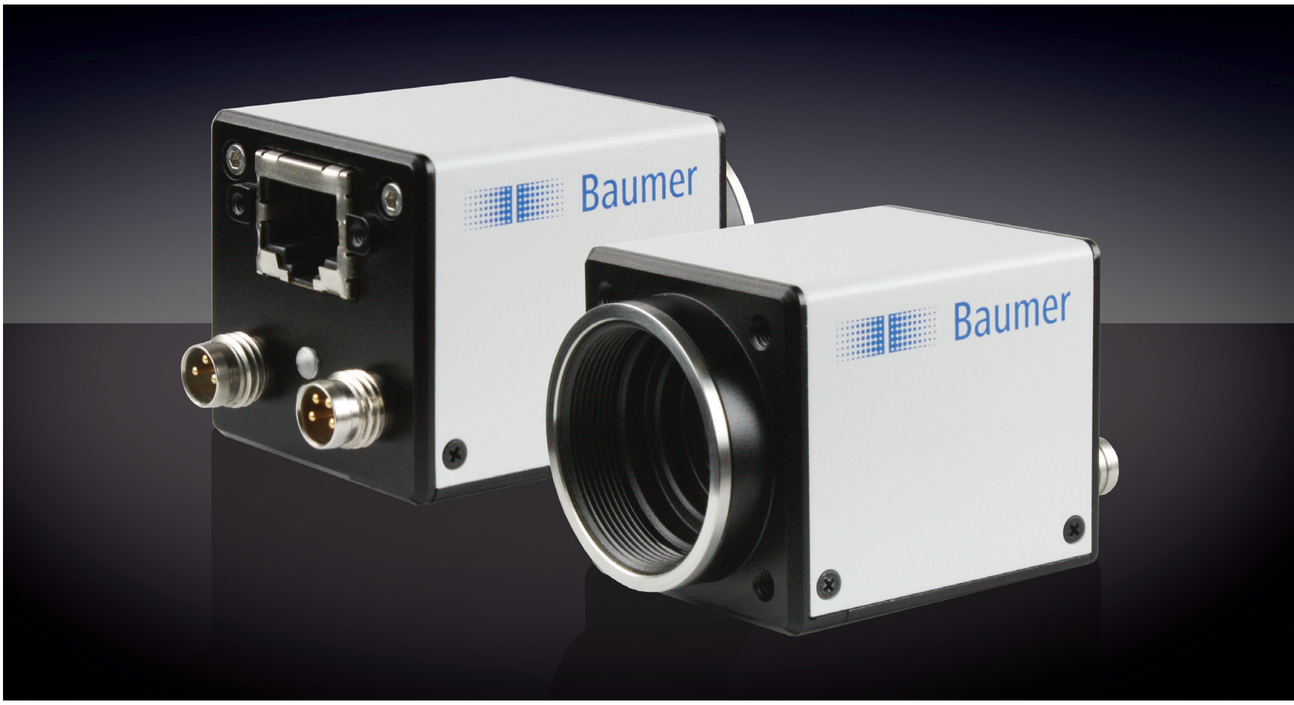

User´s Guide

EXG (Gigabit Ethernet)

Document Version: v1.1
Release: 21.06.2017
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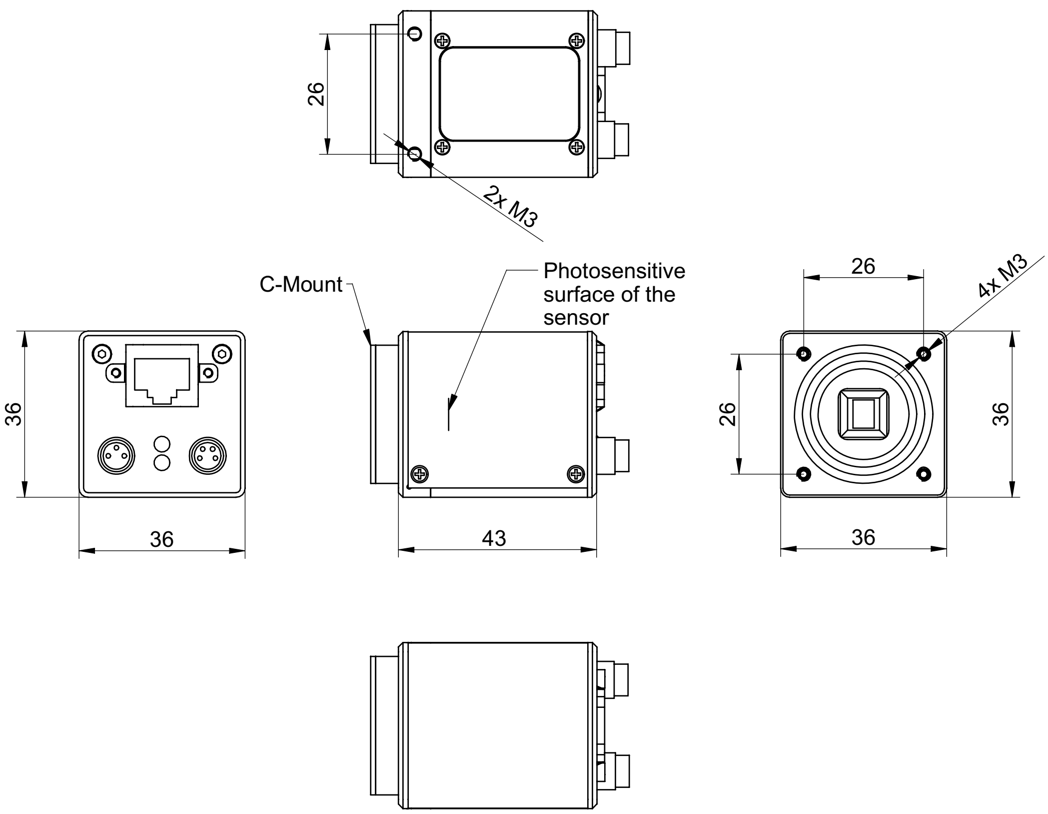
Table of Contents

1. Camera Models

◀ **Figure 1**
Front and rear view of a Baumer EXG camera.

Camera Type	Sensor Size	Resolution	Full Frames [max. fps]
Monochrome			
EXG03	1/3"	752 x 480	60
EXG50	1/2.5"	2592 x 1944	14
Color			
EXG03c	1/3"	748 x 476	60
EXG50c	1/2.5"	2592 x 1944	14

Dimensions



◀ **Figure 2**
Dimensions of a Baumer EXG camera.

2. Product Specifications

2.1 Sensor Specifications

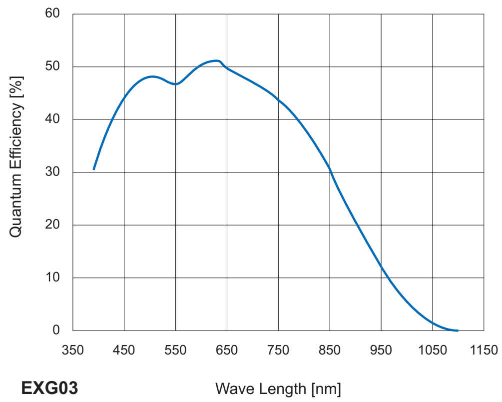
2.1.0.1 Quantum Efficiency for Baumer EXG Cameras

The quantum efficiency characteristics of monochrome and color matrix sensors for Baumer EXG 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.

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

Figure 3 ▶
Spectral sensitivities for Baumer EXG cameras with 0.3 MP*) CMOS sensor.

*) MP = Megapixels



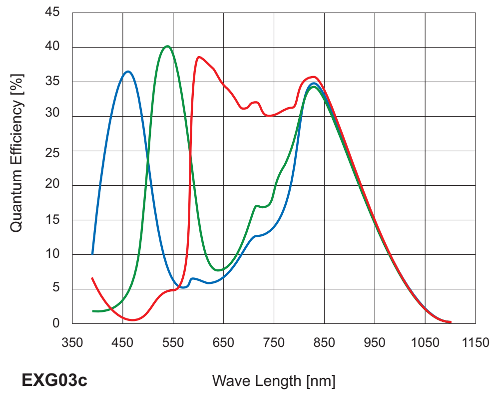
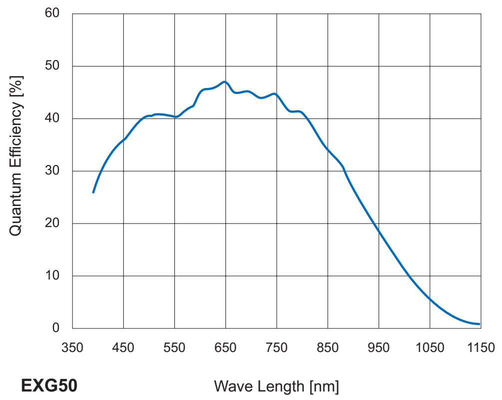


Figure 4 ▶
Spectral sensitivities for Baumer EXG cameras with 5.0 MP CMOS sensor.

