Allied Vision

APPLICATION NOTE

Image Quality versus Speed with Goldeye and Goldeye Pro

V2.1.0
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Scope of this document

This application note describes the behavior of Goldeye G/CL and Goldeye Pro G5 cameras for triggering when using the integration modes:

- **ITR mode** (Integrate **Then** Read), also called “triggering during the idle state”
- **IWR mode** (Integrate **While** Read), also called “triggering during the readout state”

Depending on the camera models, to use ITR or IWR modes means to decide between speed or quality.

Goldeye G/CL below FW V02.14.19002

Goldeye firmware prevents that exposure or readout is aborted by trigger events. Goldeye G/CL with firmware versions below V02.14.19002 does not support this.

Trigger workflow

Trigger timing diagram

Figure 1 below show the trigger workflow, Table 1: Trigger timing definitions on page 2 explains the items.

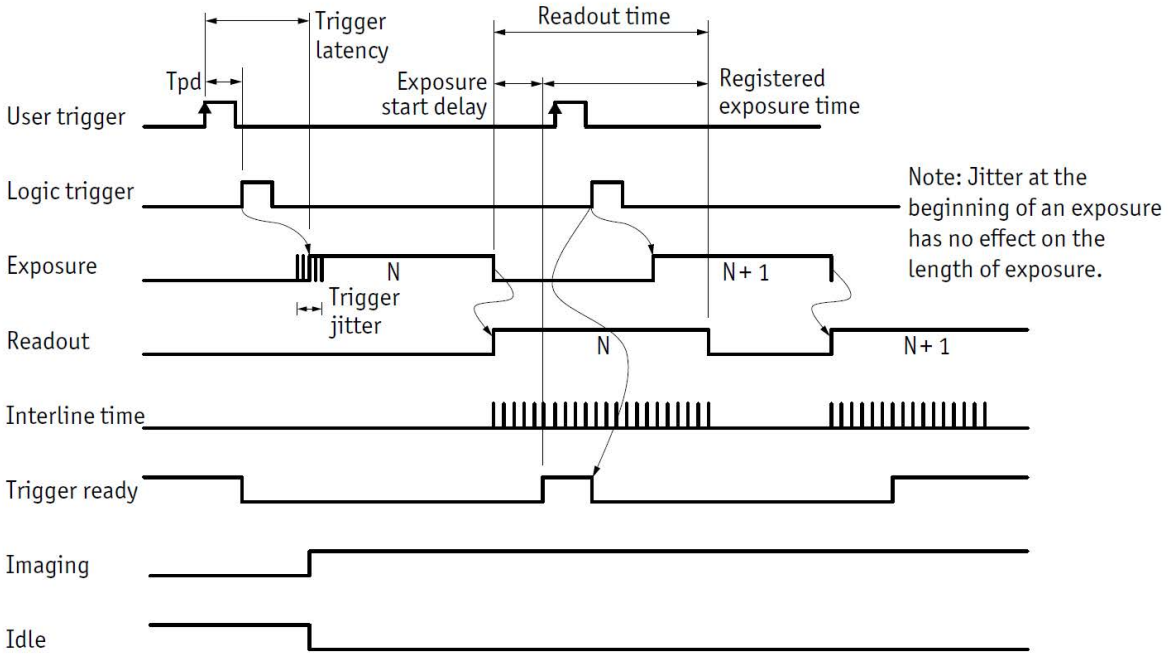

Figure 1: Trigger timing diagram

Trigger timing definitions

Term	Definition
User trigger	Trigger signal applied by the user (hardware trigger, software trigger).
Logic trigger	Trigger signal seen by the camera internal logic (not visible to the user).
T_{pd}	Propagation delay between the user trigger and the logic trigger.
Exposure	High when the camera image sensor is integrating light.
Readout	High when the camera image sensor is reading out data.
Trigger latency	Time delay between the user trigger and the start of exposure.
Trigger jitter	Statistical deviation from the typical trigger latency time.
Trigger ready	Indicates to the user that the camera is ready to accept the next trigger.
Registered exposure time	Exposure time value currently stored in the camera memory.
Exposure start delay	Equals readout time – registered exposure time. Exposure start delay indicates when the next exposure cycle can begin such that the exposure ends after the current readout.
Interline time	Time between sensor row readout cycles.
Imaging	High when the camera image sensor is either exposing and/or reading out data.
Idle	High if the camera image sensor is not exposing and/or reading out data.

