White paper about HDR mode of Aptina/ON Semiconductor CMOS sensor

Good images do not have to be expensive

Industrial cameras in outdoor applications have to face several challenges: changing light conditions because of night and day, and if they are used in traffic, backlight will be a common problem. High dynamic sensors are the solution, but they are wrongly assumed to be expensive. The CMOS sensor AR0331 from Aptina/ON Semiconductor with HDR modes proves the contrary. The features and how you can work with the sensor will show the following white paper.

HDR

HDR short for "High Dynamic Range" describes a video or single image transfer chain which tries to display high differences between light and dark in one image. For this reason, HDR is also a buzzword used in combination with new flat-screen TVs. I.e., because black can not be displayed darker, white has to be lighter; figuratively speaking if an actor points with a torch to the viewer, the viewer has to close the eyes. That's not the case at the moment.

A summary of dynamic values gives the following table available on Wikipedia:

Dynamic ranges of common devices

Device	Stops	Contrast
LCD	9,5	700:1 (250:1-1750:1)
Negative film (Kodak VISION3)	13	8000:1
Human eye	10-14	1000:1-15000:1
High-End DSLR camera (Nikon D810)	14.8	28500:1

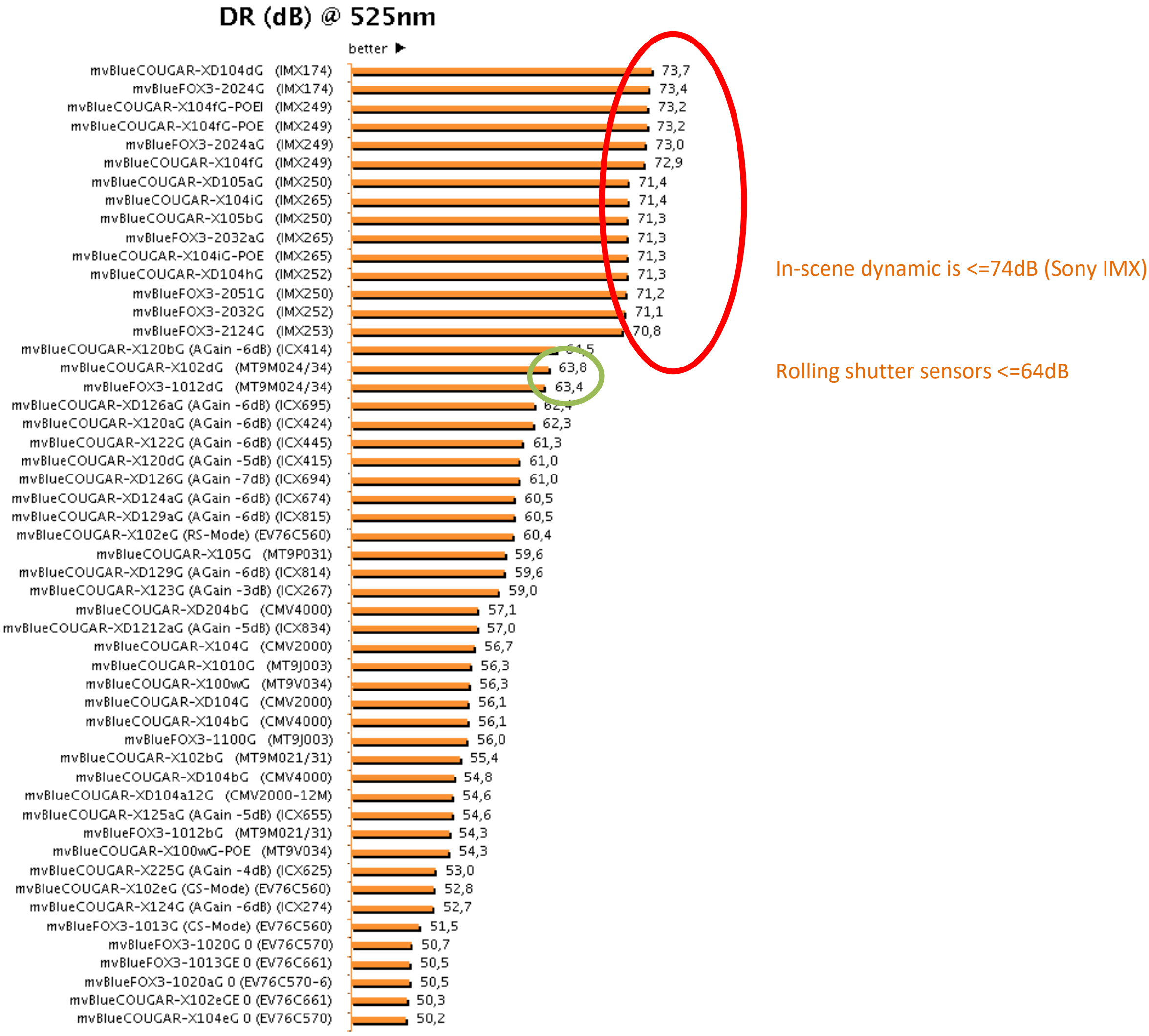
Contrast ratio

If you come from an intuitively understandable contrast ratio from light to dark, 8000:1 for example, this will lead to the logarithmic representation 20*log(8000) = 78dB. Because every bit offers ~6dB (factor 2) dynamic, 78dB/6 = 13 bit is the resulting dynamic, which is the number of F stops, which again contributes a signal doubling.