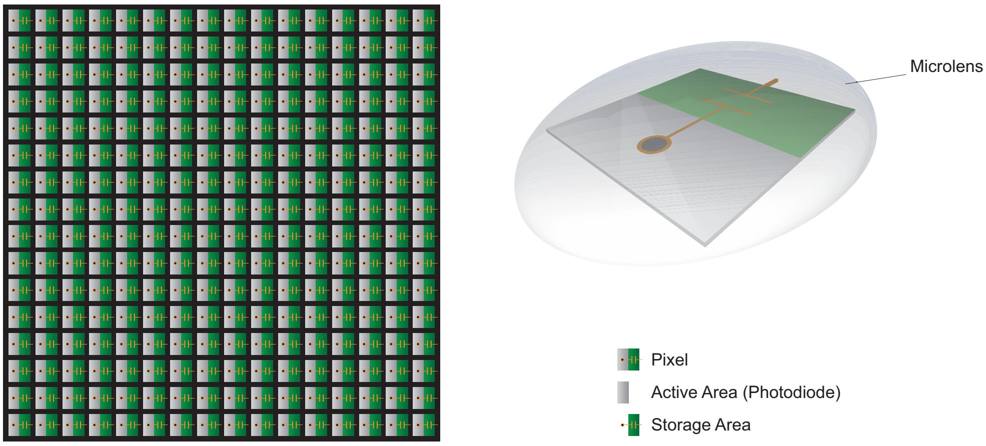


2.1.1 Shutters

The camera models of the EXG series are equipped with different shutters:

Camera Type	Shutter Type
Monochrome	
EXG03	Global
EXG50	Rolling
Color	
EXG03c	Global

2.1.1.1 Global Shutter



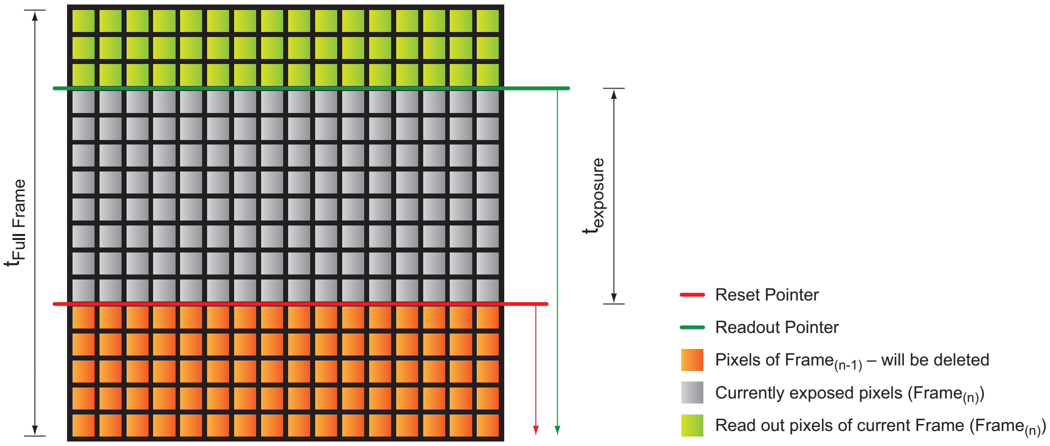
◄ **Figure 5**
Structure of an imaging sensor with global shutter (interline).

Global shutter 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 get's "lost" by the implementation of the storage area, the pixels mostly are equipped with microlenses, which focus the light to the pixels active area.

2.1.1.2 Rolling Shutter



◄ **Figure 6**
Operating mode of a rolling shutter.

Rolling shutter means that – in contrast to the global shutter – not the whole sensor is exposed at once, but single portions successively. It is said the shutter "rolls" over the sensor.

For Baumer EXG cameras with rolling shutter this means two pointers are "rolling" across the sensor:

- First, the reset pointer deletes any information of former exposures stored within the pixels ($Frame_{(n-1)}$). After that the pixels are empty and restart collecting information from incoming light – the new exposure ($Frame_{(n)}$) begins.
- Once a predefined interval – the exposure time $t_{exposure}$ – is elapsed, the readout pointer rolls across the sensor and the information of the pixels is read out.
- For example: On Baumer EXG50, the pass of a pointer lasts approx. 72 msec ($t_{Full\ Frame}$).

Notice

Due to technical issues of rolling shutter, a flash control depending on the exposure time does not make sense. Such cameras should be used in a continuously illuminated environment.

2.2 Timings

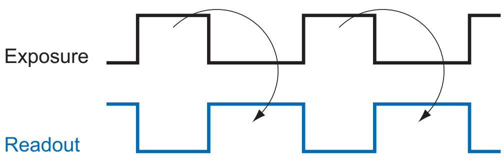
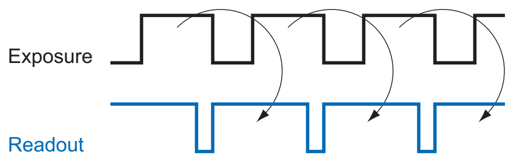
The image acquisition consists of two seperate, successively processed components.

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 used 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).
	

Due to the differing CMOS sensor models installed to the Baumer EXG cameras, the operation modes are subdevided into the respective camera models.

2.2.1 Free Running Mode

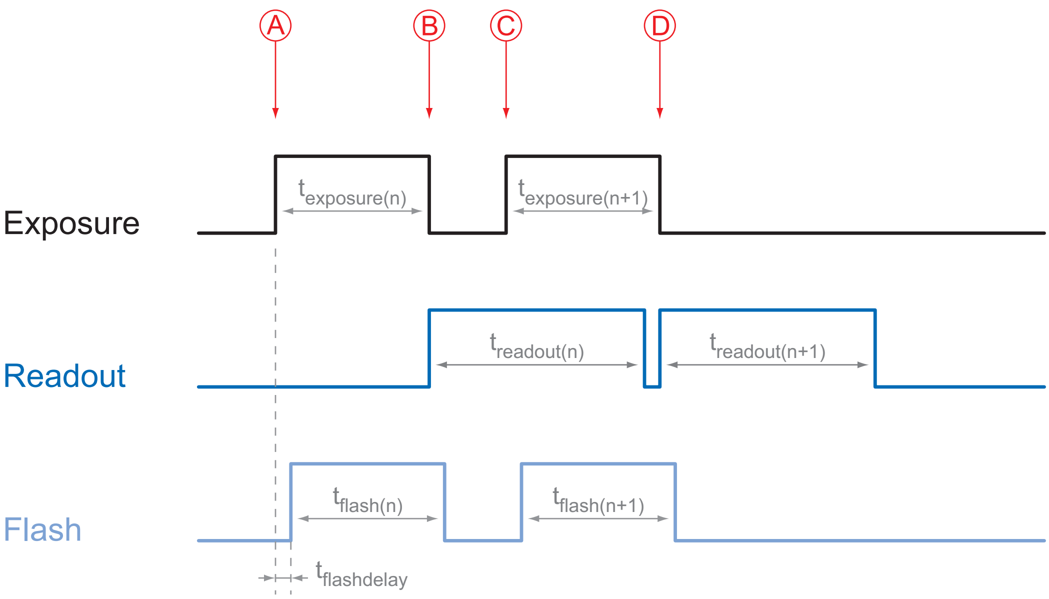
In the "Free Running" mode the camera records images permanently and sends them to the PC. In order to achieve an optimal (with regard to the adjusted exposure time $t_{exposure}$ and image format) the camera is operated overlapped.

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.

2.2.1.1 EXG03 / EXG03c

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

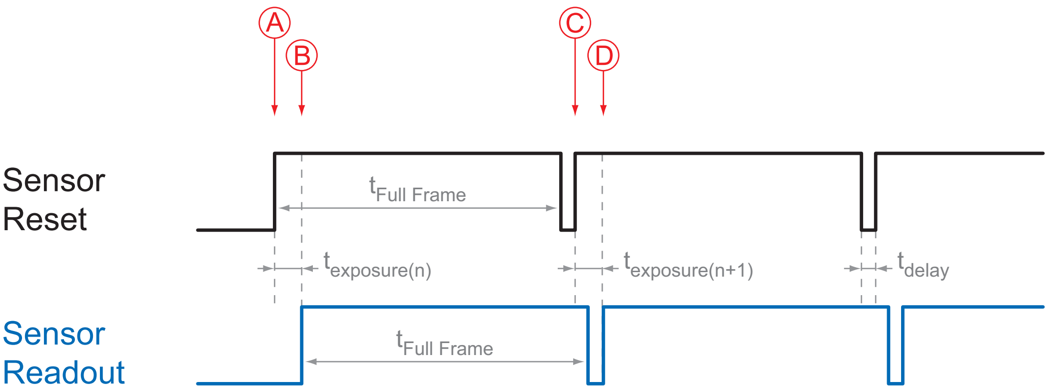
Image parameters:
Offset
Gain
Mode
Partial Scan



$t_{flash} = t_{exposure}$

*) Non-overlapped means the same as sequential.

2.2.1.2 EXG50

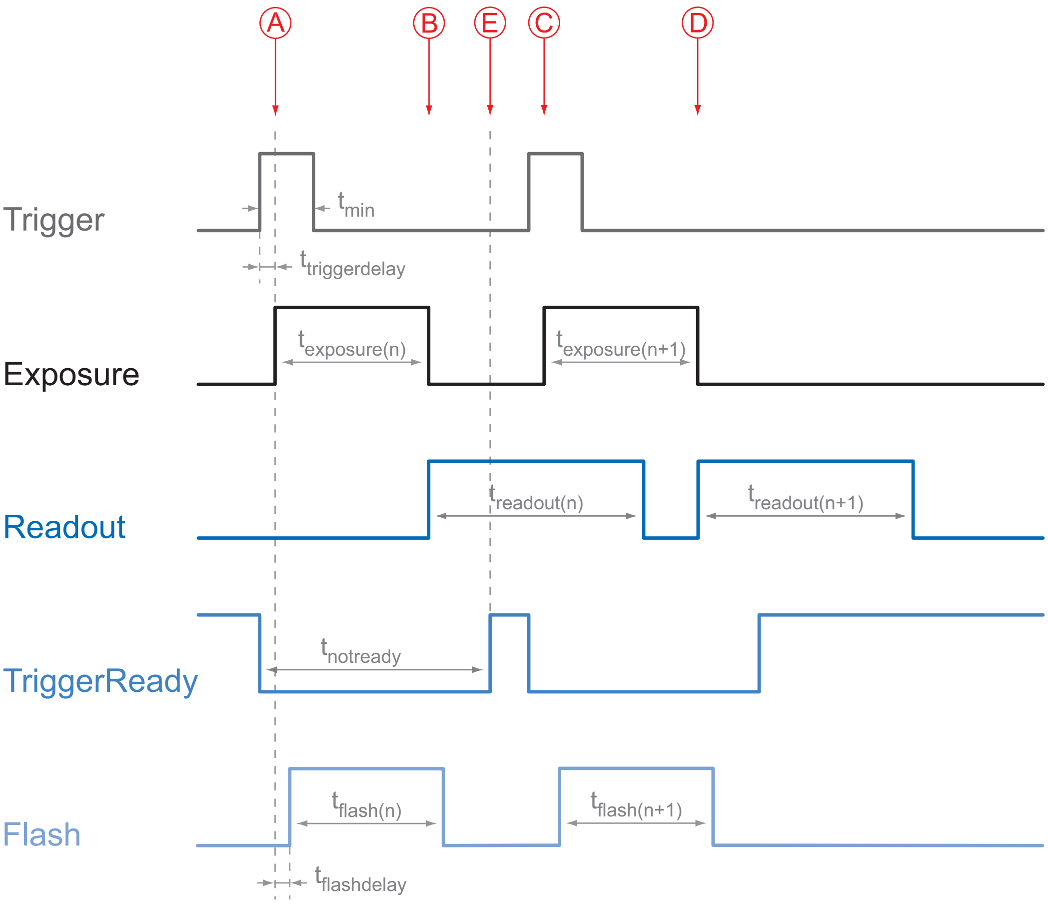


Timing	Value
$t_{Full\ Frame}$	71.66 msec
$t_{exposure}$	4 µsec ... 1 sec

2.2.2 Trigger Mode

After a specified external event (trigger) has occurred, image acquisition is started.

