



User's Guide

PXU cameras (USB3 Vision™)

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1. General Information

Thank you for purchasing a camera from the Baumer range. 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 who want to integrate camera(s) into a vision system.

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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



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

2. General safety instructions



Caution

Heat can damage the camera. Heat must be dissipated adequately to ensure that the temperatures do not exceed the values (see Heat Transmission).



As there are numerous options for installation, Baumer does not specify a specific method for proper heat dissipation.

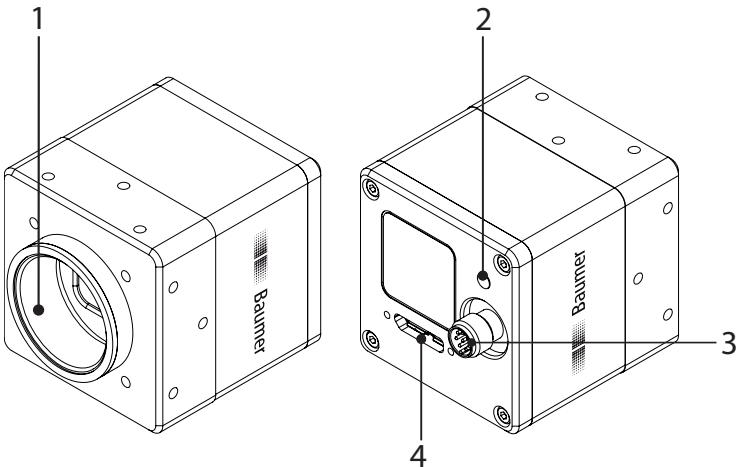
3. Intended Use

The camera is used to capture images that can then be transferred over a USB 3.0 interface to a PC.

Notice

Use the camera only for its intended purpose! For any use that is not described in the technical documentation poses dangers and will void the warranty. The risk has to be borne solely by the unit's owner.

4. General Description



No.	Description	No.	Description
1	Lens mount (C-Mount)	4	USB 3.0 port
2	LED		
3	Power supply / Digital IO		

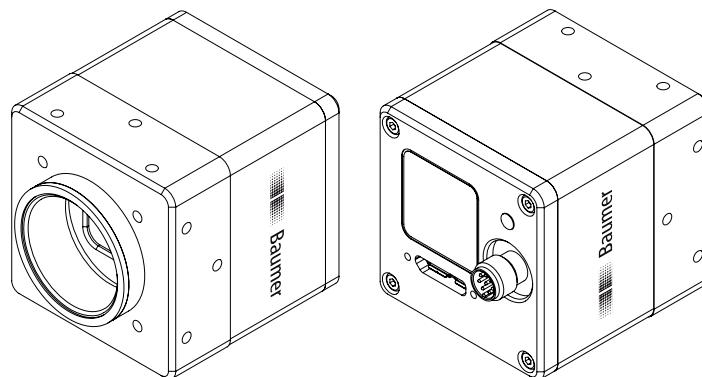
Notice

The USB 3.0 port is only used for data transfer. The power is supplied via the Power / Digital IO port.

All PX cameras with a USB 3.0 interface have the following features:

- | | |
|----------------------------|--|
| Very high image quality | ▪ Low noise and structure-free image information |
| Flexible image acquisition | ▪ Industrially compliant process interface with parameter setting capability (trigger and flash) |
| Fast image transfer | ▪ Reliable transmission at 5000 Mbit/sec according to USB 3.0 (v1.0) standard |
| Perfect integration | ▪ GenICam™ and USB3 Vision™ compliant |
| Compact design | ▪ Flexible generic programming interface (Baumer GAPI) for all Baumer cameras |
| Reliable operation | ▪ Powerful Software Development Kit (SDK) with sample codes and help files for easy integration |
| | ▪ Baumer Camera Explorer Test Tool for all camera functions |
| | ▪ Camera features according to the SFNC (v2.0) |
| | ▪ GenICam™ compliant XML file to show the camera features |
| | ▪ Supplied with installation program including automatic camera recognition for easy commissioning |
| | ▪ Light weight |
| | ▪ Flexible assembly |
| | ▪ State-of-the-art camera electronics and precision mechanics |
| | ▪ Low power consumption and minimal heat generation |

5. Camera Models



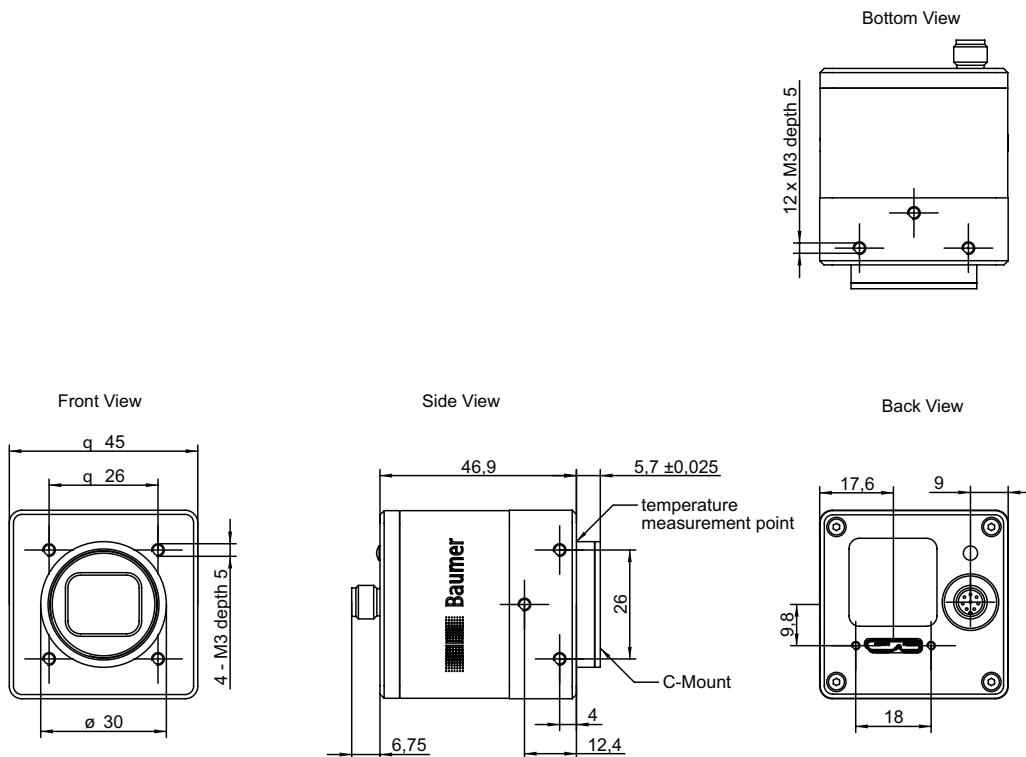
◀ Figure 1
Baumer PXU camera

Camera Type	Sensor Size	Resolution	Full Frames [max. fps]
Monochrome			
PXU-60M.Q	1"	2752 x 2200	25
PXU-120M.Q	1"	4248 x 2832	13

Notice

You can operate the camera with a USB 2.0 port. However, the frame rate will be less than on a USB 3.0 port.

Dimensions



6. Installation

6.1 Lens mounting

Notice

Ensure the sensor and lens are not contaminated with dust and airborne particles when mounting the support or the lens to the device!

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 the camera for as long as possible!
- Hold the camera downwards if the sensor is uncovered.
- Avoid contact with any of the camera's optical surfaces!

6.2 Environmental Requirements

Temperature	
Storage temperature	-10°C ... +70°C (+14°F ... +158°F)
Operating temperature*	see Heat Transmission
Humidity	
Storage and Operating Humidity	10% ... 90% Non-condensing

6.2.1 Mechanical Tests

Environment- tal Testing	Standard	Parameter	
Vibration, sinu- sodial	IEC 60068-2-6	Frequency Range	10-2000 Hz
		Amplitude under- neath crossover frequencies	1.5 mm
		Acceleration	10 g
		Test duration / Axis	150 min
Vibration, broad band	IEC 60068- 2-64	Frequency range	20-1000 Hz
		Acceleration RMS	10 g
		Test duration / Axis	300 min
Shock	IEC 60068- 2-27	Pulse time	11 ms / 6 ms
Bump	IEC60068-2- 29	Acceleration	50 g / 100 g
		Pulse Time	2 ms
		Acceleration	100 g

6.2.2 Heat Transmission



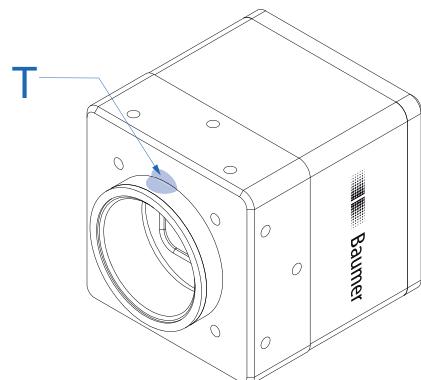
Caution

Heat can damage the camera. Heat must be dissipated adequately to ensure that the temperature does not exceed the value in the table below.

As there are numerous possibilities for installation, Baumer do not specify 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



◀ Figure 2

Temperature measuring point

Measurement Point	Maximum Temperature
T	max. 70°C (122°F)

7. Pin Assignment

7.1 USB 3.0 Interface

Notice

The USB 3.0 port is only used for data transfer. The power is supplied via the Power / Digital IO port.

Notice

You can operate the camera on a USB 2.0 port. However, the frame rate will be less than on a USB 3.0 port.

USB 3.0 Micro B

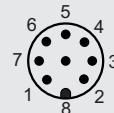


1	VBUS	6	MicB_SSTX-
2	D-	7	MicB_SSTX+
3	D+	8	GND_DRAIN
4	ID	9	MicB_SSRX-
5	GND	10	MicB_SSRX+

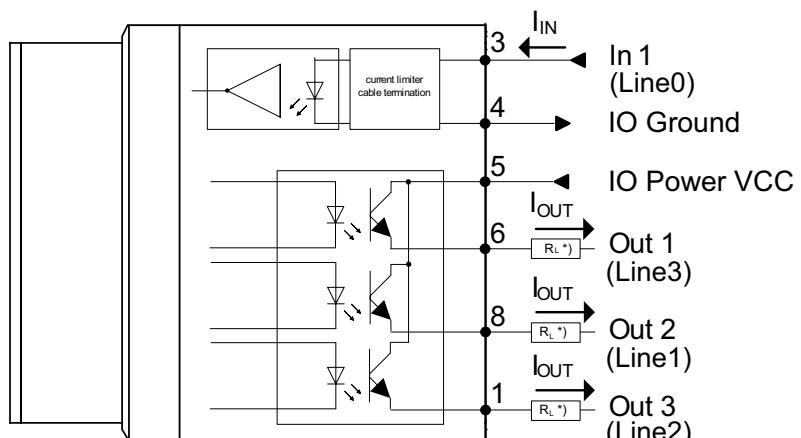
7.2 Digital IOs

Power supply / Digital IOs

(M8 / 8 pins / wire colors of the connecting cable)



1	OUT 3	white	5	IO Power VCC	grey
2	Power VCC+	brown	6	OUT 1	pink
3	IN 1	green	7	Power GND	blue
4	IO GND	yellow	8	OUT 2	red

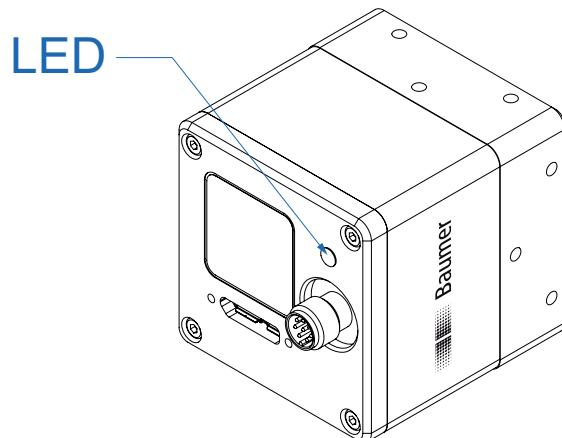


*) resistor must be used, $I_{out} = 16 \text{ mA}$
by $U_{EXT} = 24 \text{ VDC}$ recommended,
drawing shown above example
for using high active signal

7.2.1 Power Supply

Power Supply	
Power VCC	12 V DC ... 24 V DC $\pm 20\%$
I	210 mA ... 420 mA
Power consumption	approx. 5 W (25 fps)

7.2.2 LED Signalling



◀ Figure 3

LED position on Baumer PXU camera.

	Signal	Meaning
LED	green flash	Power on
	green	USB 3.0 connection
	red	USB 2.0 connection
	yellow	Data transfer
	red flash	Update

8. Product Specifications

8.1 Spectral Sensitivity for Baumer PXU Cameras

The following graphs show the spectral sensitivity characteristics for PXU cameras. The curves for the sensors do not take the characteristics of lenses and light sources without filters into account.

Values relate to the respective technical data sheets for the sensors.

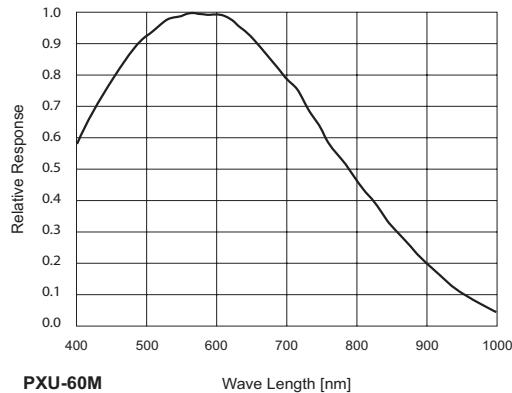


Figure 4 ▶

Spectral sensitivities for Baumer cameras with 6 MP CCD sensors.

