Baumer
Passion for Sensors

Application Note

Rolling shutter, global shutter – two principles of exposure

AN201906/0.1/2019-04-01

Description
This application note describes the difference between global and rolling shutter sensors respectively what they have in common.

Products
Baumer cameras with rolling and global shutter sensors

Content

1 Technical background

Multi-faceted inspection and image processing tasks require adequate image acquisition systems consisting of optics, camera and PC. Each component feature has a significant effect on task fulfilment. In terms of cameras, you may first think of resolution, frame rate and interface for PC data transmission.

However, a less “obvious” factor must be considered for camera selection: Exposure, meaning the shutter feature. By principle, there is a difference between global shutter and rolling shutter.

Compared to global shutter, rolling shutter readout is less complex and therefore more cost-efficient. Furthermore, a limited number of transistors will generate less heat and electronic noise. Another advantage is inferior pixel pitch which allows for higher resolutions in relation to the active sensor surface.

2 Shutters

Like mechanical shutters in analog film cameras, these fully electronic shutters in digital cameras control exposure time and this way the amount of light which is converted into electrons (charge carriers) in the sensor pixels.

Different pixel architectures entail different methods of exposure. Shutters define the time during which charge carriers are generated (exposure time) and how this is done.
As long as the camera is under power supply, the sensor pixels are active. Light is continuously “captured”, however charge carriers are not accumulated but deleted over and over. Start of exposure will stop deletion and start charge carrier accumulation. Pixel read out is after the end of exposure.

To this point, sensors behave the same in both methods of exposure – the devil is in the details.

2.1 Global shutter

Global shutters can be compared to conventional lens shutters in analog film cameras. Like the iris in the human eye they resemble lens aperture and are probably what you have in mind when thinking of shutters.

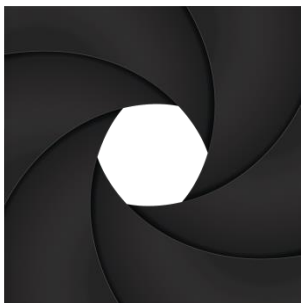


Fig. 1: Lens shutter in analog film cameras

The shutter is to open quick as lightining when released and to shut immediately at the end of exposure time. Between open and shut, the film segment to take the image is entirely exposed all at once (global exposure).

Sensors with digital global shutter do the same: Charge carrier accumulation in each pixel starts simultaneously (globally). Same applies to the end of exposure and readout.

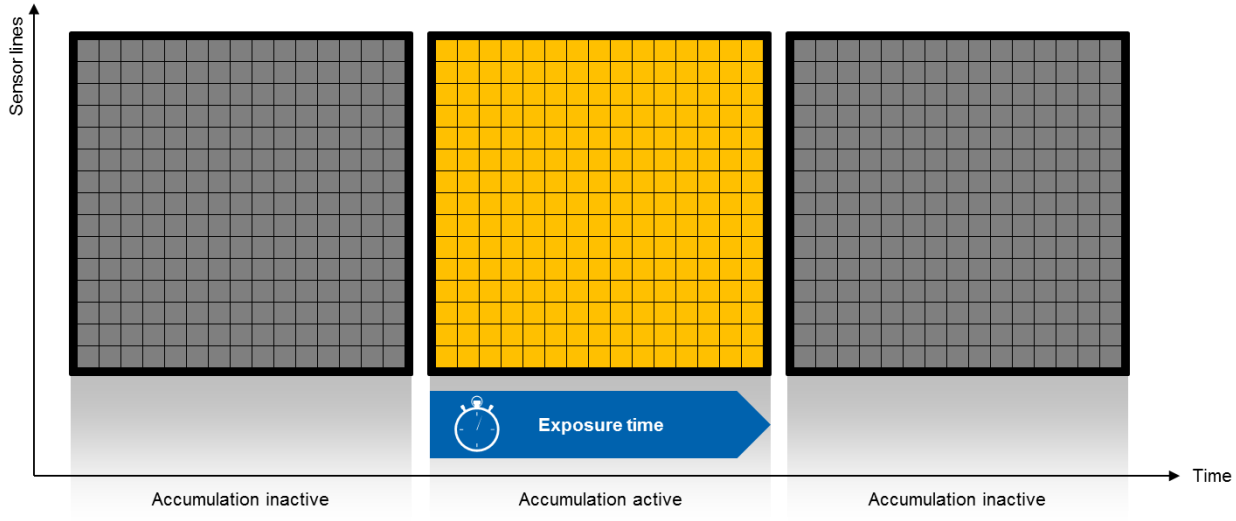


Fig. 2: Global shutter

Simultaneous, global pixel exposure will “freeze” the scene, reason why this method (short-time exposure) is appropriate for image acquisition on rapidly moving objects.