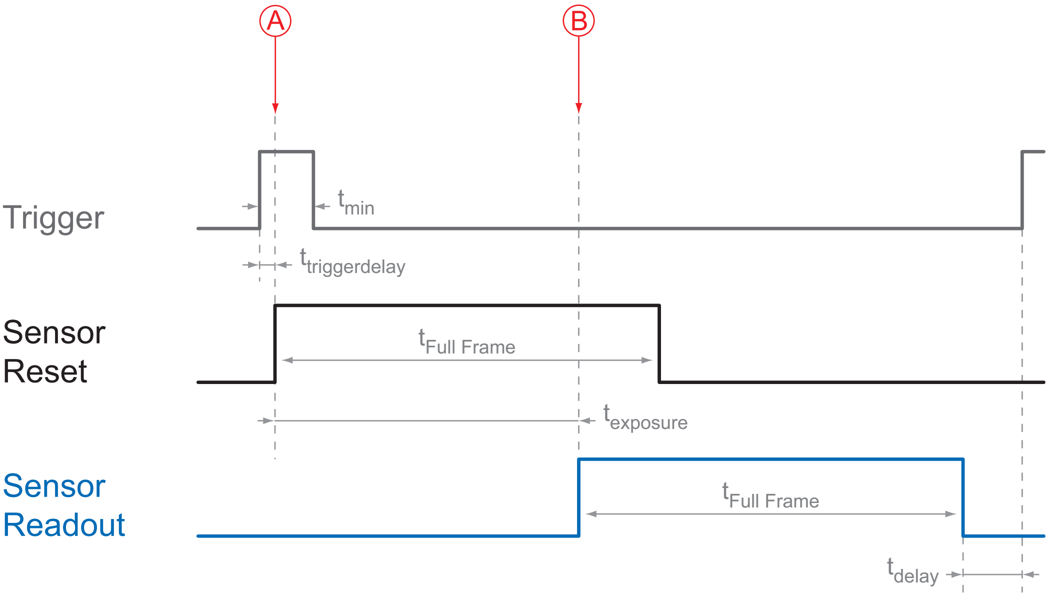
2.2.2.1 EXG03 / EXG03c



2.2.2.2 EXG50

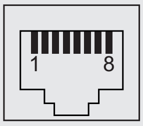
Timings:
A - exposure time frame (n) effective
B - image parameters frame (n) effective

Image parameters:
Offset
Gain
Mode
Partial Scan

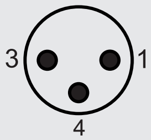
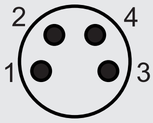


2.3 Process- and Data Interface

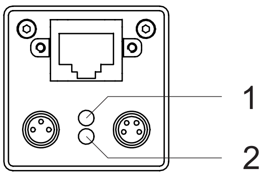
2.3.1 Pin-Assignment Gigabit Ethernet Interface

8P8C mod jack		
		
1	(gn/wh)	MX1+
2	(gn)	MX1-
3	(og/wh)	MX2+
4	(bu)	MX3+
5	(bu/wh)	MX3-
6	(og)	MX2-
7	(bn/wh)	MX4+
8	(bn)	MX4-

2.3.2 Pin-Assignment Power Supply and Digital IOs

M8 / 3 pins			M8 / 4 pins		
					
1	(bn)	Power V_{CC}	1	(bn)	TrigIN+
3	(bu)	GND	2	(wh)	TrigIN-
4	(bk)	NC	3	(bu)	$Flash_{out}$
			4	(bk)	U_{ext}

2.3.3 LED Signaling



◄ **Figure 7**
LED positions on Baumer EXG cameras.

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

2.4 Environmental Requirements

2.4.1 Temperature and Humidity Range*)

Temperature	
Storage temperature	-10°C ... +70°C (+14°F ... +158°F)
Operating temperature*	+5°C ... +50°C (+41°F ... +122°F)
Housing temperature**)***)	max. +50°C (+122°F)

* For environmental temperatures ranging from (value A) to (value B), please pay attention to the max. housing temperature. The values are listed in the table below:

Camera Type	Value A	Value B
Monochrome		
EXG03	+25°C (+77°F)	+50°C (+122°F)
EXG50	+25°C (+77°F)	+50°C (+122°F)
Color		
EXG03c	+25°C (+77°F)	+50°C (+122°F)

Humidity	
Storage and Operating Humidity	10% ... 90% Non-condensing

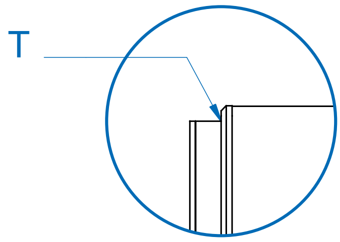


Figure 8 ►
Temperature measurement points of Baumer EXG cameras

2.4.2 Heat Transmission

It is very important to provide adequate dissipation of heat, to ensure that the temperature does not reach or exceed +50°C (+122°F). As there are numerous possibilities for installation, Baumer do 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.

3. Software

3.1 Baumer-GAPI

Baumer-GAPI stands for Baumer "Generic Application Programming Interface". With this API Baumer provides an interface for optimal integration and control of Baumer Gigabit Ethernet (GigE) 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 and FireWire™ interfaces.

This GAPI supports both Windows® (XP and Vista) 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.

3.2 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 EXG 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.

4. Camera Functionalities

4.1 Image Acquisition

4.1.1 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 4.1.6)

Camera Type	Full frame	Binning 1x2	Binning 2x1	Binning 2x2	Binning 4x4
Monochrome					
EXG03	■	■	■	■	□
EXG50	■	□	□	■	■
Color					
EXG03c	■	□	□	□	□

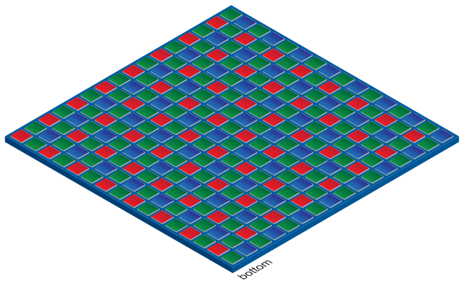
4.1.2 Pixel Format

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

4.1.2.1 Definitions

RAW: Raw data format. Here the data are stored without processing.

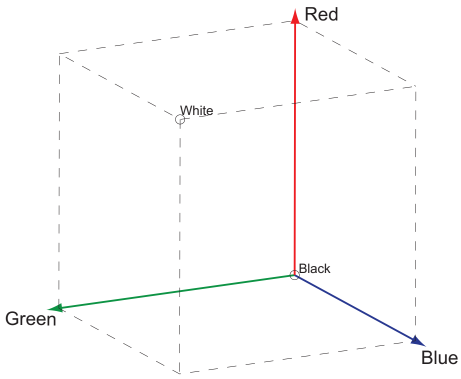
Bayer: Raw data format of color sensors.
Color filters are placed on these sensors in a checkerboard pattern, generally in a 50% green, 25% red and 25% blue array.



◄ **Figure 9**
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 10**
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.

Two bytes are needed for transmitting more than 8 bits per pixel - even if the second byte is not completely filled with data. In order to save bandwidth, the packed formats were introduced to Baumer EXG cameras. In this formats, the unused bits of one pixel are filled with data from the next pixel.

Figure 11 ▶
Bit string of Mono 8 bit and RGB 8 bit.

8 bit:

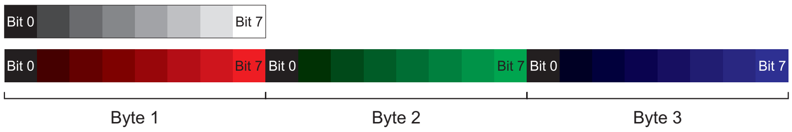


Figure 12 ▶
Spreading of Mono 10 bit over 2 bytes.

10 bit:

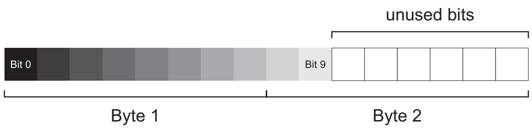


Figure 13 ▶
Spreading of Mono 12 bit over two bytes.

12 bit:

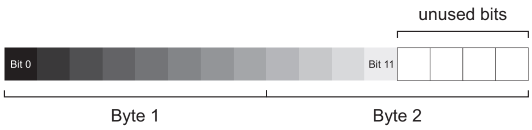
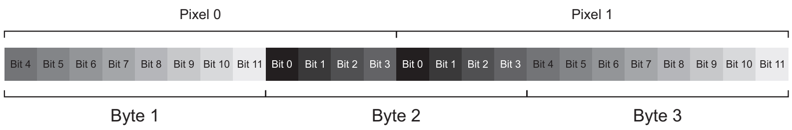


Figure 14 ▶
Spreading of two pixels in Mono 12 bit over three bytes (packed mode).