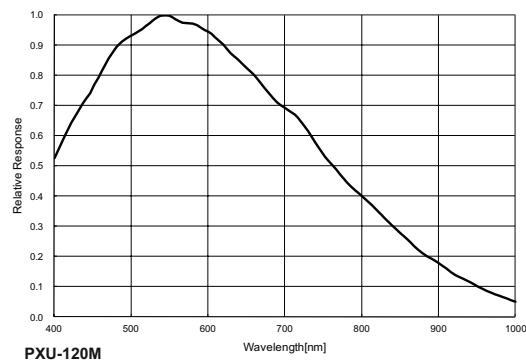
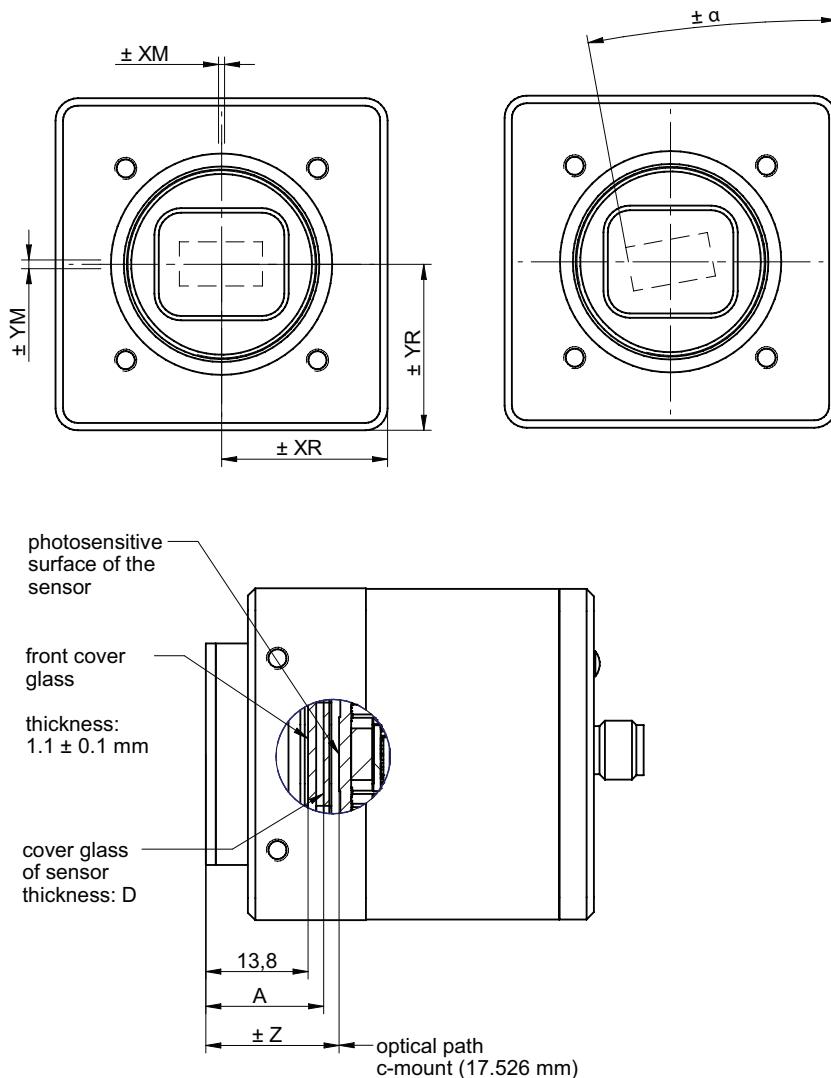


Figure 5 ▶

Spectral sensitivities for Baumer cameras with 12 MP CCD sensors.

8.2 Field of View Position

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



Camera Type	$\pm x_M$ [mm]	$\pm y_M$ [mm]	$\pm x_R$ [mm]	$\pm Y_R$ [mm]	$\pm z_{typ}$ [mm]	$\pm \alpha_{typ}$ [°]	A [mm]	D** [mm]
PXU-60*	0.08	0.08	0.085	0.085	0.025	0.6	16	0.7
PXU-120*	0.08	0.08	0.085	0.085	0.025	0.6	16	0.7

typical accuracy by assumption of the root mean square value

* C or M

** Dimension D in this table is from manufacturer datasheet

8.3 Acquisition Modes and Timings

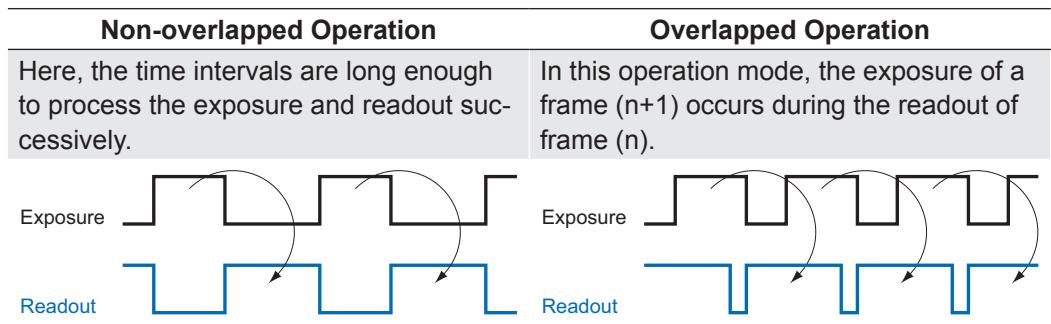
Image acquisition consists of two separate, successively processed components.

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

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

Baumer cameras can be operated in three different modes, Free Running Mode, Fixed-Frame-Rate Mode and Trigger Mode.

The cameras can be operated non-overlapped¹⁾ or overlapped, depending on the mode used and the combination of exposure and readout time:

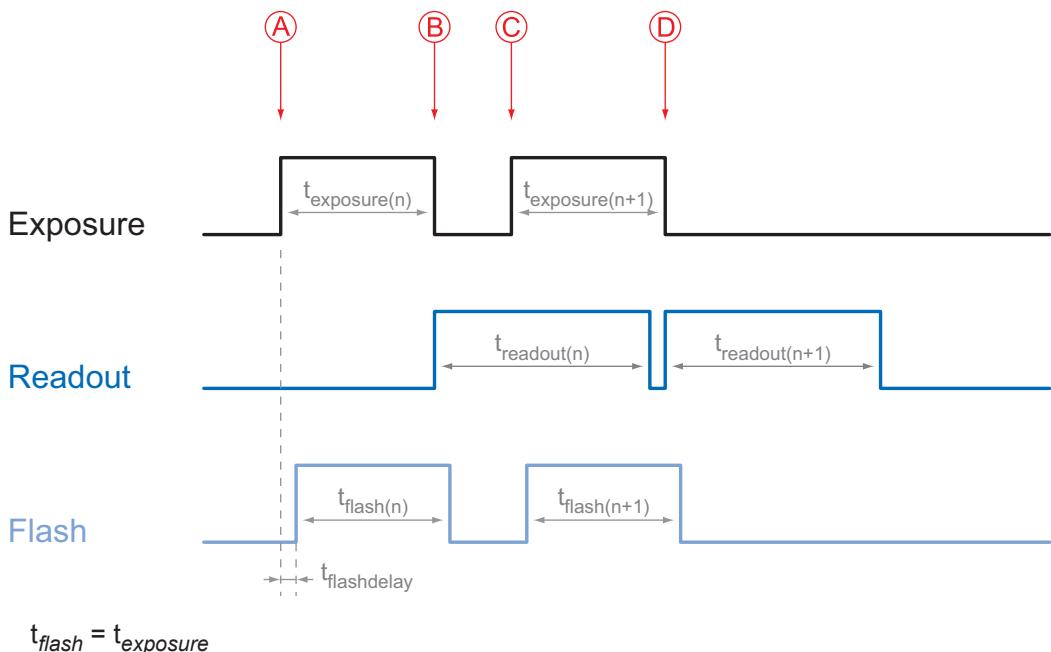


8.3.1 Free Running Mode

In the "Free Running" mode, the camera records images permanently and transfers them to the PC. To achieve the best results (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 ($t_{\text{exposure}} \leq t_{\text{readout}}$), the maximum frame rate is provided for the image format used. For longer exposure times, the frame rate of the camera is reduced.

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



1)Non-overlapped means sequential.

8.3.2 Fixed-Frame-Rate Mode

With this feature, Baumer introduces a clever technique to the PXU camera series that enables the user to predefine a desired frame rate in continuous mode.

For this mode, the cameras are equipped with an internal clock generator that creates trigger pulses.

Notice

Above a certain frame rate, skipping internal triggers becomes unavoidable. In general, this depends on the combination of the adjusted frame rate, exposure and readout times.

8.3.3 Trigger Mode

Image acquisition begins after a specified external event (trigger) occurs. Depending on the interval of triggers used, the camera can operate either 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)	$t_{notready(n+1)} = t_{exposure(n)}$

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

During overlapped operation, be mindful of the time interval during which the camera is unable to process trigger signals ($t_{notready}$) that occur. This interval occurs between two exposures. When this processing time $t_{notready}$ has elapsed, the camera is able to react to external events again.

Once $t_{notready}$ 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, dependant on 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

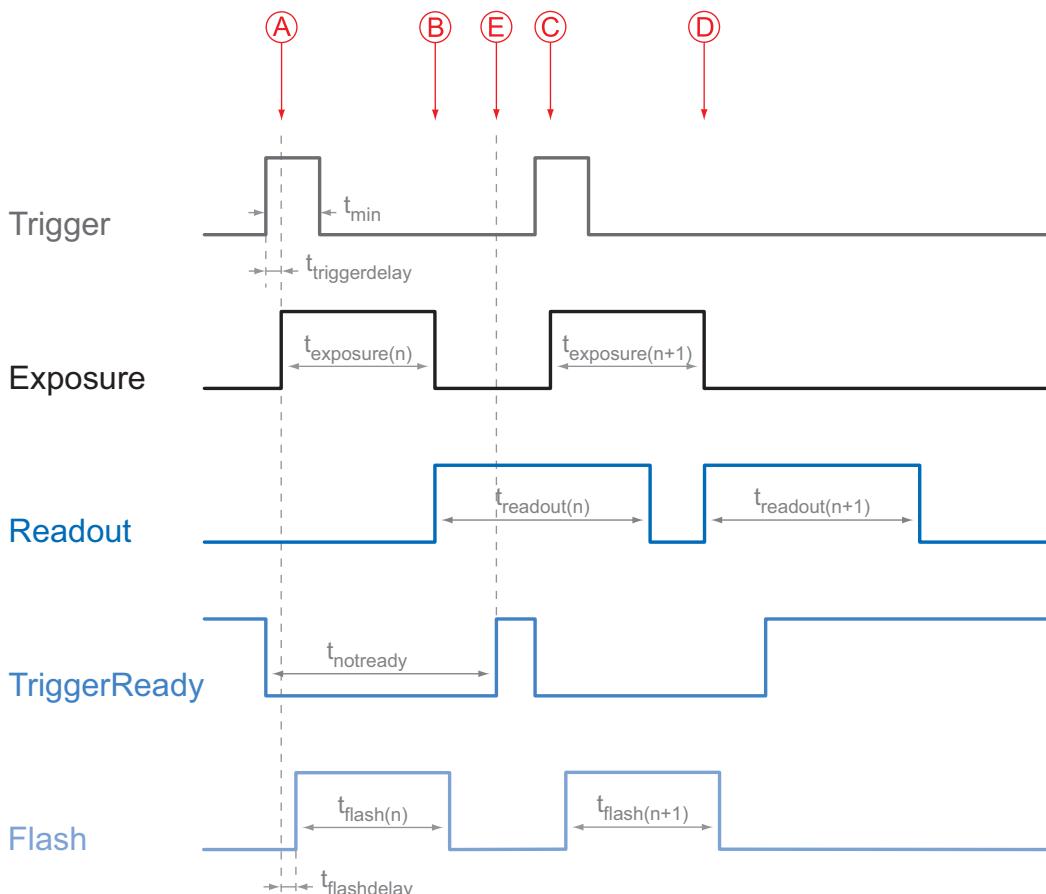
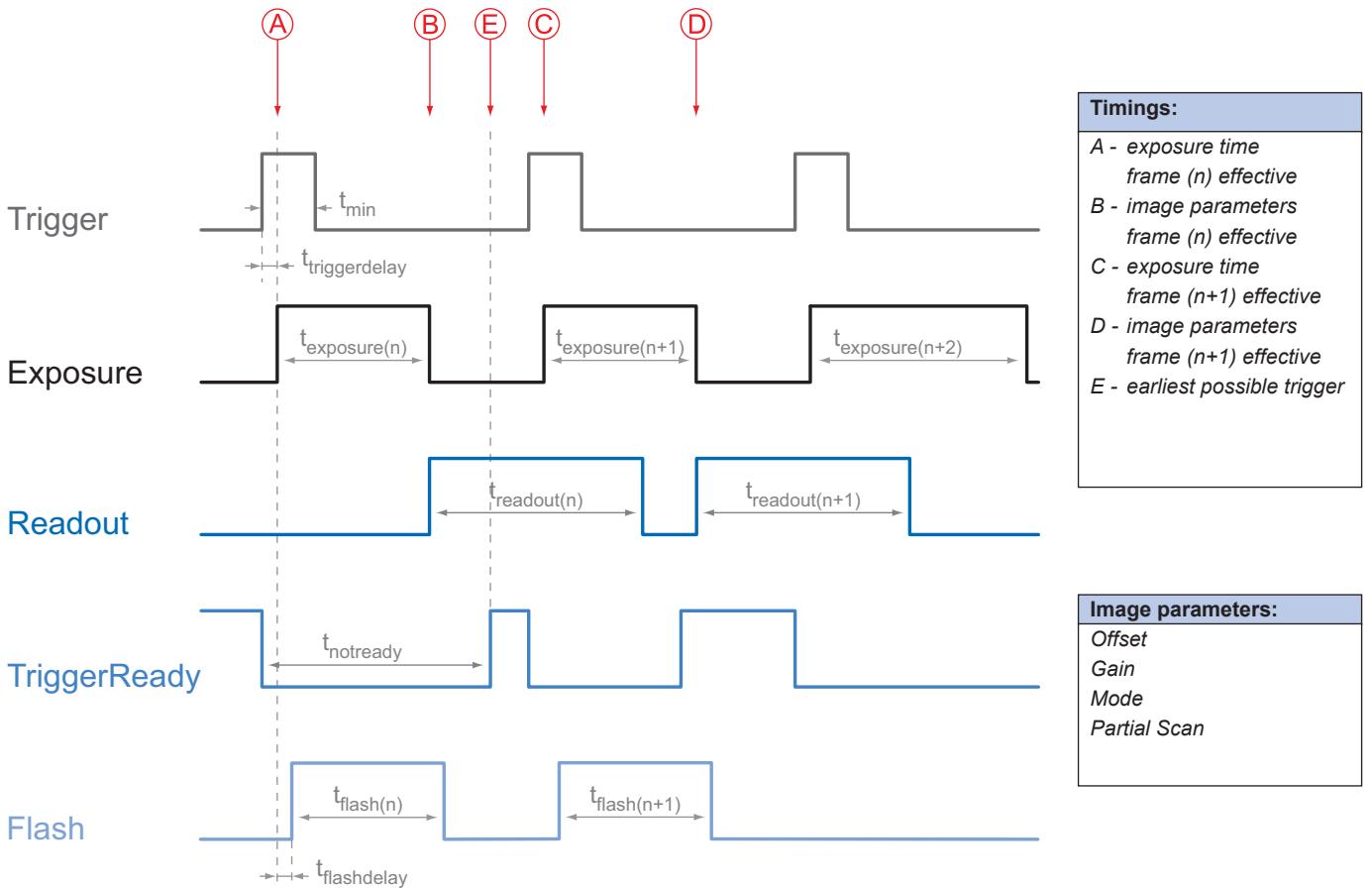


