantum efficiency for Baumer SXG cameras.

6.1.2 Progressive Scan

All cameras of the SXG series are equipped with Progressive Scan.

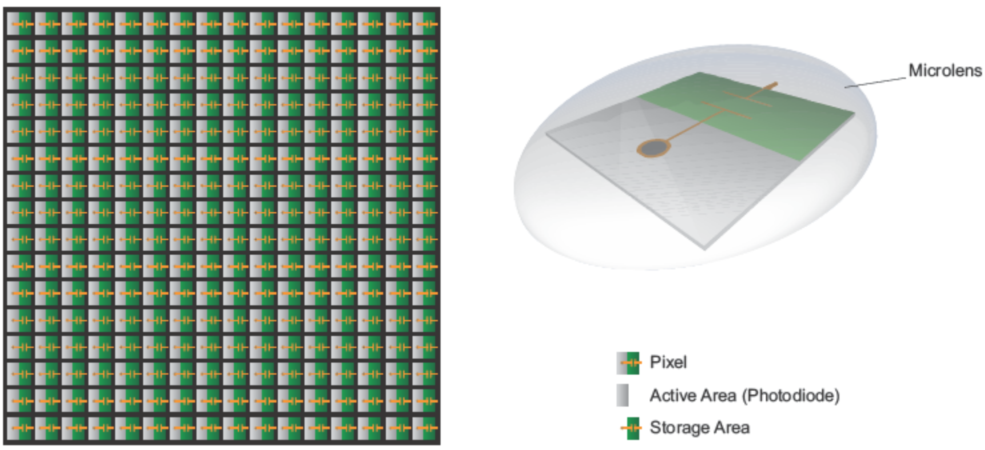


Figure 6 ►
Structure of an imaging sensor with global shutter (interline).

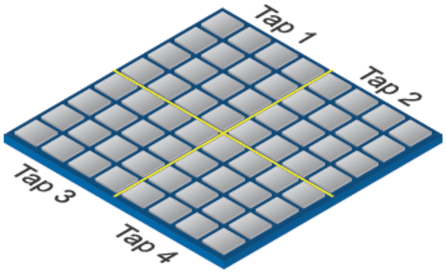
Progressive Scan means that all pixels of the sensor are reset and afterwards exposed for a specified interval ($t_{exposure}$).

For each pixel an adjacent storage area exists. Once the exposure time elapsed, the information of a pixel is transferred immediately to its storage area and read out from there.

Due to the fact that photosensitive surface gets "lost" by the implementation of the storage area, the pixels are mostly equipped with microlenses, which focus the light to the pixels active area.

6.1.3 Readout Modes

The Kodak sensors, used in Baumer SXG cameras, are subdivided into four Taps.

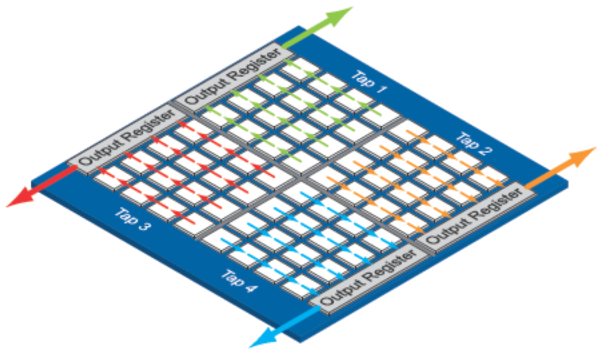


◄ **Figure 7**
Taps of the sensor.

Due to Baumer's integrated calibration technique, these taps are invisible within the recorded images, but affect the operation and the rate of the readout process and therewith the readout time ($t_{readout}$).

6.1.3.1 Quad Mode

On quad readout mode all four taps are read out simultaneously as displayed in the subsequent figure.



◄ **Figure 8**
Quad Tap Readout Mode.

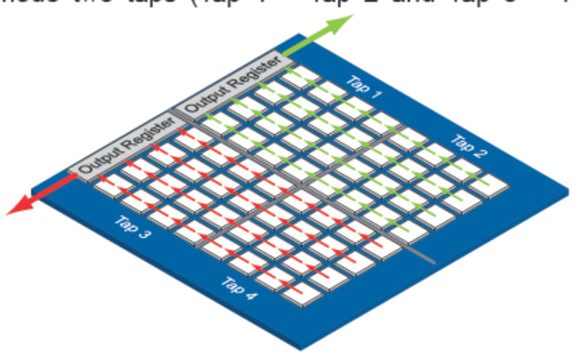
The data of all pixels of one tap are moved to the output register and afterwards transfered to the memory.

Once the information have left the output register, the readout is done.

This mode provides the full potential of the sensor and leads to the maximum frame rate.

6.1.3.2 Dual Mode

On dual readout mode two taps (Tap 1 + Tap 2 and Tap 3 + Tap 4) are combined.



◄ **Figure 9**
Dual Tap Readout Mode.

The data of all pixels of one tap are moved to the output register and afterwards transfered to the memory.

Once the information have left the output register, the readout is finished.

Due to the fact, that more data needs to be read out, the $t_{readout}$ is increased compared to the quad readout mode.

It is considered: $t_{readout(Dual\ Mode)} \approx 2 \times t_{readout(Quad\ Mode)}$

6.1.3.3 Single Mode

In single readout mode all taps are combined as displayed in the subsequent figure.

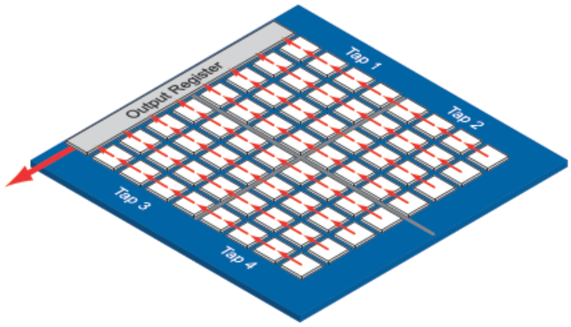


Figure 10 ►
Single Tap Readout Mode.

The data of all pixels of the sensor are moved to the output register and afterwards transfered to the memory.

Once the information have left the output register, the readout is done.

Due to the fact, that the complete sensor needs to be read out, the readout time $t_{readout}$ is increased compared to quad and dual readout mode.

It is considered: $t_{readout(Single\ Mode)} \approx 4 \times t_{readout(Quad\ Mode)}$

6.2 Timings

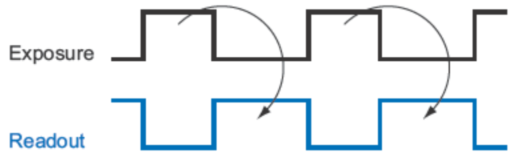
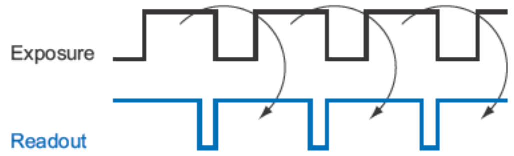
The image acquisition consists of two seperate, successively processed components.

Exposing the pixels on the photosensitive surface of the sensor is only the first part of the image acquisition. After completion of the first step, the pixels are read out.

Thereby the exposure time ($t_{exposure}$) can be adjusted by the user, however, the time needed for the readout ($t_{readout}$) is given by the particular sensor and image format.

Baumer cameras can be operated with two modes, the Free Running Mode and the Trigger Mode.

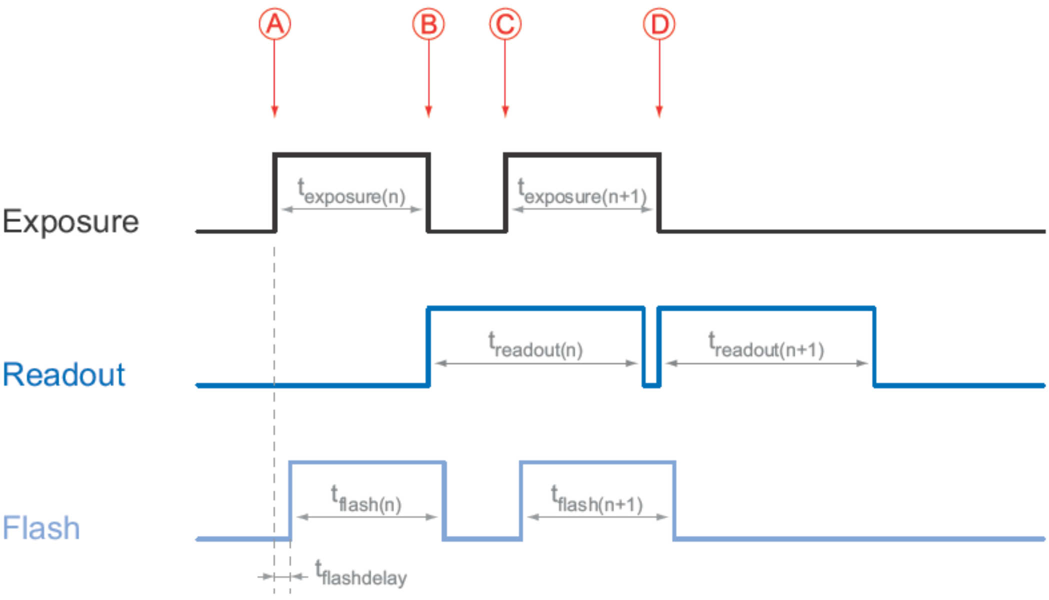
The cameras can be operated non-overlapped*) or overlapped. Depending on the mode used, and the combination of exposure and readout time:

Non-overlapped Operation	Overlapped Operation
Here the time intervals are long enough to process exposure and readout successively.	In this operation the exposure of a frame (n+1) takes place during the readout of frame (n).
	

6.2.1 Free Running Mode

In the "Free Running" mode the camera records images permanently and sends them to the PC. In order to achieve an optimal (with regard to the adjusted exposure time $t_{exposure}$ and image format) the camera is operated overlapped.

In case of exposure times equal to / less than the readout time ($t_{exposure} \leq t_{readout}$), the maximum frame rate is provided for the image format used. For longer exposure times the frame rate of the camera is reduced.



$t_{flash} = t_{exposure}$

Timings:
A - exposure time frame (n) effective
B - image parameters frame (n) effective
C - exposure time frame (n+1) effective
D - image parameters frame (n+1) effective

Image parameters:
Offset
Gain
Mode
Partial Scan

*) Non-overlapped means the same as sequential.

6.2.2 Trigger Mode

After a specified external event (trigger) has occurred, image acquisition is started. Depending on the interval of triggers used, the camera operates non-overlapped or overlapped in this mode.

With regard to timings in the trigger mode, the following basic formulas need to be taken into consideration:

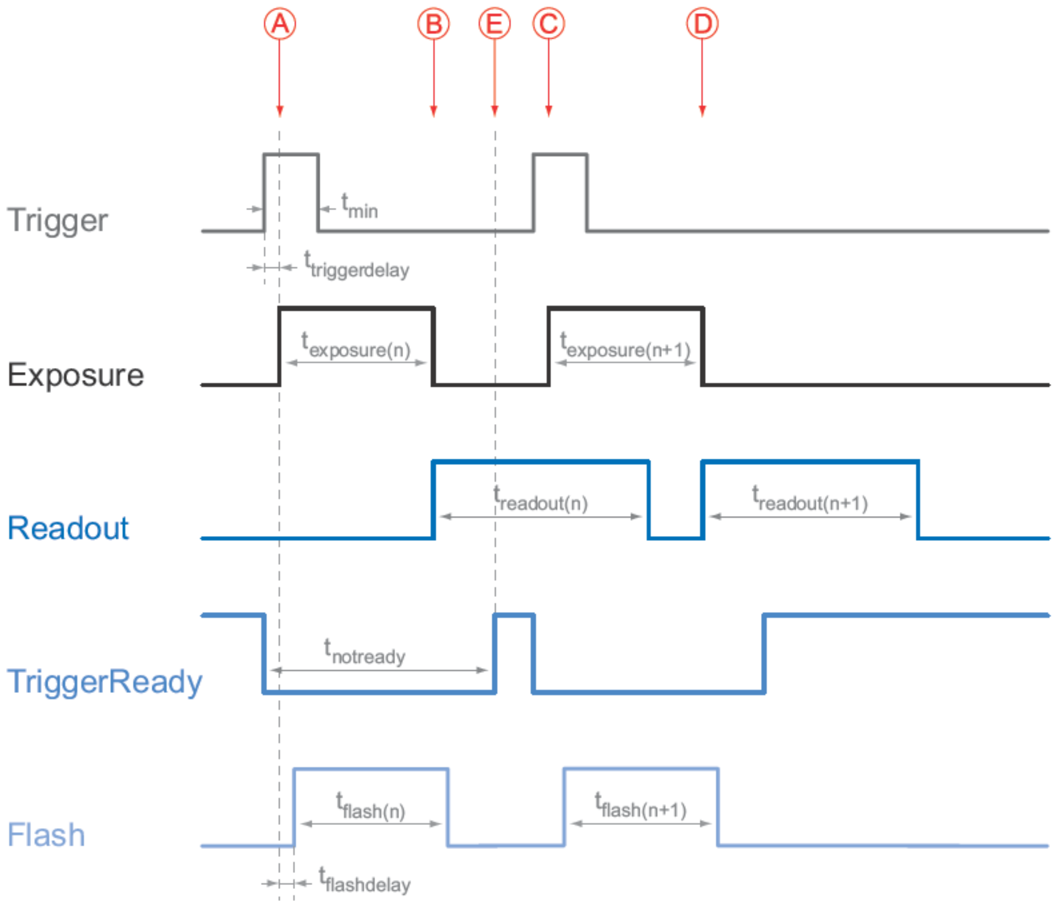
Case		Formula
$t_{exposure} < t_{readout}$	(1)	$t_{earliestpossibletrigger(n+1)} = t_{readout(n)} - t_{exposure(n+1)}$
	(2)	$t_{notready(n+1)} = t_{exposure(n)} + t_{readout(n)} - t_{exposure(n+1)}$
$t_{exposure} > t_{readout}$	(3)	$t_{earliestpossibletrigger(n+1)} = t_{exposure(n)}$
	(4)	$t_{notready(n+1)} = t_{exposure(n)}$

6.2.2.1 Overlapped Operation: $t_{exposure(n+2)} = t_{exposure(n+1)}$

In overlapped operation attention should be paid to the time interval where the camera is unable to process occuring trigger signals ($t_{notready}$). This interval is situated between two exposures. When this process time $t_{notready}$ has elapsed, the camera is able to react to external events again.

After $t_{notready}$ has elapsed, the timing of (E) depends on the readout time of the current image ($t_{readout(n)}$) and exposure time of the next image ($t_{exposure(n+1)}$). It can be determined by the formulas mentioned above (no. 1 or 3, as is the case).

In case of identical exposure times, $t_{notready}$ remains the same from acquisition to acquisition.



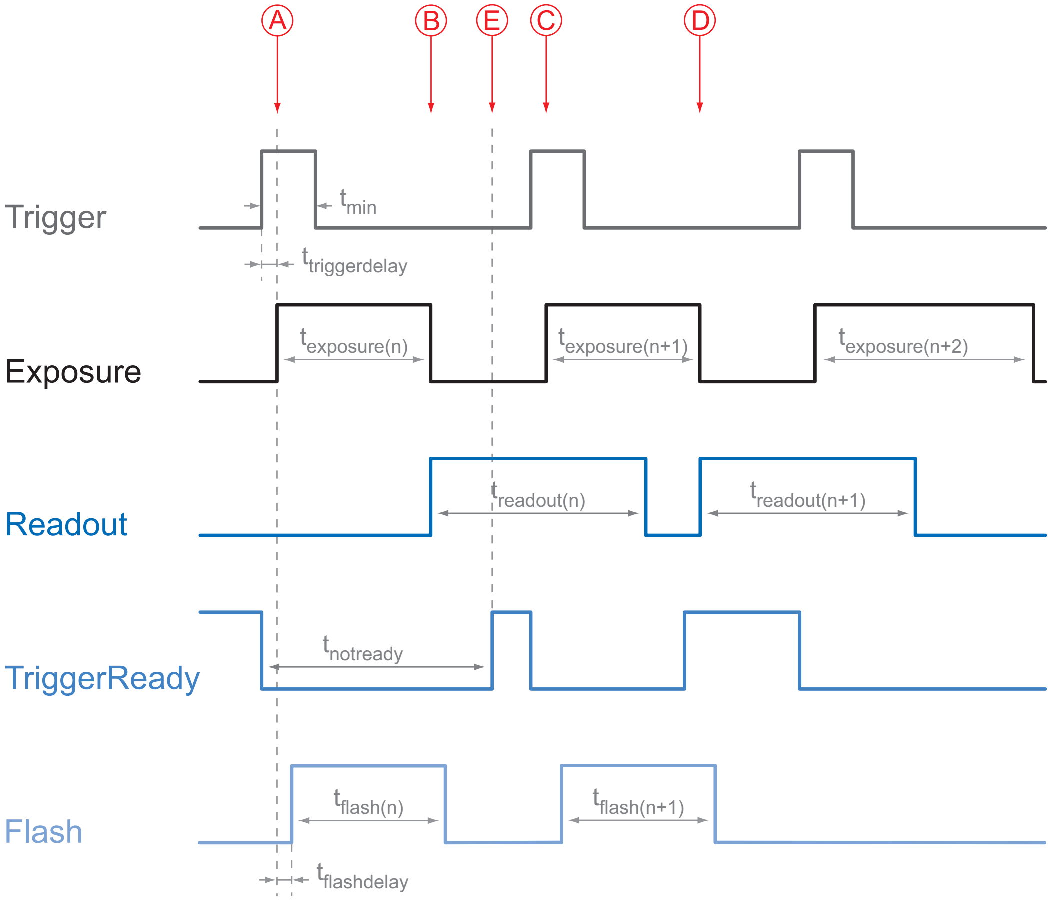
Timings:
A - exposure time frame (n) effective
B - image parameters frame (n) effective
C - exposure time frame (n+1) effective
D - image parameters frame (n+1) effective
E - earliest possible trigger

Image parameters:
Offset
Gain
Mode
Partial Scan

6.2.2.2 Overlapped Operation: $t_{exposure(n+2)} > t_{exposure(n+1)}$

If the exposure time ($t_{exposure}$) is increased form the current acquisition to the next acquisition, the time the camera is unable to process occuring trigger signals ($t_{notready}$) is scaled down.