Packed:

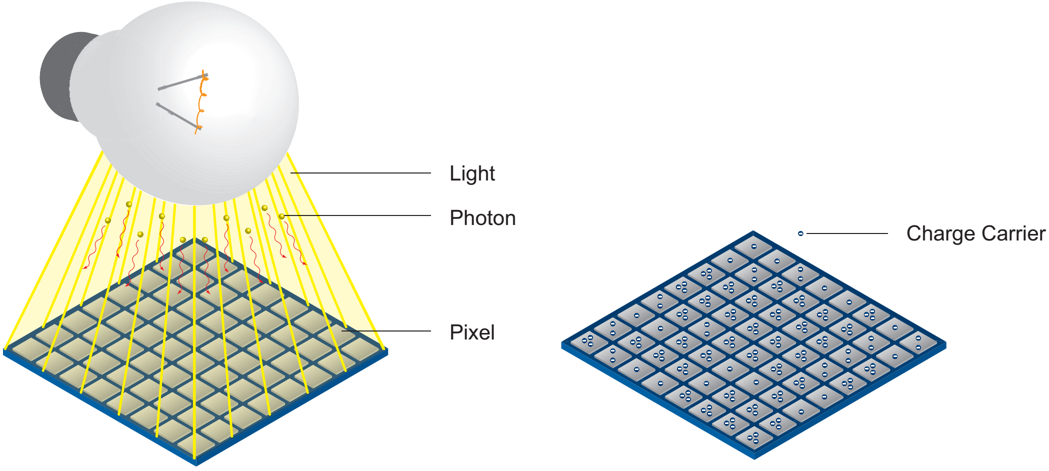


4.1.2.2 Pixel Formats on Baumer EXG Cameras

Camera Type	Mono 8	Mono 10	Mono 10 Packed	Mono 12	Mono 12 Packed	Bayer RG 8	Bayer RG 10	Bayer RG 12	RGB 8 Packed	BGR 8 Packed	YUV 444 Packed	YUV 422 Packed	YUV 411 Packed
Monochrome													
EXG03	■	■	■	□	□	□	□	□	□	□	□	□	□
EXG50	■	□	□	■	■	□	□	□	□	□	□	□	□
Color													
EXG03c	■	□	□	□	□	■	■	□	■	■	■	■	■

4.1.3 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 15**
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 EXG cameras, the exposure time can be set within the following ranges (step size 1µsec):

Camera Type	$t_{exposure}$ min	$t_{exposure}$ max
Monochrome		
EXG03	32 µsec	1 sec
EXG50	4 µsec	1 sec
Color		
EXG03c	32 µsec	1 sec

Auto Exposure:
Some models of the EXG series are equipped with the ability for automatic adjustment of the exposure time by means of target-settings in respect of the intensity of the recorded images.

4.1.4 High Dynamic Range (HDR)

The term "HDR" envelops several techniques to increase the dynamic range of brightness (from the brightest spot to the darkest spot of an image) beyond the native dynamic range of the imaging sensor. On Baumer cameras HDR-Images are created from a bracketing of several recorded – so called "Low Dynamic Range" (LDR) – images.

4.1.5 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.

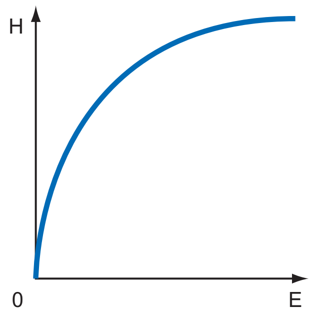
In this example the LUT is used to overwrite levels of gray which are not of interest or in the case of overdrive.

4.1.6 Gamma Correction

With this feature, Baumer EXG 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 16**
Non-linear perception of the human eye.
H - Perception of brightness
E - Energy of light

On Baumer EXG cameras the correction factor γ is adjustable from 0.001 to 2.

The values of the calculated intensities are entered into the Look-Up-Table (see 4.1.4.). Thereby previously existing values within the LUT will be overwritten.

Notice
If the LUT feature is disabled on the software side, the gamma correction feature also is disabled.

4.1.7 Partial Scan / Area of Interest (AOI)

With the "Partial Scan" function it is possible to predefine a so-called Area / Region of Interest (AOI / ROI). This ROI is an area 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

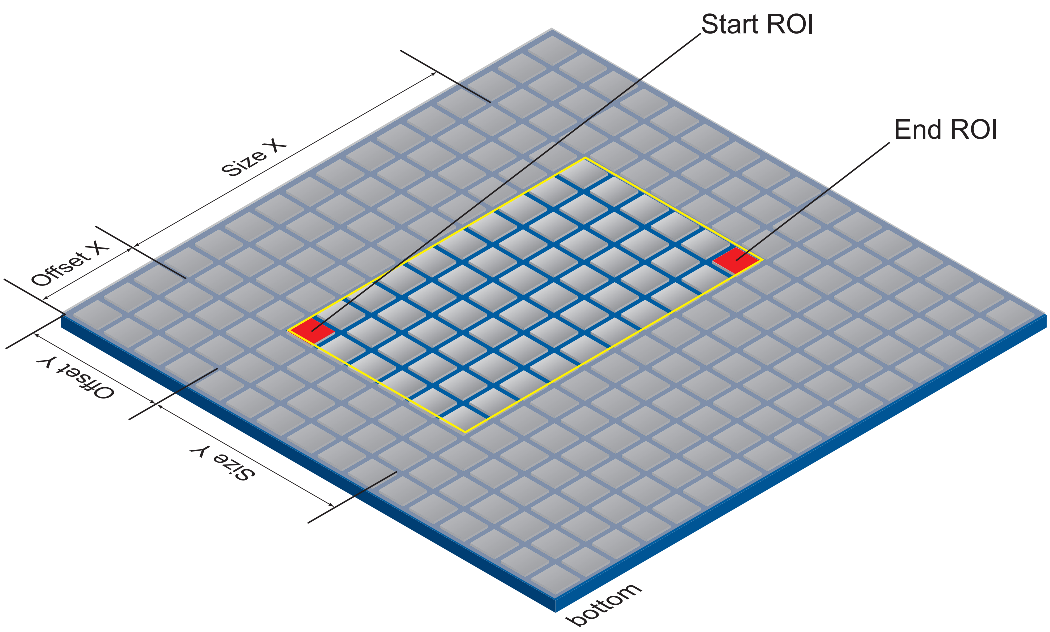


Figure 17 ►
Partial Scan:
Parameters of the ROI.

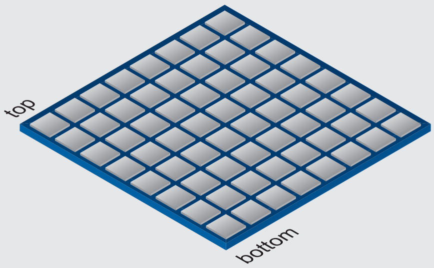
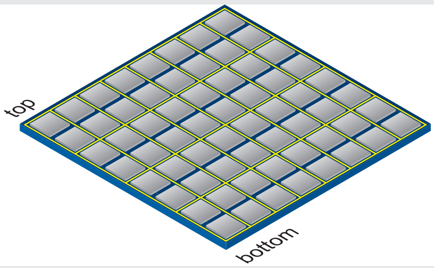
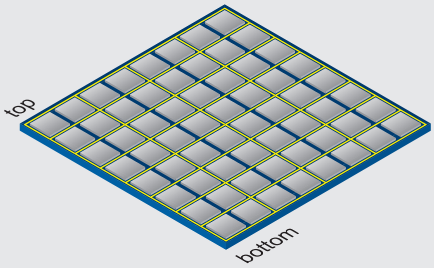
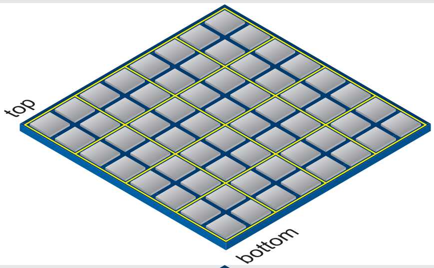
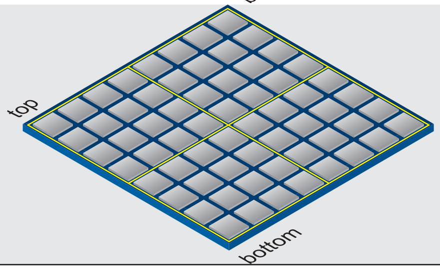
4.1.8 Binning

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		
4x4		

◄ **Figure 18**
Full frame image, no binning of pixels.

◄ **Figure 19**
Vertical binning causes a vertically compressed image with doubled brightness.

◄ **Figure 20**
Horizontal binning causes a horizontally compressed image with doubled brightness.

◄ **Figure 21**
Bidirectional binning causes both a horizontally and vertically compressed image with quadruple brightness.

◄ **Figure 22**
Bidirectional binning causes both a horizontally and vertically compressed image with sixteenfold brightness.

4.1.9 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.

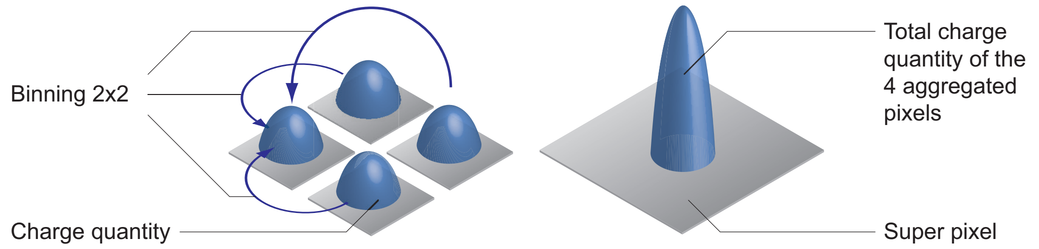


Figure 23 ►
Aggregation of charge carriers from four pixels in bidirectional binning.

4.2 Color Processing

Baumer color cameras are balanced to a color temperature of 5000 K.

Oversimplified, color processing is realized by 4 modules.

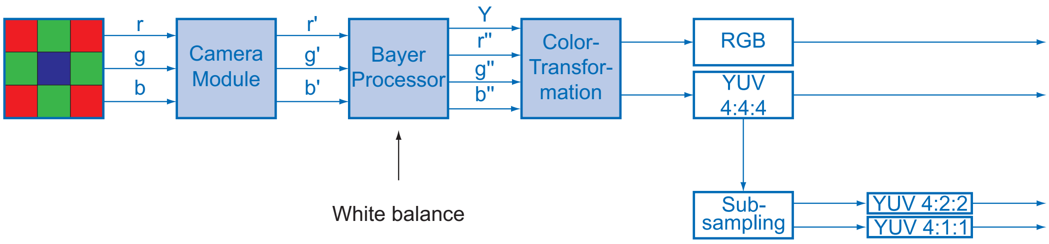


Figure 24 ►
Color processing modules of Baumer color cameras.