Image parameters:
Offset
Gain
Mode
Partial Scan

8.3.3.2 Overlapped Operation: $t_{\text{exposure}(n+2)} > t_{\text{exposure}(n+1)}$

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

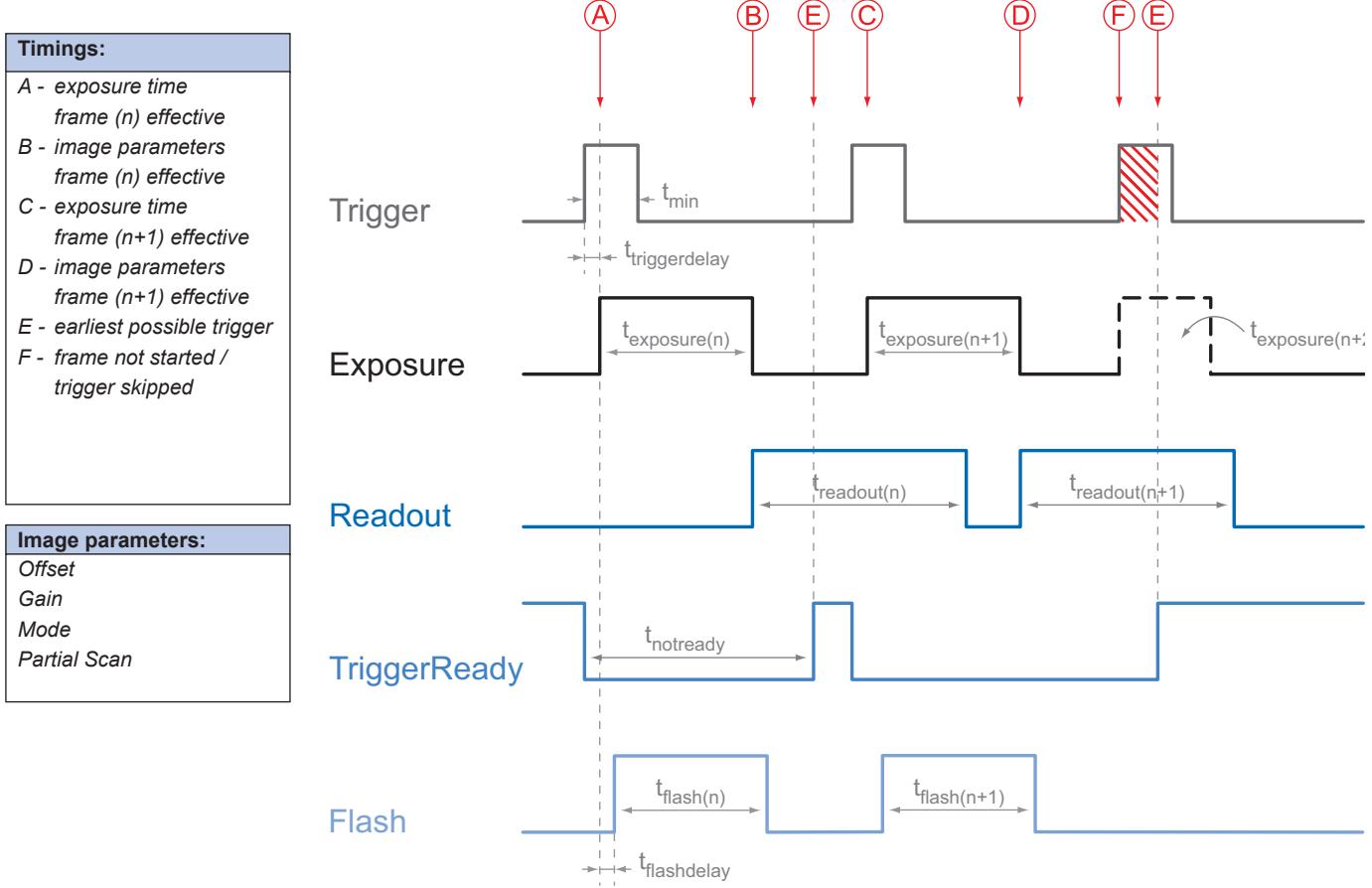
This can be simulated with the formulas mentioned above (no. 2 or 4, dependant on the case).



8.3.3.3 Overlapped Operation: $t_{\text{exposure}(n+2)} < t_{\text{exposure}(n+1)}$

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

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

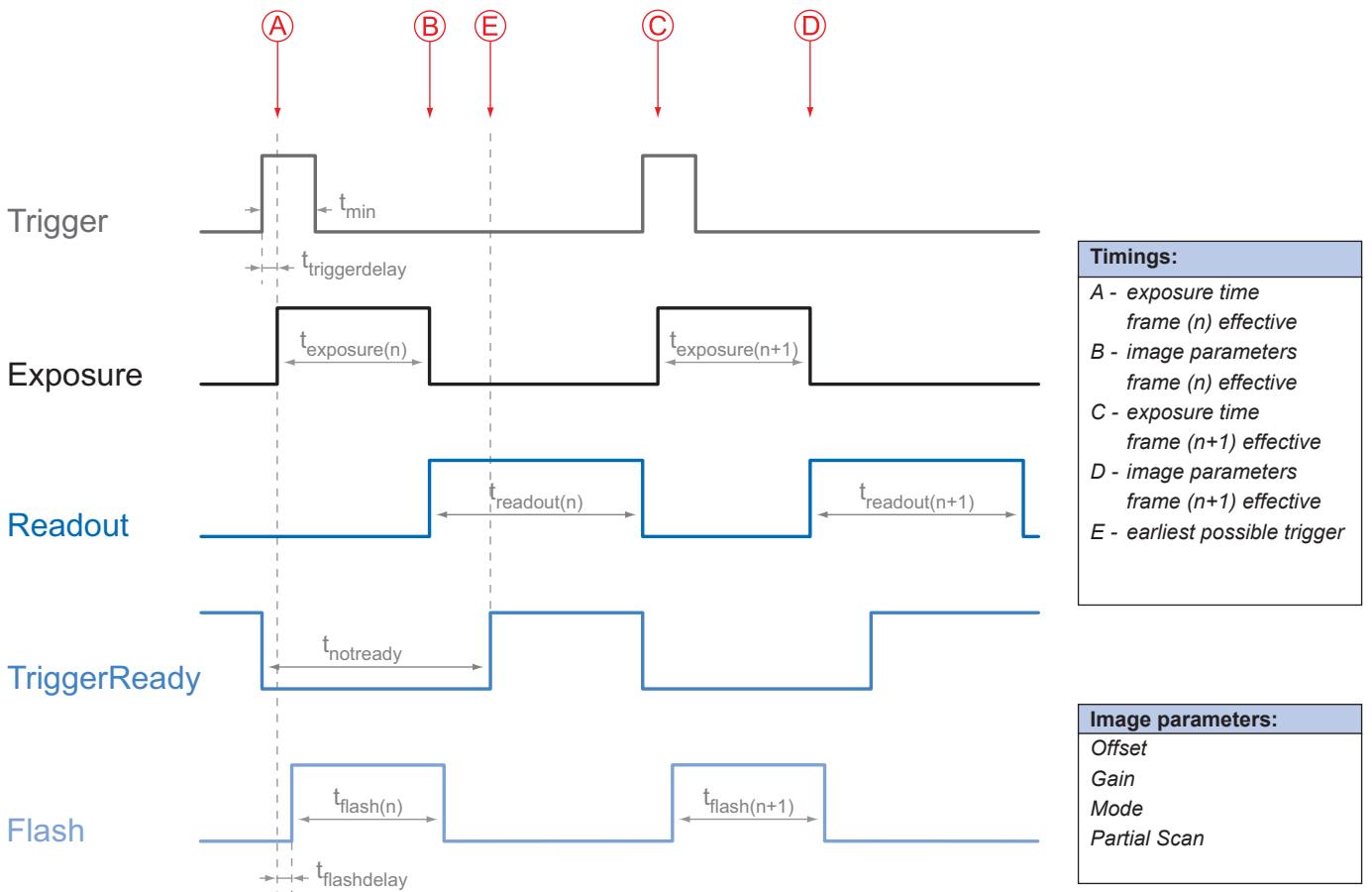


Notice

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

8.3.3.4 Non-overlapped Operation (sequential)

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



8.3.4 Advanced Timings for USB 3.0 Vision™ Message Channel

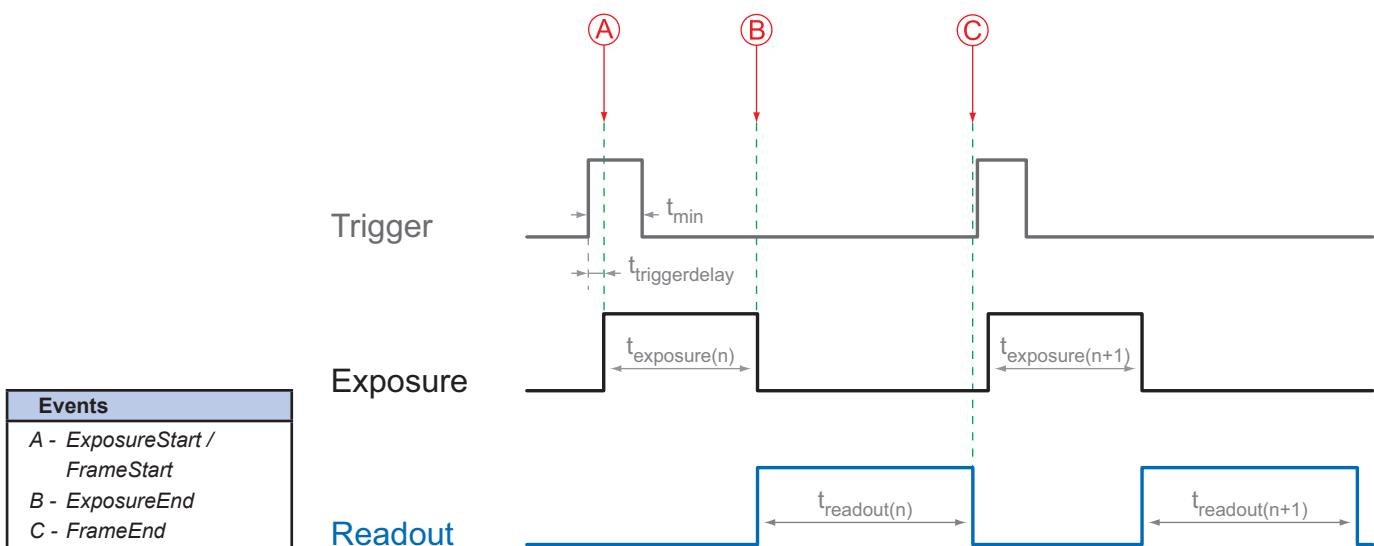
The following charts show some timings for event signalling by the asynchronous message channel. Explanations are provided for vendor-specific events such as "EventLost", "ExposureStart", "ExposureEnd", "FrameStart", "FrameEnd", "TriggerReady", "Trigger-Skipped", "TriggerOverlapped" and "ReadoutActive".