2.2 Rolling shutter

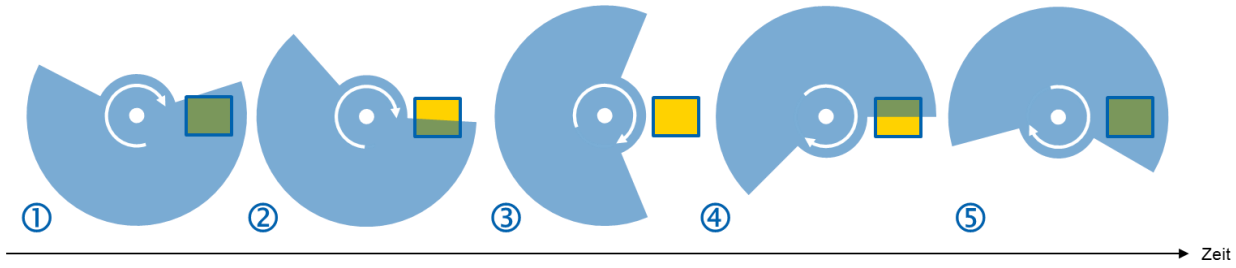
Rolling shutter exposure resembles analog film cameras. It helps understand the function principle and transfer it to the digital equivalent. In conventional technology, rolling shutters regulate film exposure and shading.

Rolling shutters look like a metal disc missing a segment, as in the illustration below.
The disc is mounted on a rotating shaft in front of the film strip.

Fig. 3: Rolling shutter (schematic sketch)

For a better illustration, the rolling shutter is sketched semi-transparently below.

Start of exposure (1). The rolling shutter gradually uncovers the film segment, which is exposed to light to take the image (2). Fully open, the entire image respectively film segment is exposed (3). The shutter is closing (4) until fully shading the segment again(5).



Though the exposure time for each image pixel is the same, exposure is not global (all pixels at the same time) but sequential (line by line), causing blur with fast-moving objects. All in all, with the same exposure time more time will elapse in total between shutter opening (start of exposure) and closing (fully shaded). Continued object movement in this time will cause image distortion.