The color signals r (red), g (green) and b (blue) of the sensor are amplified in total and digitized within the camera module.

Within the Bayer processor, the raw signals r', g' and b' are amplified by using of independent factors for each color channel. Then the missing color values are interpolated, which results in new color values (r'', g'', b''). The luminance signal Y is also generated.

The next step is the color transformation. Here the previously generated color signals r'', g'' and b'' are converted to the chroma signals U and V, which conform to the standard. Afterwards theses signals are transformed into the desired output format. Thereby the following steps are processed simultaneously:
- Transformation to color space RGB or YUV
- External color adjustment
- Color adjustment as physical balance of the spectral sensitivities

In order to reduce the data rate of YUV signals, a subsampling of the chroma signals can be carried out. Here the following items can be customized to the desired output format:
- Order of data output
- Subsampling of the chroma components to YUV 4:2:2 or YUV 4:1:1
- Limitation of the data rate to 8 bits

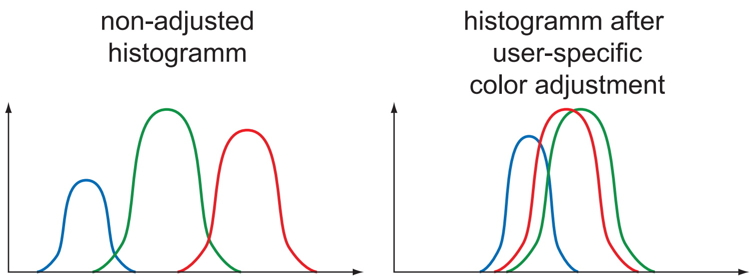
4.3 Color Adjustment – White Balance

This feature is available on all color cameras of the Baumer EXG 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.

4.3.1 User-specific Color Adjustment

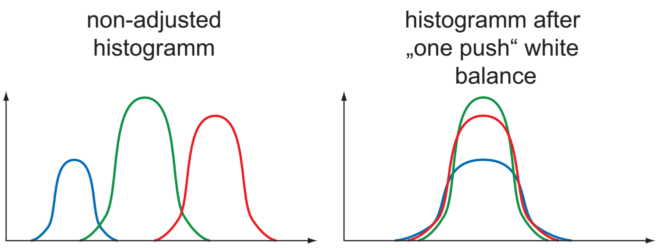
The user-specific color adjustment in Baumer color cameras facilitates adjustment of the correction factors for each color gain. This way, the user is able to adjust the amplification of each color channel exactly to his needs. The correction factors for the color gains range from 1 to 4.



◄ **Figure 25**
Examples of histogramms for a non-adjusted image and for an image after user-specific white balance.

4.3.2 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 26**
Examples of histogramms for a non-adjusted image and for an image after "one push" white balance.

4.4 Analog Controls

4.4.1 Offset / Black Level

On Baumer cameras, the offset (or black level) is adjustable from 0 to 16 LSB (relating to 8 bit).

Notice

The given values refer to the digital Offset.

The analog offset works automatically and is not adjustable.

Camera Type	Step Size 1 LSB Relating to
Monochrome	
EXG03	10 bit
EXG50	12 bit
Color	
EXG03c	10 bit

4.4.2 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 a user-defined gain factor within the camera. This gain factor is adjustable from 1 to 10.

Notice

Increasing the gain factor causes an increase of image noise.

Auto Gain:
Some models of the EXG series are equipped with the ability for automatic adjustment of the gain factor by means of target-settings in respect of the intensity of the recorded images.

4.5 Pixel Correction

4.5.1 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.

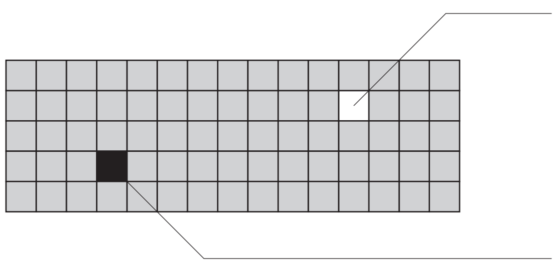


Figure 27 ▶
Distinction of "hot" and "cold" pixels within the recorded image.

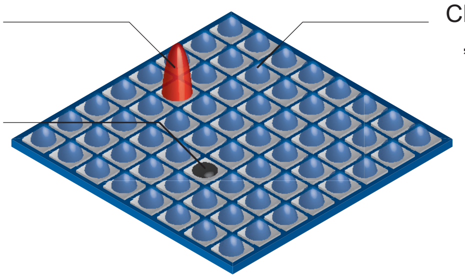


Figure 28 ▶
Charge quantity of "hot" and "cold" pixels compared with "normal" pixels.

4.5.2 Correction Algorithm

On monochrome cameras of the Baumer EXG 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 4.5.3. Defectpixellist).
- Once the sensor readout is completed, correction takes place:
  - Before any other processing, the values of the two neighboring pixels on the left and the right side of the defect pixel, will be read out
  - Then the average value of these 4 pixels is determined
  - Finally, the value of the defect pixel is substituted by the previously determined average value

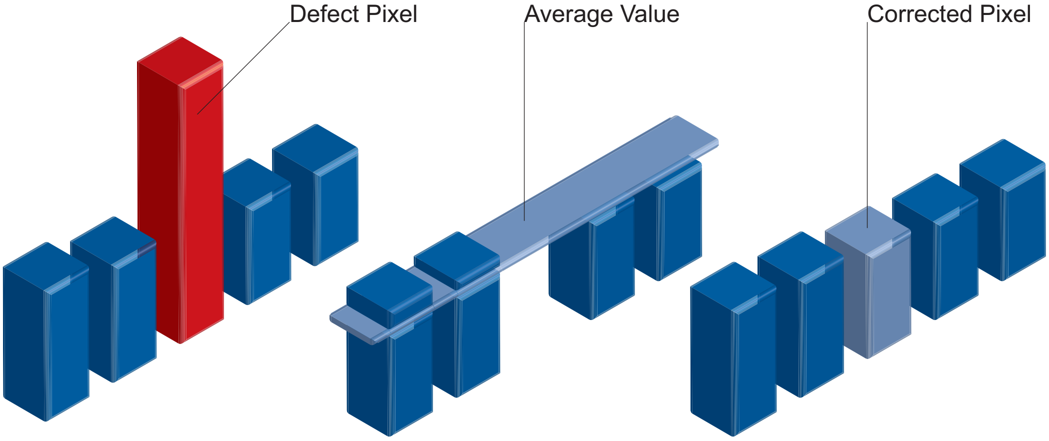


Figure 29 ▶
Schematic diagram of the Baumer pixel correction.

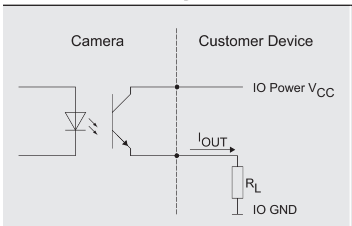
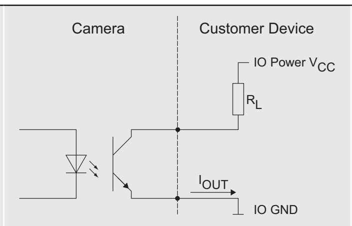
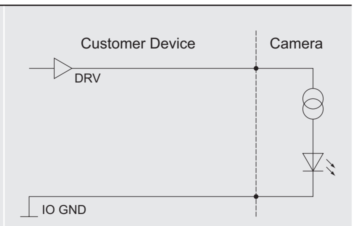
4.5.3 Defectpixellist

As stated previously, this list is determined within the production process of Baumer cameras and stored in the factory settings (see 4.8.1.).

Additional hot or cold pixels can develop during the lifecycle of a camera. In this case Baumer offers the possibility of adding their coordinates to the defectpixellist. The user can determine the coordinates*) of the affected pixels and add them to the list. Once the defect pixel list is stored in a user set (see 4.8.), pixel correction is executed for all coordinates on the defectpixellist.

4.6 Process Interface

4.6.1 IO Circuits

Output high active	Output low active	Input
		

*) Position in relation to Full Frame Format.

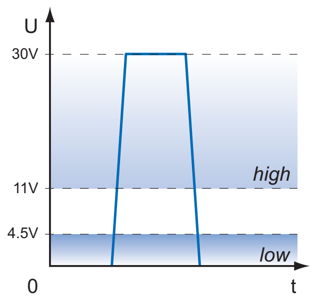


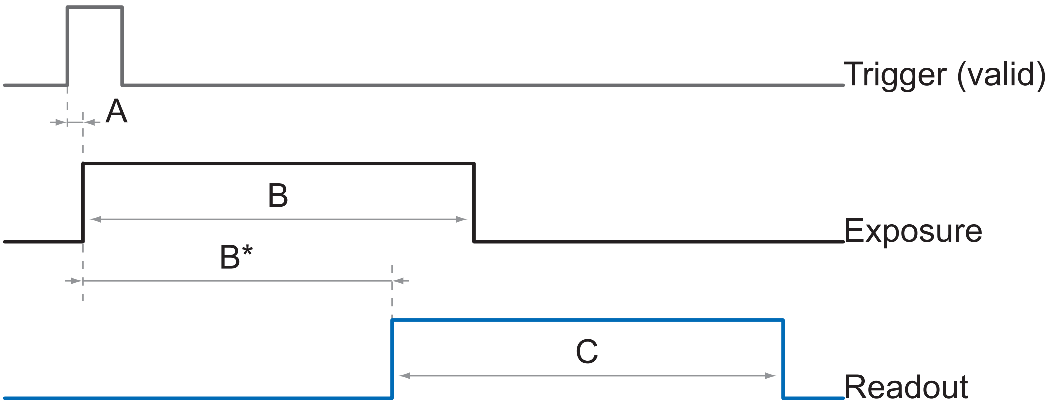
Figure 30 ▲
Trigger signal, valid for Baumer cameras.

Figure 31 ►
Camera in trigger mode:
A - Trigger delay
B - Exposure time (global shutter)
B*- Exposure time (rolling shutter)
C - Readout time

Trigger Delay:
The trigger delay is a flexible user-defined delay between the given trigger impulse and the image capture. The delay time can be set between 0.0 µsec and 2.0 sec with a stepsize of 1 µsec. In the case of multiple triggers during the delay the triggers will be stored and delayed, too. The buffer is able to store up to 512 trigger signals during the delay. Your benefits:
▪ *No need for a perfect alignment of an external trigger sensor*
▪ *Different objects can be captured without hardware changes*

4.6.2 Trigger Input

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.