This can be simulated with the formulas mentioned above (no. 2 or 4, as is the case).



Timings:
A - exposure time frame (n) effective
B - image parameters frame (n) effective
C - exposure time frame (n+1) effective
D - image parameters frame (n+1) effective
E - earliest possible trigger

Image parameters:
Offset
Gain
Mode
Partial Scan

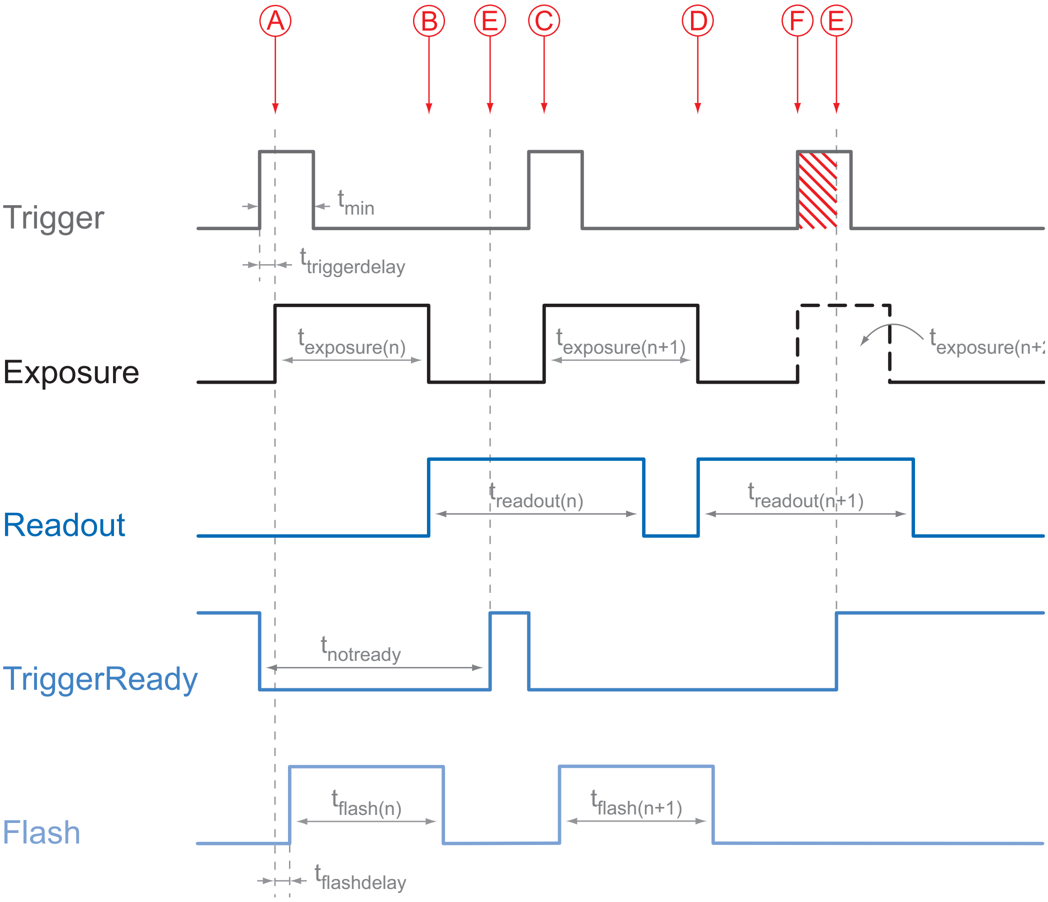
6.2.2.3 Overlapped Operation: $t_{exposure(n+2)} < t_{exposure(n+1)}$

If the exposure time ($t_{exposure}$) is decreased from the current acquisition to the next acquisition, the time the camera is unable to process occuring trigger signals ($t_{notready}$) is scaled up.

When decreasing the $t_{exposure}$ such, that $t_{notready}$ exceeds the pause between two incoming trigger signals, the camera is unable to process this trigger and the acquisition of the image will not start (the trigger will be skipped).

Timings:
A - exposure time frame (n) effective
B - image parameters frame (n) effective
C - exposure time frame (n+1) effective
D - image parameters frame (n+1) effective
E - earliest possible trigger
F - frame not started / trigger skipped

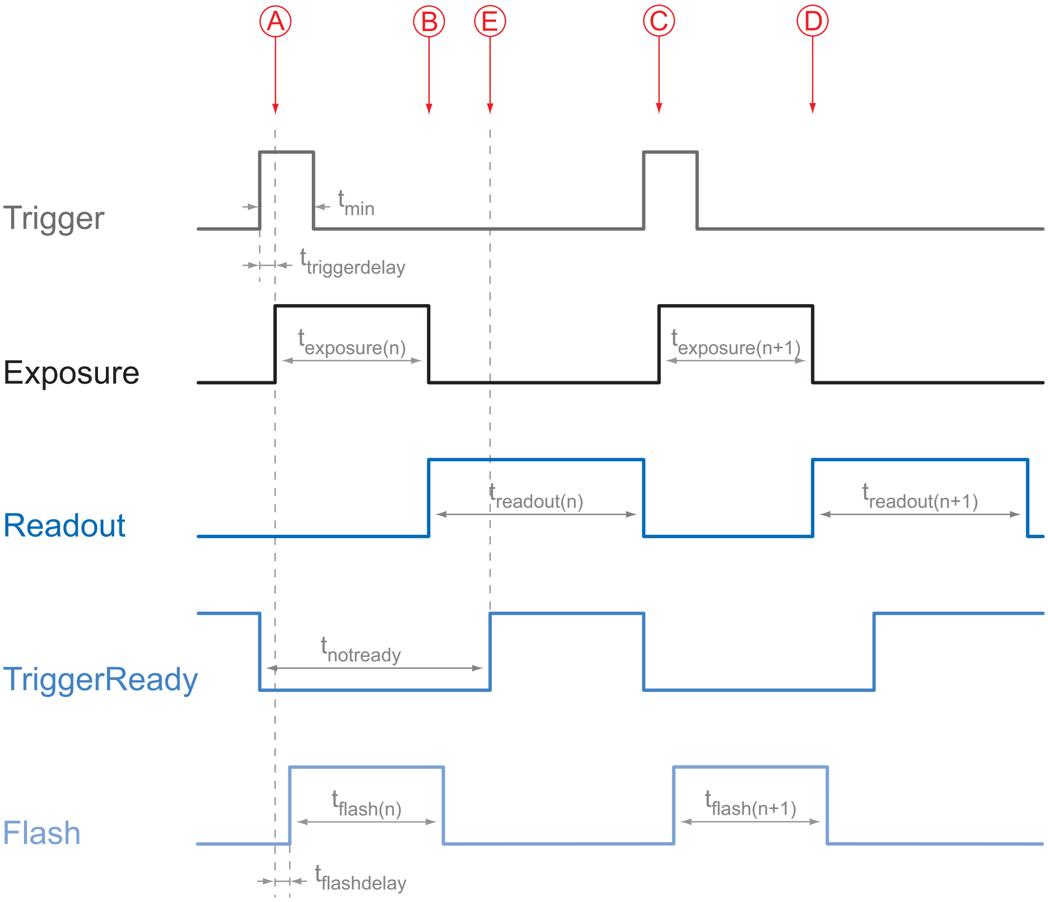
Image parameters:
Offset
Gain
Mode
Partial Scan



Notice
From a certain frequency of the trigger signal, skipping triggers is unavoidable. In general, this frequency depends on the combination of exposure and readout times.

6.2.2.4 Non-overlapped Operation

If the frequency of the trigger signal is selected for long enough, so that the image acquisitions ($t_{exposure}$ + $t_{readout}$) run successively, the camera operates non-overlapped.



Timings:	
A -	*exposure time frame (n) effective*
B -	*image parameters frame (n) effective*
C -	*exposure time frame (n+1) effective*
D -	*image parameters frame (n+1) effective*
E -	*earliest possible trigger*

Image parameters:
Offset
Gain
Mode
Partial Scan

6.3 Field of View Position

The typical accuracy by assumption of the root mean square value is displayed in the figures and the table below:

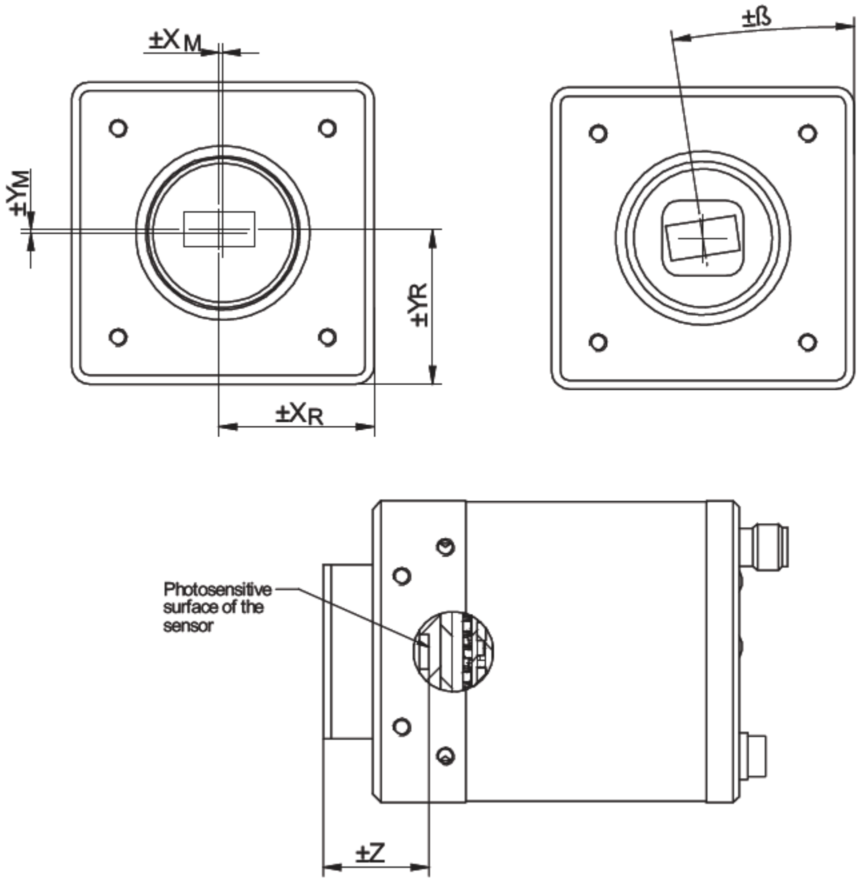


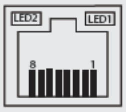
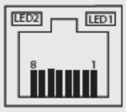
Figure 11 ►
Sensor accuracy of Baumer SXG cameras.

Camera Type	$\pm x_{M,typ}$ [mm]	$\pm y_{M,typ}$ [mm]	$\pm x_{R,typ}$ [mm]	$\pm y_{R,typ}$ [mm]	$\pm \beta_{typ}$ [°]	$\pm z_{typ}$ [mm] (C-Mount)	$\pm z_{typ}$ [mm] (F-Mount)
SXG10	0,11	0,11	0,11	0,11	0,51	0,025	-
SXG20	0,11	0,11	0,11	0,11	0,51	0,025	-
SXG21	0,11	0,11	0,11	0,11	0,51	0,025	0,05
SXG40	0,11	0,11	0,11	0,11	0,55	0,025	0,05
SXG80	0,11	0,11	0,11	0,11	0,47	0,025	0,05

6.4 Process- and Data Interface

6.4.1 Pin-Assignment Interface

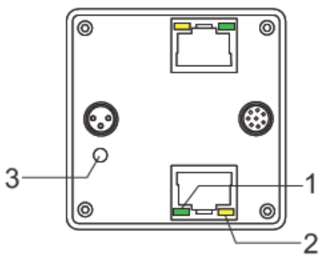
Notice
Only Port 0 supports Power over Ethernet (38 VDC .. 57 VDC). For the data transfer, the ports are equal. For Single GigE connect one Port and for Dual GigE connect the second Port additionally. The order does not matter.

Data / Control 1000 Base-T (Port 0)				Data / Control 1000 Base-T (Port 1)			
							
1	MX1+ (green/white) (negative/positive V_{port})	5	MX3- (blue/white)	1	MX1+ (green/white) (negative/positive V_{port})	5	MX3- (blue/white)
2	MX1- (green) (negative/positive V_{port})	6	MX2- (orange) (positive/negative V_{port})	2	MX1- (green) (negative/positive V_{port})	6	MX2- (orange) (positive/negative V_{port})
3	MX2+ (orange/white) (positive/negative V_{port})	7	MX4+ (brown/white)	3	MX2+ (orange/white) (positive/negative V_{port})	7	MX4+ (brown/white)
4	MX3+ (blue)	8	MX4- (brown)	4	MX3+ (blue)	8	MX4- (brown)

6.4.2 Pin-Assignment Power Supply and Digital IOs

M8 / 3 pins			M8 / 8 pins		
					
1	(brown)	Power V_{CC}	1	(white)	Line 5
3	(blue)	GND	2	(brown)	Line 1
4	(black)	not used	3	(green)	Line 0
			4	(yellow)	GND
	Power Supply		5	(grey)	U_{ext}
Power V_{CC}	20 VDC ... 30 VDC		6	(pink)	Line 3
			7	(blue)	Line 4
			8	(red)	Line 2

6.4.3 LED Signaling



◄ **Figure 12**
LED positions on Baumer SXG camera.

LED	Signal	Meaning
1	green / green flash	Link active / Receiving
2	yellow	Transmitting
3	green / yellow	Power on / Readout active

6.5 Environmental Requirements

6.5.1 Temperature and Humidity Range for Storage and Operation*)

Temperature	
Storage temperature	-10°C ... +70°C (+14°F ... +158°F)
Operating temperature*	+5 °C ... +60°C (+41°F ... +140°F)
Housing temperature**)***)	max. +60°C (+140°F)

* If the environmental temperature exceeds the values listed in the table below, the camera must be cooled. (see Heat Transmission)

Camera Type	Environmental Temperature
Monochrome	
SXG10	+19°C (+66.2°F)
SXG20	+18°C (+64.4°F)
SXG21	+18°C (+64.4°F)
SXG40	+16°C (+60.8°F)
SXG80	+14°C (+57.2°F)
Color	
SXG10c	+20°C (+68°F)
SXG20c	+20°C (+68°F)
SXG21c	+20°C (+68°F)
SXG40c	+19°C (+66.2°F)
SXG80c	+19°C (+66.2°F)

Humidity	
Storage and Operating Humidity	10% ... 90% non condensing

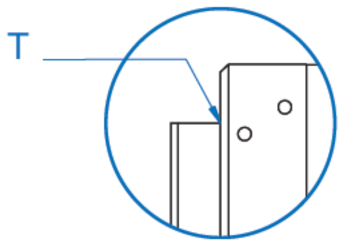


Figure 13 ▶
Temperature measurement point (T) of Baumer SXG cameras.

6.5.2 Heat Transmission

⚠ Caution

Provide adequate dissipation of heat, to ensure that the temperature does not exceed +60°C (+140°F).

The surface of the camera may be hot during operation and immediately after use. Be careful when handling the camera and avoid contact over a longer period.

As there are numerous possibilities for installation, Baumer does not specifiy a specific method for proper heat dissipation, but suggest the following principles:

- operate the cameras only in mounted condition
- mounting in combination with forced convection may provide proper heat dissipation

*) Please refer to the respective data sheet.
**) Measured at temperature measurement point (T).
***) Housing temperature is limited by sensor specifications.

6.5.3 Mechanical Tests

Environmental Testing	Standard	Parameter	
Vibration, sinusodial	IEC 60068-2-6	Search for Resonance	10-2000 Hz
		Amplitude underneath crossover frequencies	1.5 mm
		Acceleration	1 g
		Test duration	15 min
Vibration, broad band	IEC 60068-2-64	Frequency range	20-1000 Hz
		Acceleration	10 g
		Displacement	5.7 mm
		Test duration	300 min
Shock	IEC 60068-2-27	Puls time	11 ms / 6 ms
		Acceleration	50 g / 80 g
Bump	IEC60068-2-29	Pulse Time	2 ms
		Acceleration	80 g

7. Software

7.1 Baumer GAPI

Baumer GAPI stands for Baumer "**G**eneric **A**pplication **P**rogramming **I**nterface". With this API Baumer provides an interface for optimal integration and control of Baumer Gigabit Ethernet (GigE) , Baumer CameraLink® and Baumer FireWire™ (IEEE1394) cameras.

This software interface allows changing to other camera models or interfaces. It also allows the simultaneous operation of Baumer cameras with Gigabit Ethernet, CameraLink® and FireWire™ interfaces.

This GAPI supports Windows® (XP, Vista and Win 7) and Linux® (from Kernel 2.6.x) operating systems in 32 bit, as well as in 64 bit. It provides interfaces to several programming languages, such as C, C++ and the .NET™ Framework on Windows®, as well as Mono on Linux® operating systems, which offers the use of other languages, such as e.g. C# or VB.NET.

The SXG camera features are supported from Baumer GAPI V 1.7.0

7.2 3rd Party Software

Strict compliance with the Gen<I>Cam™ standard allows Baumer to offer the use of 3rd Party Software for operation with cameras of the SX series.

You can find a current listing of 3rd Party Software, which was tested successfully in combination with Baumer cameras, at http://www.baumer.com.

8. Camera Functionalities

8.1 Image Acquisition

8.1.1 Image Format

A digital camera usually delivers image data in at least one format - the native resolution of the sensor. Baumer cameras are able to provide several image formats (depending on the type of camera).

Compared with standard cameras, the image format on Baumer cameras not only includes resolution, but a set of predefined parameter.

These parameters are:

- Resolution (horizontal and vertical dimensions in pixels)
- Binning Mode (see chapter 8.1.8)

Camera Type	Full frame	Binning 2x2	Binning 1x2	Binning 2x1
Monochrome				
SXG10	■	□	□	□
SXG20	■	□	□	□
SXG21	■	■	■	■
SXG40	■	■	■	■
SXG80	■	■	■	■
Color				
SXG10c	■	□	□	□
SXG20c	■	□	□	□
SXG21c	■	□	□	□
SXG40c	■	□	□	□
SXG80c	■	□	□	□

8.1.2 Pixel Format

On Baumer digital cameras the pixel format depends on the selected image format.