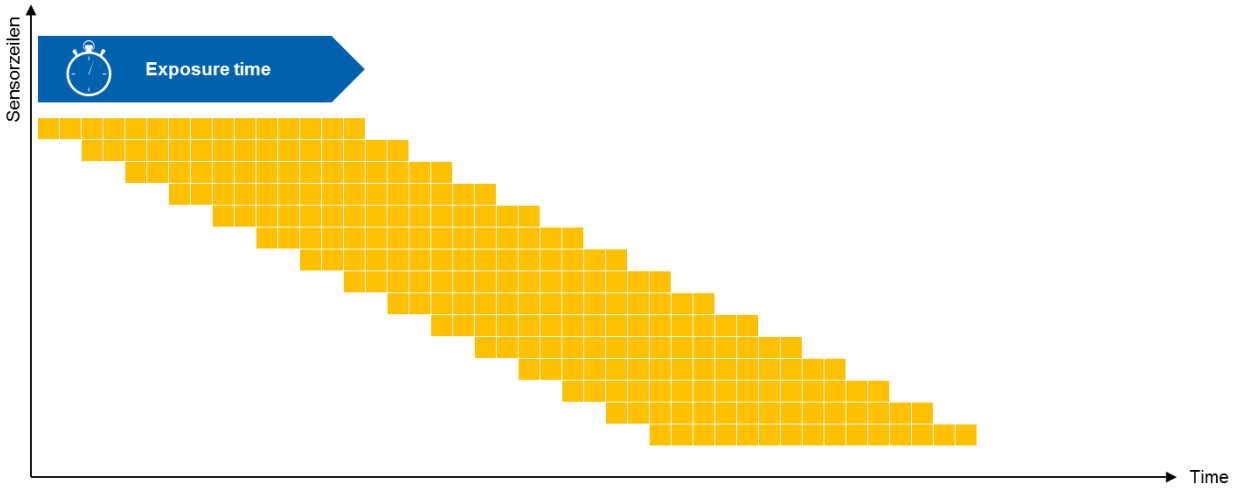


Fig. 5: Rolling shutter

Rolling shutters operate on sequential line-by-line carrier accumulation and exposure. Each pixel is exposed for the same time, but not all pixels in the image at the same time (globally).

Notice
For this reason, rolling shutter sensors are not a general recommendation in image acquisition on moving objects.

3 Rolling shutter effect

Image blur resulting from object movement in line-by-line exposure is known as Rolling Shutter effect.

The graphs below show the time offset in line-by-line rolling shutter exposure versus global shutter. Blur is rather present in Rolling Shutter exposure.

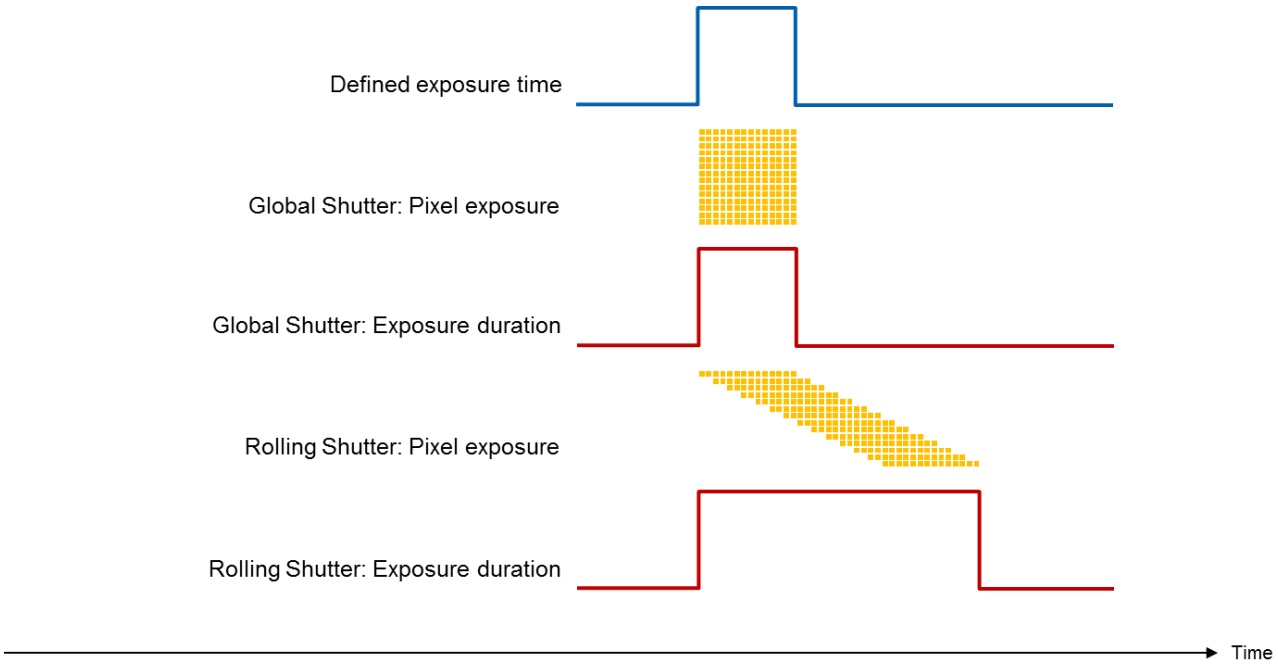


Fig. 6: Rolling shutter effect

The degree of blur not only depends on exposure time considering object speed and amount of light available, but also on the sensor's readout capacity: State-of-the art sensors reduce rolling shutter effects by higher readout speed rather than sensors operating on previous technologies.