Table 1: Trigger timing definitions

Triggering behavior

- The start of exposure corresponds with the interline time during readout.
- Exposure start delay = Readout time – Registered exposure time
- If the registered exposure time for Frame 1 ends while the readout for Frame 0 is in progress, the actual exposure time for Frame 1 is extended above the registered value.
- The end of exposure triggers the next readout.

We recommend setting **user trigger pulse width** = 3 × **trigger latency**.

Scope of factors affecting trigger timing

Table 1 lists the main factors that affect trigger timing. The following factors are disregarded in this document:

- Pixel format and ROI that mainly influence exposure time
- The sensor's architecture that determine the characteristic readout time.
- Trigger jitter, trigger latency, and exposure start delay
- The data transfer between camera and the host.

Triggering with ITR and IWR modes

The camera is overtriggered if triggers occur before the camera can react.

- In **ITR mode**, overtriggering occurs if triggers occur before the readout is completed.
- In **IWR mode**, overtriggering occurs if triggers occur before the exposure is completed.

This is explained below.

ITR mode: Triggering during the idle state

ITR mode (Integrate Then Read) is used when the camera is triggered during the idle state.

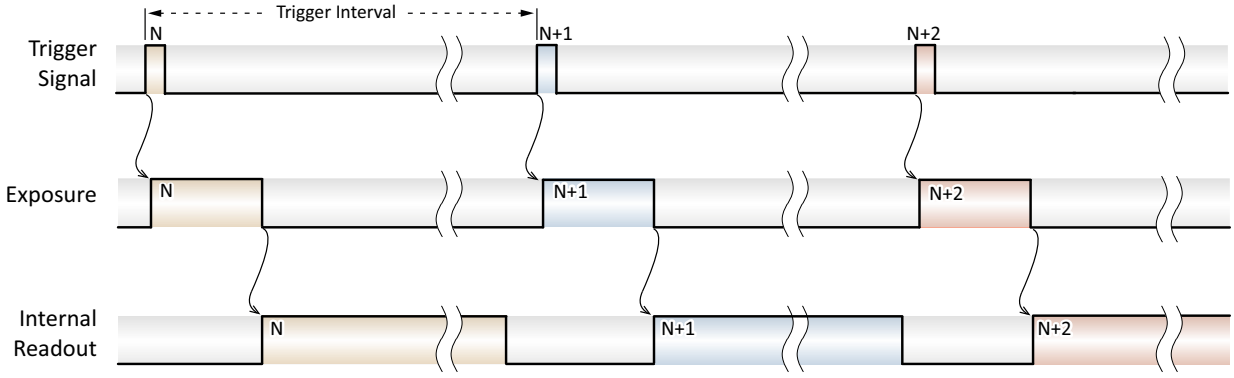

Figure 2: ITR mode: Triggering during the idle state

For ITR mode, `AcquisitionControl` > `IntegrationMode`. is set to ***`IntegrateThenRead`***. In this mode, the start of a new exposure is triggered only after readout has been completed.

Therefore, the trigger interval must be longer than the sum of exposure time and readout time.

IWR mode: Triggering during the readout state

IWR mode (Integrate While Read) is used to trigger the camera during the readout state.
For **IWR mode**, `AcquisitionControl` > `IntegrationMode`. is set to ***`IntegrateWhileRead`***.

If ***`IntegrateWhileRead`*** is selected, the camera switches between **ITR mode** and **IWR mode**. This depends on various circumstances, as described further below.

The following example counts exposure and readout to ease understanding:

In IWR mode, the start of a Exposure N+1 is triggered before the readout of Exposure N is completed. This means the trigger interval is shorter than the sum of Exposure 1 and Readout 1.

Readout 1 is ongoing while Exposure N+1 already runs.

Because the end of the exposure starts the next readout, it makes a difference if the exposure time is longer or shorter than the readout time.

Exposure time shorter than readout time

In Figure 3, the camera is triggered on the rising edge of the trigger signal.

The readout time is the determining factor because it is much longer than the exposure time. Because the exposure of Frame N+1 starts while Frame N is being read out, the interval between consecutive readouts is minimized. This enables a maximum frame rate. Reducing the ROI size reduces the readout time, enabling higher even frame rates.