8.1.2.1 Pixel Formats on Baumer SXG Cameras

Camera Type	Mono 8	Mono 10	Mono 12	Bayer RG 8	Bayer RG 10	Bayer RG 12
Monochrome						
SXG10	■	■	■	□	□	□
SXG20	■	■	■	□	□	□
SXG21	■	■	■	□	□	□
SXG40	■	■	■	□	□	□
SXG80	■	■	■	□	□	□
Color						
SXG10c	□	□	□	■	■	■
SXG20c	□	□	□	■	■	■
SXG21c	□	□	□	■	■	■
SXG40c	□	□	□	■	■	■
SXG80c	□	□	□	■	■	■

8.1.2.2 Definitions

Notice

Below is a general description of pixel formats. The table above shows, which camera support which formats.

Bayer: Raw data format of color sensors.
Color filters are placed on these sensors in a checkerboard pattern, generally in a 50% green, 25% red and 25% blue array.

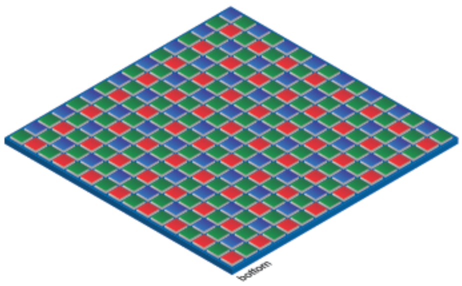
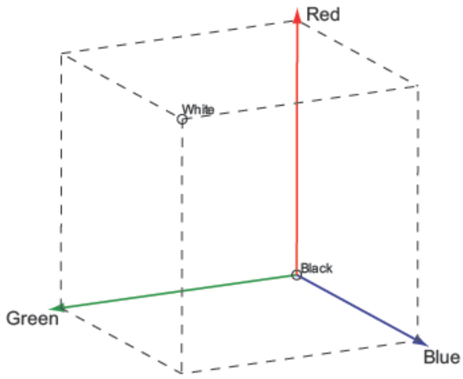


Figure 14 ► Sensor with Bayer Pattern.

Mono: Monochrome. The color range of mono images consists of shades of a single color. In general, shades of gray or black-and-white are synonyms for monochrome.

RGB: Color model, in which all detectable colors are defined by three coordinates, Red, Green and Blue.



◀ **Figure 15**
RBG color space displayed as color tube.

The three coordinates are displayed within the buffer in the order R, G, B.

BGR: Here the color alignment mirrors RGB.

YUV: Color model, which is used in the PAL TV standard and in image compression. In YUV, a high bandwidth luminance signal (Y: luma information) is transmitted together with two color difference signals with low bandwidth (U and V: chroma information). Thereby U represents the difference between blue and luminance (U = B - Y), V is the difference between red and luminance (V = R - Y). The third color, green, does not need to be transmitted, its value can be calculated from the other three values.

YUV 4:4:4 Here each of the three components has the same sample rate. Therefore there is no subsampling here.

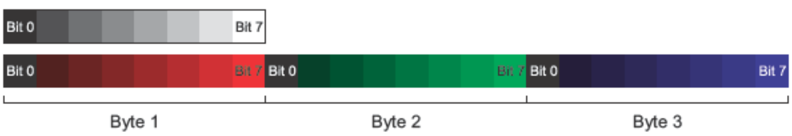
YUV 4:2:2 The chroma components are sampled at half the sample rate. This reduces the necessary bandwidth to two-thirds (in relation to 4:4:4) and causes no, or low visual differences.

YUV 4:1:1 Here the chroma components are sampled at a quater of the sample rate.This decreases the necessary bandwith by half (in relation to 4:4:4).

Pixel depth: In general, pixel depth defines the number of possible different values for each color channel. Mostly this will be 8 bit, which means 2^8 different "colors".

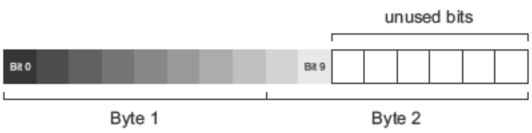
For RGB or BGR these 8 bits per channel equal 24 bits overall.

8 bit:



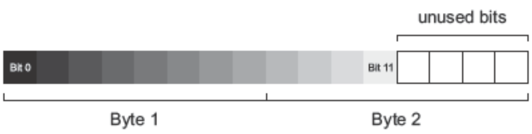
◀ **Figure 16**
Bit string of Mono 8 bit and RGB 8 bit.

10 bit:



◀ **Figure 17**
Spreading of Mono 10 bit over 2 bytes.

12 bit:



◀ **Figure 18**
Spreading of Mono 12 bit over two bytes.

8.1.3 Exposure Time

On exposure of the sensor, the inclination of photons produces a charge separation on the semiconductors of the pixels. This results in a voltage difference, which is used for signal extraction.

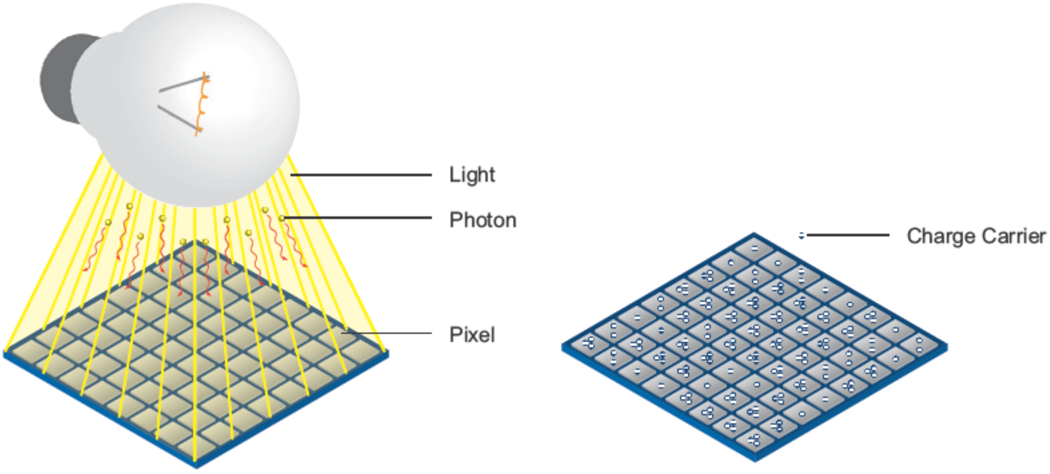


Figure 19 ▶
Incidence of light causes charge separation on the semiconductors of the sensor.

The signal strength is influenced by the incoming amount of photons. It can be increased by increasing the exposure time ($t_{exposure}$).

On Baumer SXG cameras, the exposure time can be set within the following ranges (step size 1µsec):

Camera Type	$t_{exposure}$ min	$t_{exposure}$ max
Monochrome		
SXG10	10 µsec	1 sec
SXG20	10 µsec	1 sec
SXG21	10 µsec	1 sec
SXG40	10 µsec	1 sec
SXG80	10 µsec	1 sec
Color		
SXG10c	10 µsec	1 sec
SXG20c	10 µsec	1 sec
SXG21c	10 µsec	1 sec
SXG40c	10 µsec	1 sec
SXG80c	10 µsec	1 sec

8.1.4 Look-Up-Table

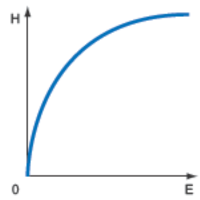
The Look-Up-Table (LUT) is employed on Baumer monochrome cameras. It contains 2^{12} (4096) values for the available levels of gray. These values can be adjusted by the user.

8.1.5 Gamma Correction

With this feature, Baumer SXG cameras offer the possibility of compensating nonlinearity in the perception of light by the human eye.

For this correction, the corrected pixel intensity (Y') is calculated from the original intensity of the sensor's pixel ($Y_{original}$) and correction factor γ using the following formula (in over-simplified version):

$$Y' = Y_{original}^{\gamma}$$



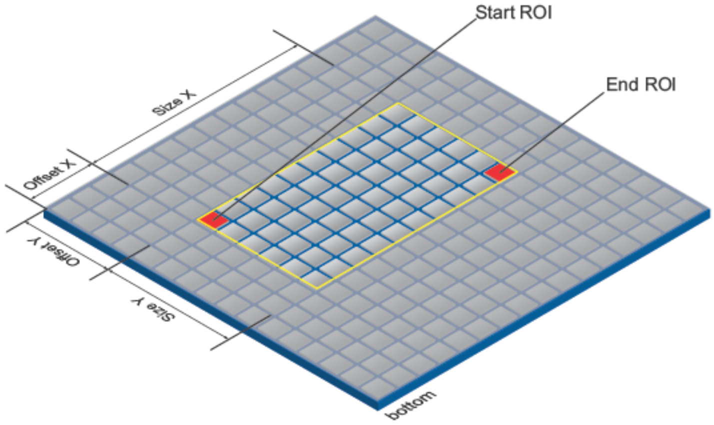
▲ **Figure 20**
Non-linear perception of the human eye.
H - Perception of brightness
E - Energy of light

8.1.6 Region of Interest (ROI)

With this function it is possible to predefine a so-called Region of Interest (ROI) or Partial Scan. This ROI is an region of pixels of the sensor. On image acquisition, only the information of these pixels is sent to the PC. Therefore all the lines of the sensor need not be read out, which decreases the readout time ($t_{readout}$). This increases the frame rate.

This function is employed, when only a region of the field of view is of interest. It is coupled to a reduction in resolution.

The ROI is specified by four values:
- Offset X - x-coordinate of the first relevant pixel
- Offset Y - y-coordinate of the first relevant pixel
- Size X - horizontal size of the ROI
- Size Y - vertical size of the ROI

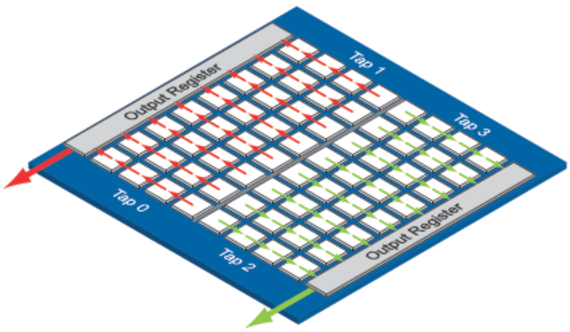


◄ **Figure 21**
Parameters of the ROI.

8.1.7 ROI Readout

For the readout of the ROI, the vertical subdivision of the sensor (see 6.1.3. Readout Modes) is unimportant – only the horizontal subdivision is of note.

Both sensor halves are read out simultaneously as displayed in the subsequent figure.



◄ **Figure 22**
ROI: Readout.

The readout is line based, which means always a complete line of pixels needs to be read out and afterwards the irrelevant information is discarded.

Due to the fact, that the sensor halves are always read out symmetrically, the readout time $t_{readout}$ is significantly affected both by the size of the ROI and also by its position.

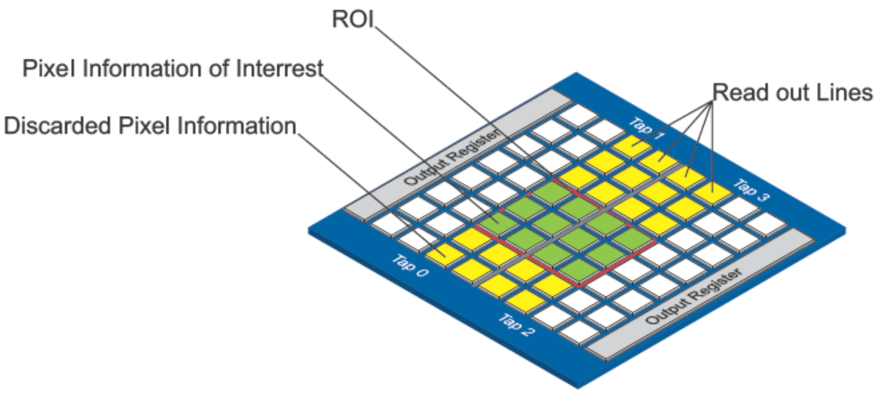


Figure 23 ▶

ROI:
Read out Lines.

The most significant reduction of the readout time – compared to a full frame readout in dual mode – can be achieved if the ROI is positioned as follows:

- within one of the sensor halves
- symmetrically spread to both sensor halves

For example, the readout time of the ROI's in the figures 21 and 22 is the same.

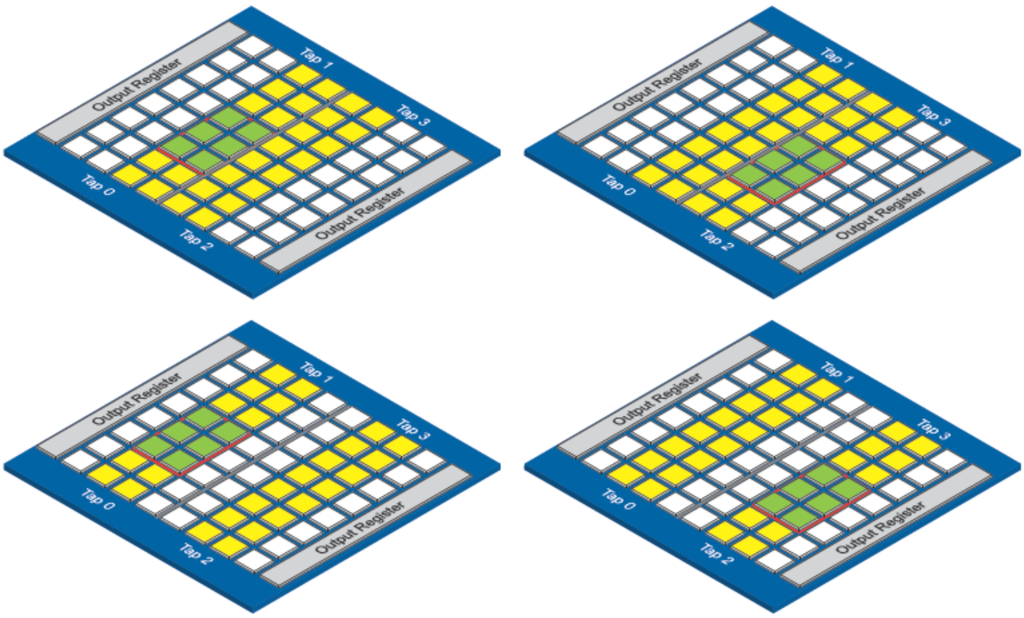


Figure 24 ▶

ROI:
Example ROI's with identical readout times.

On asymmetrically spread ROI's, the readout time is affected by the bigger part of the ROI.

An example for this fact is shown in the figure below:

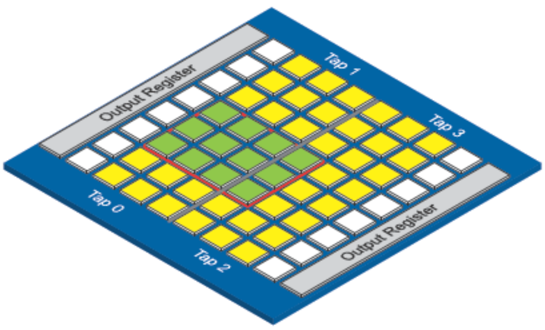


Figure 25 ▶

ROI:
Read out time linked with position of the ROI.

The ROI has the same size as in figure 21, but is not symmetrically spread to both sensor halves. In this special case the time for the readout of the same number of pixels is increased by 50%, caused only by ROI's position.

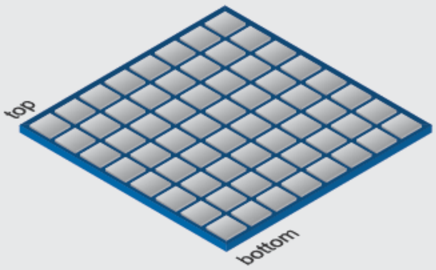
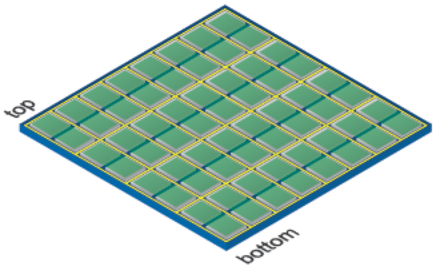
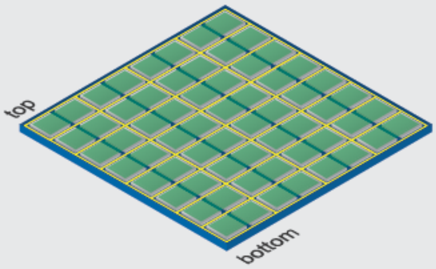
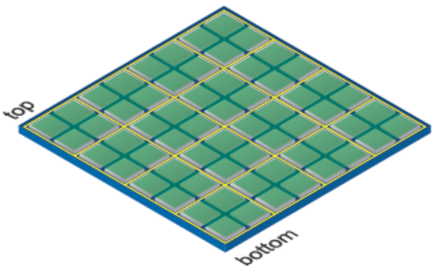
8.1.8 Binning

On digital cameras, you can find several operations for progressing sensitivity. One of them is the so-called "Binning". Here, the charge carriers of neighboring pixels are aggregated. Thus, the progression is greatly increased by the amount of binned pixels. By using this operation, the progression in sensitivity is coupled to a reduction in resolution.

Baumer cameras support three types of Binning - vertical, horizontal and bidirectional.

In unidirectional binning, vertically or horizontally neighboring pixels are aggregated and reported to the software as one single "superpixel".

In bidirectional binning, a square of neighboring pixels is aggregated.

Binning	Illustration	Example
without		
1x2		
2x1		
2x2		

◄ **Figure 26**
Full frame image, no binning of pixels.

◄ **Figure 27**
Vertical binning causes a vertically compressed image with doubled brightness.

◄ **Figure 28**
Horizontal binning causes a horizontally compressed image with doubled brightness.

◄ **Figure 29**
Bidirectional binning causes both a horizontally and vertically compressed image with quadruple brightness.

