

Application Note

Using Emulated Shutter

In the DVL camera range, not all the sensors feature an electronic shutter. In order to allow exposure control, separately from line rate, Lord Ingenierie developed a emulation of shutter mode.

This document explains how it works, similarities and differences with electronic shutter, and the timing limits.

Definitions

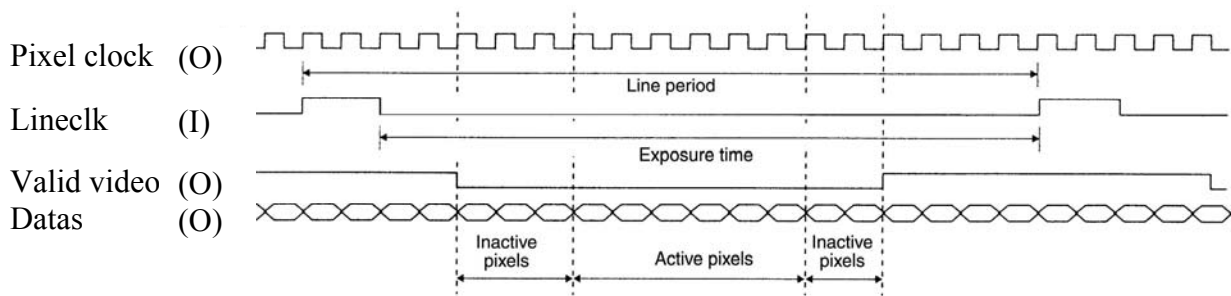
Exposure Time (ET)	The time during which the sensor is accumulating charges
Line Period (LP)	The time between the starts of two successive video lines (= 1 / Line rate)
Readout Time (RT)	The time required to output a whole video line and reset the sensor to be ready for the next line
Blind Area (BA)	When using a shutter, the sensor is not exposed during the whole line period. On each video line, a part of the product scanned is not seen by the camera. This percentage is calculated as $(LP-ET) / LP$

Reminders : Continuous mode or shutter mode

For sensors with an electronic shutter, exposure of the sensor can be controlled by an electric signal. Exposure starts on the falling edge of the input signal “lineclk” and ends at the next rising edge of this signal. The transfer of charges starts at the next rising edge of “lineclk” (see the following timing chart).

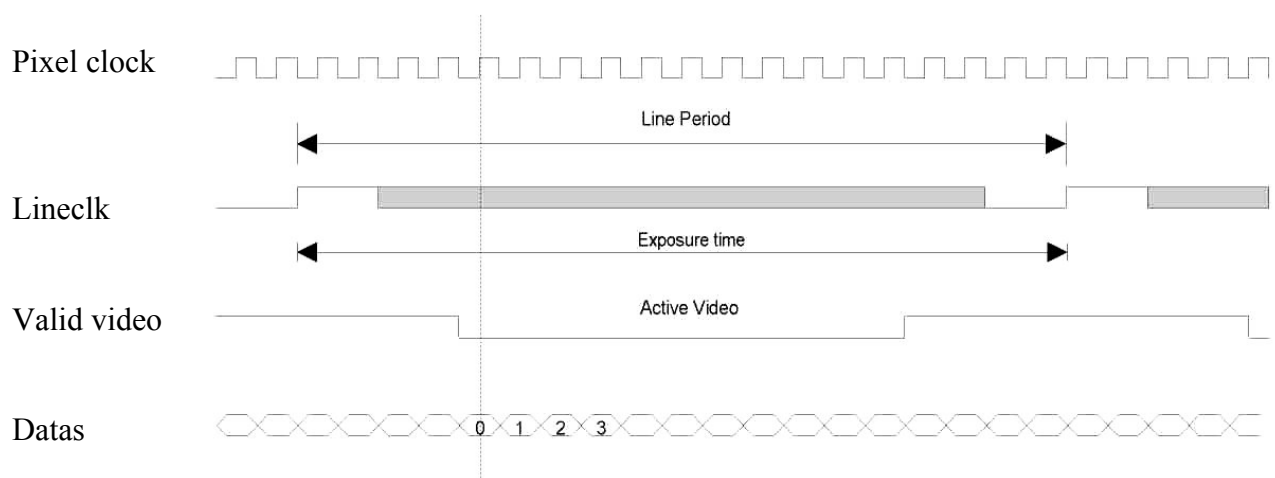
Without using a shutter, the sensor is permanently exposed, thus accumulating charges. This charges are periodically output at line rate. Therefore, exposure time is imposed equal to line period.

Emulating a shutter on such a sensor means considering as valid datas only the ones gathered within the low state of lineclk, and throw the others away.



Timing chart in shutter mode

The sensor is exposed during low state of LineClk.



Timing chart in continuous mode

The sensor is permanently exposed.

