

## **In-pixel versus algorithm based high-dynamic-range imaging**

High dynamic range imaging (HDR) is becoming more and more popular. Besides high dynamic range photography, industrial and security markets have increased their requirements in terms of dynamic range imaging beyond the dynamic range of a traditional CMOS or CCD sensor that is usually in the range of 60 to 75dB.

In-pixel high dynamic range CMOS designs started about 15 to 20 years ago mostly driven by the requirements of automotive machine vision and some scientific applications. Such designs increase the dynamic range of a pixel in the charge domain within the frame time and are not affected by motion blur, however they may present additional noise and some design artifacts. There are several pixel designs that offer an extended non-linear dynamic range but only few of them are commercially used. Most of the devices feature a multiple segments piecewise-linear response that interpolate a logarithmic curve. The dynamic range of a CMOS sensor can be extended up to 120dB to 150dB without compromising with fill factor or other design parameters.

Algorithm based high-dynamic-range imaging is based on multiple exposures of a static scene from the same vantage point. In the past years, sensor manufacturers have released sensors that alternate long and short linear exposures and either stream the frames as two alternating sub-streams or merge the images on-chip to provide a high dynamic range linear output. Extreme dynamic range values can be achieved but because the number of images merged is usually limited to two to four exposures, the practical dynamic range extension rarely exceeds +30dB. Advanced off-chip algorithms can perform a more advanced merging of the frames and can include a compensation for vantage point motion or scene motion as well as additional noise reduction. Unfortunately the processing time can be very long and motion artifacts still remain.

More advanced sensors dedicated to scientific and hyperspectral applications now combine this method with a scientific CMOS pixel design. Scientific CMOS image sensors are HDR in their principle.