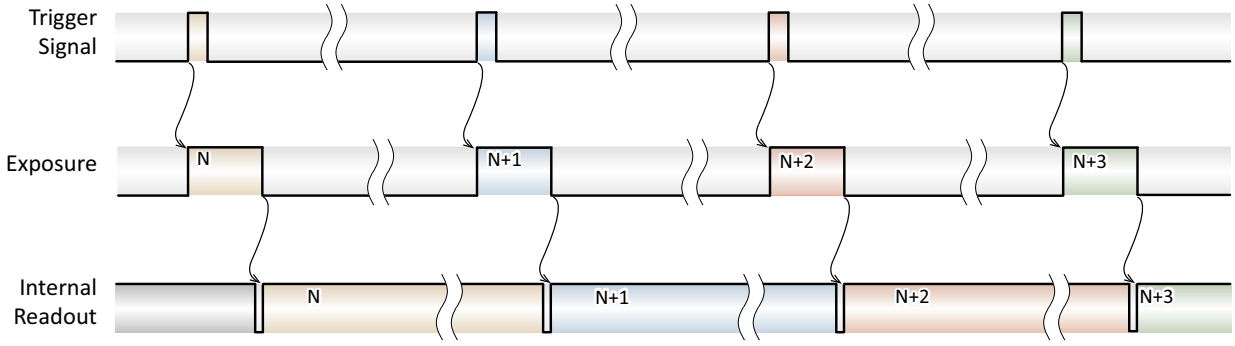

Figure 3: IWR mode: Exposure time is shorter than readout time

Exposure time longer than readout time

The camera is triggered on the rising edge of the trigger signal again. In Figure 4, the exposure time is the determining factor because it is longer than the readout time. Frame N+2's exposure can start only after Frame N+1's exposure has ended. Frame rates can be increased by reducing the exposure time.

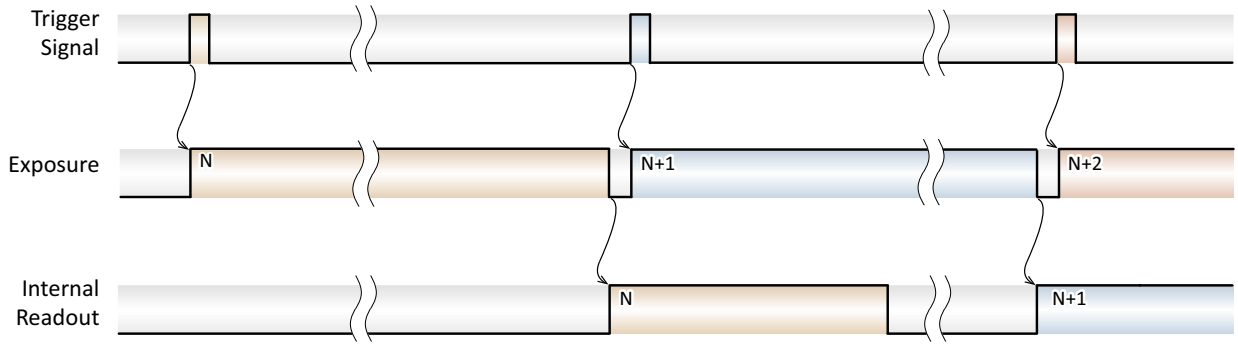

Figure 4: IWR mode: Exposure time is longer than readout time

Varying trigger intervals

The examples above use continuous trigger intervals. When trigger intervals vary, timing depends whether **ITR mode** or **IWR mode** is used.

IWR mode

When `IntegrationMode` is set to *`IntegrateWhileRead`*, the camera switches automatically between ITR mode and IWR mode, as displayed in Figure 5.

If Trigger interval > exposure time + readout time, then...

ITR mode is used:
After the readout of Frame N+4 has ended, the exposure of Frame N+5 starts.

If Trigger interval < exposure time + readout time, then...

IWR mode is used:
While the readout of Frame N+2 is ongoing, the exposure of Frame N+3 starts.

Enabling shorter trigger intervals

The trigger interval between Trigger N and Trigger N+1 is extremely short. Readout can start only after exposure has ended. Therefore, the exposure time for Frame N+1 has been extended over the dotted line to match the end of Frame N's readout.