8.1.9 Brightness Correction (Binning Correction)

The aggregation of charge carriers may cause an overload. To prevent this, binning correction was introduced. Here, three binning modes need to be considered separately:

Binninig	Realization
1x2	1x2 binning is performed within the sensor, binning correction also takes place here. A possible overload is prevented by halving the exposure time.
2x1	2x1 binning takes place within the FPGA of the camera. The binning correction is realized by aggregating the charge quantities, and then halving this sum.
2x2	2x2 binning is a combination of the above versions.

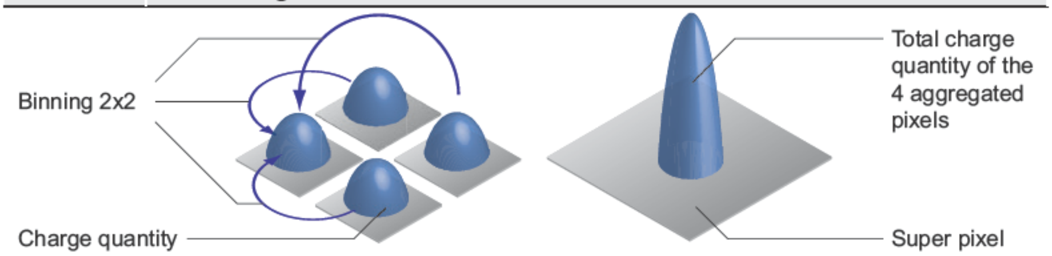


Figure 30 ►
Aggregation of charge carriers from four pixels in bidirectional binning.

8.2 Color Adjustment – White Balance

This feature is available on all color cameras of the Baumer SXG series and takes place within the Bayer processor.

White balance means independent adjustment of the three color channels, red, green and blue by employing of a correction factor for each channel.

8.2.1 User-specific Color Adjustment

The user-specific color adjustment in Baumer color cameras facilitates adjustment of the correction factors for each color gain. This way, the user is able to adjust the amplification of each color channel exactly to his needs. The correction factors for the color gains range from 1 to 4.

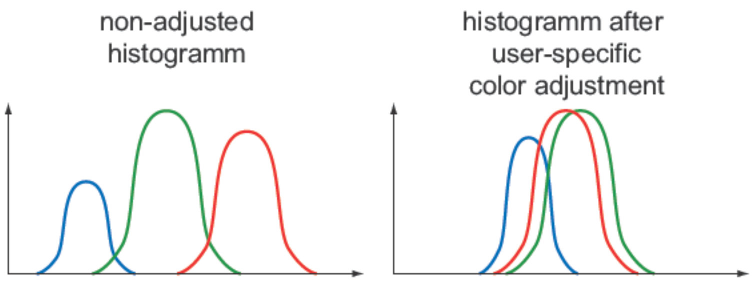


Figure 31 ►
Examples of histogramms for a non-adjusted image and for an image after user-specific white balance..

8.2.2 One Push White Balance

Here, the three color spectrums are balanced to a single white point. The correction factors of the color gains are determined by the camera (one time).

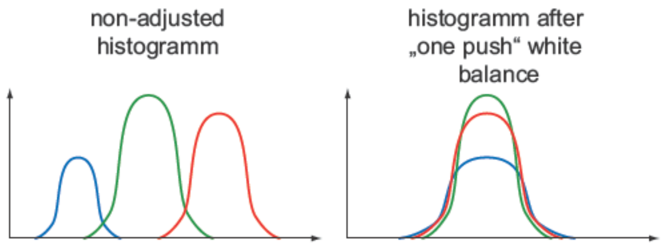
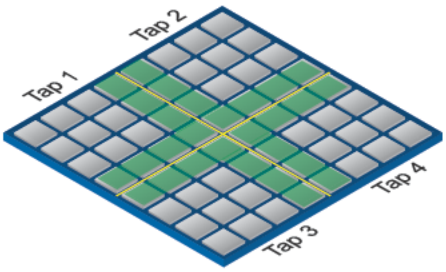


Figure 32 ►
Examples of histogramms for a non-adjusted image and for an image after "one push" white balance.

8.3 Auto Tap Balance

The feature "Auto Tap Balance" corrects the possible differences in brightness of the four Taps.

This is achieved by calculating the average of the brightness of the pixels at the border of the taps (on the figure below green).



8.4 Analog Controls

8.4.1 Brightness (Offset / Black Level)

On Baumer cameras, the Offset / Black Level is adjustable from 0 to 1023 LSB (least significant bit).

Camera Type	Step Size 1 LSB Relating to
Monochrome	
SXG10	14 bit
SXG20	14 bit
SXG21	14 bit
SXG40	14 bit
SXG80	14 bit
Color	
SXG10c	14 bit
SXG20c	14 bit
SXG21c	14 bit
SXG40c	14 bit
SXG80c	14 bit

8.4.2 Gain

In industrial environments motion blur is unacceptable. Due to this fact exposure times are limited. However, this causes low output signals from the camera and results in dark images. To solve this issue, the signals can be amplified by user within the camera. This gain is adjustable from 0 to 26 db.

Notice
Increasing the gain factor causes an increase of image noise.

8.5 Pixel Correction

8.5.1 General information

A certain probability for abnormal pixels - the so-called defect pixels - applies to the sensors of all manufacturers. The charge quantity on these pixels is not linear-dependent on the exposure time.

The occurrence of these defect pixels is unavoidable and intrinsic to the manufacturing and aging process of the sensors.

The operation of the camera is not affected by these pixels. They only appear as brighter (warm pixel) or darker (cold pixel) spot in the recorded image.

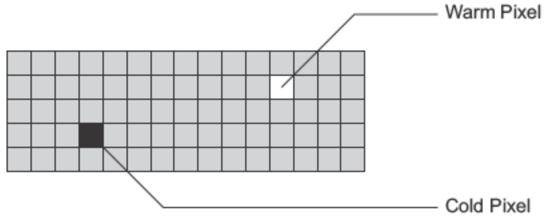


Figure 33 ►
Distinction of "hot" and "cold" pixels within the recorded image.

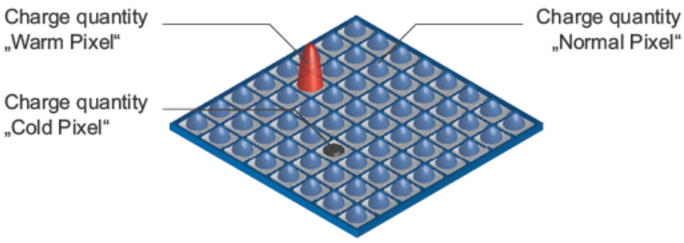


Figure 34 ►
Charge quantity of "hot" and "cold" pixels compared with "normal" pixels.

8.5.2 Correction Algorithm

On monochrome cameras of the Baumer SXG series, the problem of defect pixels is solved as follows:

- Possible defect pixels are identified during the production process of the camera.
- The coordinates of these pixels are stored in the factory settings of the camera (see 8.5.3 Defectpixellist).
- Once the sensor readout is completed, correction takes place:
  - Before any other processing, the values of one neighboring pixels on the left and the right side of the defect pixel, will be read out
  - Then the average value of these 2 pixels is determined
  - Finally, the value of the defect pixel is substituted by the previously determined average value

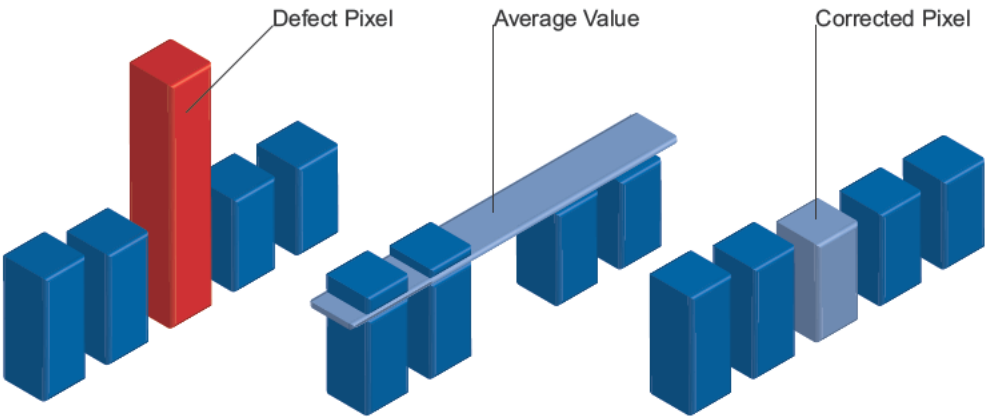


Figure 35 ►
Schematic diagram of the Baumer pixel correction.

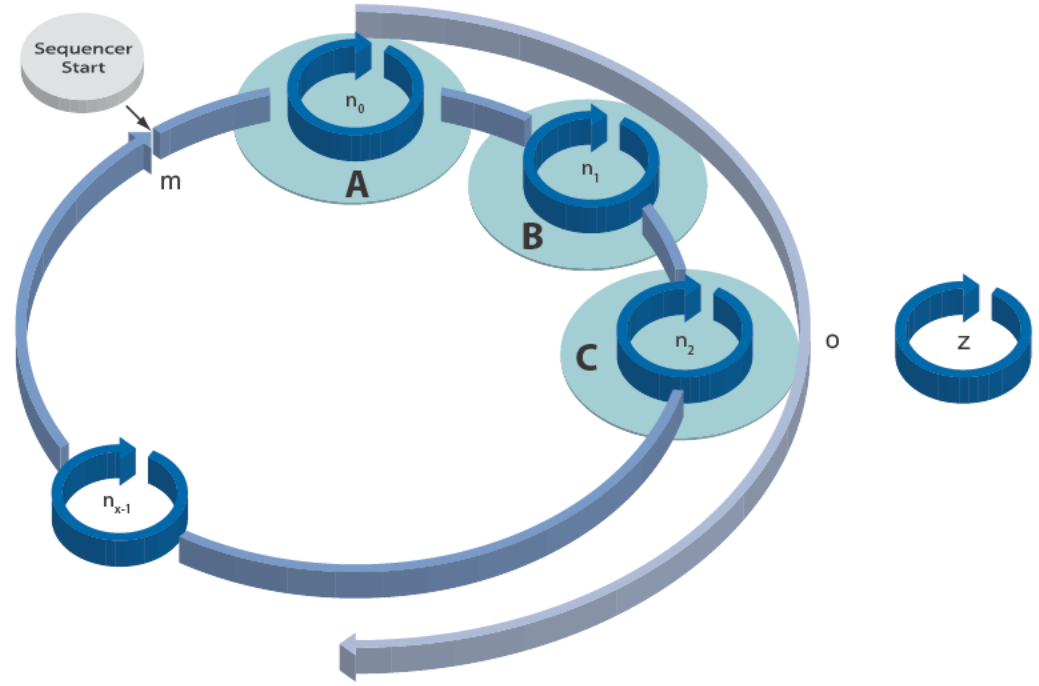
8.5.3 Defectpixellist

As stated previously, this list is determined within the production process of Baumer cameras and stored in the factory settings. This list is editable.

8.6 Sequencer

8.6.1 General Information

A sequencer is used for the automated control of series of images using different sets of parameters.



◄ **Figure 36**
Flow chart of sequencer.
m - number of sequence repetitions
n - number of set repetitions
o - number of sets of parameters
z - number of frames per trigger

The figure above displays the fundamental structure of the sequencer module.

The loop counter (m) represents the number of sequence repetitions.

The repeat counter (n) is used to control the amount of images taken with the respective sets of parameters. For each set there is a separate n.

The start of the sequencer can be realized directly (free running) or via an external event (trigger). The source of the external event (trigger source) must be determined before.

The additional frame counter (z) is used to create a half-automated sequencer. It is absolutely independent from the other three counters, and used to determine the number of frames per external trigger event.

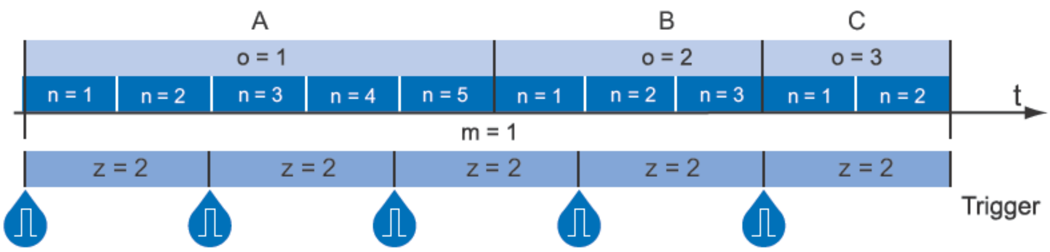
Sequencer Parameter:

The mentioned sets of parameter include the following:

- *Exposure time*
- *Gain factor*
- *Output line value*
- *Repeat counter (n)*

The following timeline displays the temporal course of a sequence with:

- n = (A=5), (B=3), (C=2) repetitions per set of parameters
- o = 3 sets of parameters (A,B and C)
- m = 1 sequence and
- z = 2 frames per trigger



◄ **Figure 37**
Timeline for a single sequence

8.6.2 Baumer Optronic Sequencer in Camera xml-file

The Baumer Optronic seqencer is described in the category "`BOSequencer`" by the following features:

Static Sequencer Features These values are valid for all sets.	
`BoSequencerEnable`	Enable / Disable
`BoSequencerFramesPerTrigger`	Number of frames per trigger (z)
`BoSequencerIsRunning`	Check whether the sequencer is running
`BoSequencerLoops`	Number of sequences (m)
`BoSequencerMode`	Running mode of Sequencer
`BoSequencerSetNumberOfSets`	Number of sets - 1
`BoSequencerStart`	Start / Stop
Set-specific Features These values can be set individually for each set.	
`BoSequencerExposure`	Parameter exposure
`BoSequencerGain`	Parameter gain
`BoSequencerIOSelector`	Selected output lines
`BoSequencerIOStatus`	Status of all Sequencer outputs
`BoSequencerSetRepeats`	Number of repetitions (n)
`BoSequencerSetSelector`	Configure set of parameters

8.6.3 Examples

8.6.3.1 Sequencer without Machine Cycle

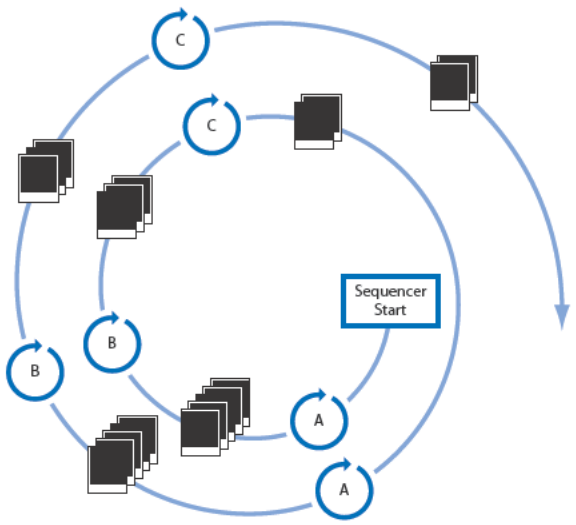


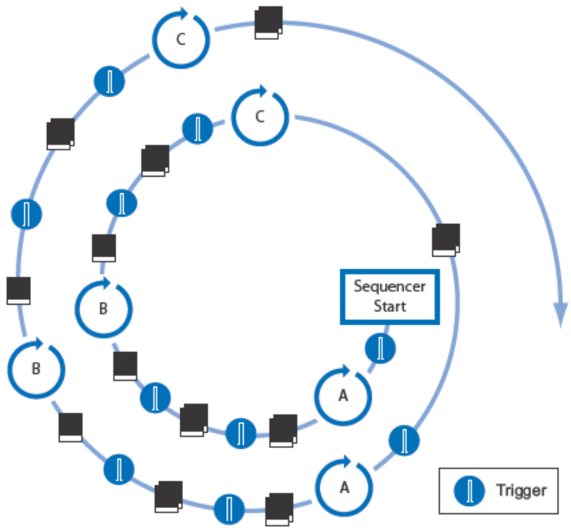
Figure 38 ►
Example for a fully automated sequencer.

The figure above shows an example for a fully automated sequencer with three sets of parameters (A,B and C). Here the repeat counter (n) is set for (A=5), (B=3), (C=2) and the loop counter (m) has a value of 2.

When the sequencer is started, with or without an external event, the camera will record the pictures using the sets of parameters A, B and C (which constitutes a sequence).

After that, the sequence is started once again, followed by a stop of the sequencer - in this case the parameters are maintained.

8.6.3.2 Sequencer Controlled by Machine Steps (trigger)



◄ **Figure 39**
Example for a half-automated sequencer.

The figure above shows an example for a half-automated sequencer with three sets of parameters (A,B and C) from the previous example. The frame counter (z) is set to 2. This means the camera records two pictures after an incoming trigger signal.

8.6.4 Capability Characteristics of Baumer-GAPI Sequencer Module

- up to 128 sets of parameters
- up to 2 billion loop passes
- up to 2 billion repetitions of sets of parameters
- up to 2 billion images per trigger event
- free running mode without initial trigger

8.6.5 Double Shutter

This feature offers the possibility of capturing two images in a very short interval. Depending on the application, this is performed in conjunction with a flash unit. Thereby the first exposure time ($t_{exposure}$) is arbitrary and accompanied by the first flash. The second exposure time must be equal to, or longer than the readout time ($t_{readout}$) of the sensor. Thus the pixels of the sensor are recepitve again shortly after the first exposure. In order to realize the second short exposure time without an overrun of the sensor, a second short flash must be employed, and any subsequent extraneous light prevented.