3.1 Linear movement

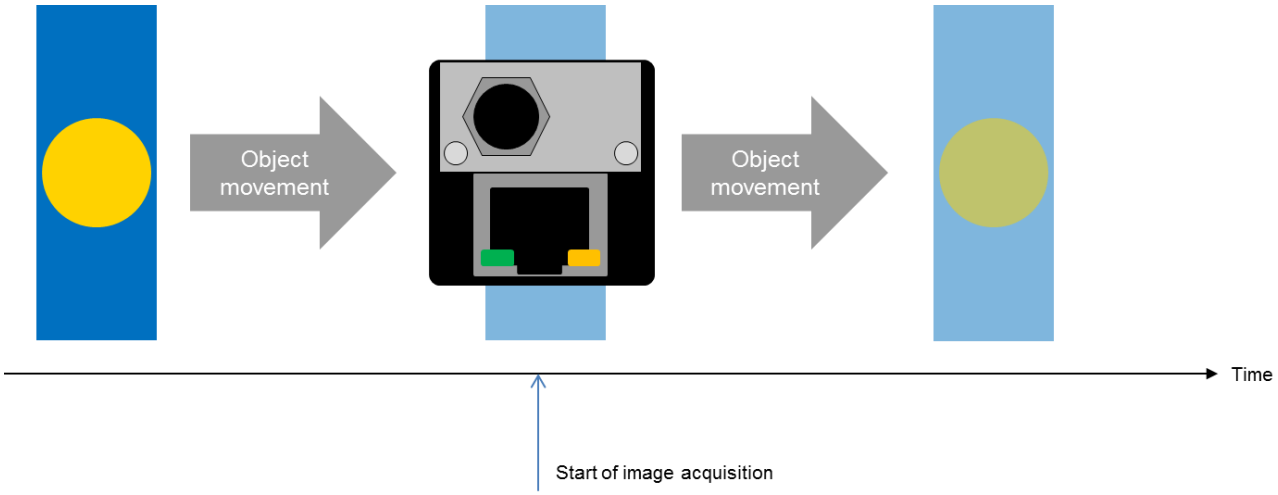


Fig. 7: Linear movement

Object movement in linear direction in front of the camera during the time of image acquisition (fig. 7) will create rolling shutter effects in the form of horizontal blur.

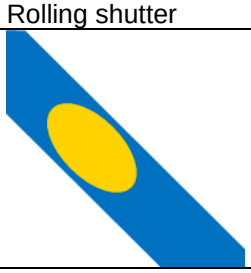
Global shutter	Rolling shutter
	

Fig. 8: Linear movement: Global shutter vs rolling shutter

The illustrations below show where the blur comes from: left is the moving object with line-by-line-exposure (orange line). Right you see the acquired image content at pixel level.