8.3.4.1 EventLost

This signal can be put out when a selected event was lost. The cause may be that too many events occurs.

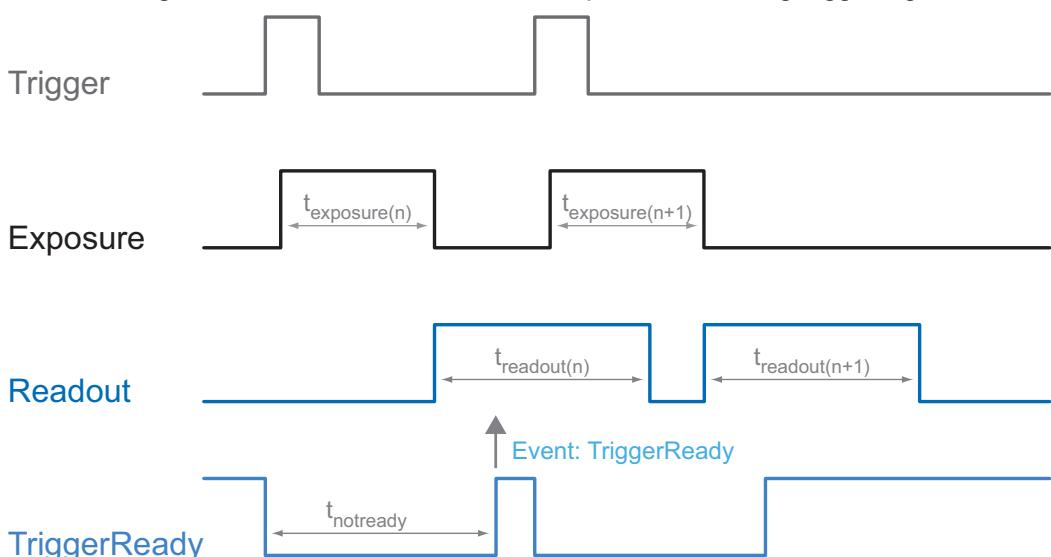
8.3.4.2 ExposureStart / FrameStart / ExposureEnd / FrameEnd

These events can be put out during a frame recording process.



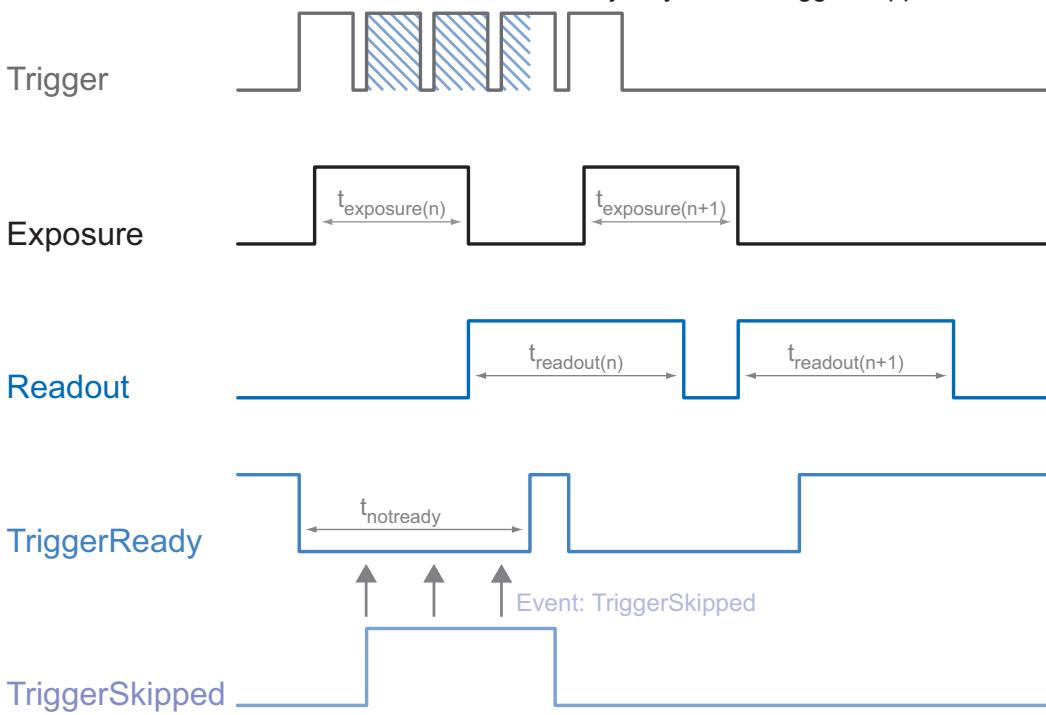
8.3.4.3 TriggerReady

This event signals whether the camera is able to process incoming trigger signals or not.



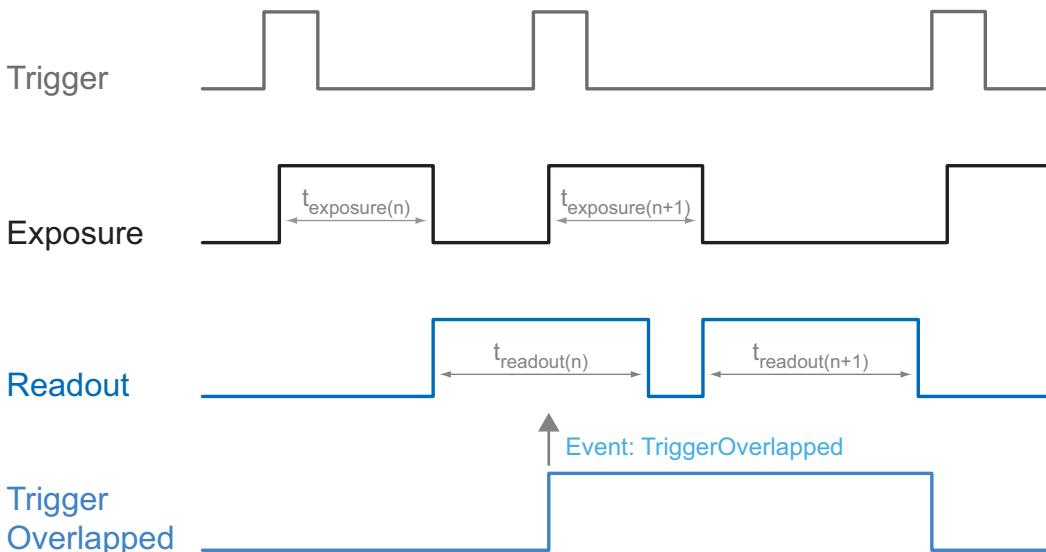
8.3.4.4 TriggerSkipped

If the camera is unable to process incoming trigger signals, meaning that the camera should be triggered within the interval $t_{notready}$, these triggers are skipped. On Baumer PXU cameras, the user will be informed about this fact by way of the "TriggerSkipped" event.



8.3.4.5 TriggerOverlapped

This signal is active for as long as the sensor is exposed and read out at the same time, meaning that the camera is operated overlapped.



Once a valid trigger signal occurs outside of a readout, the "TriggerOverlapped" signal changes to state low.

8.4 Software

8.4.1 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 cameras.

It provides interfaces to several programming languages, such as C, C++ and the .NET™ Framework on Windows®, meaning that other languages, such as e.g. C# or VB.NET can also be used.

Baumer GAPI SDK higher than v2.3 supports USB3 Vision™.

8.4.2 3rd Party Software

Strict compliance with the GenICam™ and USB3 Vision™ standards allows Baumer to offer the use of 3rd Party software.

You can find a current list of 3rd Party software that has been tested successfully in combination with Baumer cameras at <http://www.baumer.com/?id=2851>

9. Camera Functionalities

9.1 Image Acquisition

Notice

To change parameters that affect the format (e.g. Pixel Format or Image Format), the camera must be stopped.

9.1.1 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 includes not only the resolution, but also a set of predefined parameters.

These parameters are:

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

Camera Type	Full frame	Binning 2x2	Binning 1x2	Binning 2x1
Monochrome				
PXU-60M.Q	■	■	■	■
PXU-120M.Q	■	■	■	■

9.1.2 Pixel Format

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

9.1.2.1 Pixel Formats on Baumer PXU Cameras

Camera Type	Mono8	Mono12p	Mono16
Monochrome			
PXU-60M.Q	■	■	■
PXU-120M.Q	■	■	■

9.1.2.2 Definitions

Notice

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

RAW: Raw data format. Here, the data is stored without being processed.

Bayer: Raw data format of color sensors.

Color filters are placed on these sensors in a bayer pattern, generally in a 50% green, 25% red and 25% blue array.

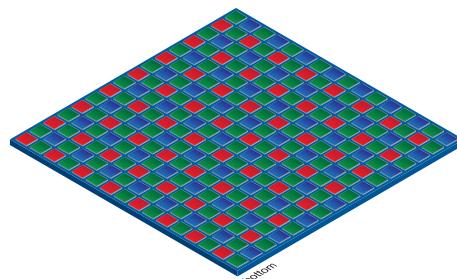


Figure 6 ▶

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 synonymous with monochrome.

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

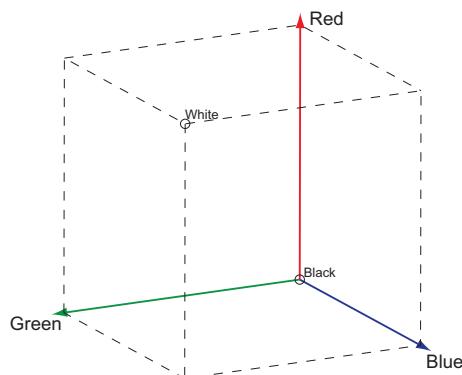


Figure 7 ▶

RGB 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). 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 as 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. There is therefore no sub-sampling in this case.

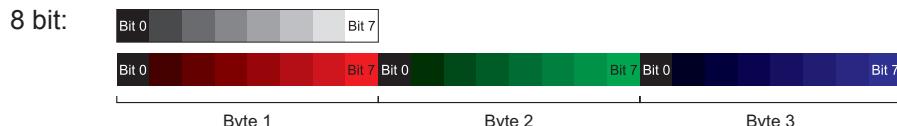
YUV 4:2:2: The chroma components are sampled at half the sample rate. This reduces the necessary bandwidth to two-thirds (in relation to 4:4:4) and causes no, or low visual differences.

YUV 4:1:1: Here, the chroma components are sampled at a quarter of the sample rate. This decreases the necessary bandwidth 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".

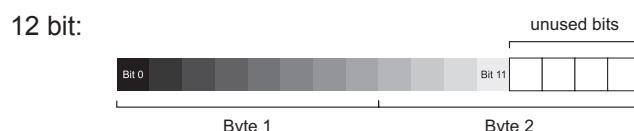
For RGB or BGR these 8 bits per channel equate to 24 bits overall.

Two bytes are needed to transmit more than 8 bits per pixel - even if the second byte is not completely filled with data. In order to save bandwidth, packed formats have been added to Baumer PXU cameras. In these formats, the unused bits of one pixel are filled with data from the next pixel.



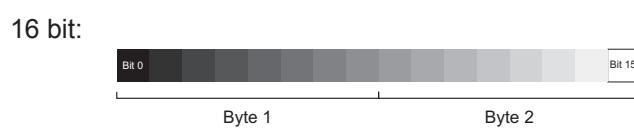
◀ **Figure 8**

Bit string of Mono 8 bit and RGB 8 bit.



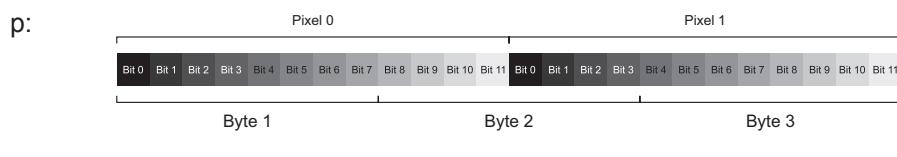
◀ **Figure 9**

Spreading of Mono 12 bit over two bytes.



◀ **Figure 10**

Spreading of Mono 16 bit over two bytes.



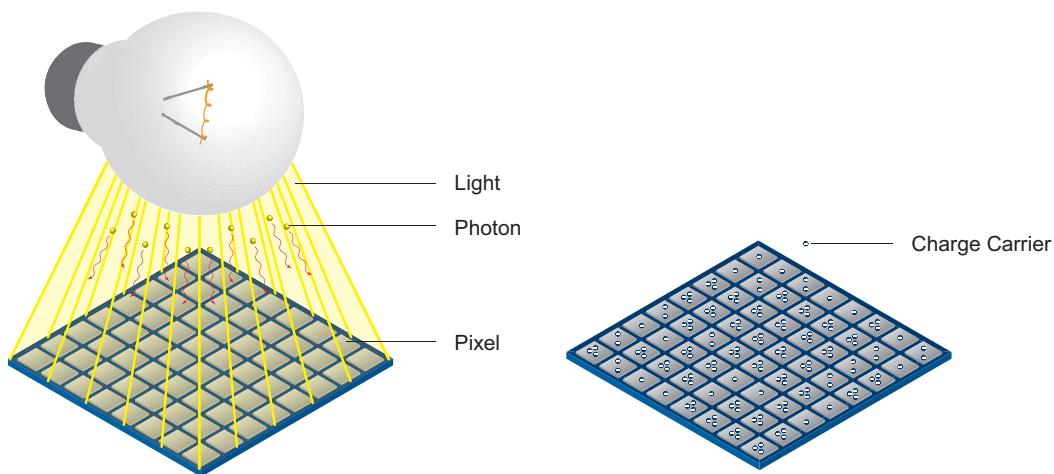
◀ **Figure 11**

Spreading of two pixels in Mono 12 bit over three bytes (p mode).