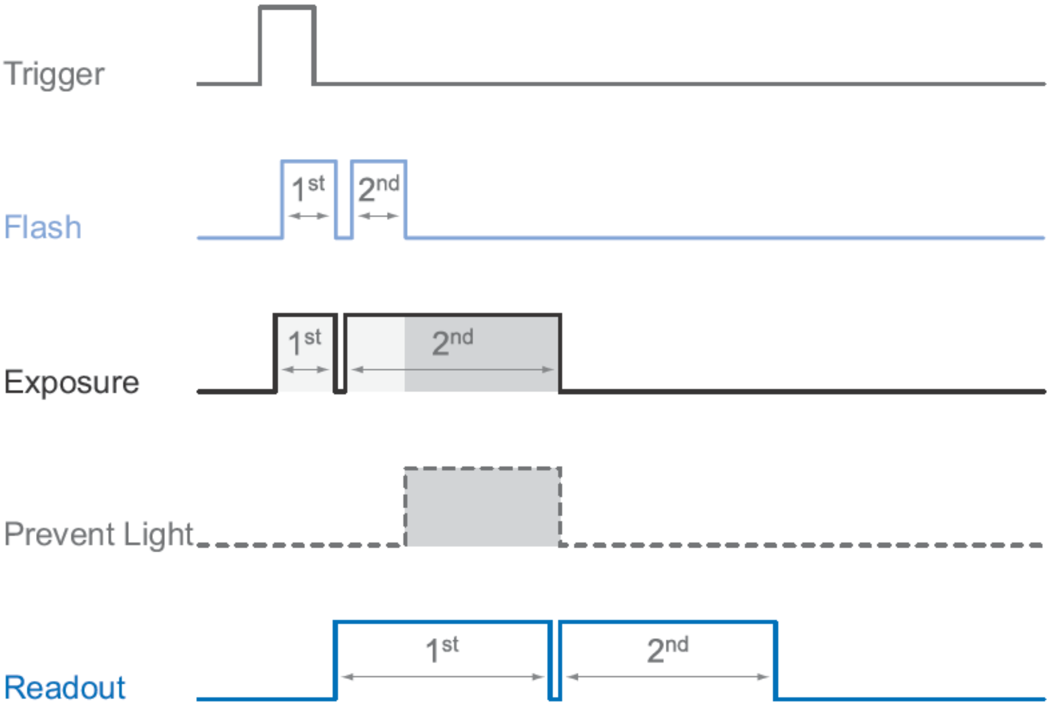


Figure 40 ▶
Example of a double shutter.

On Baumer SXG cameras this feature is realized within the sequencer.

In order to generate this sequence, the sequencer must be configured as follows:

Parameter	Setting:
Sequencer Run Mode	Once by Trigger
Sets of parameters (o)	2
Loops (m)	1
Repeats (n)	1
Frames Per Trigger (z)	2

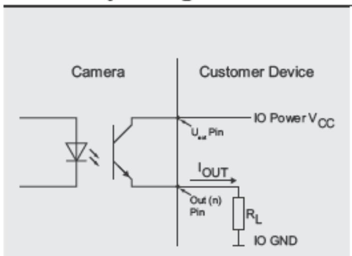
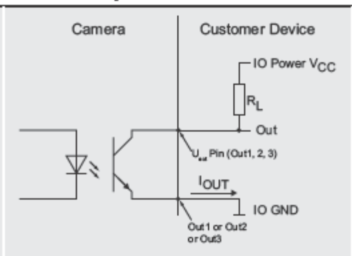
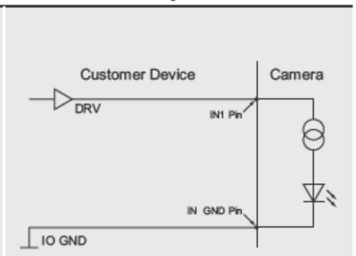
8.7 Process Interface

8.7.1 Digital IOs

Cameras of the Baumer SXG series are equipped with three input lines and three output lines.

8.7.1.1 IO Circuits

Notice
Low Active: At this wiring, only one consumer can be connected. When all Output pins (1, 2, 3) connected to IO_GND, then current flows through the resistor as soon as one Output is switched. If only one output connected to IO_GND, then this one is only usable. The other two Outputs are not usable and may not be connected (e.g. IO Power V_{CC})!

Output high active	Output low active	Input
		

8.7.1.2 User Definable Inputs

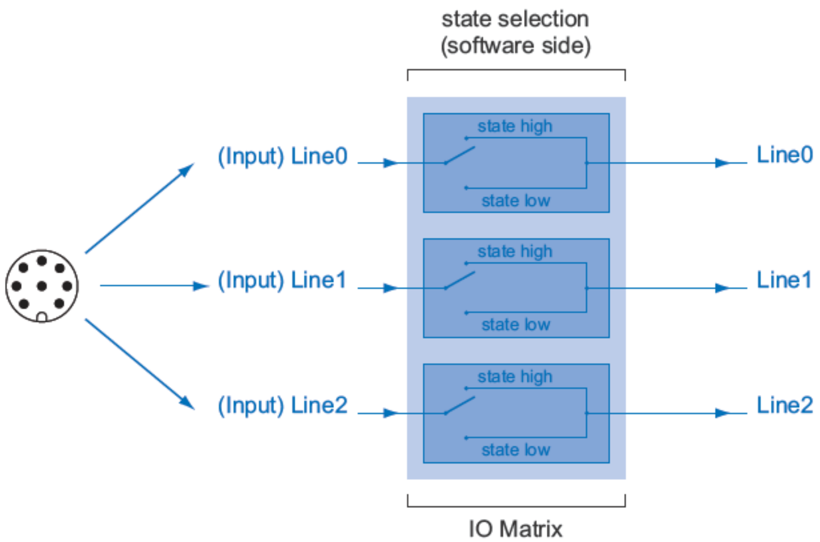
The wiring of these input connectors is left to the user.

Sole exception is the compliance with predetermined high and low levels (0 .. 4,5V low, 11 .. 30V high).

The defined signals will have no direct effect, but can be analyzed and processed on the software side and used for controlling the camera.

The employment of a so called "IO matrix" offers the possibility of selecting the signal and the state to be processed.

On the software side the input signals are named "Line0", "Line1" and "Line2".



◄ **Figure 41**
IO matrix of the Baumer SXG on input side.

8.7.1.3 Configurable Outputs

With this feature, Baumer offers the possibility of wiring the output connectors to internal signals, which are controlled on the software side.

Hereby on cameras of the SXG series, 17 signal sources – subdivided into three categories – can be applied to the output connectors.

The first category of output signals represents a loop through of signals on the input side, such as:

Signal Name	Explanation
Line0	Signal of input "Line0" is loopthroughed to this ouput
Line1	Signal of input "Line1" is loopthroughed to this ouput
Line2	Signal of input "Line2" iys loopthroughed to this ouput

Within the second category you will find signals that are created on camera side:

Signal Name	Explanation
FrameActive	The camera processes a Frame consisting of exposure and readout
TriggerReady	Camera is able to process an incoming trigger signal
TriggerOverlapped	The camera operates in overlapped mode
TriggerSkipped	Camera rejected an incoming trigger signal
ExposureActive	Sensor exposure in progress
TransferActive	Image transfer via hardware interface in progress
ExposureEnlarged	This output marks the period of enlarged exposure time

Beside the 10 signals mentioned above, each output can be wired to a user-defined signal ("UserOutput0", "UserOutput1", "UserOutput2", "SequencerOut 0...2" or disabled ("OFF").

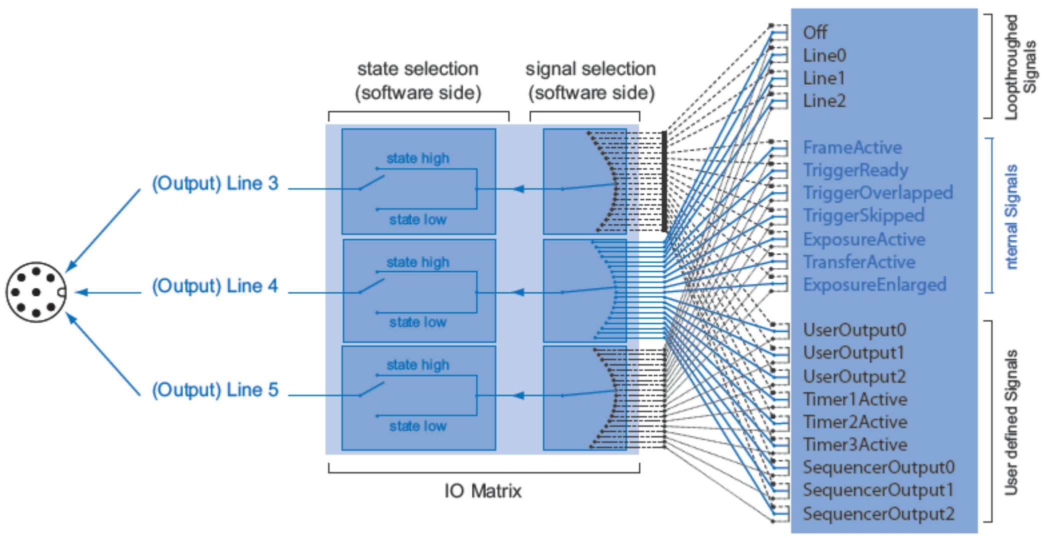


Figure 42 ►
IO matrix of the Baumer SXG on output side.

8.8 Trigger Input / Trigger Delay

Trigger signals are used to synchronize the camera exposure and a machine cycle or, in case of a software trigger, to take images at predefined time intervals.

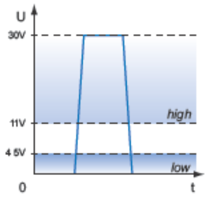


Figure 43 ▲
Trigger signal, valid for Baumer cameras.

Different trigger sources can be used here:

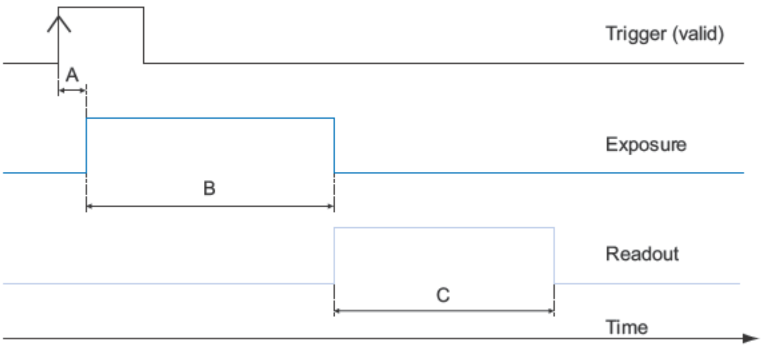
Line0	Actioncommand
Line1	Off
Line2	
SW-Trigger	

Possible settings of the Trigger Delay

Delay	0-2 sec
Number of tracked Triggers	512
Step	1 µsec

There are three types of trigger modes. The timing diagrams for the three types you can see below.

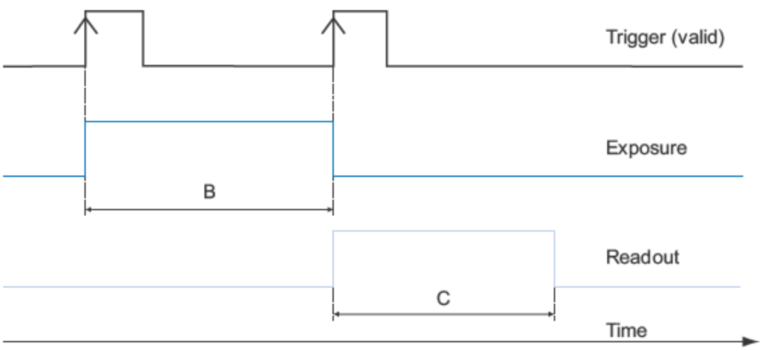
Normal Trigger with adjusted Exposure



Camera in trigger mode:
A - Trigger delay
B - Exposure time
C - Readout time

Pulse Width controlled Exposure

Edge controlled Exposure



8.8.1 Trigger Source

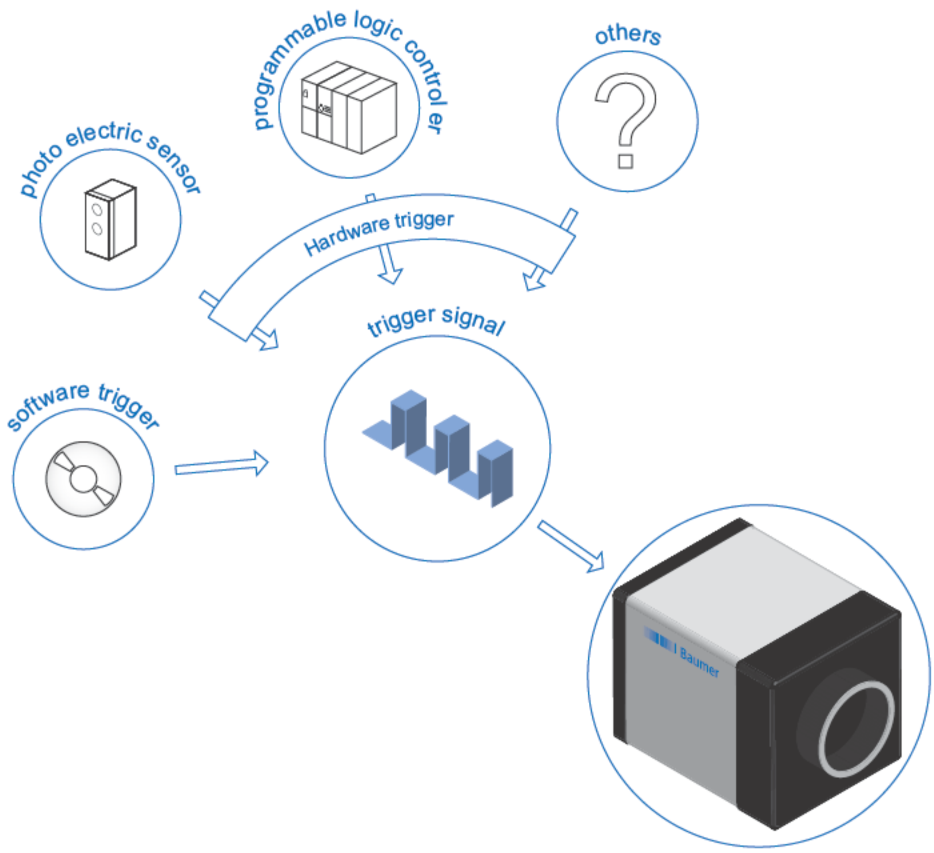


Figure 44 ►
Examples of possible trigger sources.

Each trigger source has to be activated separately. When the trigger mode is activated, the hardware trigger is activated by default.

8.8.2 Debouncer

The basic idea behind this feature was to seperate interfering signals (short peaks) from valid square wave signals, which can be important in industrial environments. Debouncing means that invalid signals are filtered out, and signals lasting longer than a user-defined testing time $t_{DebounceHigh}$ will be recognized, and routed to the camera to induce a trigger.

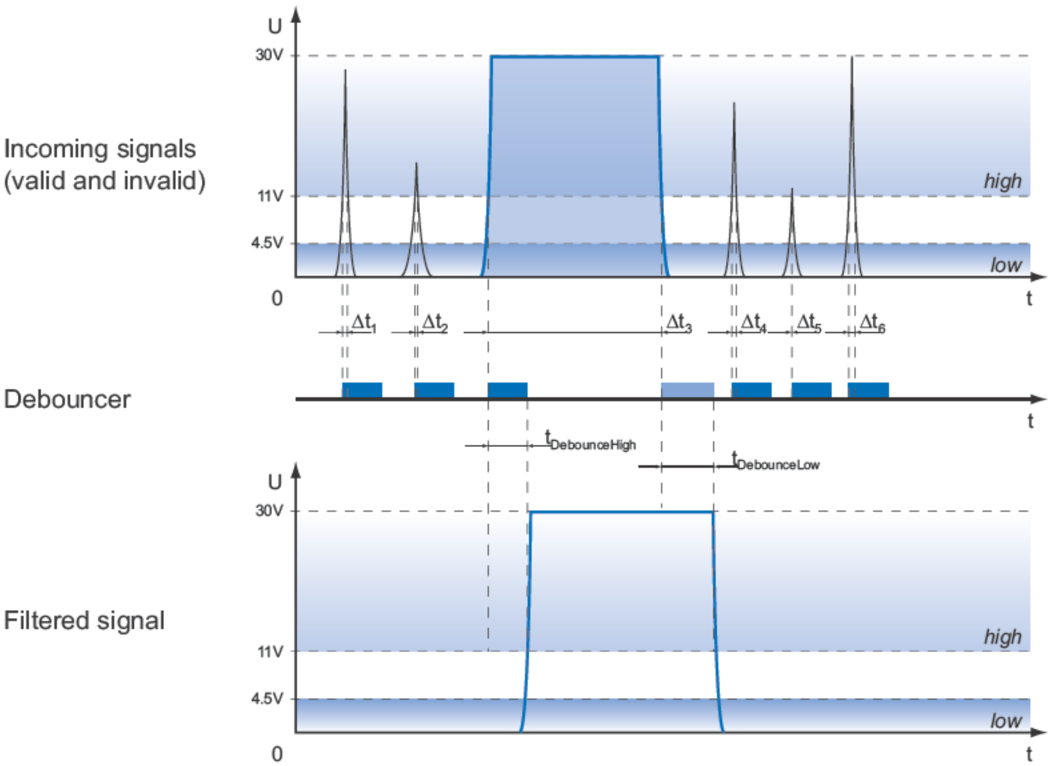
In order to detect the end of a valid signal and filter out possible jitters within the signal, a second testing time $t_{DebounceLow}$ was introduced. This timing is also adjustable by the user. If the signal value falls to state low and does not rise within $t_{DebounceLow}$, this is recognized as end of the signal.

The debouncing times $t_{DebounceHigh}$ and $t_{DebounceLow}$ are adjustable from 0 to 5 msec in steps of 1 µsec.

This feature is disabled by default.

Debouncer:

Please note that the edges of valid trigger signals are shifted by $t_{DebounceHigh}$ and $t_{DebounceLow}$!
Depending on these two timings, the trigger signal might be temporally stretched or compressed.



Δt_x high time of the signal
$t_{DebounceHigh}$ user defined debouncer delay for state high
$t_{DebounceLow}$ user defined debouncer delay for state low

◄ **Figure 45**
Principle of the Baumer debouncer.

8.8.3 Flash Signal

On Baumer cameras, this feature is realized by the internal signal "ExposureActive", which can be wired to one of the digital outputs.

8.8.4 Timer

Timers were introduced for advanced control of internal camera signals.