You are able to see, that the human eye is a benchmark which is just achieved by a professional DSLR camera or a negative film. A LCD display cannot reach the contrast at the moment.

Dynamic with machine vision cameras

The EMVA1288 standard makes it possible to measure the dynamic of cameras and to compare them. The following figure shows a dynamic summary of different cameras form MATRIX VISION:



The figure shows that the already legendary Sony IMX sensor of the Pregius series achieves about 70dB, which corresponds to ~12 bit. Furthermore, high-quality CCD sensors from Sony achieve about 60dB (10 bit) and less expensive rolling shutter sensors achieve more than 60dB. At the moment, it is not possible to get more with machine vision cameras.

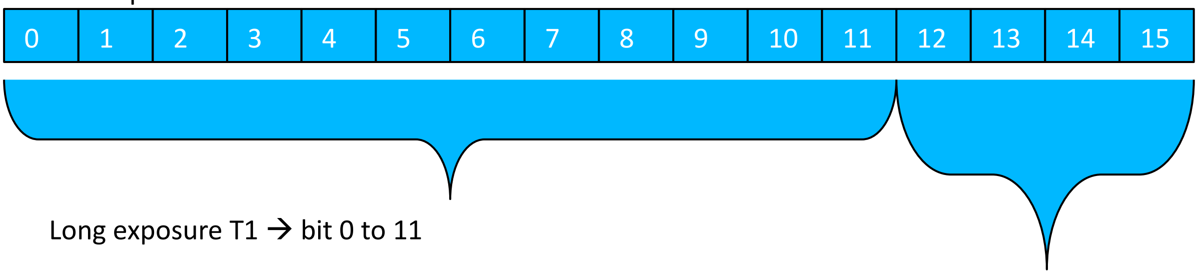
How can HDR be achieved for live images?

Driven by the innovations of the sensors used in mobile devices, which create good images even with small pixels and rolling shutter, there are following interesting possibilities in combination with the sensor AR0331 from Aptina/ON Semiconductor:

While the sensors achieves a very good dynamic of ~70dB with the 12 bit ADC, the rolling shutter can even control two nested Reset → Exposure pointers. This functionality can be used, to create a 16 bit linear signal. In this signal, the two exposure times have a specific ratio. If the shorter exposure time is 1/16 of the longer exposure time, the higher 4 bit will be added to the lower 12 bit to get a 16 bit value.

AR0331 has a 12 bit ADC (~72dB)