9.1.3 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 12 ▶
Incidence of light causes charge separation on the semiconductors of the sensor.



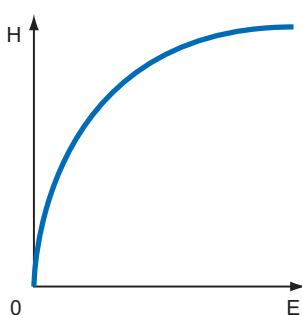
The signal strength is influenced by the incoming amount of photons. It can be increased by increasing the exposure time (t_{exposure}).

On Baumer PXU cameras, the exposure time can be set within the following ranges (increments of 1μsec):

Camera Type	t_{exposure} min	t_{exposure} max
Monochrome		
PXU-60M.Q	4 μsec	60 sec
PXU-120M.Q	4 μsec	60 sec

9.1.4 Look-Up-Table

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



▲ Figure 13

Non-linear perception of the human eye.
H - Perception of brightness
E - Energy of light

9.1.5 Gamma Correction

With this feature, Baumer PXU cameras provide the option to compensate nonlinearity in the perception of light by the human eye.

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

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

On Baumer PXU cameras the correction factor γ is adjustable from 0.1 to 2.

The values of the calculated intensities are entered into the Look-Up-Table (see 9.1.5). Previously existing values within the LUT will be overwritten.

Notice

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

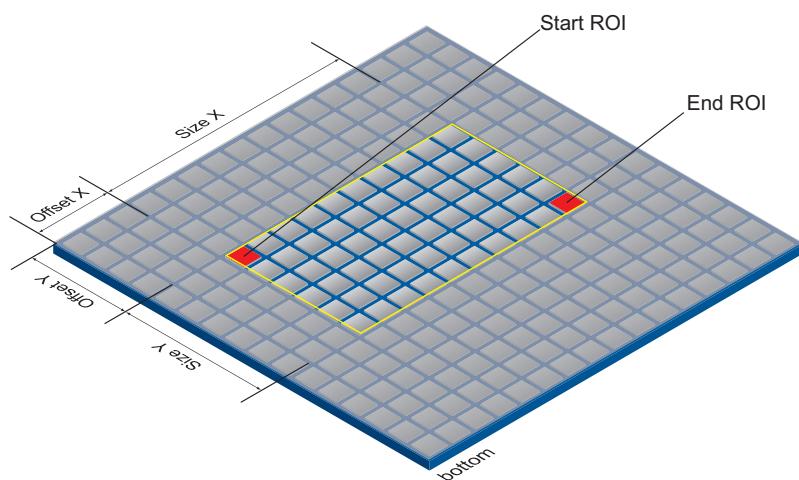
9.1.6 Region of Interest (ROI) or Partial Scan

ROI is an area of pixels of the sensor. When an image is acquired, only the information about these pixels is transferred to the PC. Not all lines of the sensor are read out, which therefore decreases the readout time (t_{readout}). This increases the frame rate.

This function is used when only a particular region of the field of view is of interest. It is coupled with a reduction in resolution.

The ROI is specified by four values:

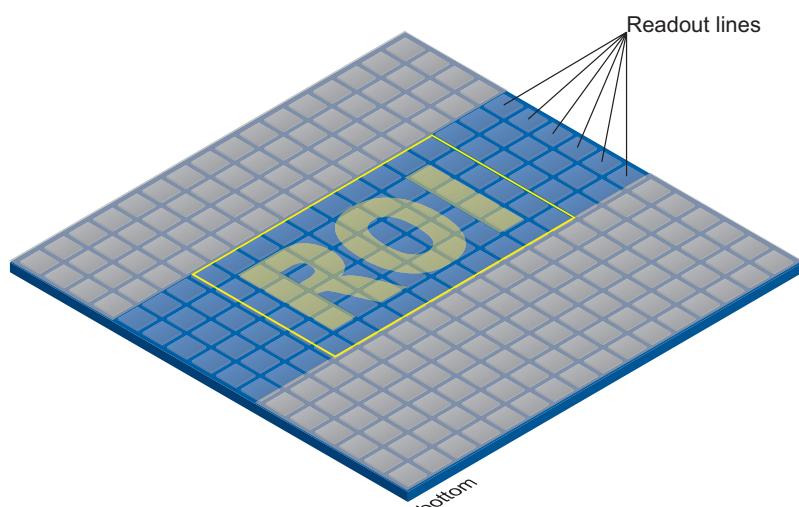
- Offset X - x-coordinate of the first relevant pixel
- Offset Y - y-coordinate of the first relevant pixel
- Size X - horizontal size of the ROI
- Size Y - vertical size of the ROI



◀ Figure 14
ROI: Parameters

ROI Readout

In the illustration below, readout time would decrease to 40% of a full frame readout.



◀ Figure 15
Decrease in readout time by using partial scan.

9.1.7 Binning

On digital cameras, you can find several operations for progressing sensitivity. One of these is "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 with 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 a single "superpixel".

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

Binning	Illustration	Example
without		
1x2		
2x1		
2x2		

Figure 16 ▶

Full frame image, no binning of pixels.

Figure 17 ▶

Vertical binning causes a doubly bright, vertically compressed image.

Figure 18 ▶

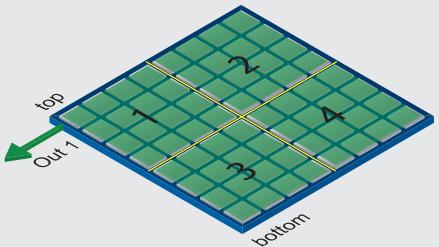
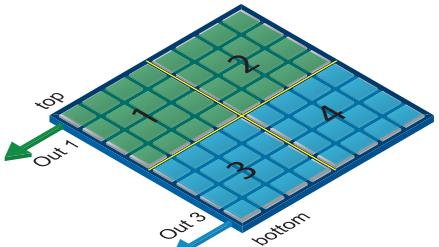
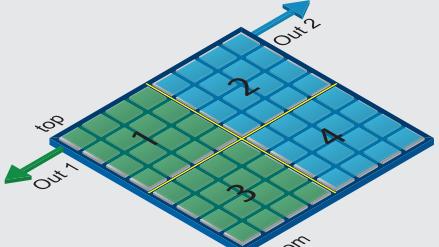
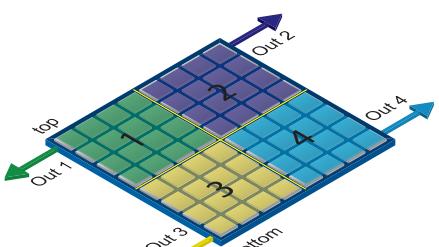
Horizontal binning causes a doubly bright, horizontally compressed image.

Figure 19 ▶

Bidirectional binning causes both a horizontally and vertically compressed image with quadruple brightness.

9.1.8 Sensor Digitalization Taps

With this feature, it is possible to affect the readout of the sensor taps. A larger number of outputs increases the frame rate.

Outputs	Illustration	Description
1		Readout of the four sensor taps via Tap 1.
1, 3		Readout of the four sensor taps via Tap 1 and Tap 3.
1, 2		Readout of the four sensor taps via Tap 1 and Tap 2.
1, 2, 3, 4		Each tap is read out individually.

9.1.9 Brightness Correction (Binning Correction)

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

Binning	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.

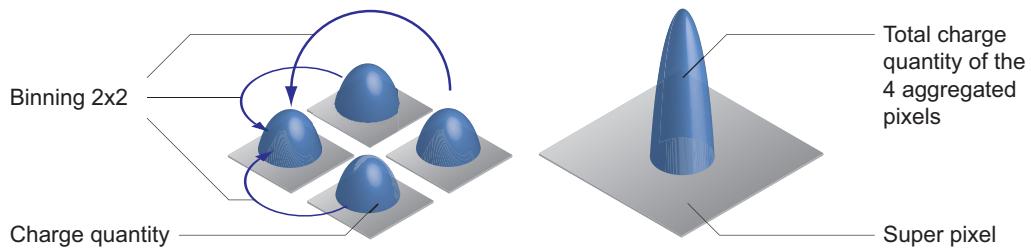


Figure 20 ▶

Aggregation of charge carriers from four pixels in bidirectional binning.

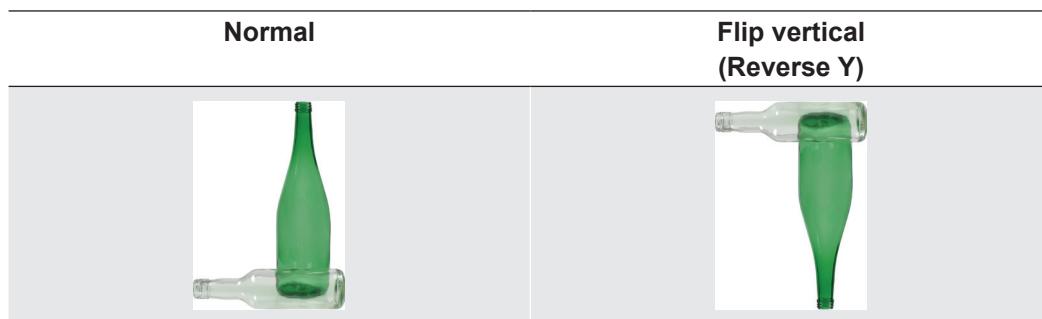
9.1.10 Flip Image

The Flip Image function lets you flip the captured images horizontally and/or vertically before they are transmitted from the camera.

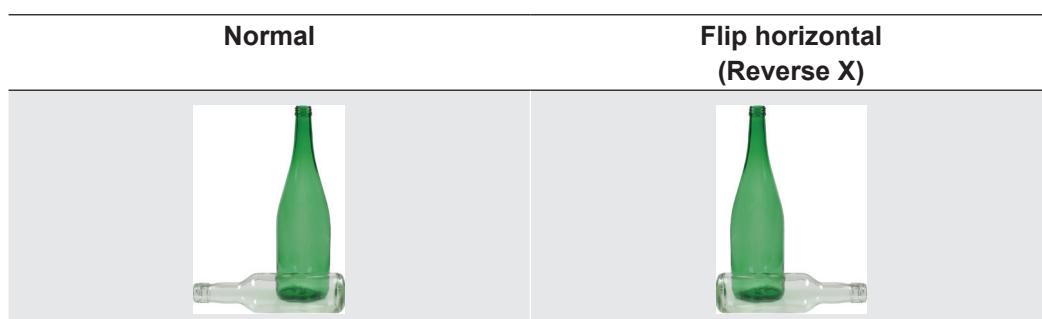
Notice

Any defined ROI will also be flipped.

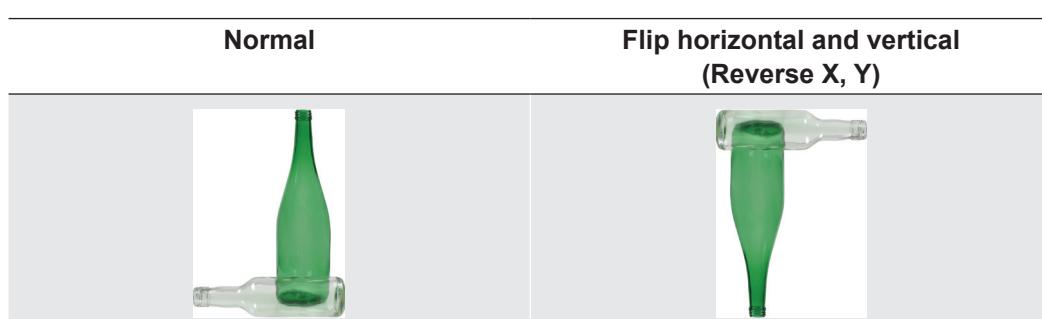
Camera Type	Horizontal	Vertical
PXU-60M.Q	■	■
PXU-120M.Q	■	■



◀ Figure 21
Flip image vertically



◀ Figure 22
Flip image horizontally



◀ Figure 23
Flip image horizontally
and vertically

9.2 Analog Controls

9.2.1 Offset / Black Level

On Baumer PXU cameras the offset (or black level) is adjustable in 1023 steps (from 0 to 4092 LSB).

Camera Type	1 step = 4 LSB
Relating to [bit]	
Monochrome	
PXU-60M.Q	16
PXU-120M.Q	16

9.2.2 Gain

In industrial environments, motion blur is unacceptable. Therefore, 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.

Notice

Increasing the gain factor causes an increase in image noise.