Different trigger sources can be used here.

4.6.3 Trigger Source

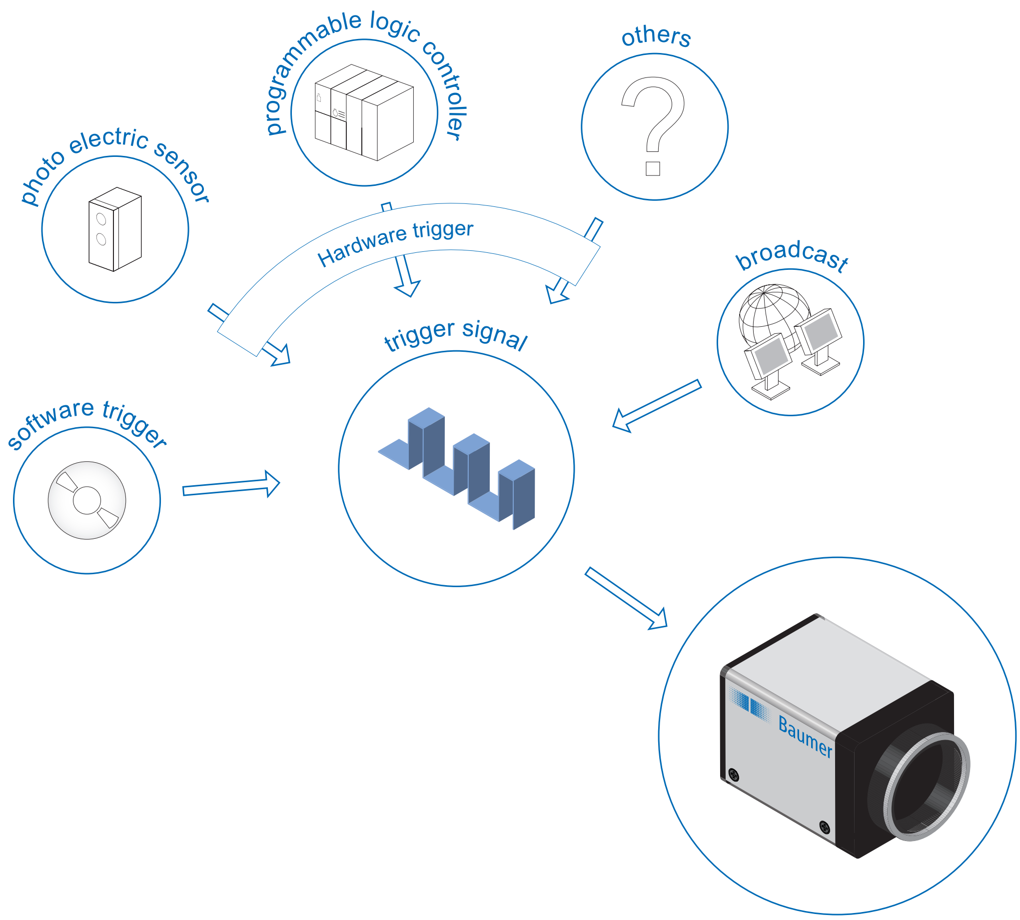


Figure 32 ►
Examples of possible trigger sources.

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

4.6.4 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.

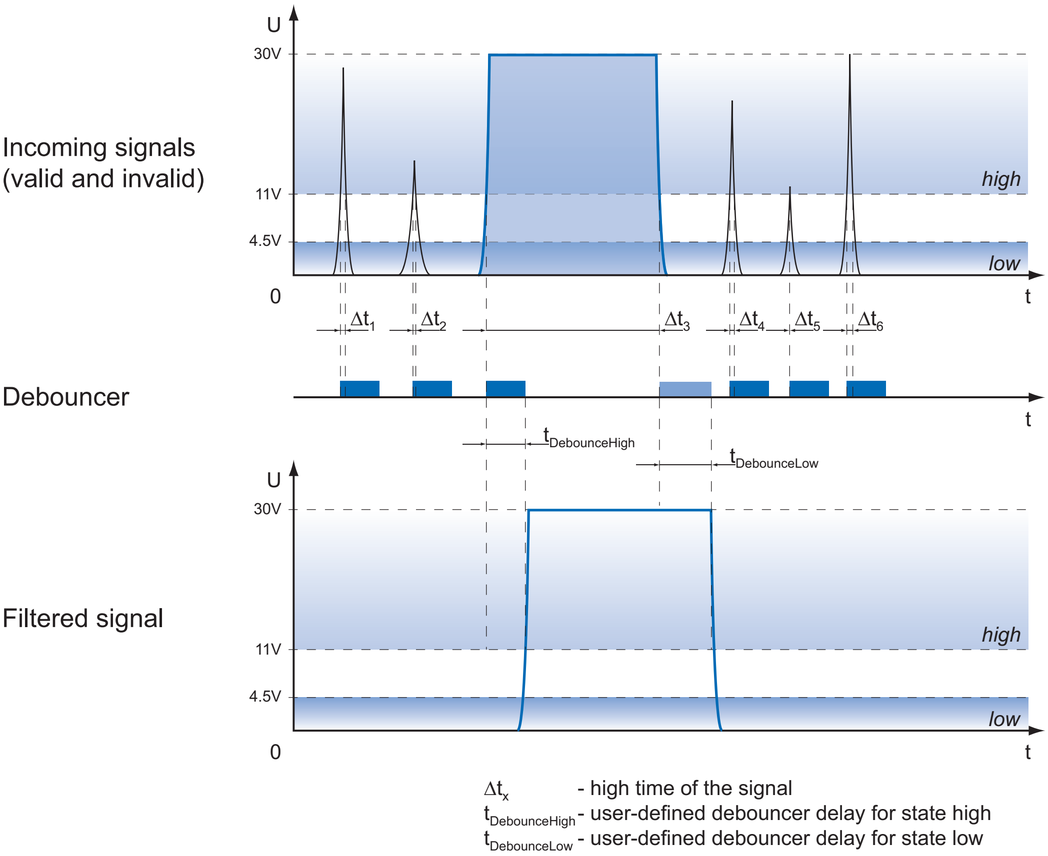
In order to detect the end of a valid signal and filter out possible jitters within the signal, a second testing time $t_{DebounceLow}$ was introduced. This timing is also adjustable by the user. If the signal value falls to state low and does not rise within $t_{DebounceLow}$, this is recognized as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



◄ **Figure 33**
Principle of the Baumer debouncer.

4.6.5 Flash Signal

This signal is managed by exposure of the sensor.

Furthermore, the falling edge of the flash output signal can be used to trigger a movement of the inspected objects. Due to this fact, the span time used for the sensor readout $t_{readout}$ can be used optimally in industrial environments.

4.6.6 Frame Counter

The frame counter is part of the Baumer image infoheader and supplied with every image, if the chunkmode is activated. It is generated by hardware and can be used to verify that every image of the camera is transmitted to the PC and received in the right order.

4.7 User Sets

Four user sets (0-3) are available for the Baumer cameras of the EXG series. User set 0 is the default set and contains the factory settings. User sets 1 to 3 are user-specific and can contain the following information:

Parameter	Parameter
Binning	Image Format
Brightness Correction	Look-Up-Table
Defect Pixel Correction	Message Channel
Defectpixellist	Offset (Black Level)
Flash Settings	Partial Scan
Gain	Pixel Format
Flash Settings	Trigger Settings

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 four possible user sets can be selected as default, which means, the camera starts up with these adjusted parameters.

4.8 Factory Settings

The factory settings are stored in "user set 0" which is the default user set. This is the only user set, that is not editable.

4.9 Timestamp

The timestamp is part of the GigE Vision® standard. It is 64 bits long and denoted in Ticks*). Any image or event includes its corresponding timestamp.

At power on or reset, the timestamp starts running from zero.

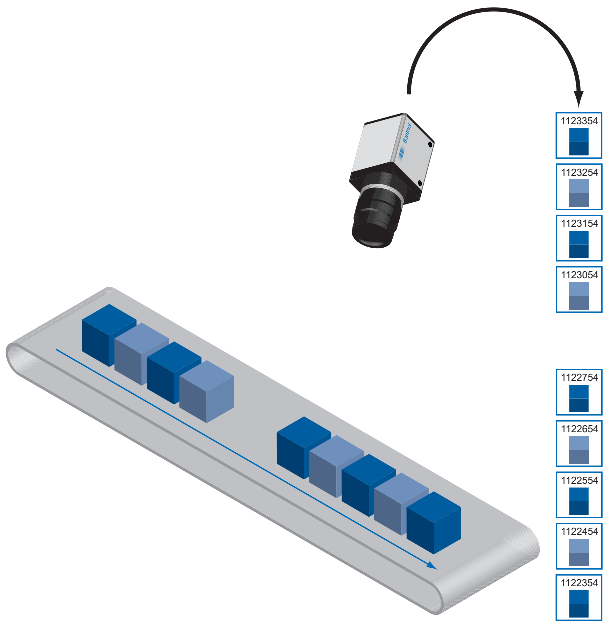


Figure 34 ►
Timestamps of recorded images.

*) Tick is the internal time unit of the camera, it lasts 32 nsec.

5. Interface Functionalities

5.1 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)

5.2 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 1500 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 EXG cameras can handle a MTU of up to 65535 Bytes.

5.3 Inter Packet Gap

To achieve optimal results in image transfer, several Ethernet-specific factors need to be considered when using Baumer EXG 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 "inter packet gap" (IPG). In addition to the minimal IPG, the GigE Vision® standard stipulates that the IPG be scalable (user-defined).

IPG:
The IPG is measured in ticks (described in chapter 5.2). *An easy rule of thumb is:* *1 Tick is equivalent to 4 Bytes of data.* *You should also not forget to add the various ethernet headers to your calculation.*

5.3.1 Example 1: Multi Camera Operation – Minimal IPG

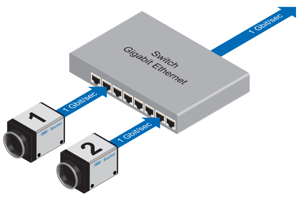


Figure 35 ▲
Operation of two cameras employing a Gigabit Ethernet switch.
Data processing within the switch is displayed in the next two figures.