Exposures of different lengths causes flicker since the longer exposed frames are brighter.

Trigger N+6 is ignored because the interval from Trigger N+5 is too short, overtriggering occurs.

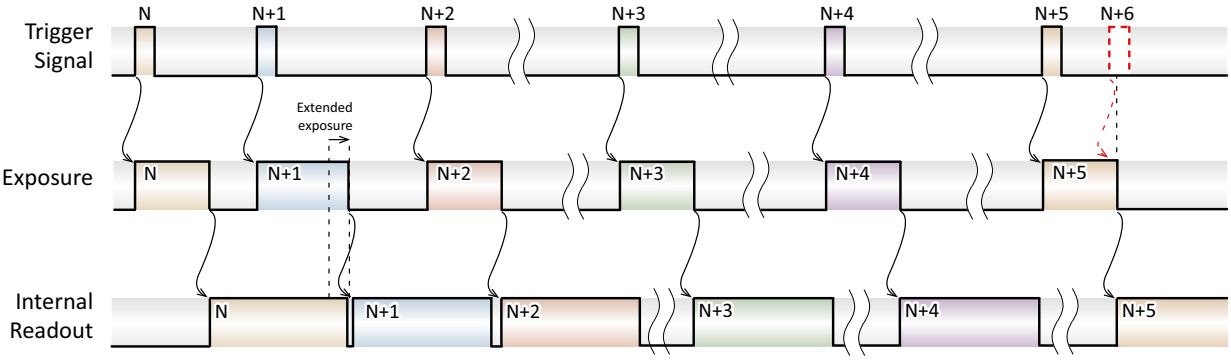

Figure 5: IWR: Varying trigger intervals

ITR mode

When `IntegrationMode` is set to *`IntegrateThenRead`*, the camera is forced to stay in **ITR mode**. Every trigger event that occurs before the end of a readout is ignored, another case of overtriggering.

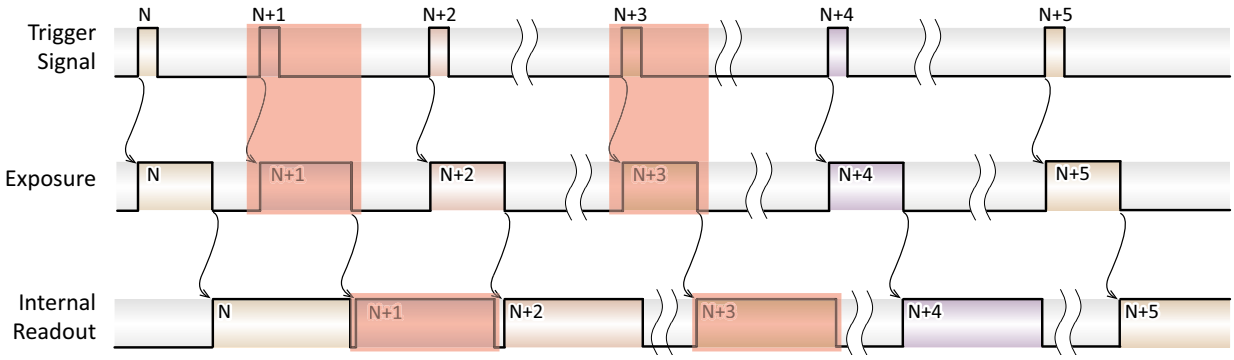

Figure 6: ITR: Varying trigger intervals

Figure 6 shows examples for overtriggering in **ITR mode**. **Red overlays** signal where triggers are **ignored**.

- Trigger N+1 is **ignored**, because the readout of Frame N is ongoing.
- Frame N+2 is acquired, because the trigger occurs after the readout of Frame N is completed.
- Trigger N+3 is **ignored**, because the readout of Frame N+2 is ongoing.
- Frame N+4 is acquired, because the trigger occurs after the readout of Frame N+2 is completed.
- Frame N+5 is acquired, because the trigger occurs after the readout of Frame N+4 is completed.

The above examples show that even if the trigger interval is approximately equal, overtriggering may or may not occur. However, if overtriggering occurs, it cuts down the framerate up to almost 50%.