Camera Type	Gain factor [db]
Monochrome	
PXU-60M.Q	0...20
PXU-120M.Q	0...20

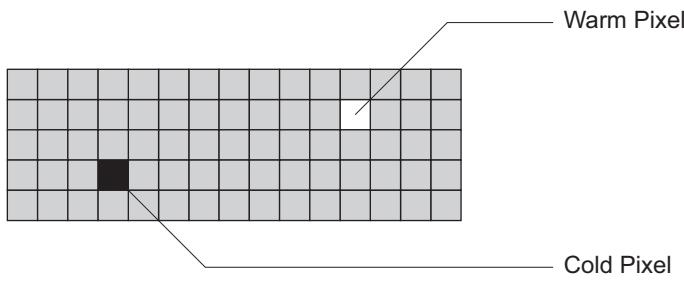
9.3 Pixel Correction

9.3.1 General information

There is a certain probability of abnormal pixels - so-called defect pixels - occurring for sensors from all manufacturers. The charge quantity on these pixels is not linearly dependent on the exposure time.

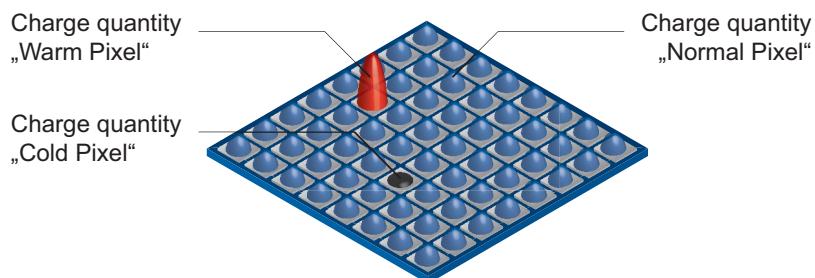
The occurrence of these defect pixels is unavoidable and intrinsic to the manufacturing and aging process of the sensors.

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



◀ Figure 27

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



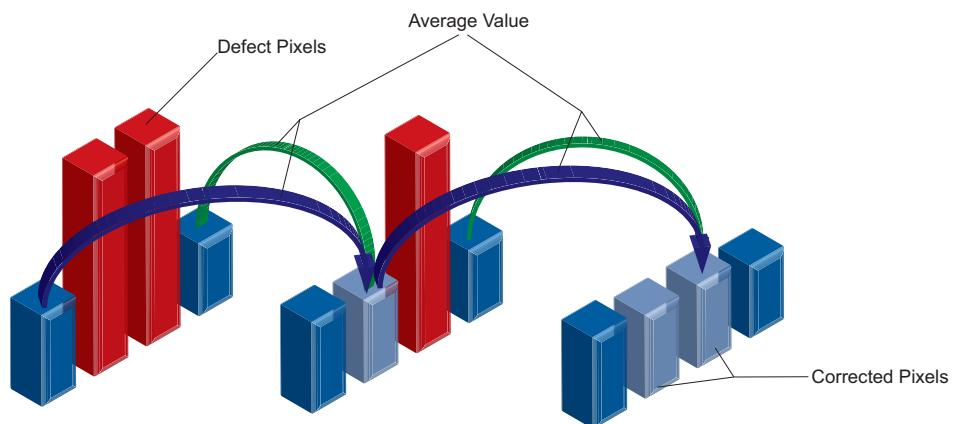
◀ Figure 28

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

9.3.2 Correction Algorithm

On cameras in the Baumer PXU series, the problem of defect pixels is solved as follows:

- Possible defect pixels are identified during the camera's production process.
- The coordinates of these pixels are stored in the factory settings of the camera.
- Once the sensor readout is completed, correction takes place:
 - Before any other processing, the values of the neighboring pixels on the left and the right side of the defect pixels are read out.
 - Then, the average value of these 2 pixels is determined to correct the first defect pixel
 - Finally, the value of the second defect pixel is corrected by using the previously corrected pixel and the pixel on the other side of the defect pixel.
 - The correction process is able to correct up to two neighboring defect pixels.



9.3.3 Defectpixellist

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

Additional hot or cold pixels can develop during the lifecycle of a camera. In this case, Baumer gives you the option to add their coordinates to the defectpixellist.

You can determine the coordinates¹⁾ of the affected pixels and add them to the list. Once the defectpixellist is stored in a user set, pixel correction is carried out for all coordinates on the defectpixellist.

9.4 Process Interface

9.4.1 Digital IOs

9.4.1.1 User Definable Inputs

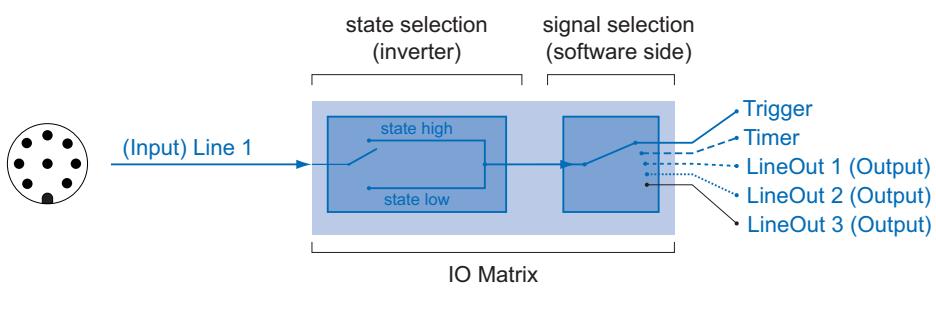
The wiring of these input connectors is left to the user.

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 "Trigger", "Timer" and "LineOut 1..3".



◀ Figure 29

IO matrix of the
Baumer PXU on the in-
put side.

9.4.1.2 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 PXU cameras, the output connector can be wired to one of provided internal signal: "Off", "ExposureActive", "Line 0", "Timer 1 ... 3", "ReadoutActive", "User0 ... 2", "TriggerReady", "TriggerOverlapped", "TriggerSkipped", "Sequencer Output 0 ... 2". Beside this, the output can be disabled.

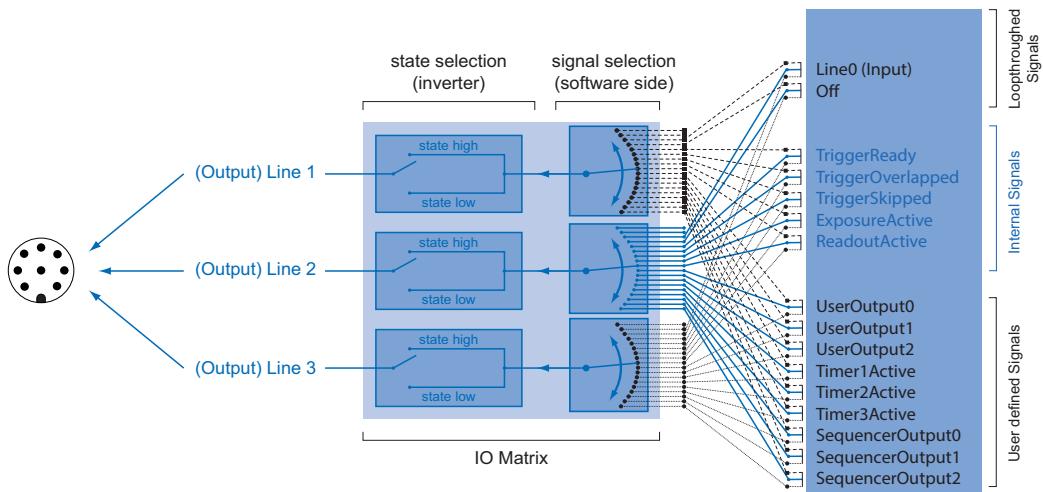


Figure 30 ►

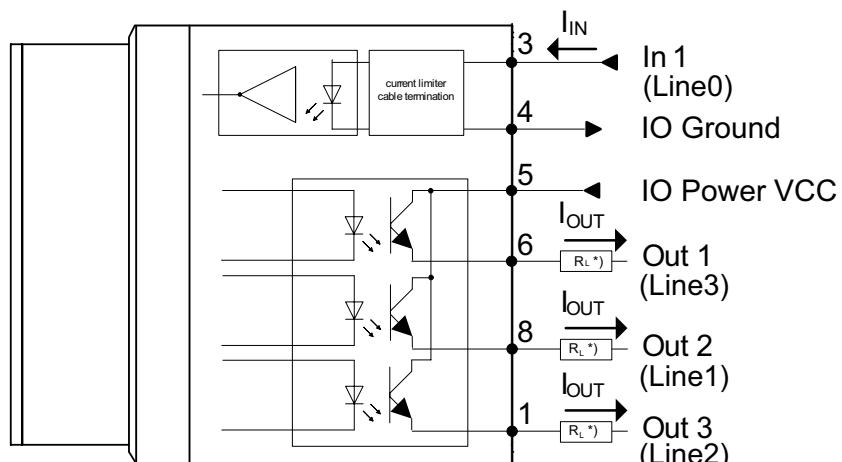
IO matrix of the
Baumer PXU on the
output side.

9.4.2 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.

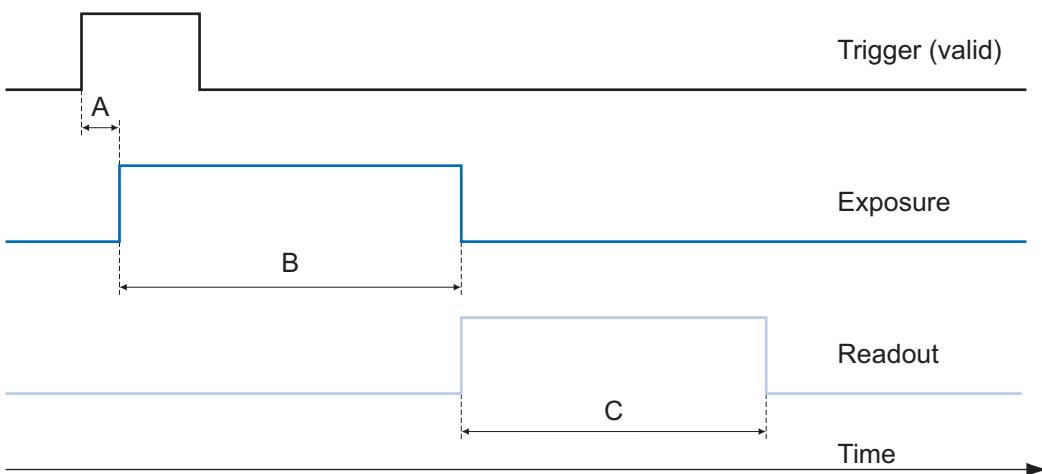
The other three outputs are not usable and may not be connected (e.g. IO Power V_{CC})!



*) resistor must be used, $I_{out} = 16 \text{ mA}$
by $U_{EXT} = 24 \text{ VDC}$ recommended,
drawing shown above example
for using high active signal

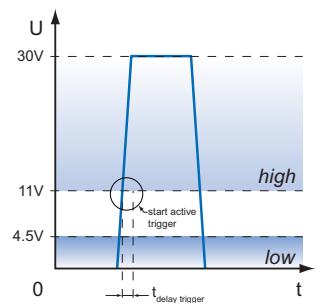
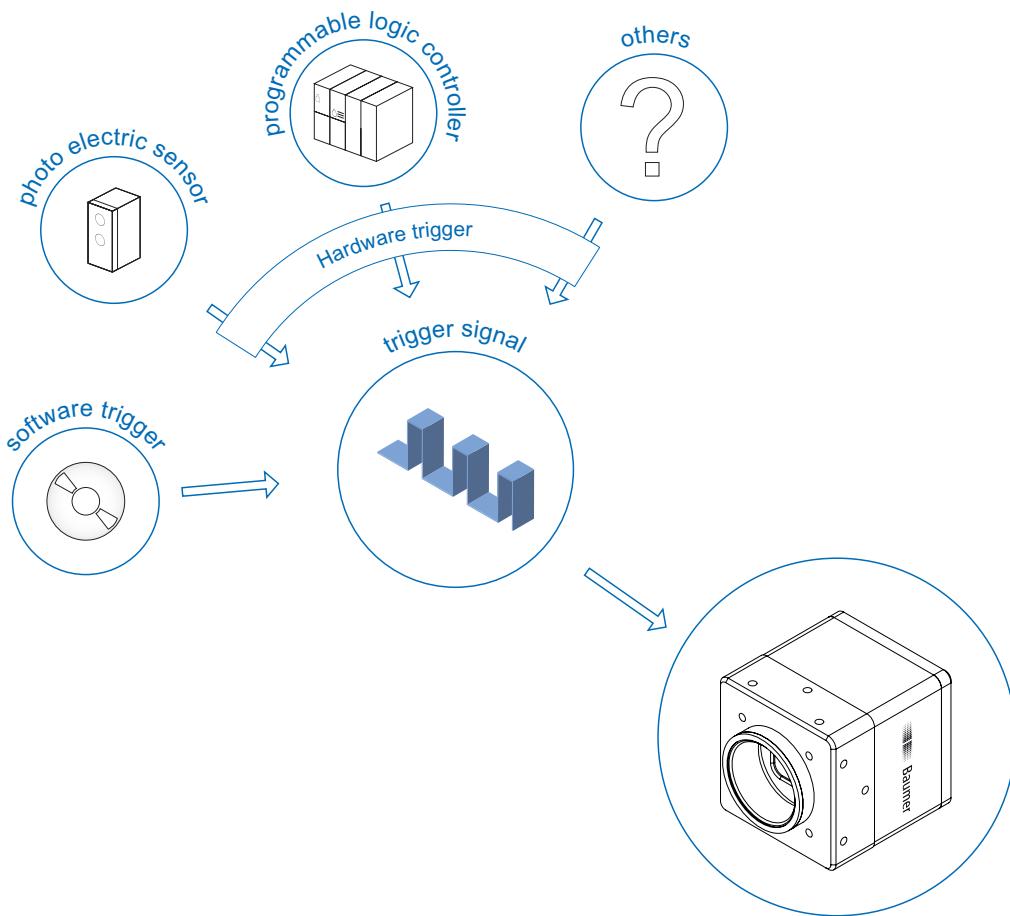
9.4.3 Trigger

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.