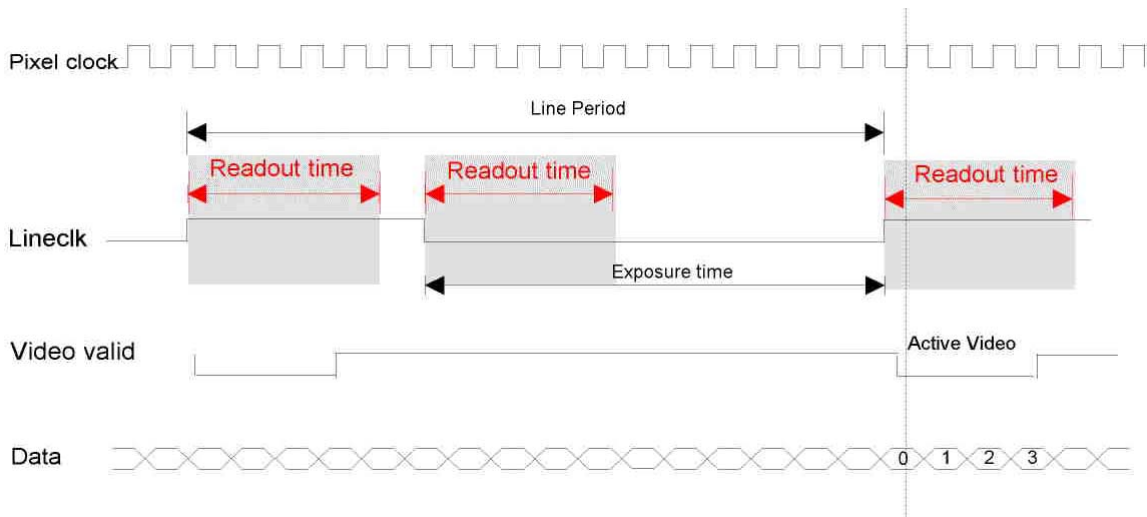
Emulation of shutter mode

The base principle is the following : the control signals are the same as in usual shutter mode. Exposure is triggered on a falling edge of lineclk and stops at rising edge of this signal.

When the sensor is not supposed to be exposed (high state of lineclk) : the charges are periodically output and ignored. As an exposure start is asked (falling edge of lineclk), the current charges in the CCD are readout and ignored. So the sensor starts to accumulate new charges. It is necessary to wait for the previous charges to be eliminated before stopping exposure and outputting the valid datas : it imposes a minimum exposure time equal to the Readout Time of the camera.

On a rising edge of lineclk, the charges are output from the CCD, converted and treated, and output from the camera as a valid line. Therefore it is necessary to wait for the Readout Time before being able to receive a new trigger.

Consequently, the emulated shutter behaves like an electronic shutter but it has some more restrictive limits in the timings.



Timing chart of emulated shutter

During the grey area (RT) the camera is not able to receive a new start or stop of exposure.

Summary : Timing limits in different modes

	Min Exposure Time	Min Line Period	Exp Time vs Line Period	Blind Areas = (LP-ET)/ LP
No shutter	RT	RT	$ET = LP$	None
Electronic shutter	0	RT	$0 \leq ET \leq LP$	$\geq 0\%$
Emulated shutter	RT	2xRT	$RT \leq ET \leq LP - RT$	$\geq RT / LP^1$

Note 1 : When using the emulated shutter mode, maximum line rate is divided by a factor of 2.

Note 2 : Minimum blind area depends on the line rate used in the application. Please refer to following examples.

Readout Time for DVL cameras equipped with an emulated shutter

Camera	Readout Time (µs)
DVL2500T	133
DVL3750T	193
DVL5000T	265
DVL5000T2	133
DVL7500T	385
DVL7500T2	193

¹ Blind Area (BA) = $(LP-ET)/LP = 1 - ET/LP$
with $ET \leq LP - RT$
 $\Rightarrow BA \geq 1 - (LP-RT)/LP = RT / LP$

Examples

Choose a DVL5000T2 :

Without shutter, minimum exposure time is equal to minimum line period = 133 μ s. Max line rate is 7.5 kHz.

Using the emulated shutter, minimum line period is 266 μ s.

At maximum line rate (3.7 kHz), the only available value for exposure time is 133 μ s. Blind area is 50 % of the scanned product.

At 1 kHz, LP = 1000 μ s and exposure time is between 133 and 867 μ s. Minimum blind area is 13,3 %.

At 250 Hz, LP = 4000 μ s, ET is between 133 and 3867 μ s. Minimum blind area is 3.4 %.

Note :

The percentage of blind area calculated here is an pessimistic approximation.

Indeed it doesn't take into account the impact of the pixel size combined to product speed and optical magnification nor the effect of the lens (point spread function). Practically these contributions tends to enlarge the size of the object area seen on a video line. Then it reduces the blind area percentage.

Therefore, the values calculated above are a worst case estimation.