The examples also point to measures that help keeping the framerate as close as possible to the maximum.

Conclusion

IntegrationMode settings and camera operation

Selected value for `IntegrationMode` →	*`IntegrateThenRead`*	*`IntegrateWhileRead`*
Trigger N+1 occurs... ↓	**Resulting camera operation**	
After the readout of Frame N	ITR	**ITR**
Before the end of readout of Frame N	ITR	IWR

Table 2: IntegrationMode settings and camera operation

Conditions for overtriggering

Trigger N+1 occurs...	**IWR mode**	**ITR mode**
After the readout of Frame N.	Proper triggering	Proper triggering
During the readout of Frame N.	Proper triggering	Overtriggering
During the exposure of Frame N.	Overtriggering	Overtriggering

Table 3: Conditions for overtriggering

Maximum frame rates for ITR and IWR modes in practice

Maximum available frame rates can be calculated based on:

- Explanations above
- Formulas in the user guide specifications
- Readout time, depending on settings for ROI and pixel formats
- Exposure time

The example graph in Figure 7 shows maximum frame rates in relation to exposure time.

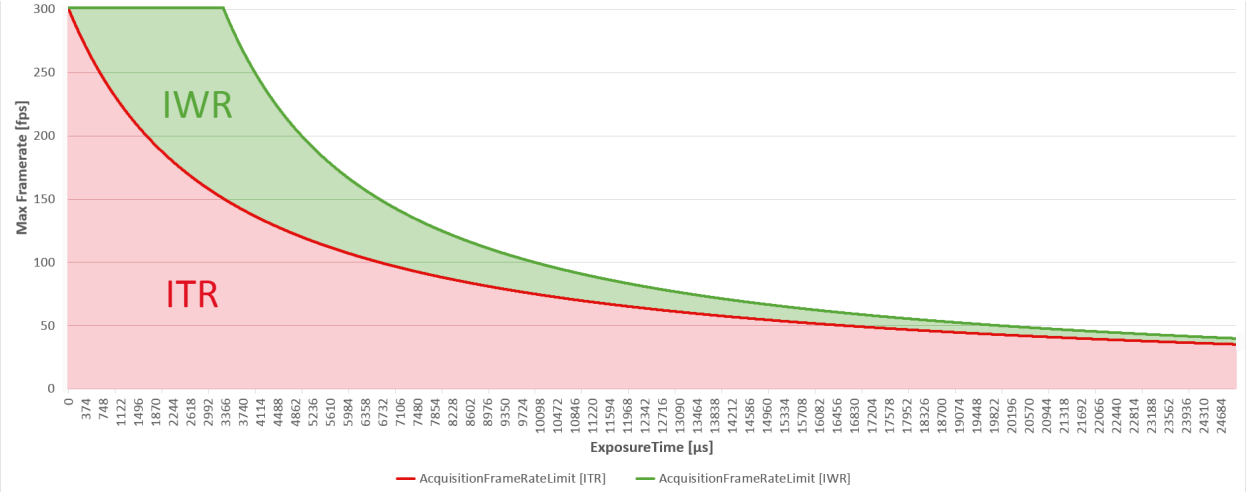

Figure 7: Frame rates with ITR and IWR (Goldeye G-033 VSWIR, Mono8, 640 × 512 px)

The camera operates most efficiently in the green range. The camera can be operated with an adequate exposure time, even close to the maximum frame rate.

Speed and quality with ITR and IWR modes

Integration mode	Timing behavior	Remarks	Frame rate values	Brightness for the sensor area
ITR mode	Exposure time and readout time determine the available frame rate.	Idle time reduces the efficiency for this mode, see Figure 2 on page 3.	See the calculation below.	Brightness is homogeneous.
IWR mode	When exposure times are increased, frame rates stay constant...	...as long as the exposure time has not reached the length of the readout time.	See the specifications chapters of the Goldeye user guides	**Goldeye G/CL**: Shutter line **Goldeye G5-130 VSWIR**: Brightness varies between sensor top and bottom lines (compensation by `BlackLevelEqualization`).

Table 4: Maximum frame rates in ITR and IWR modes

Formula to calculate maximum frame rates in **ITR mode**:

$$\text{Frame rate}_{\text{ITR,max}} = \frac{1}{\text{Exposure time + readout time}}$$

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