9.4.4 Trigger Source



▲ Figure 31

Trigger signal, valid for Baumer cameras.

◀ Figure 32

Camera in trigger mode:
 A - Trigger delay
 B - Exposure time
 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 μ sec and 2.0 sec in increments of 1 μ sec. Where there are multiple triggers during the delay, the triggers will also be stored and delayed. The buffer is able to store up to 512 trigger signals during the delay.

Your benefits:

- No need for an external trigger sensor to be perfectly aligned
- Different objects can be captured without hardware changes

◀ Figure 33

Examples of possible trigger sources.

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

9.4.5 Debouncer

The basic idea behind this feature was to separate 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 $t_{\text{DebounceHigh}}$ will be recognized and routed to the camera to induce a trigger.

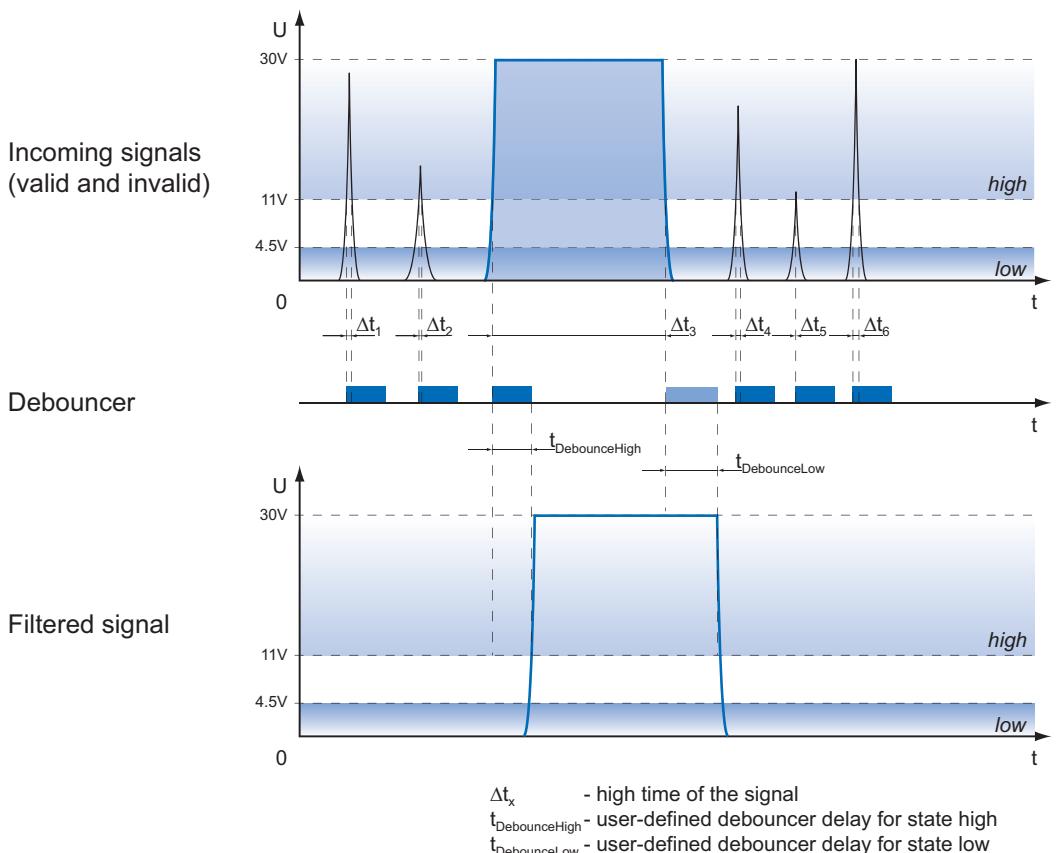
In order to detect the end of a valid signal and filter out possible jitters within the signal, a second testing time $t_{\text{DebounceLow}}$ was introduced. The timing for this can also be adjusted by the user. If the signal value falls to state low and does not rise within $t_{\text{DebounceLow}}$,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

Debouncer:

Please note that the edges of valid trigger signals are shifted by $t_{\text{DebounceHigh}}$ and $t_{\text{DebounceLow}}$!

Depending on these two timings, the trigger signal may be temporally stretched or compressed.

The debouncing times $t_{\text{DebounceHigh}}$ and $t_{\text{DebounceLow}}$ are adjustable from 0 to 5 msec in increments of 1 μ sec.

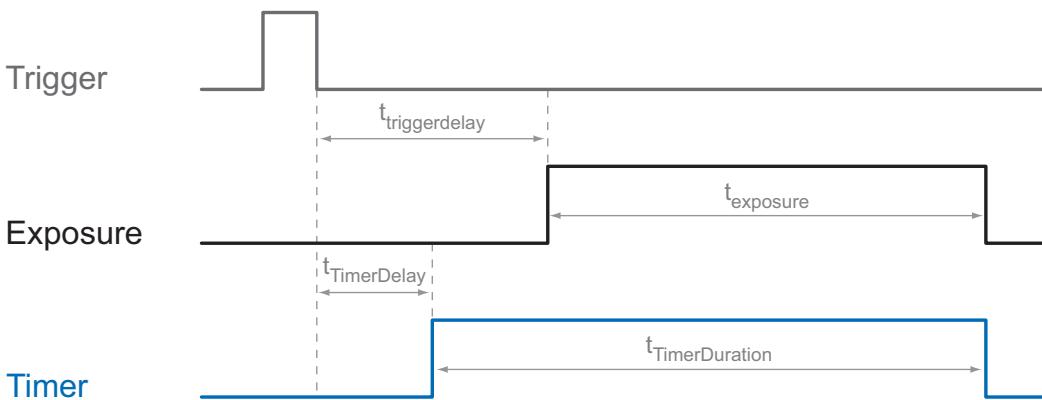


9.4.6 Timers

Timers were introduced for advanced control of internal camera signals.

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

On Baumer PXU cameras, the timer configuration includes four components:



◀ Figure 34

Possible timer configuration on a Baumer PXU.

Component	Description
TimerTriggerSource	This feature provides a source selection for each timer.
TimerTriggerActivation	This feature selects the part of the trigger signal (edges or states) that activates the timer.
TimerDelay	This feature represents the interval between the incoming trigger signal and the start of the timer.
TimerDuration	This feature is used to adjust the activation time of the timer.

9.4.7 Frame counter

The frame counter is part of the Baumer Image Info Header and is supplied with every image, if chunk mode is activated. It is generated by hardware and can be used to verify that each of the camera's images is transmitted to the PC and received in the right order.

9.5 Sequencer

9.5.1 General Information

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

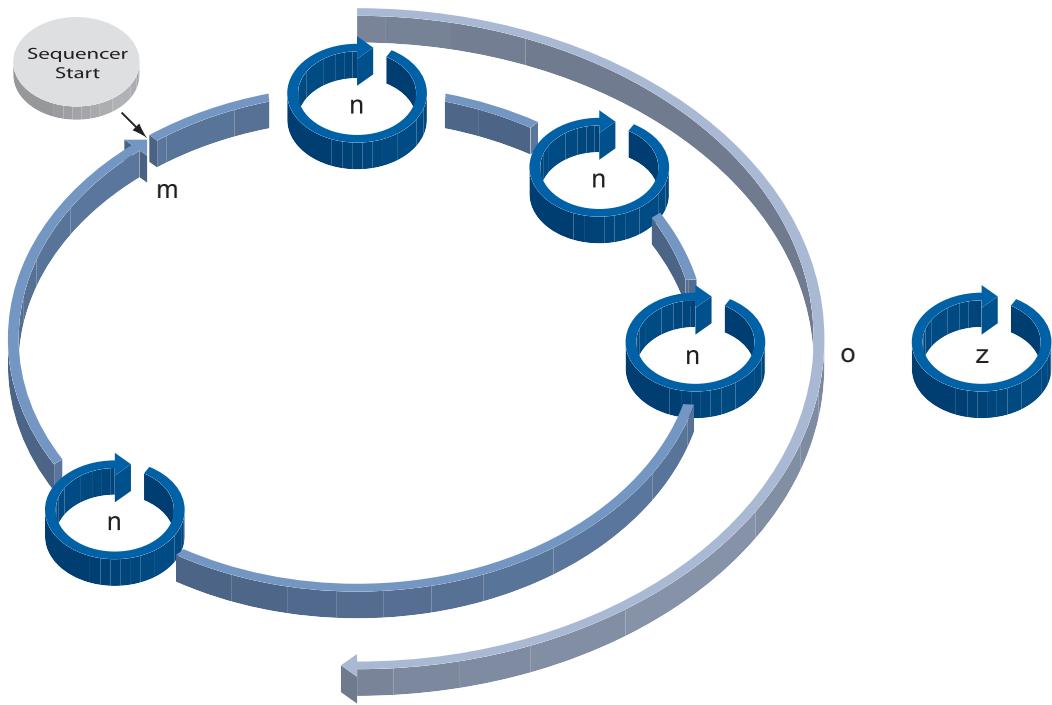


Figure 35 ►

Flow chart of sequencer.
m - number of loop passes
n - number of set repetitions
o - number of sets of parameters

z - number of frames per trigger

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

A sequence (o) is defined as a complete pass through all sets of parameters.

The SequencerLoops (m) represents the number of sequence repetitions.

The SequencerSetRepeats (n) is used to control the amount of images taken with the respective sets of parameters.

The start of the sequencer can be initiated directly (free running) or via an external event (trigger).

The additional FramesPerTrigger (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.

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

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

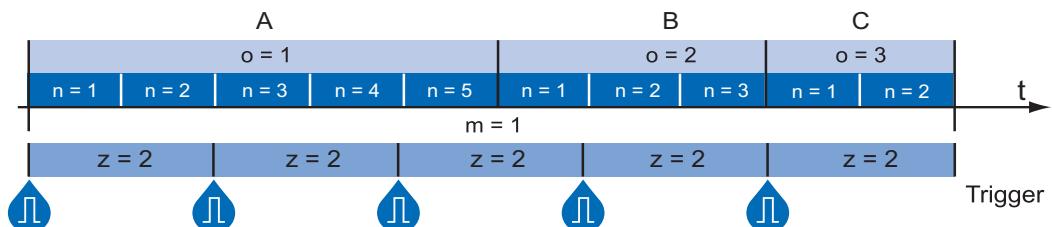


Figure 36 ►

Timeline for a single sequence

9.5.2 Baumer Optronic Sequencer in Camera xml-file

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

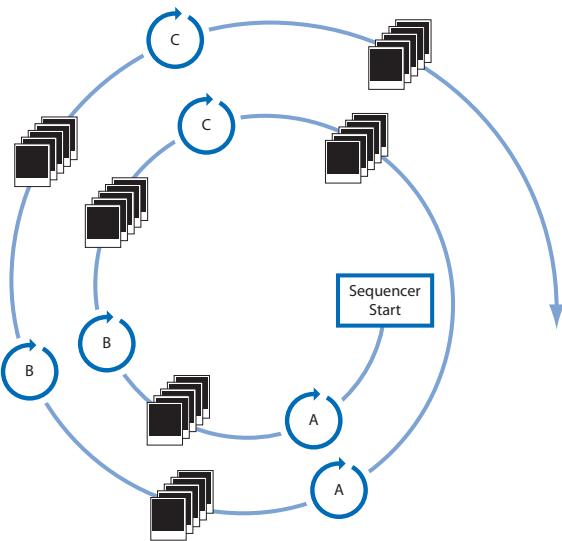
Static Image Formats	
The values are valid for all sets.	
BoSequencerOffsetX	ROI Offset X
BoSequencerOffsetY	ROI Offset Y
BoSequencerHeight	Image height
BoSequencerWidth	Image width
BoSequencerSensorDigitizationTaps	Number of Sensor Taps
BoSequencerSetReadOutTime	Read out time
Static Sequencer Features	
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
BoSequencerSetActive	Returns the index of the active set of the running sequencer.
Set-specific Features	
These values can be set individually for each set.	
BoSequencerExposure	Parameter exposure
BoSequencerGain	Parameter gain
BoSequencerBinningHorizontal	Binning horizontal
BoSequencerBinningVertical	Binning vertical
BoSequencerIOSelector	Selected output lines
BoSequencerIOSTatus	Status of all Sequencer outputs
BoSequencerSetRepeats	Number of repetitions (n)
BoSequencerSetSelector	Configure set of parameters

Sequencer Running Modes

Mode	Description
SingleStepTrigger	On each trigger, the sequencer goes acquires Z images.Z is the count of freerunning images to take on one trigger event. When the end of the cycle is reached, the sequencer will restart automatically.
SingleStepTriggerOnce	On each trigger, the sequencer goes acquires Z images. Z is the count of freerunning frames to take on one trigger event. When the end of the cycle is reached, the sequencer will not restart automatically.
FreeRunning (continuous)	The sequencer will not wait for an incoming event but starts immediately taking freerunning frames. When the end of the cycle is reached, the sequencer will restart automatically.
FreeRunningOnce	The sequencer will not wait for an incoming event but starts immediately taking freerunning frames. When the end of the cycle is reached, the sequencer will not restart automatically.
FreeRunningInit-Trigger	On the first incoming event, the sequencer will start with freerunning a full cycle. After completion, it will restart on the next incoming event automatically.
FreeRunningInit-TriggerOnce	On the first incoming event, the sequencer will start with freerunning a full cycle. After completion, it will not restart automatically.