On Baumer SXG cameras the timer configuration includes four components:

Setting	Description
Timeselector	There are three timers. Own settings for each timer can be made. (Timer1, Timer2, Timer3)
TimerTriggerSource	This feature provides a source selection for each timer.
TimerTriggerActivation	This feature selects that part of the trigger signal (edges or states) that activates the timer.
TimerDelay	This feature represents the interval between incoming trigger signal and the start of the timer. (0 µsec .. 2 sec, step: 1 µsec)
TimerDuration	By this feature the activation time of the timer is adjustable. (10 µsec .. 2 sec, step: 1 µsec)

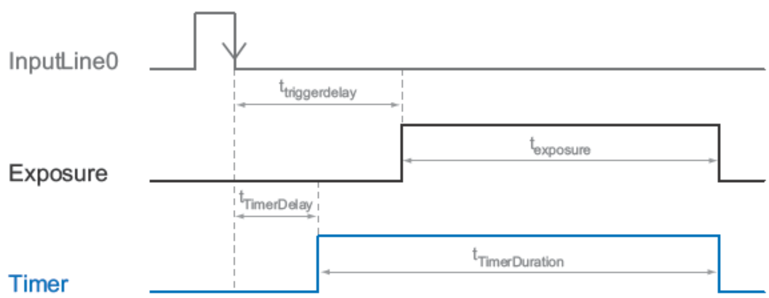
Different Timer Trigger sources can be used:

Timer Trigger sources	
Input Line0	Exposure Start
Input Line1	Exposure End
Input Line2	Frame Start
SW-Trigger	Frame End
ActionCommandTrigger	TriggerSkipped

For example the using of a timer allows you to control the flash signal in that way, that the illumination does not start synchronized to the sensor exposure but a predefined interval earlier.

For this example you must set the following conditions:

Setting	Value
TriggerSource	InputLine0
TimerTriggerSource	InputLine0
Outputline7 (Source)	Timer1Active
TimerTriggerActivation	Falling Edge
Trigger Polarity	Falling Edge



8.8.5 Counter

You can count the Events in the table below. The count values of these Events are readable and writable.

With the function "Event Source/activation" you can specify which event should be counted. These events can also be used as a CounterResetSource.

These events are:

CounterTriggerSources / CounterResetSources	
Input Line0	ExposureStart
Input Line1	ExposureEnd
Input Line2	FrameStart
Softwaretrigger	FrameEnd
ActCmdTrigger	TriggerSkipped

You can set a counter duration. You can therefore set the number of events to be counted. When the set value is 0, then the maximum number of countable events is 2^{32}-1 (4294967295).

If you specify a value, then the counter counts up to that value and stops. Then a GigE event is triggered ("Counter1/2End") and the status of the counter changes from ACTIVE to the readable status COMPLETED.

Reset the counter

When the reset event is reached or the counter is reset by software with "reset counter", then the count value is stored under "CounterValueAtReset" and set the counter value back to 0.

8.9 User Sets

Three user sets (1-3) are available for the Baumer cameras of the SXG series. The user sets can contain the following information:

Parameters	
Binning Mode	Mirroring Control
Defectpixellist	Partial Scan
Digital I/O Settings	Pixelformat
Exposure Time	Readout Mode
Gain Factor	Testpattern
Look-Up-Table	Trigger Settings
Sequencer	Action Command Parameter
Timer	Counter
Fixed Frame Rate	Frame Delay
Gamma	Offset

These user sets are stored within the camera and and cannot be saved outside the device.

By employing a so-called "user set default selector", one of the three possible user sets can be selected as default, which means, the camera starts up with these adjusted parameters.

8.10 Factory Settings

The factory settings are stored in an additional parametrization set which is used by default. This settings are not editable.

9. Interface Functionalities

9.1 Link Aggregation Group Configuration

Link Aggregation (LAG) allows grouping the two links of the SXG camera to form a “virtual” link, enabling the camera to treat the LAG as if it was a single link. This is done in a transparent way from the application perspective.

It is important to note that LAG does not define the distribution algorithm to be used at the transmission end of a link aggregation group. Since LAG shows a single MAC/IP, then switches cannot figure out how to distribute the image traffic: the traffic might end-up on one outgoing port of the switch.

Characteristic	Static LAG
Number of network interfaces	2
Number of IP address	1
Number of stream channels	1
Load balancing	Round-robin distribution algorithm
Physical link down recovery	Packets redistributed on remaining physical link
Grouping configuration	All links are automatically grouped on the device. Manual grouping must be performed on the PC (often called teaming)

9.1.1 Camera Control

The communication for the camera control is always sent on the same physical link of the LAG.

9.1.2 Image data stream

A round-robin distribution algorithm allows for a uniform distribution of the bandwidth associated to the image data since all image packets have the same size. So it adequately balances the bandwidth across the two available links. A suitable packet size must be selected to ensure all physical links can handle it.

Because of this loose definition of conversation and the selected distribution algorithm, it is necessary for the receiver of the image data to be tolerant to out-of-order packets and accommodate longer timeouts than seen with Single Link configuration.

Special provision must be taken for the inter-packet delay: it represents the delay between packets of the image data stream travelling on a given physical link.

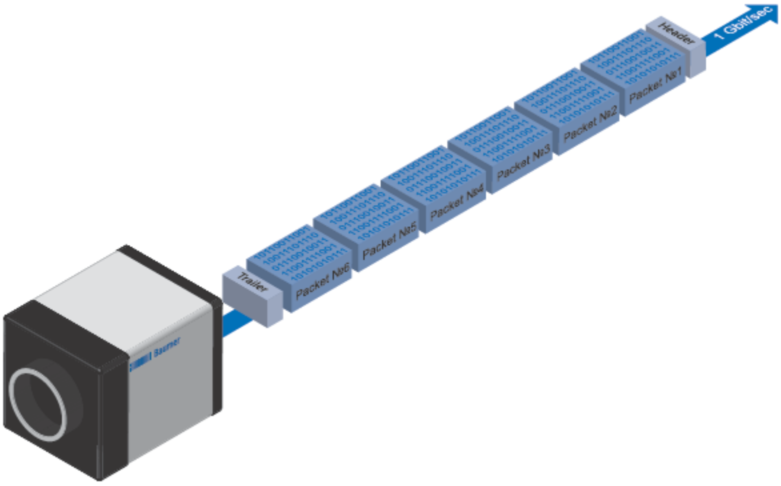
9.2 Device Information

This Gigabit Ethernet-specific information on the device is part of the Discovery-Acknowledge of the camera.

Included information:

- MAC address
- Current IP configuration (persistent IP / DHCP / LLA)
- Current IP parameters (IP address, subnet mask, gateway)
- Manufacturer's name
- Manufacturer-specific information
- Device version
- Serial number
- User-defined name (user programmable string)

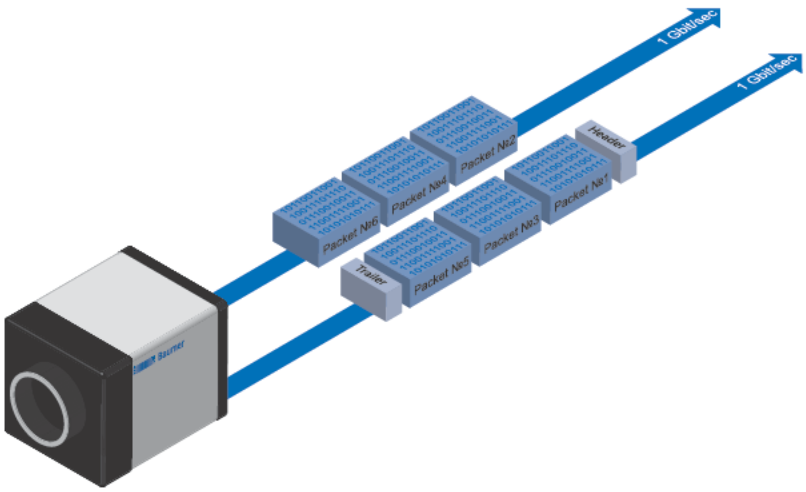
Single GigE



◄ **Figure 46**
Transmission of data packets with single GigE

By using Single GigE all data packets are sequentially transmitted over one cable. At the beginning of a frame will transmitted a Header and at the end will transmitted a Trailer.

Dual GigE



◄ **Figure 47**
Transmission of data packets with Dual GigE

By using Dual GigE the data packets are alternately distributed over both cables.The Header and the Trailer are always transmitted over the same cable.

9.3 Baumer Image Info Header

The Baumer Image Info Header is a data packet, which is generated by the camera and integrated in the first data packet of every image, if chunk mode is activated.

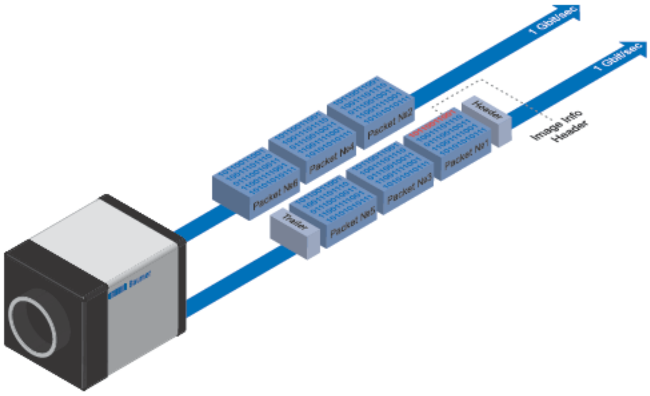


Figure 48 ►
Baumer Image Info Header

In this integrated data packet are different settings for this image. BGAPI can read the Image Info Header. Third Party Software, which supports the chunk mode, can read the features in the table below.

Feature	Description
ChunkOffsetX	Horizontal offset from the origin to the area of interest (in pixels).
ChunkOffsetY	Vertical offset from the origin to the area of interest (in pixels).
ChunkWidth	Returns the Width of the image included in the payload.
ChunkHeight	Returns the Height of the image included in the payload.
ChunkPixelFormat	Returns the PixelFormat of the image included in the payload.
ChunkExposureTime	Returns the exposure time used to capture the image.
ChunkBlackLevelSelector	Selects which Black Level to retrieve data from.
ChunkBlackLevel	Returns the black level used to capture the image included in the payload.
ChunkFrameID	Returns the unique Identifier of the frame (or image) included in the payload.

9.4 Packet Size and Maximum Transmission Unit (MTU)

Network packets can be of different sizes. The size depends on the network components employed. When using GigE Vision®- compliant devices, it is generally recommended to use larger packets. On the one hand the overhead per packet is smaller, on the other hand larger packets cause less CPU load.

The packet size of UDP packets can differ from 576 Bytes up to the MTU.

The MTU describes the maximal packet size which can be handled by all network components involved.

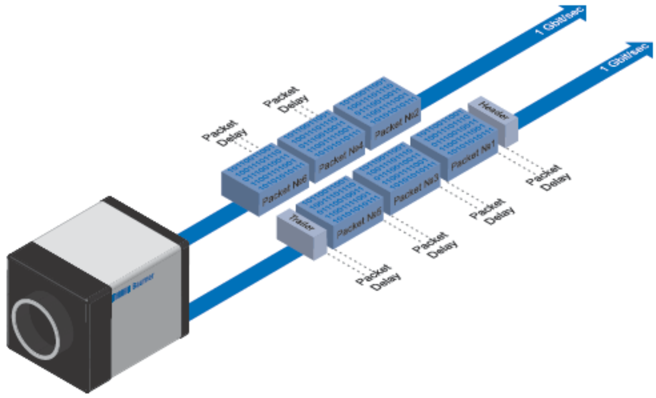
In principle modern network hardware supports a packet size of 1518 Byte, which is specified in the network standard. However, so-called "Jumboframes" are on the advance as Gigabit Ethernet continues to spread. "Jumboframes" merely characterizes a packet size exceeding 1500 Bytes.

Baumer SXG cameras can handle a MTU of up to 16384 Bytes.

9.5 "Packet Delay" (PD)

To achieve optimal results in image transfer, several Ethernet-specific factors need to be considered when using Baumer SXG cameras.

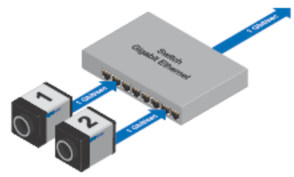
Upon starting the image transfer of a camera, the data packets are transferred at maximum transfer speed (1 Gbit/sec). In accordance with the network standard, Baumer employs a minimal separation of 12 Bytes between two packets. This separation is called "Packet Delay" (PD). In addition to the minimal PD, the GigE Vision® standard stipulates that the PD be scalable (user-defined).



◄ **Figure 49**
Principle of Packet Delay

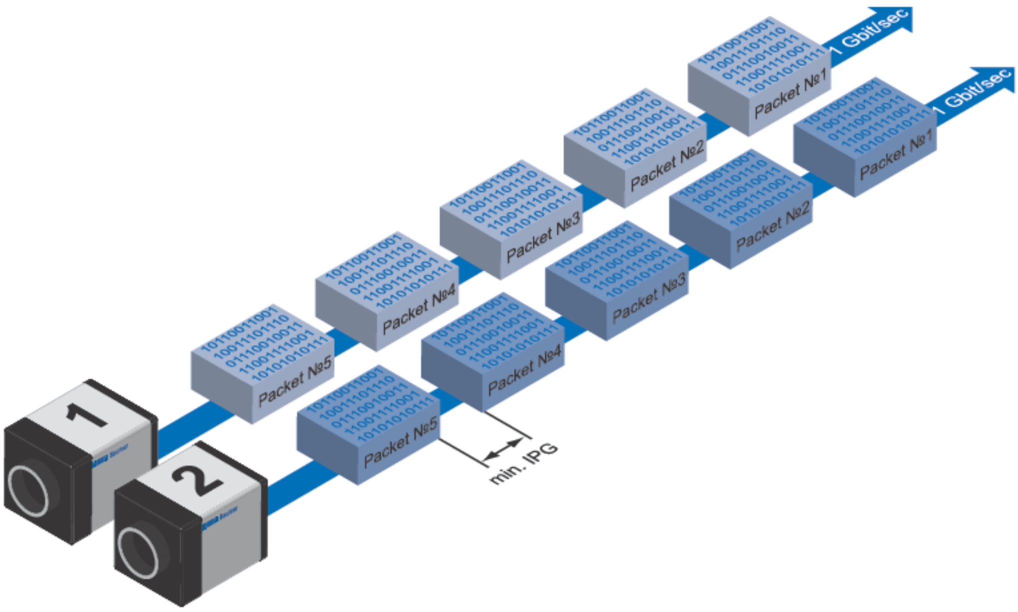
9.5.1 Example 1: Multi Camera Operation – Minimal IPG

Setting the IPG to minimum means every image is transfered at maximum speed. Even by using a frame rate of 1 fps this results in full load on the network. Such "bursts" can lead to an overload of several network components and a loss of packets. This can occur, especially when using several cameras.



▲ **Figure 50**
Operation of two cameras employing a Gigabit Ethernet switch.
Data processing within the switch is displayed in the next two figures.

In the case of two cameras sending images at the same time, this would theoretically occur at a transfer rate of 2 Gbits/sec. The switch has to buffer this data and transfer it at a speed of 1 Gbit/sec afterwards. Depending on the internal buffer of the switch, this operates without any problems up to n cameras (n ≥ 1). More cameras would lead to a loss of packets. These lost packets can however be saved by employing an appropriate resend mechanism, but this leads to additional load on the network components.



◄ **Figure 51**
Operation of two cameras employing a minimal inter packet gap (IPG).

9.5.2 Example 2: Multi Camera Operation – Optimal IPG

A better method is to increase the IPG to a size of

optimal IPG = packet size + 2 × minimal IPG

In this way both data packets can be transferred successively (zipper principle), and the switch does not need to buffer the packets.

Max. IPG:
On the Gigabit Ethernet the max. IPG and the data packet must not exceed 1 Gbit. Otherwise data packets can be lost.

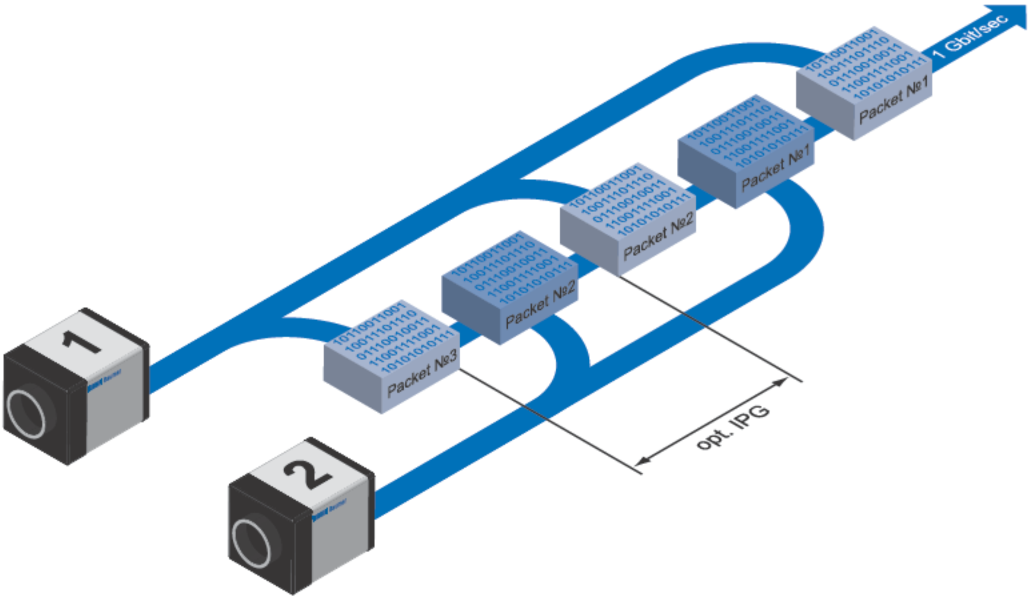


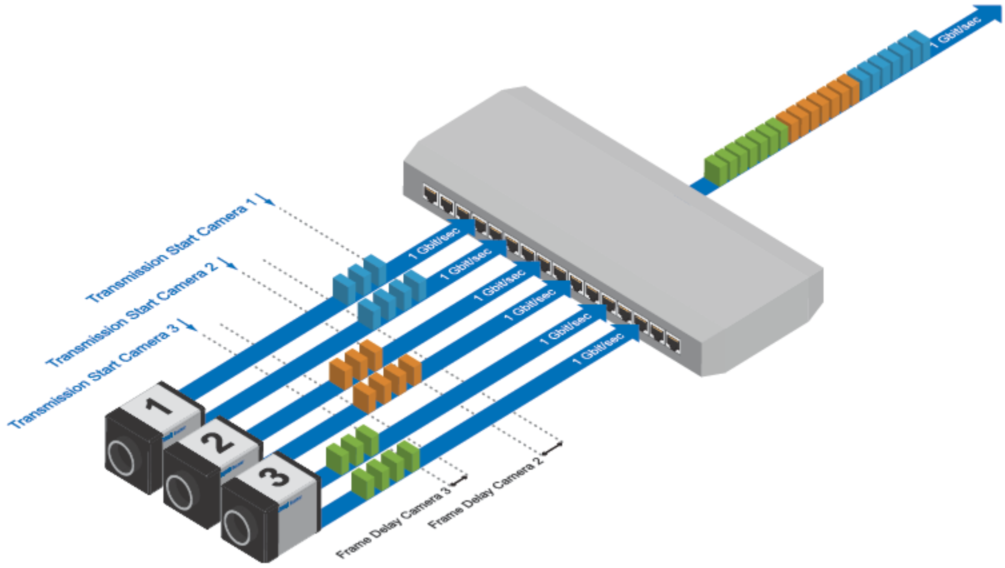
Figure 52 ▶
Operation of two cameras employing an optimal inter packet gap (IPG).