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.

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.

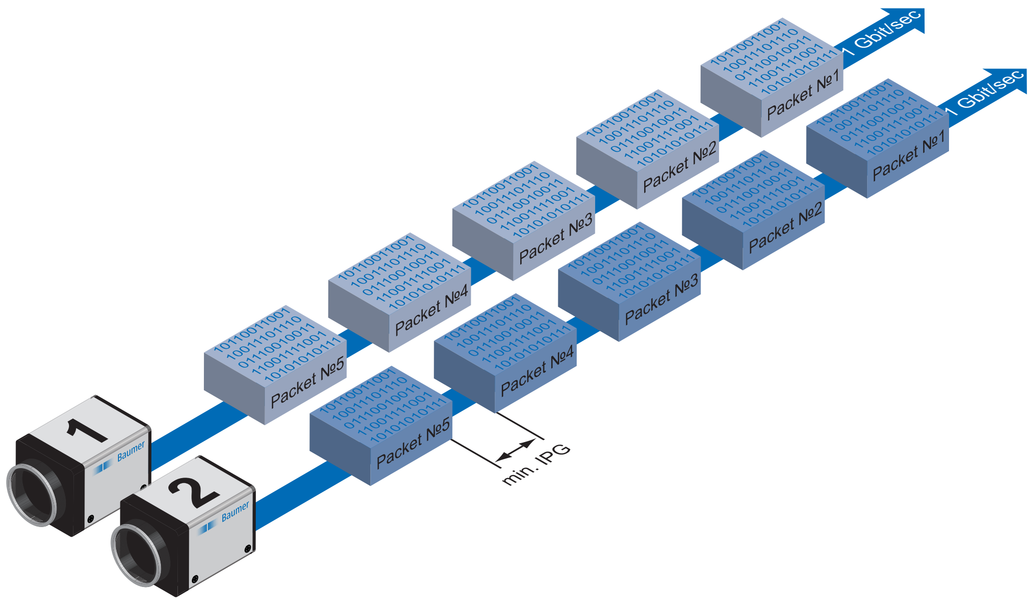


Figure 36 ▶
Operation of two cameras employing a minimal inter packet gap (IPG).

5.3.2 Example 2: Multi Camera Operation – Optimal IPG

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

$$optimal\ IPG = packet\ size + 2 \times minimal\ IPG$$

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.

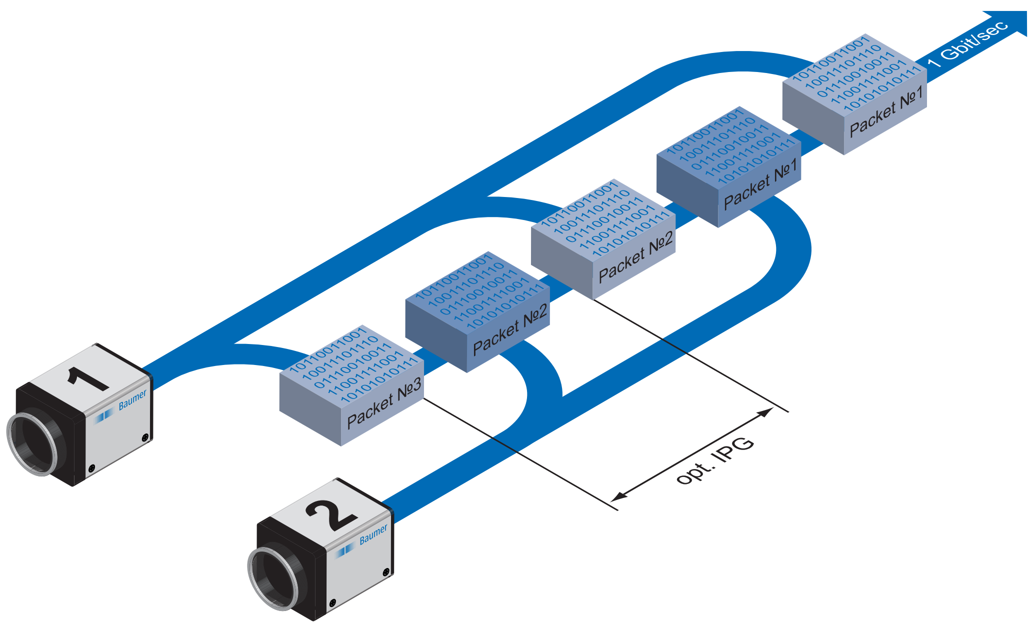


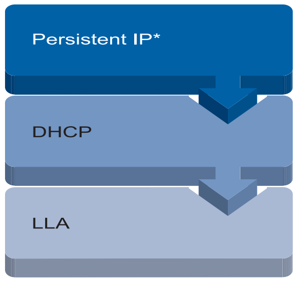
Figure 37 ▶
Operation of two cameras employing an optimal inter packet gap (IPG).

5.4 IP Configuration

Internet Protocol:
On Baumer cameras IP v4 is employed.

5.4.1 Persistent IP

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



▲ **Figure 38**
Connection pathway for Baumer Gigabit Ethernet cameras:
The device connects step by step via the three described mechanisms.

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.

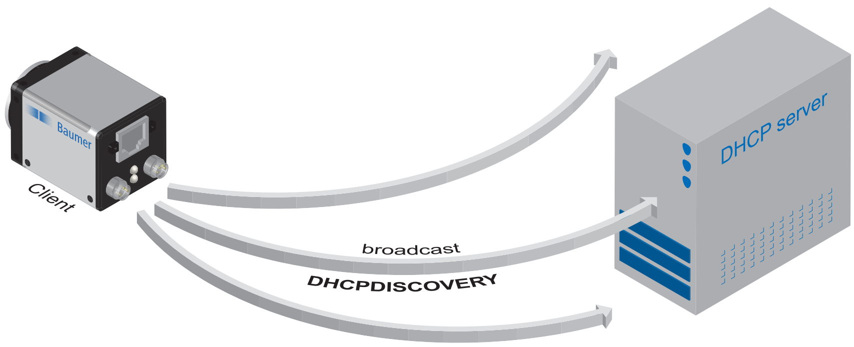
5.4.2 DHCP (Dynamic Host Configuration Protocol)

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:
Please pay attention to the DHCP Lease Time.

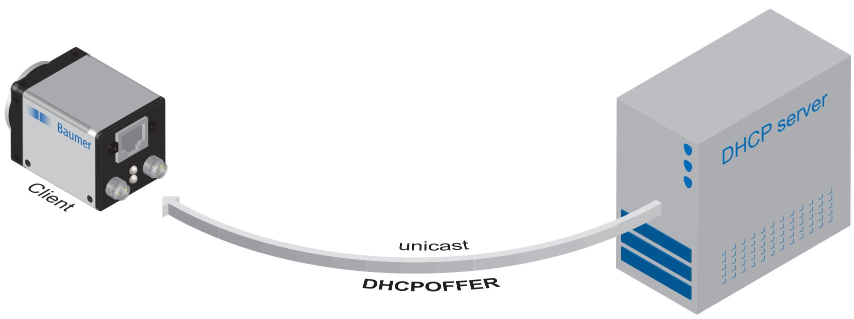
- DHCP Discovery
  In order to find a DHCP server, the client sends a so called DHCPDISCOVER broadcast to the network.



◄ **Figure 39**
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 40**
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.

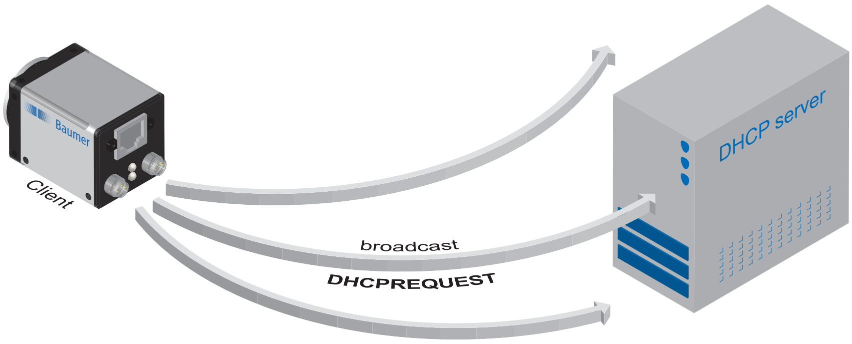


Figure 41 ▶
DHCP Request (broadcast)

- 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.

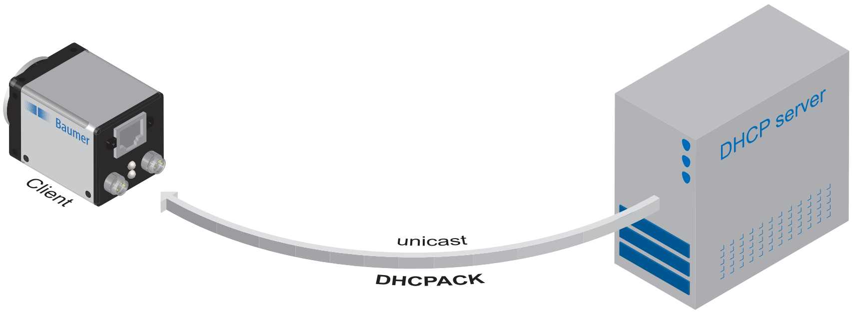


Figure 42 ▶
DHCP Acknowledgement (unicast)

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

5.4.3 LLA

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 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.

5.4.4 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".

5.5 Packet Resend

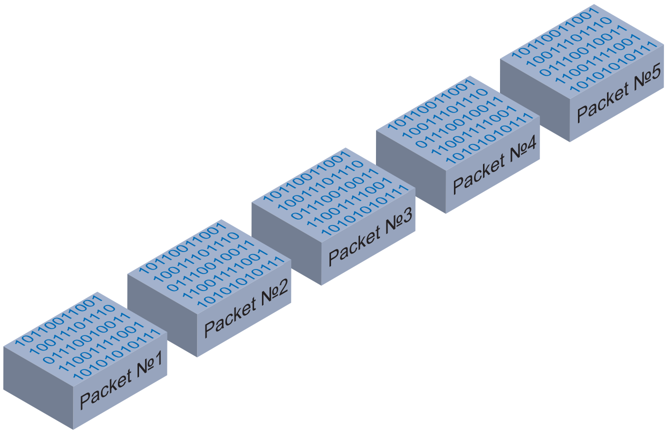
Due to the fact, that the GigE Vision® standard stipulates using a UDP - a stateless user datagram protocol - for data transfer, a mechanism for saving the "lost" data needs to be employed.