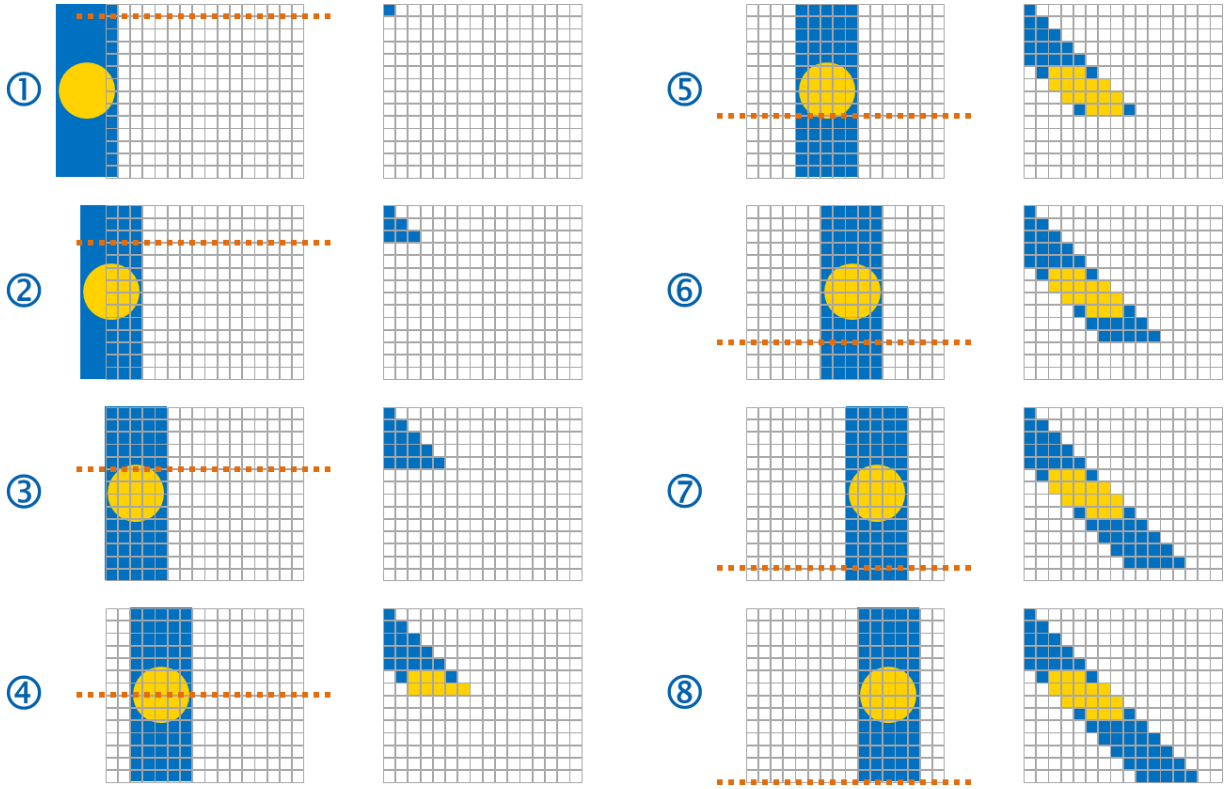


Fig. 9: Rolling shutter effect – blur by horizontal object movement

3.2 Rotating objects

Object rotation for the time of image acquisition will blur contours as illustrated by the four colored quadrants in the picture below.

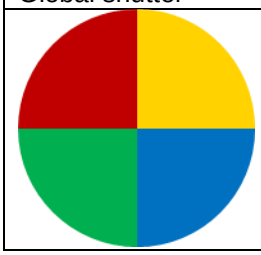
Global shutter	Rolling shutter
	

Fig. 10: Global shutter and rolling shutter effect on rotating objects

The illustrations below show where the rather bizarre looking rolling shutter effect comes from. The interaction of line-by-line exposure (orange line) and object rotation is visualized at pixels level in the acquired image (left).