9.6 Frame Delay

Another approach for packet sorting in multi-camera operation is the so-called Frame Delay, which was introduced to Baumer Gigabit Ethernet cameras in hardware release 2.1.

Due to the fact, that the currently recorded image is stored within the camera and its transmission starts with a predefined delay, complete images can be transmitted to the PC at once.

The following figure should serve as an example:

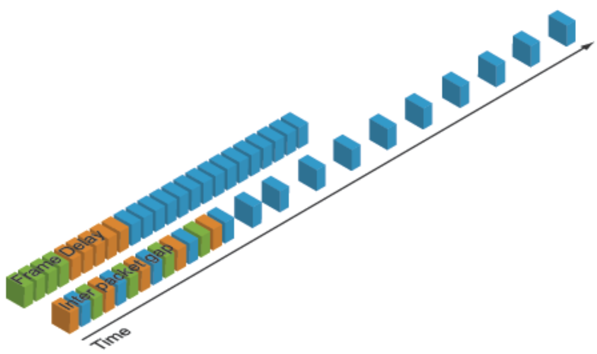


◄ **Figure 53**
Principle of the Frame delay.

Due to process-related circumstances, the image acquisitions of all cameras end at the same time. Now the cameras are not trying to transmit their images simultaniously, but – according to the specified transmission delays – subsequently. Thereby the first camera starts the transmission immediately – with a transmission delay "0".

9.6.1 Time Saving in Multi-Camera Operation

As previously stated, the Frame delay feature was especially designed for multi-camera operation with employment of different camera models. Just here an significant acceleration of the image transmission can be achieved:



◄ **Figure 54**
Comparison of frame delay and inter packet gap, employed for a multi-camera system with different camera models.

For the above mentioned example, the employment of the transmission delay feature results in a time saving – compared to the approach of using the inter paket gap – of approx. 45% (applied to the transmission of all three images).

9.6.2 Configuration Example

For the three used cameras the following data are known:

Camera Model	Sensor Resolution	Pixel Format (Pixel Depth)	Data Volume	Readout Time	Exposure Time	Transfer Time (DualGigE)
	[Pixel]	[bit]	[bit]	[msec]	[msec]	[msec]
SXG10	1024 x 1024	8	8388608	8	6	≈ 3,91
SXG20	1600 x 1200	8	15360000	15	6	≈ 7.15
SXG80	3296 x 2472	8	65181696	56	6	≈ 30.35

- The sensor resolution and the readout time ($t_{readout}$) can be found in the respective Technical Data Sheet (TDS). For the example a full frame resolution is used.
- The exposure time ($t_{exposure}$) is manually set to **6** msec.

- The resulting data volume is calculated as follows:
  Resulting Data Volume = horizontal Pixels × vertical Pixels × Pixel Depth

- The transfer time ($t_{transferGigE}$) for full Dual-GigE transfer rate is calculated as follows:
  Transfer Time (Dual-GigE) = Resulting Data Volume / 1024³ × 500 [msec]

All the cameras are triggered simultaniously.

The transmission delay is realized as a counter, that is started immediately after the sensor readout is started.

Timings:
A - exposure start for all cameras
B - all cameras ready for transmission
C - transmission start camera 2
D - transmission start camera 3

** Due to technical issues the data transfer of camera 1 does not take place with full Dual-GigE speed.*

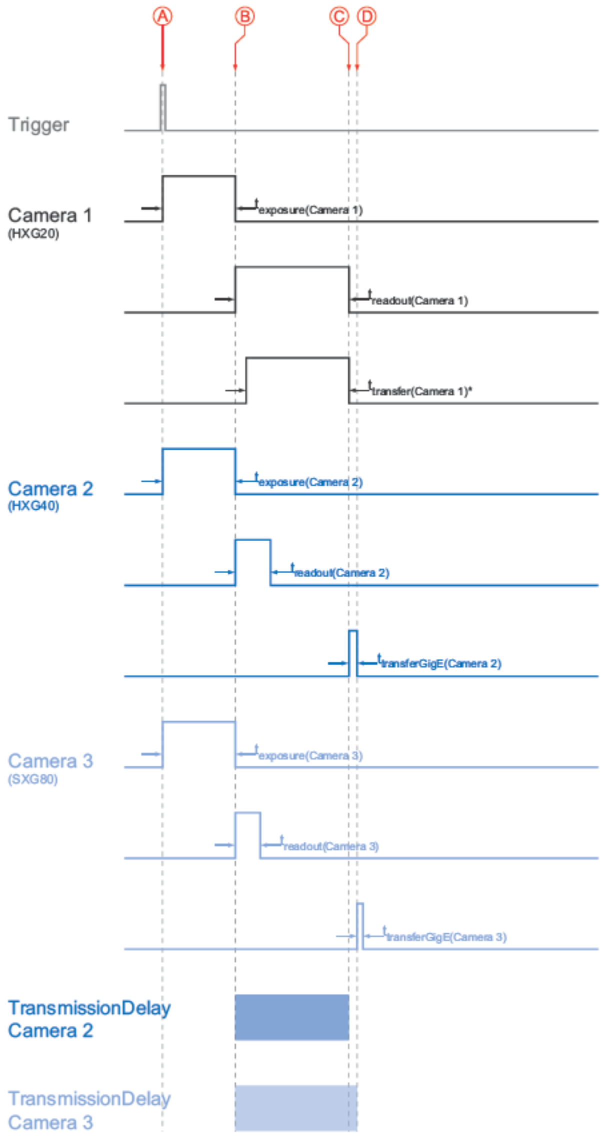


Figure 55 ►
Timing diagram for the transmission delay of the three employed cameras, using even exposure times.

In general, the transmission delay is calculated as:

$$t_{TransmissionDelay(Camera\ n)} = t_{exposure(Camera\ 1)} + t_{readout(Camera\ 1)} - t_{exposure(Camera\ n)} + \sum_{n\geq 3}^{n} t_{transferGigE(Camera\ n\ \ 1)}$$

Therewith for the example, the transmission delays of camera 2 and 3 are calculated as follows:

$$t_{TransmissionDelay(Camera\ 2)} = t_{exposure(Camera\ 1)} + t_{readout(Camera\ 1)} - t_{exposure(Camera\ 2)}$$

$$t_{TransmissionDelay(Camera\ 3)} = t_{exposure(Camera\ 1)} + t_{readout(Camera\ 1)} - t_{exposure(Camera\ 3)} + t_{transferGige(Camera\ 2)}$$

Solving this equations leads to:

$$\begin{aligned} t_{TransmissionDelay(Camera\ 2)} &= 6\ msec + 8\ msec - 6\ msec \\ &= 8\ msec \\ &= 8000000\ ticks \end{aligned}$$

$$\begin{aligned} t_{TransmissionDelay(Camera\ 3)} &= 6\ msec + 8\ msec - 6\ msec + 7.15\ msec \\ &= 15.15\ msec \\ &= 15150000\ ticks \end{aligned}$$

Notice

In BGAPI the delay is specified in ticks. How do convert microseconds into ticks?

1 tick = 1 ns

1 msec = 1000000 ns

1 tick = 0,000001 msec

ticks= $t_{TransmissionDelay}$ *[msec] / 0,000001* = $t_{TransmissionDelay}$*[ticks]*

9.7 Multicast

Multicasting offers the possibility to send data packets to more than one destination address – without multiplying bandwidth between camera and Multicast device (e.g. Router or Switch).

The data is sent out to an intelligent network node, an IGMP (Internet Group Management Protocol) capable Switch or Router and distributed to the receiver group with the specific address range.

In the example on the figure below, multicast is used to process image and message data separately on two differents PC's.

Multicast Addresses:
For multicasting Baumer suggests an adress range from 232.0.1.0 to 232.255.255.255.

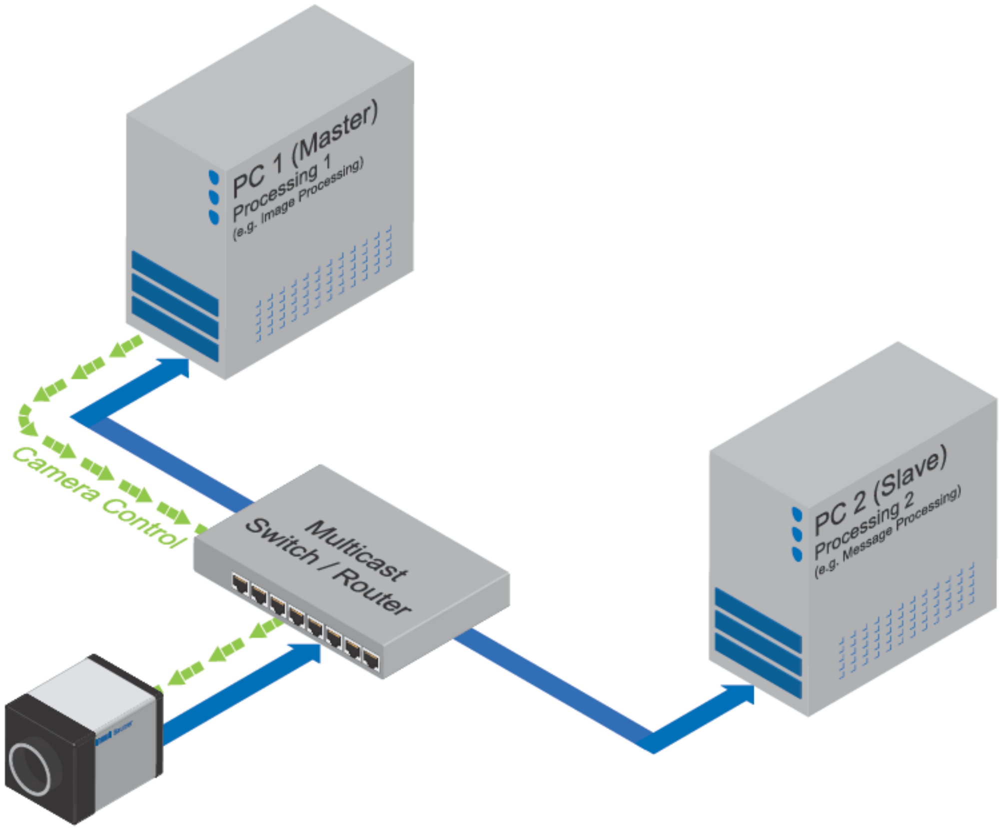


Figure 56 ▶
Multicast Data Flow

9.8 IP Configuration

Internet Protocol:

On Baumer cameras IP v4 is employed.

9.8.1 Persistent IP

A persistent IP adress is assigned permanently. Its validity is unlimited.

Notice

Please ensure a valid combination of IP address and subnet mask.

IP range:	Subnet mask:
0.0.0.0 – 127.255.255.255	255.0.0.0
128.0.0.0 – 191.255.255.255	255.255.0.0
192.0.0.0 – 223.255.255.255	255.255.255.0

These combinations are not checked by Baumer-GAPI, Baumer-GAPI Viewer or camera on the fly. This check is performed when restarting the camera, in case of an invalid IP - subnet combination the camera will start in LLA mode.

* This feature is disabled by default.

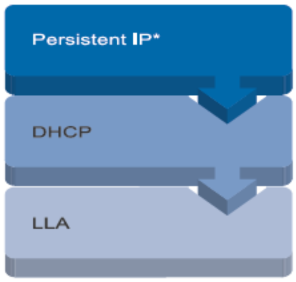


Figure 57 ▲
Connection pathway for Baumer Gigabit Ethernet cameras:
The device connects step by step via the three descr bed mechanisms.

9.8.2 DHCP (Dynamic Host Configuration Protocol)

The DHCP automates the assignment of network parameters such as IP addresses, subnet masks and gateways. This process takes up to 12 sec.

Once the device (client) is connected to a DHCP-enabled network, four steps are processed:

- **DHCP Discovery**
  In order to find a DHCP server, the client sends a so called DHCPDISCOVER broadcast to the network.

DHCP:

Please pay attention to the DHCP Lease Time.

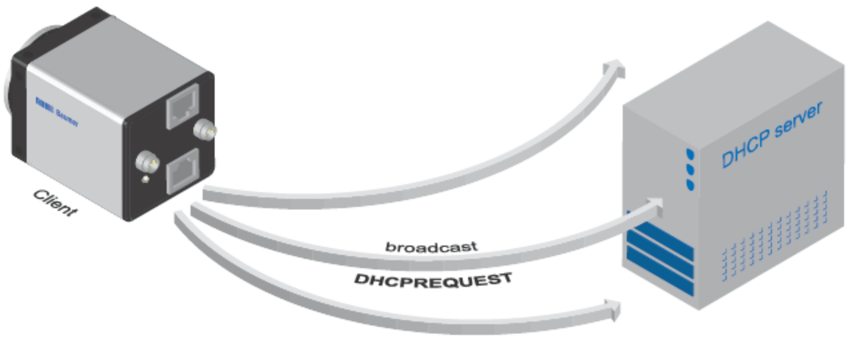
◄ Figure 58
DHCP Discovery (broadcast)

- **DHCP Offer**
  After reception of this broadcast, the DHCP server will answer the request by a unicast, known as DHCPOFFER. This message contains several items of information, such as:

Information for the client	MAC address
	offered IP address
Information on server	IP adress
	subnet mask
	duration of the lease

◄ Figure 59
DHCP offer (unicast)

▪ **DHCP Request**
Once the client has received this DHCPOFFER, the transaction needs to be confirmed. For this purpose the client sends a so called DHCPREQUEST broadcast to the network. This message contains the IP address of the offering DHCP server and informs all other possible DHCPservers that the client has obtained all the necessary information, and there is therefore no need to issue IP information to the client.



Figue 60 ▶
DHCP Request (broadcast)

▪ **DHCP Acknowledgement**
Once the DHCP server obtains the DHCPREQUEST, a unicast containing all necessary information is sent to the client. This message is called DHCPACK.
According to this information, the client will configure its IP parameters and the process is complete.

DHCP Lease Time:
The validity of DHCP IP addresses is limited by the lease time. When this time is elapsed, the IP configuration needs to be redone. This causes a connection abort.

Figure 61 ▶
DHCP Acknowledgement (unicast)

9.8.3 LLA

LLA:
Please ensure operation of the PC within the same subnet as the camera.

LLA (Link-Local Address) refers to a local IP range from 169.254.0.1 to 169.254.254.254 and is used for the automated assignment of an IP address to a device when no other method for IP assignment is available.

The IP address is determined by the host, using a pseudo-random number generator, which operates in the IP range mentioned above.

Once an address is chosen, this is sent together with an ARP (Address Resolution Protocol) query to the network to check if it already exists. Depending on the response, the IP address will be assigned to the device (if not existing) or the process is repeated. This method may take some time - the GigE Vision® standard stipulates that establishing connection in the LLA should not take longer than 40 seconds, in the worst case it can take up to several minutes.

9.8.4 Force IP*)

Inadvertent faulty operation may result in connection errors between the PC and the camera. In this case "Force IP" may be the last resort. The Force IP mechanism sends an IP address and a subnet mask to the MAC address of the camera. These settings are sent without verification and are adapted immediately by the client. They remain valid until the camera is de-energized.

*) In the GigE Vision® standard, this feature is defined as "Static IP".

9.9 Packet Resend

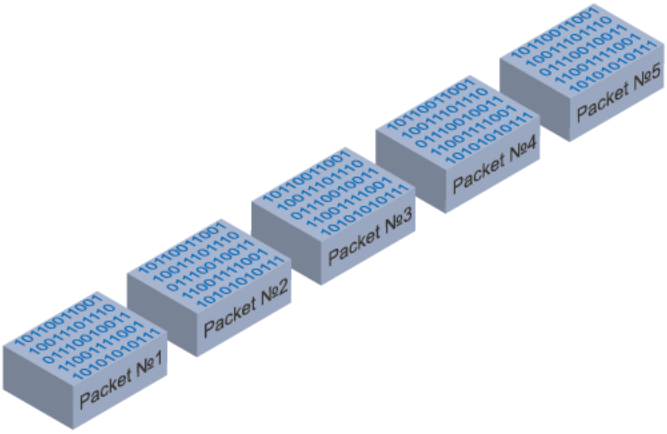
Due to the fact, that the GigE Vision® standard stipulates using a UDP - a stateless user datagram protocol - for data transfer, a mechanism for saving the "lost" data needs to be employed.

Here, a resend request is initiated if one or more packets are damaged during transfer and - due to an incorrect checksum - rejected afterwards.