9.5.3 Examples

9.5.3.1 Sequencer without Machine Cycle



◀ Figure 37

Example using 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 `SequencerSetRepeats (n)` is set to 5 and the `SequencerLoops (m)` has a value of 2.

When the sequencer is started, with or without an external event, the camera will record 5 images successively in each case, using the sets of parameters A, B and C (which constitutes a sequence). After that, the sequence is started again, then the sequencer stops - in this case the parameters are maintained.

9.5.3.2 Sequencer Controlled by Machine Steps (trigger)

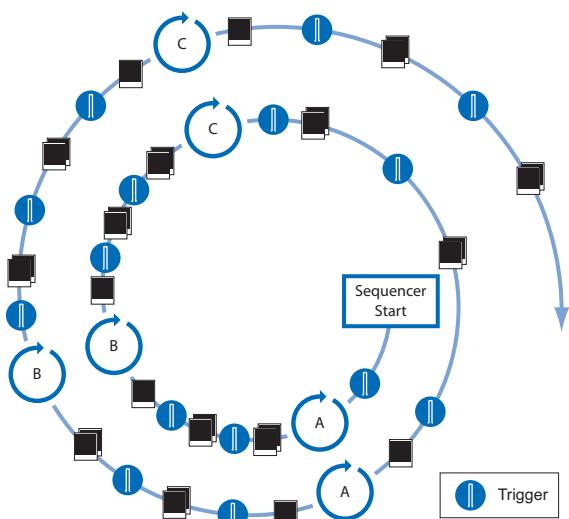


Figure 38 ▶

Example using a semi-automated sequencer.

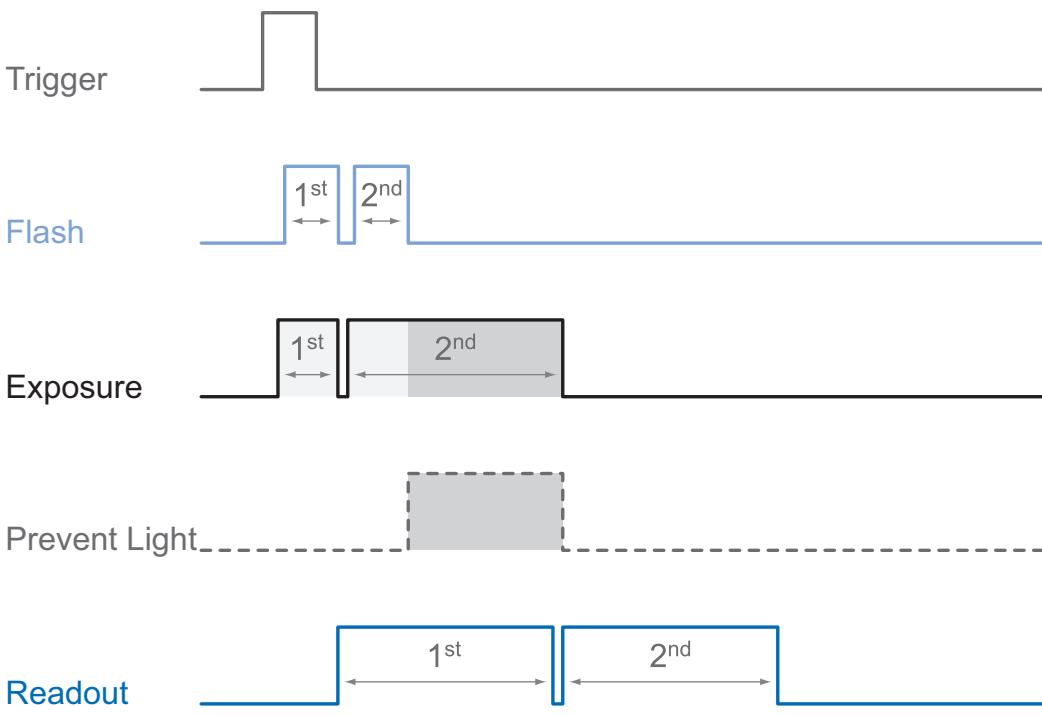
The figure above shows an example for a semi-automated sequencer with three sets of parameters (A,B and C) from the previous example. `FramesPerTrigger (z)` is set to 2. This means the camera records two pictures after an incoming trigger signal.

9.5.4 Capability Characteristics of Baumer GAPI Sequencer Module

- up to 128 sets of parameters
- up to 65536 loop passes
- up to 65536 repetitions of sets of parameters
- up to 65536 images per trigger event
- free running mode without initial trigger

9.5.5 Double Shutter

This feature gives you the option to capture two images within a very short period of time. Depending on the application, this is performed in conjunction with a flash unit. 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. The pixels of the sensor are therefore receptive 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 used, and any subsequent extraneous light prevented.



◀ **Figure 39**
Example of a double shutter.

On Baumer PXU 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

9.6 Device Reset

The Device Reset feature corresponds with the turn off and turn on of the camera. The camera starts up again with the adjusted User Set.

It is therefore no longer necessary to interrupt the power supply.

9.7 User Sets

Four user sets (0-3) are available for the Baumer cameras in the PXU 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 parameters in the table below.

These user sets are stored within the camera and can be loaded, saved and transferred to other PXU cameras.

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

Parameter	
AcquisitionStart	BoSequencerSetRepeats
AcquisitionStop	ChunkModeActive
AcquisitionFrameRate	ChunkEnable
TriggerMode	TimerDuration
TriggerSource	TimerDelay
TriggerActivation	TimerTriggerSource
TriggerDelay	TimerTriggerActivation
ExposureMode	FrameCounter
ExposureTime	ReadOutBuffering
AcquisitionFrameRateEnable	LineInverter
ReadoutMode	LineSource
Gain	UserOutputValue
Gamma	UserOutputValueAll
BlackLevel	LineDebouncerHighTimeAbs
BrightnessCorrection	LineDebouncerLowTimeAbs
BoSequencerEnable	EventNotification
BoSequencerExposure	Width
BoSequencerFramesPerTrigger	Height
BoSequencerGain	OffsetX
BoSequencerIOStatus	OffsetY
BoSequencerLoops	BinningHorizontal
BoSequencerMode	BinningVertical
BoSequencerOffsetX	ReverseX
BoSequencerOffsetY	ReverseY
BoSequencerHeight	PixelFormat
BoSequencerWidth	TestImageSelector
BoSequencerBinningHorizontal	TestPattern
BoSequencerBinningVertical	LUTEnable
BoSequencerSetNumberOfSets	LUTValue
BoSequencerSetRepeats	DefectPixelCorrection
BoSequencerStart	
BoSequencerSetNumberOfSets	

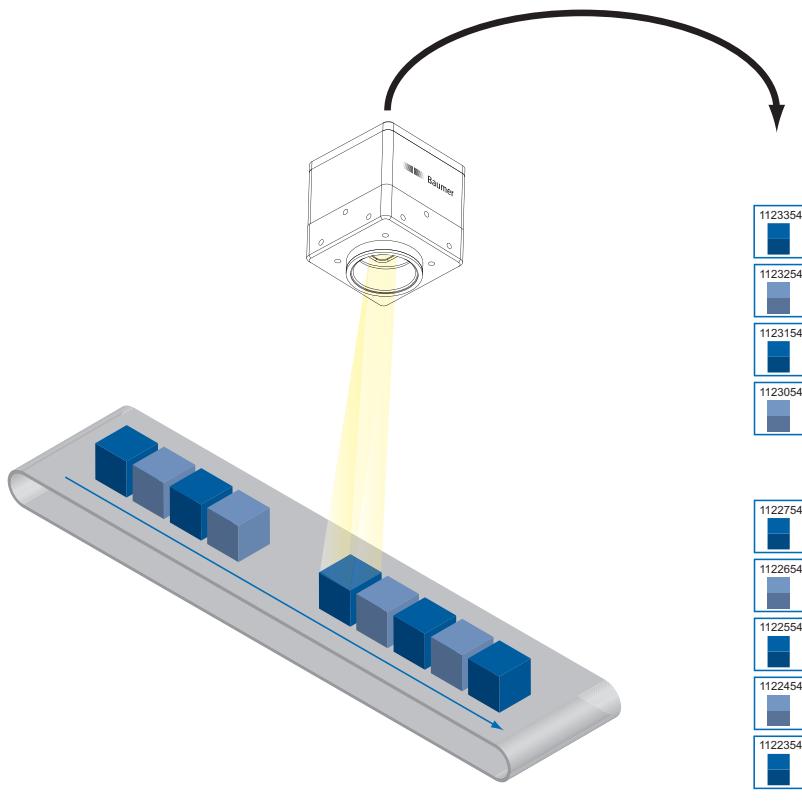
9.8 Factory Settings

The factory settings are stored in "user set 0", the default user set. This is the only user set that cannot be edited.

9.9 Timestamp

The timestamp is part of the USB 3.0 Vision™ standard. It is 64 bits long and denoted in nanoseconds. Any image or event includes its corresponding timestamp.

The timestamp is not resettable with a function. At power on or reset, the timestamp starts running from zero.



◀ **Figure 40**
Timestamps of recorded images.

10. Interface Functionalities

10.1 Device Information

This information on the device is part of the camera's USB descriptor.

Included information:

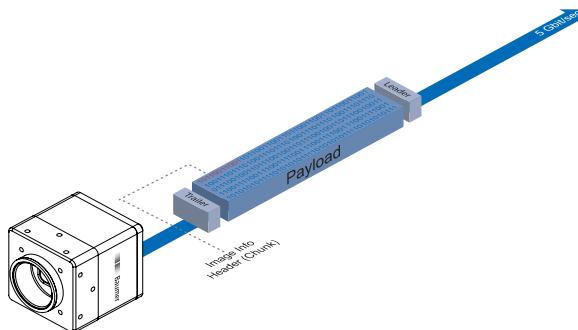
- Product ID (PID)
- Vendor ID (VID)

Model Name	Baumer USB Vendor ID [Hexadecimal]	Baumer USB Product ID [Hexadecimal]
PXU-60M.Q	2825	0116
PXU-120M.Q	2825	011E

- General Unique Identifier (GUID)
- Device vendor name (Manufacturer)
- Serial number (iSerialNumber)

10.2 Baumer Image Info Header (Chunk)

The Baumer Image Info Header is a data packet that is generated by the camera and integrated into the Payload (every image), if chunk mode is activated.



◀ Figure 41
Location of the Baumer Image Info Header

This integrated data packet contains different settings for the image. Baumer GAPI can read the Image Info Header (Chunk). Third party software that supports chunk mode can read the features in the table below. These settings are (not exhaustive):

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 pixel format of the image included in the payload.
ChunkTimestamp	Returns the Timestamp of the image included in the payload at the time of the FrameStart internal event.
ChunkExposureTime	Returns the exposure time used to capture the image.
ChunkGainSelector	Selects which Gain to retrieve data from.
ChunkGain	Returns the gain used to capture the image.
ChunkFrameID	Returns the unique Identifier of the frame (or image) included in the payload.
ChunkBinningHorizontal	Number of horizontal photo-sensitive cells to combine together.
ChunkBinningVertical	Number of vertical photo-sensitive cells to combine together.
ChunkBlackLevel	Returns the currently value of the Black Level.
ChunkTemperature	Returns the currently measured temperature.

10.3 Message Channel

The asynchronous message channel is described in the USB 3.0 Vision™ standard and allows you to signal events. There is a timestamp (64 bits) for each announced event, which contains the accurate time at which the event occurred.

Each event can be activated and deactivated separately.

10.3.1 Event Generation

Event	Description
GenICam™	
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
Vendor-specific	
EventDiscarded	Event discarded
EventLost	Event occurred but not analyzed
TriggerReady	$t_{notready}$ elapsed, camera is able to process incoming trigger
TriggerOverlapped	Overlapped Mode detected
TriggerSkipped	Camera over-triggered

11. Start-Stop Behaviour

11.1 Start / Stop / Abort Acquisition (Camera)

Once 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, this process is repeated 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 completed before the camera is stopped. If the stop signal occurs during an exposure, this will be aborted.

Abort Acquisition

The acquisition abort process is a special case where the current acquisition is stopped.

When an exposure is running, the exposure is aborted immediately and the image is not read out.

11.2 Start / Stop Interface

Transmission of image data from the camera to the PC will not proceed until the interface is started. If image acquisition is started before the interface is activated, the recorded images are lost.

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

11.3 Acquisition Modes

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

11.3.1 Free Running

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

11.3.2 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 rather triggered by external events.

11.3.3 Sequencer

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

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 sensor glass 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

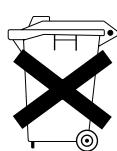
Notice

Transport the camera only in its original packaging. When the camera is not installed, store it in its original packaging.

Storage Environment

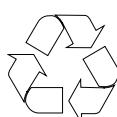
Storage temperature	-10°C ... +70°C (+14°F ... +158°F)
Storage Humidity	10% ... 90% non condensing

14. Disposal



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

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



Returning the packaging to the material cycle helps conserve raw materials and 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 Notes

Notice

If it is obvious that the device is / was dismantled, reworked or repaired by anyone 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, feel free to contact our support.

Worldwide

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Cameras of the Baumer PXU family comply with:

- CE
- RoHS

17.1 CE

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

17.2 RoHS

All PXU cameras comply with the recommendation of the European Union concerning RoHS Rules.



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