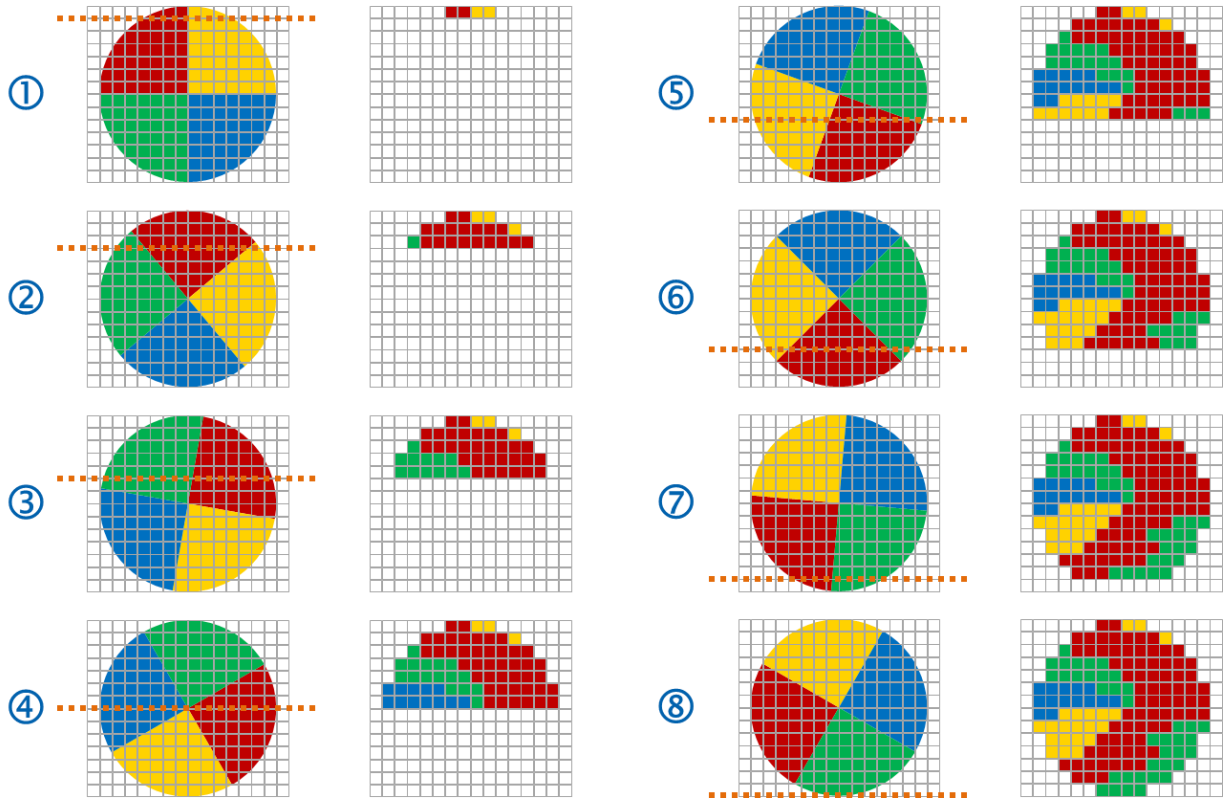


Fig. 11: Rolling shutter effect – blur by rotation

3.3 How to compensate the rolling shutter effect

Some rolling shutter sensors provide a special feature, so-called global reset. Like in global shutter exposure, charge carrier accumulation in each pixel starts at the same time. Readout however is line by line with a time offset – typical for rolling shutter sensors.

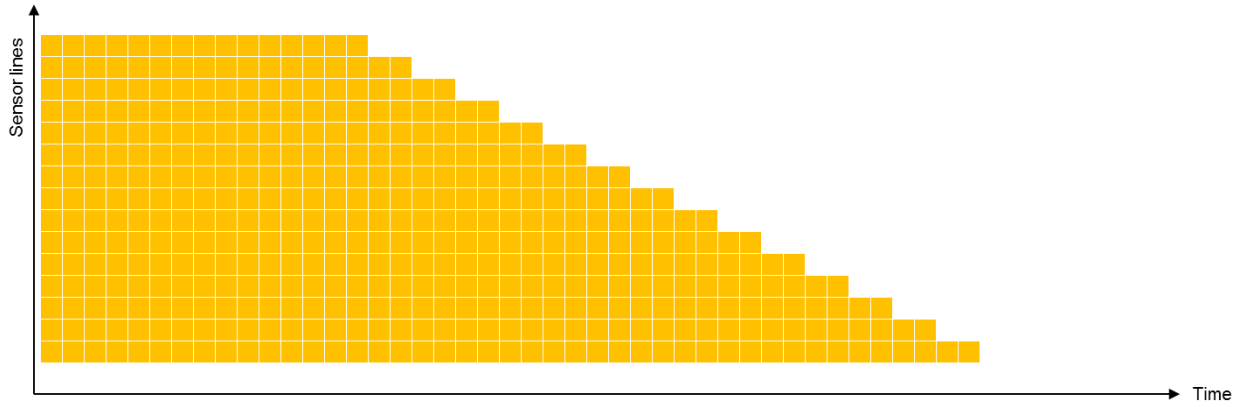


Fig. 12: Rolling shutter exposure with global reset feature

Each line is exposed for a different length of time which is visualized by the brightness gradient.