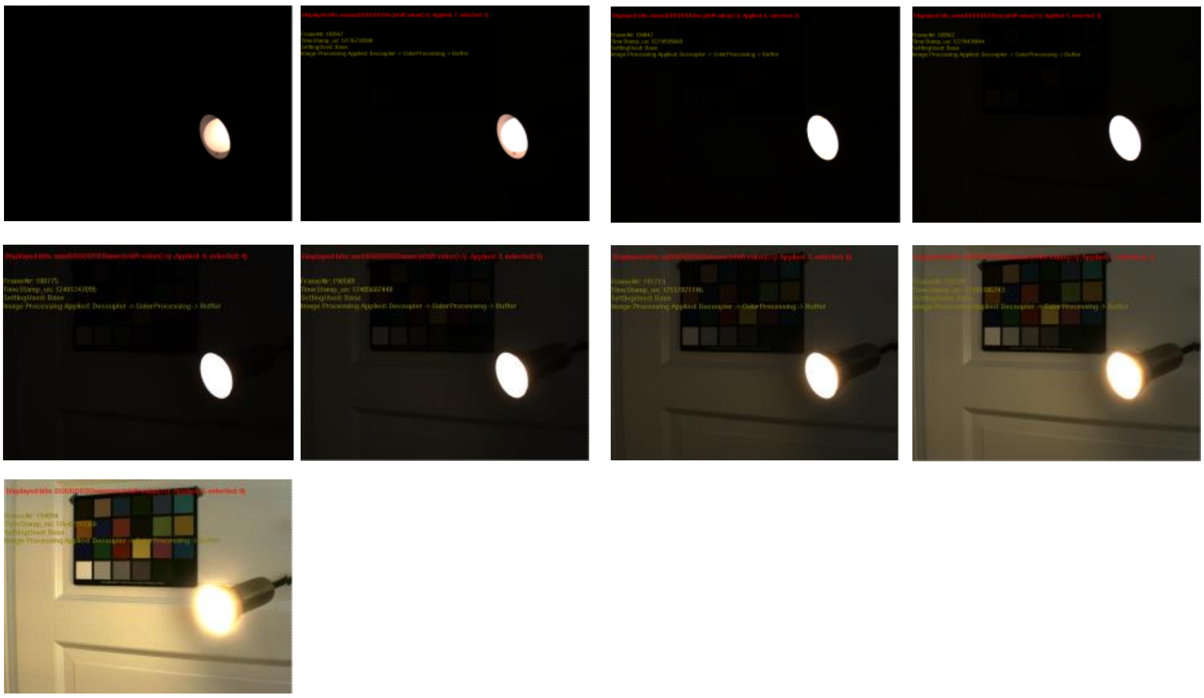
100 dB requires ~16 bits



Long exposure T1 → bit 0 to 11

Short exposure: R=16 → T2 = T1/R → bit 12 to 15

A linear 16 bit image, which is created with an exposure time of 4ms and a second exposure time of 250µs, will look like as follows:

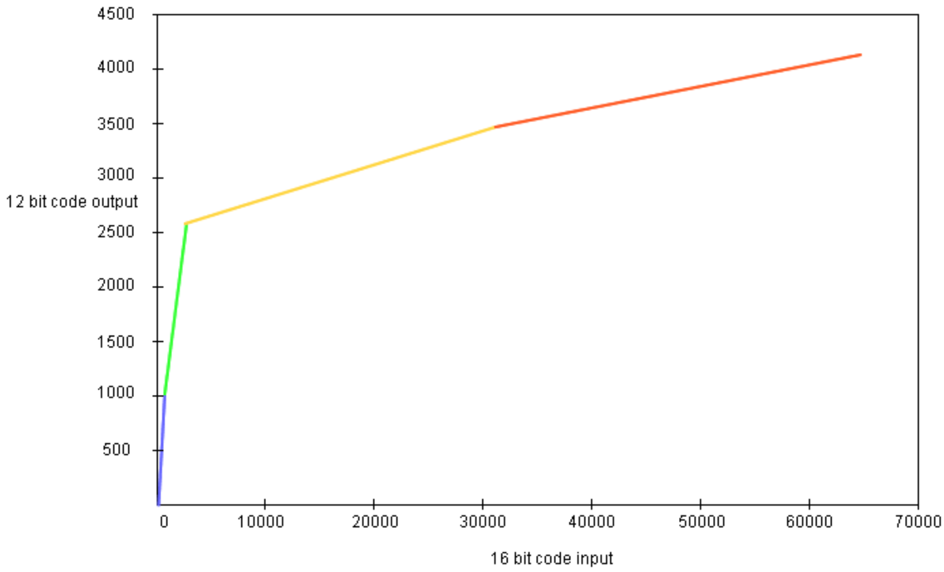


From the left side above to the right side below the image will be shifted downwards by one bit, i.e. the exposure values will be doubled per shift. You are able to see, that the lamp is not overloaded in the higher bits and that you can see the rest of the image in the lower bits.

Where are the challenges?

The most important thing is, that the image with a high dynamic range can be displayed on a display naturally, which cannot display the high dynamic according to the table at the beginning.

ALTM This procedure is called Adaptive Local Tone Mapping (ALTM). This works for example because of the special adaptive control characteristics line of the sensor:



The result will look like the following image, which combines the lamp and the dark image content.

Additional, functions like motion compensation, or avoiding colored saturation effects in order that images with motions can also benefit from a higher dynamic without any artefacts. It should be recalled that these will be done automatically, with 30 images per second at full HD resolution, and with a perfect color quality.

The AR0331 from Aptina/ON Semiconductor is available in the USB3 Vision camera mvBlueFOX3-1031C from MATRIX VISION. Furthermore, MATRIX VISION offers additional fine tunings, by letting the driver access the sensor's register directly to switch on or off some options. A use case in the manual provides a detailed insight:

https://www.matrix-vision.com/manuals/mvBlueFOX3/UseCases_page_0.html#UseCases_section_HDR_1031C

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https://www.matrix-vision.com