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:

5.5.1 Normal Case

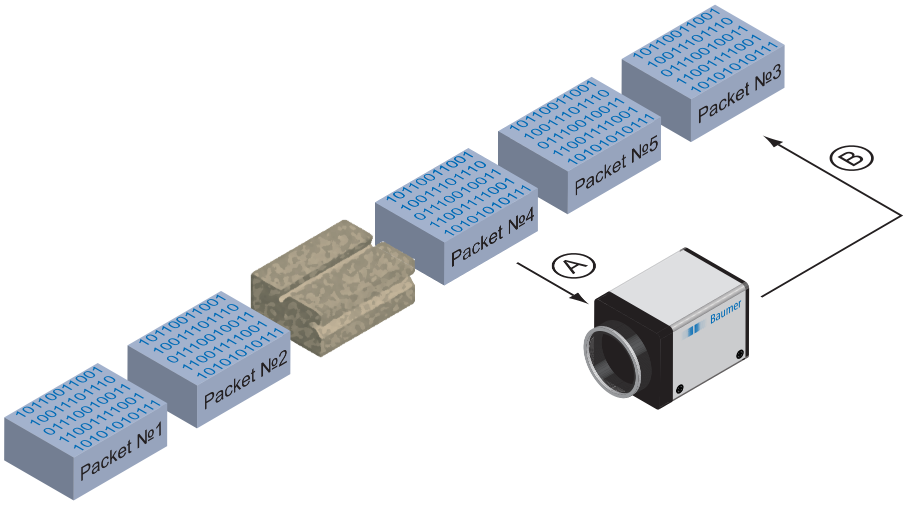
In the case of unproblematic data transfer, all packets are transferred in their correct order from the camera to the PC. The probability of this happening is more then 99%.



◄ **Figure 43**
Data stream without damaged or lost packets.

5.5.2 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 44**
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 resend request triggered. Then the camera sends packet no. 5, followed by resending packet no. 3.

5.5.3 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.

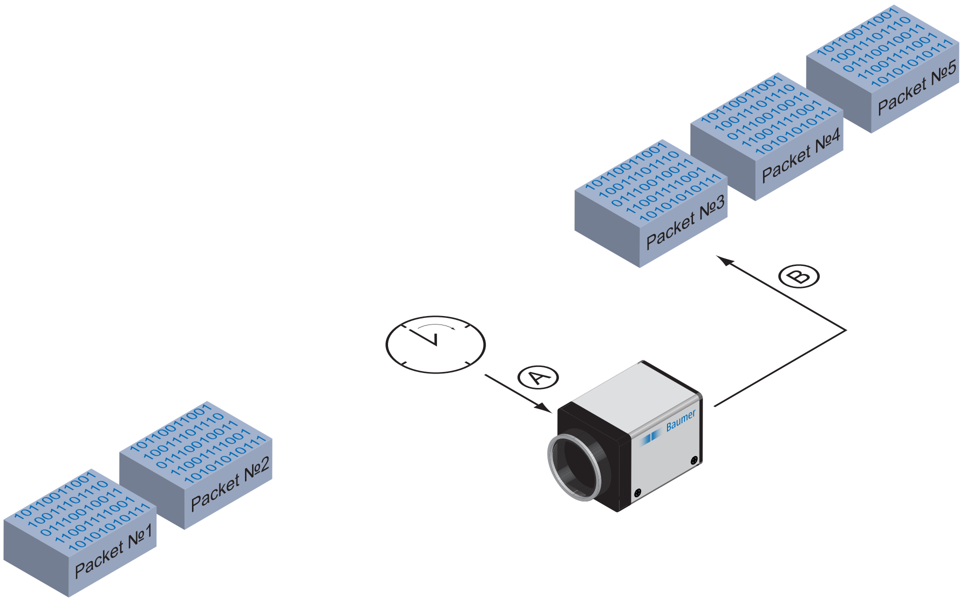


Figure 45 ►
Resending of lost packets at the end of the data stream.

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.

5.5.4 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.

5.6 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.

5.6.1 Event Generation

Event	Description
Gen<i>Cam™	
ExposureStart	Exposure started
ExposureEnd	Exposure ended
FrameStart	Acquisition of a frame started
FrameEnd	Acquisition of a frame ended
Line0Rising	Rising edge detected on IO-Line 0
Line0Falling	Falling edge detected on IO-Line 0
Line1Rising	Rising edge detected on IO-Line 1
Line1Falling	Falling edge detected on IO-Line 1
Line2Rising	Rising edge detected on IO-Line 2
Line2Falling	Falling edge detected on IO-Line 2
Line3Rising	Rising edge detected on IO-Line 3
Line3Falling	Falling edge detected on IO-Line 3
Line4Rising	Rising edge detected on IO-Line 4
Line4Falling	Falling edge detected on IO-Line 4
Line5Rising	Rising edge detected on IO-Line 5
Line5Falling	Falling edge detected on IO-Line 5
Vendor-specific	
EventError	Error in event handling
EventLost	Occured event not analyzed
TemperatureExceeded	Reference value of temperature exceeded
TriggerReady	$t_{notready}$ (see chapter 2.4) elapsed, camera is able to process incoming trigger
TriggerOverlapped	Overlapped Mode (see chapter 2.4) detected
TriggerSkipped	Camera overtriggered (see chapter 2.4)

Notice

By the individual cameras of the Baumer EXG series the GigE Vision® Message Channel is supported in different degrees.

5.7 Action Command / Trigger over Ethernet

The basic idea behind this feature was to achieve a simultaneous trigger for multiple 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
- an Action ID - for identification of the action signal
- a Group Key - for triggering actions on separated groups of devices
- a Group Mask - for extension of the range of separate device groups

5.7.1 Example: Triggering Multiple Cameras

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

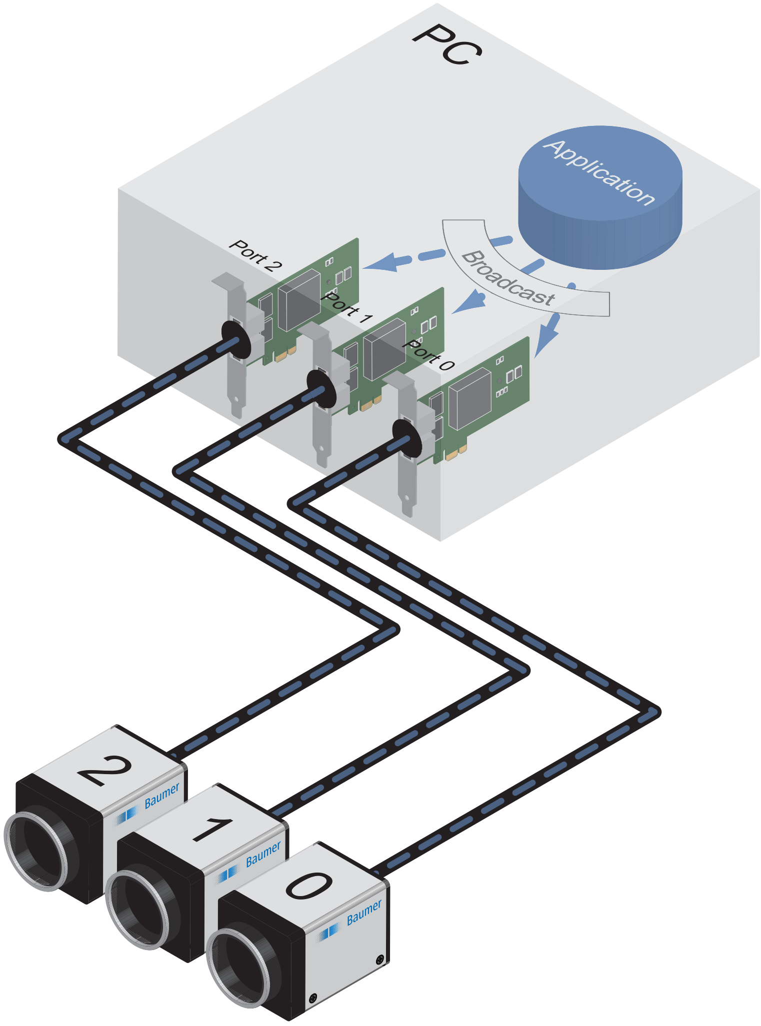


Figure 46 ►
Triggering of multiple cameras via trigger over Ethernet (ToE).

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

6. Start-Stop-Behaviour

6.1 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.

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.

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

6.2 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.

6.3 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.

6.4 Acquisition Modes

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

6.4.1 Free Running

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

6.4.2 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.

This feature is described in chapter 4.6. Process Interface.

7. Notes and Instructions

7.1 Warranty Notes

Notice

Keep camera housing closed.

There are no adjustable parts inside the camera!

In order to avoid the loss of warranty do not open the housing!

Notice

Dismantling / Rework / Repair of Baumer Cameras

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!

7.2 Lens Mounting

Notice

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

Therefore the following points are very important:

- Install the camera in an environment that is as dust free as possible!
- Keep the dust cover (bag) on camera as long as possible!
- Hold the camera downwards with unprotected sensor.
- Avoid contact with any optical surface of the camera!

8. Conformity

Cameras of the Baumer EXG family comply with:
- CE,
- FCC Part 15 Class B,
- RoHS
- KC

8.1 CE

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

8.2 FCC – Class B Device

Note: 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 instructios, 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.

8.3 RoHS

All EXG cameras comply with the recommendation of the European Union concerning RoHS rules.

8.4 Korean Conformity

Registration of Broadcasting and Communication Equipments

Several of the described Baumer EXG cameras conform with the directives of the Korean Conformity.

Product	Article No.	Registration No.	Date of Registration
Color			
EXG50c	11012596	MSIP-REI BkR-EXG50	2017-06-13

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