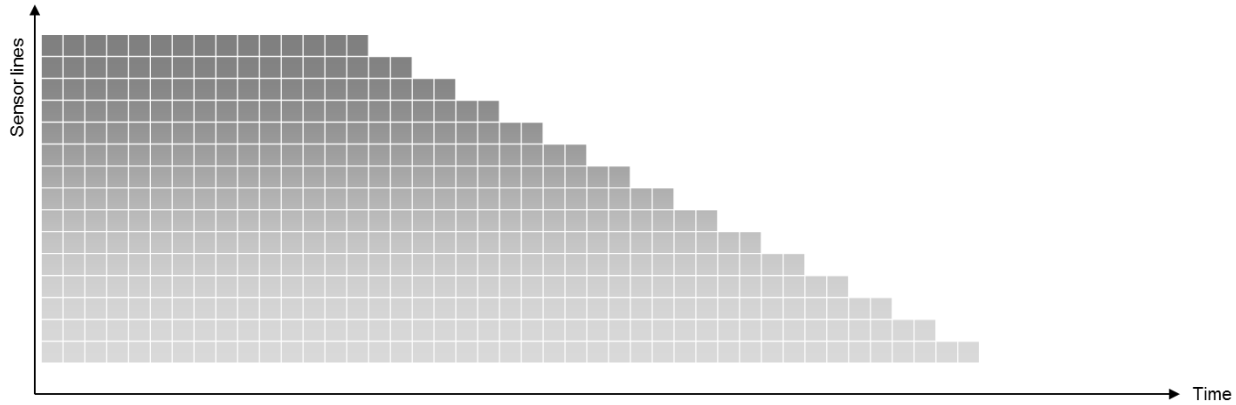


Fig. 13: Brightness gradient resulting from different exposure times in rolling shutter exposure with global reset feature

The global reset feature alone would not suffice to compensate rolling shutter effects.
Exposure time remains the same and hence the potential risk of blur in image acquisition on moving objects.

This can be remedied by combining global reset feature, flash and ambient light suppression.

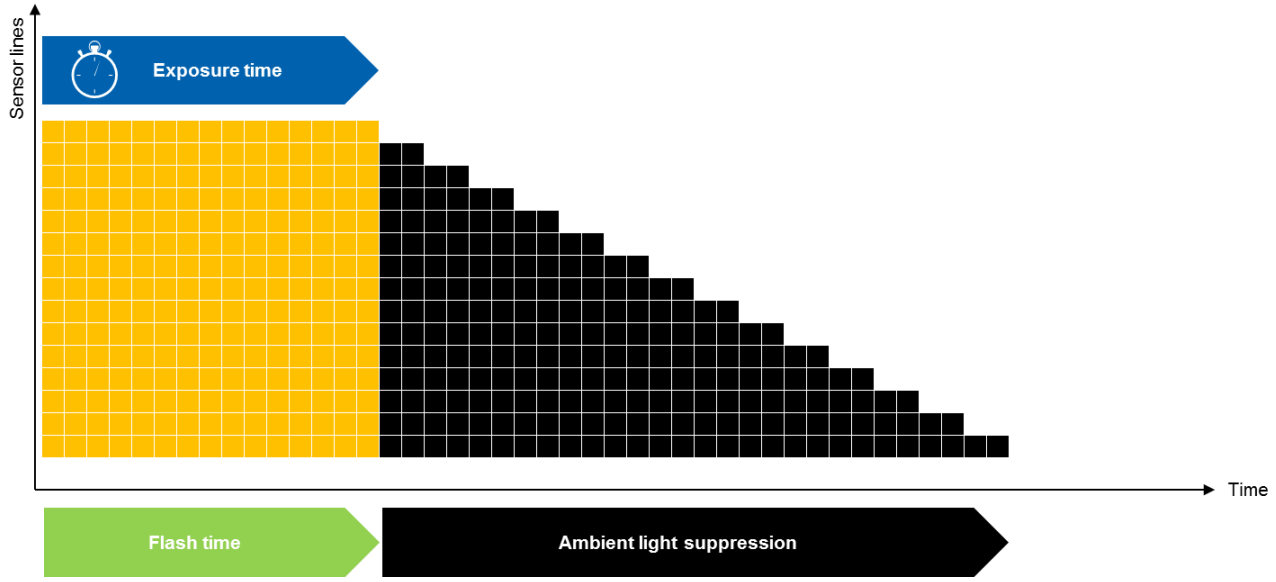


Fig. 14: Flash used with rolling shutter sensors with global reset feature

The illustration shows the basic function principle: Flash is on when starting exposure and active for the time of exposure. Make sure any ambient light is suppressed until exposure of the last line has been completed. In this way, rolling shutter sensors “simulate” global shutter behavior in image acquisition on moving objects.