On this topic one must distinguish between three cases:

9.9.1 Normal Case

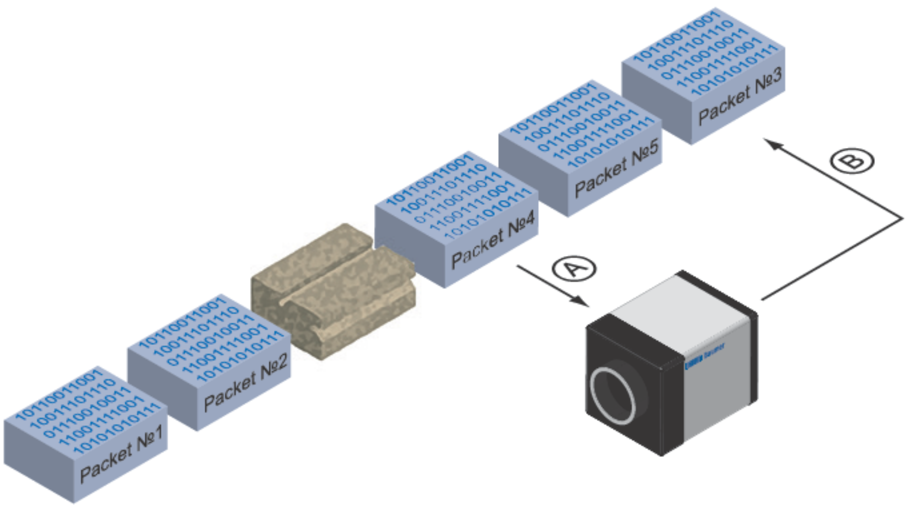
In the case of unproblematic data transfer, all packets are transferred in their correct order from the camera to the PC. The probability of this happening is more then 99%.



◄ **Figure 62**
Data stream without damaged or lost packets.

9.9.2 Fault 1: Lost Packet within Data Stream

If one or more packets are lost within the data stream, this is detected by the fact, that packet number n is not followed by packet number (n+1). In this case the application sends a resend request (A). Following this request, the camera sends the next packet and then resends (B) the lost packet.



◄ **Figure 63**
Resending lost packets within the data stream.

In our example packet no. 3 is lost. This fault is detected on packet no. 4, and the re-send request triggered. Then the camera sends packet no. 5, followed by resending packet no. 3.

9.9.3 Fault 2: Lost Packet at the End of the Data Stream

In case of a fault at the end of the data stream, the application will wait for incoming packets for a predefined time. When this time has elapsed, the resend request is triggered and the "lost" packets will be resent.

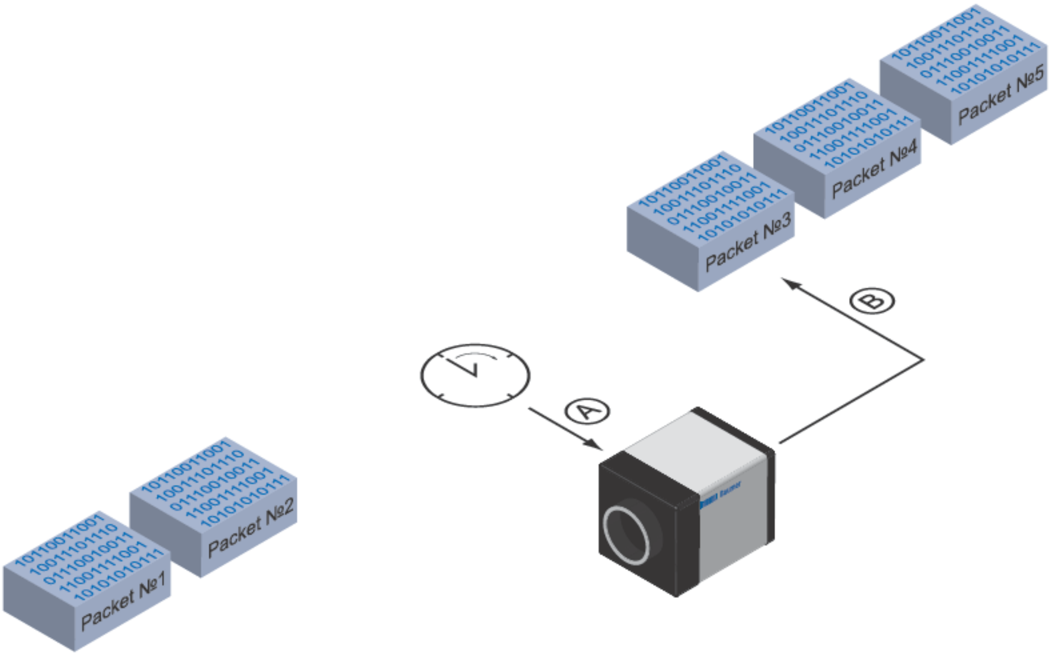


Figure 64 ►
Resending of lost packets at the end of the data stream.

In our example, packets from no. 3 to no. 5 are lost. This fault is detected after the predefined time has elapsed and the resend request (A) is triggered. The camera then resends packets no. 3 to no. 5 (B) to complete the image transfer.

9.9.4 Termination Conditions

The resend mechanism will continue until:
- all packets have reached the pc
- the maximum of resend repetitions is reached
- the resend timeout has occured or
- the camera returns an error.

9.10 Message Channel

The asynchronous message channel is described in the GigE Vision® standard and offers the possibility of event signaling. There is a timestamp (64 bits) for each announced event, which contains the accurate time the event occurred. Each event can be activated and deactivated separately.

Eventmap SXG:

Bit	Edge	Event-ID	XML-Event-Description
GigE Vision Standard Events			
		0x0007	PrimaryApplicationSwitch
SXG Hardware-Events			
0	rising	0x9000	Line0RisingEdge
1	falling	0x9001	Line0FallingEdge
2	rising	0x9002	Line1RisingEdge
3	falling	0x9003	Line1FallingEdge
4	rising	0x9004	Line2RisingEdge
5	falling	0x9005	Line2FallingEdge
6	rising	0x9006	Line3RisingEdge
7	falling	0x9007	Line3FallingEdge
8	rising	0x9008	Line4RisingEdge
9	falling	0x9009	Line4FallingEdge
10	rising	0x900A	Line5RisingEdge
11	falling	0x900B	Line5FallingEdge
12	rising	0x900C	ExposureStart
13	rising	0x900D	ExposureEnd
14	rising	0x900E	FrameStart
15	rising	0x900F	FrameEnd
16	rising	0x9010	TriggerReady
17	rising	0x9011	TriggerOverlapped
18	rising	0x9012	TriggerSkipped
19	rising	0x9013	Software
20	rising	0x9014	Action1
21	rising	0x9015	Action2
22	rising	0x9016	Link0Up
23	falling	0x9017	Link0Down
24	rising	0x9018	Link1Up
25	falling	0x9019	Link1Down
26	rising	0x901A	Timer1End
27	rising	0x901B	Timer2End
28	rising	0x901C	Timer3End
29	rising	0x901D	Counter1End
30	rising	0x901E	Counter2End
31	rising	0x901F	Gev_Event_Link_Speed_Change
SXG-Software-Events			
		0x9020	GigEVisionError
		0x9021	EventLost
		0x9022	EventDiscarded
		0x9023	GigEVisionHeartbeatTimeOut

9.11 Action Commands

The basic idea behind this feature was to achieve a simultaneous trigger for multiple cameras.

Action Command:
Since hardware release 2.1 the implemetation of the Action Command follows the regulations of the GigE Vision® standard 1.2.

Action Command	Description
Action Command Trigger	used to send a trigger to all connected cameras.
Action Command Timestamp	used to reset the Timestamp of the connected cameras

Therefore a broadcast ethernet packet was implemented. This packet can be used to induce a trigger as well as other actions.

Due to the fact that different network components feature different latencies and jitters, the trigger over the Ethernet is not as synchronous as a hardware trigger. Nevertheless, applications can deal with these jitters in switched networks, and therefore this is a comfortable method for synchronizing cameras with software additions.

The action command is sent as a broadcast. In addition it is possible to group cameras, so that not all attached cameras respond to a broadcast action command.

Such an action command contains:
- a Device Key - for authorization of the action on this device
- a Group Key - for triggering actions on separated groups of devices
- a Group Mask - for extension of the range of separate device groups

9.11.1 Action Command Trigger

The figure below displays three cameras, which are triggered synchronously by a software application.

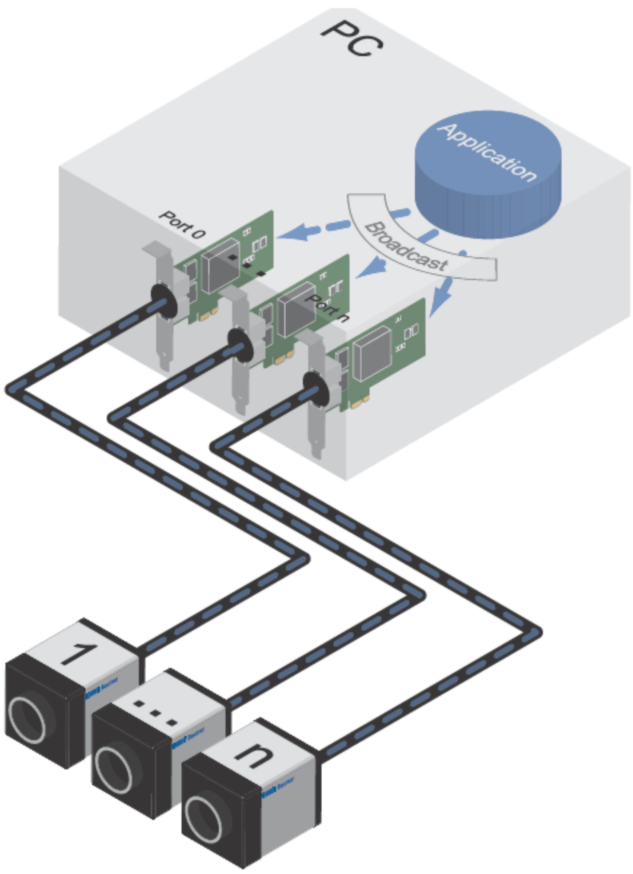
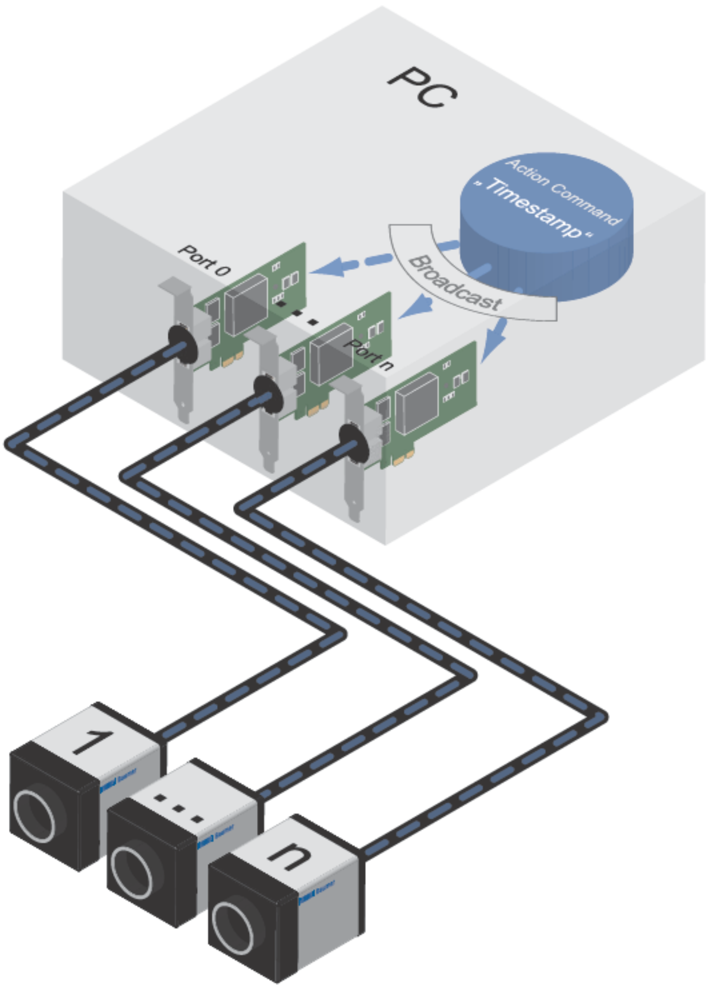


Figure 65 ►
Triggering of multiple cameras via trigger over Ethernet (ToE).

Another application of action command is that a secondary application or PC or one of the attached cameras can actuate the trigger.

9.11.2 Action Command Timestamp

The figure below show a PC with 1-n connected cameras, which are receives the Action Command "Timestamp" from the PC. Thus, the time signal of all 1-n cameras can simultaneously set to 0.



◄ **Figure 66**
Timestamping of multiple cameras over Ethernet.

10. Start-Stop-Behaviour

10.1 Start / Stop Acquisition (Camera)

Once the image acquisition is started, three steps are processed within the camera:

- Determination of the current set of image parameters
- Exposure of the sensor
- Readout of the sensor.

Afterwards a repetition of this process takes place until the camera is stopped.

Stopping the acquisition means that the process mentioned above is aborted. If the stop signal occurs within a readout, the current readout will be finished before stopping the camera. If the stop signal arrives within an exposure, this will be aborted.

Asynchronous Reset:
For further information on the timings of this feature, please see the respective data sheets.

Special Case: Asynchronous Reset

The asynchronous reset represents a special case of stopping the current acquisition. Thereby exposure is aborted immediately. Thus the current image is not read out and the image is upcasted.

This feature was introduced to accelerate the changing of image parameters.

10.2 Start / Stop Interface

Without starting the interface, transmission of image data from the camera to the PC will not proceed. If the image acquisition is started befor the interface is activated, the recorded images are lost.

If the interface is stopped during a transmission, this is aborted immediately.

10.3 Pause / Resume Interface

Pausing while the interface is operational, results in an interim storage of the recorded images within the internal buffer of the camera.

After resuming the interface, the buffered image data will be transferred to the PC.

10.4 Acquisition Modes

In general, three acquisition modes are available for the cameras in the Baumer SXG series.

10.4.1 Free Running

Free running means the camera records images continuously without external events.

10.4.2 Trigger

The basic idea behind the trigger mode is the synchronization of cameras with machine cycles. Trigger mode means that image recording is not continuous, but triggered by external events.

10.4.3 Sequencer

A sequencer is used for the automated control of series of images, using different settings for exposure time and gain.

11. Lens install

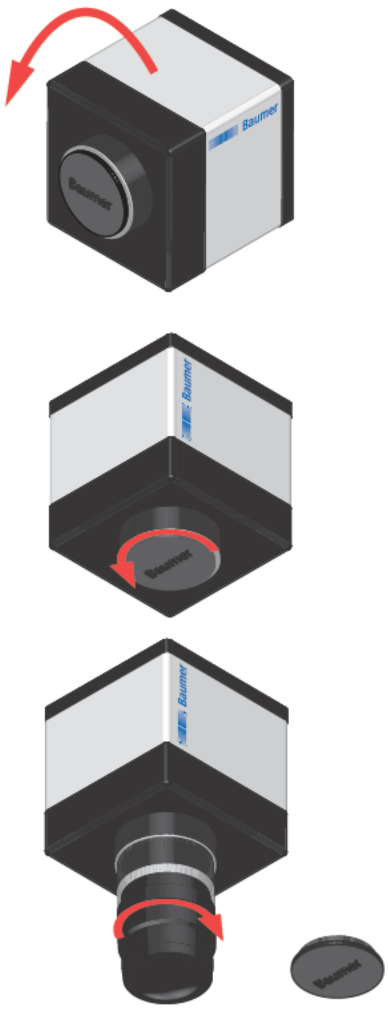
Notice

Avoid contamination of the sensor and the lens by dust and airborne particles when mounting a lens to the device!

Therefore the following points are very important:

- Attach lenses in an environment that is as dust free as possible!
- Keep the dust covers on camera and lens as long as possible!
- Hold the camera downwards with unprotected sensor (or filter- /cover glass)!
- Avoid contact with any optical surface of the camera or lens!

1. Turn the camera with the lens mount to the bottom.
2. Unscrew the protective cap.
3. Screw the lens on the lens mount.



◄ **Figure 67**
Procedure of lens install

12. Cleaning

Cover glass

Notice
The sensor is mounted dust-proof. Remove of the cover glass for cleaning is not necessary.

Avoid cleaning the cover glass of the CCD sensor if possible. To prevent dust, follow the instructions under "Install lens".

If you must clean it, use compressed air or a soft, lint free cloth dampened with a small quantity of pure alcohol.

Housing

⚠ Caution!

Volatile solvents for cleaning.
Volatile solvents damage the surface of the camera.
Never use volatile solvents (benzine, thinner) for cleaning!

To clean the surface of the camera housing, use a soft, dry cloth. To remove persistent stains, use a soft cloth dampened with a small quantity of neutral detergent, then wipe dry.

13. Transport / Storage

Notice
Transport the camera only in the original packaging. When the camera is not installed, then storage the camera in original packaging.

Storage Environment	
Storage temperature	-10°C ... +70°C (+14°F ... +158°F)
Storage Humidy	10% ... 90% non condensing

14. Disposal

Dispose of outdated products with electrical or electronic circuits, not in the normal domestic waste, but rather according to your national law and the directives 2002/96/EC and 2006/66/EC for recycling within the competent collectors.

Through the proper disposal of obsolete equipment will help to save valuable resources and prevent possible adverse effects on human health and the environment.

The return of the packaging to the material cycle helps conserve raw materials an reduces the production of waste. When no longer required, dispose of the packaging materials in accordance with the local regulations in force.

Keep the original packaging during the warranty period in order to be able to pack the device properly in the event of a warranty claim.

15. Warranty Information

Notice
There are no adjustable parts inside the camera! In order to avoid the loss of warranty do not open the housing!

Notice
If it is obvious that the device is / was dismantled, reworked or repaired by other than Baumer technicians, Baumer Optronic will not take any responsibility for the subsequent performance and quality of the device!

16. Support

If you have any problems with the camera, then feel free to contact our support.

Worldwide

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Tel: +49 (0)3528 4386 845 mail: support.cameras@baumer.com

Website: www.baumer.com

17. Conformity

Cameras of the Baumer SXG family comply with:

- CE
- FCC Part 15 Class B
- RoHS

17.1 CE

We declare, under our sole responsibility, that the previously described Baumer SXG cameras conform with the directives of the CE.

17.2 FCC – Class B Device

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occure in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off an on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

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