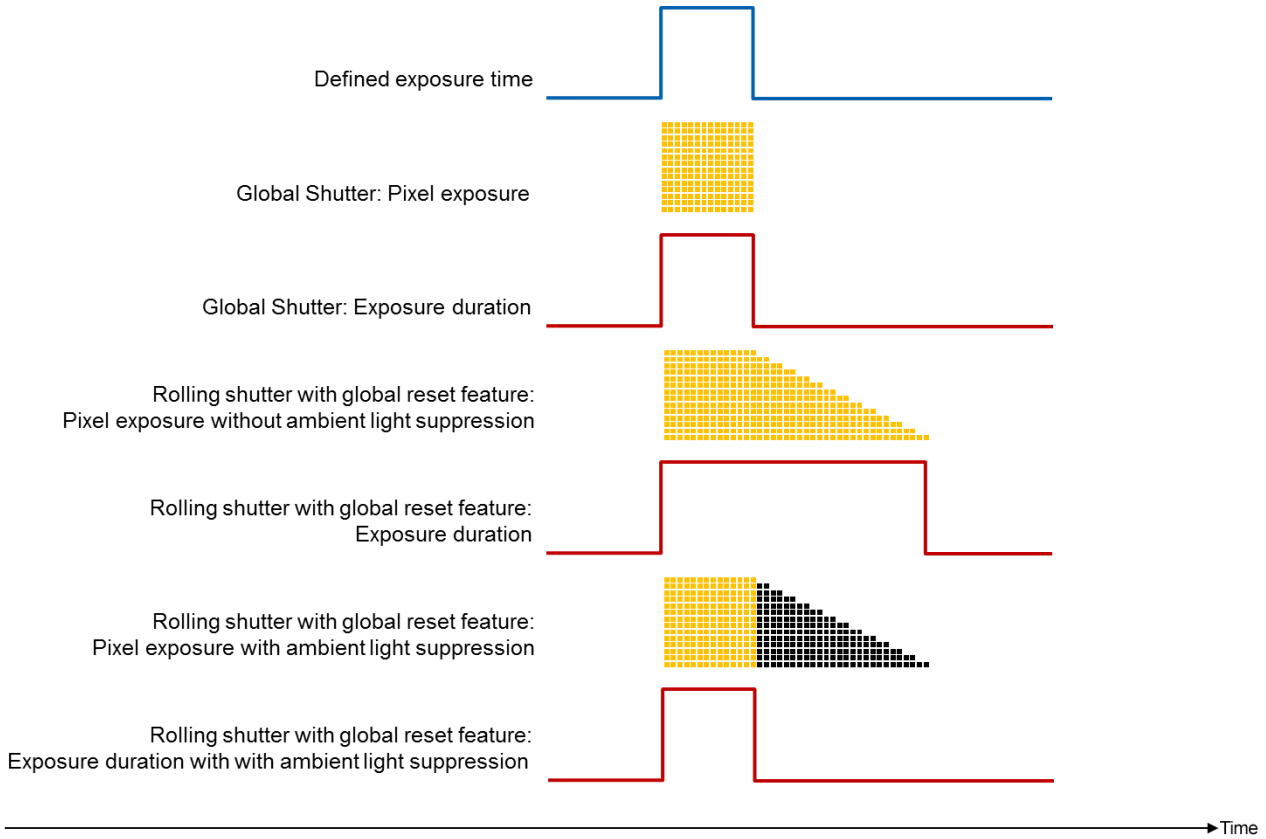


Fig. 15: Simulated global exposure and shading by rolling shutter sensors with global reset feature

4 Support

Please contact our Technical & Application Support Center with any questions.

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5 Legal Notes

Baumer Group
The Baumer Group is one of the worldwide leading manufacturers of sensors, encoders, measuring instruments and components for automated image processing. Baumer combines innovative technologies and customer-oriented service into intelligent solutions for factory and process automation and offers an unrivalled wide technology and product portfolio. With around 2,700 employees and 38 subsidiaries in 19 countries, the family-owned group of companies is always close to the customer. Baumer provides clients in most diverse industries with vital benefits and measurable added value by worldwide consistent high quality standards and outstanding innovative potential. Learn more at www.baumer.com on the internet.