Super−Exposure Pixels Mitigate LED Flicker in the Most Demanding Automotive Environments

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Automotive cameras with new generation of image sensors enable the latest advancements in autonomous and assisted driving systems. Advanced driver assistance systems (ADAS) use the images captured by these cameras to identify objects around the vehicle and calculate distance (with stereo cameras), which can be used in features like automatic braking, highway cruise control, lane departure, or parking assist. However, the light−emitting diodes (LEDs) used in most modern automotive lights and traffic signs can cause problems for some image sensors. **onsemi** utilizes image sensors with pixel overflow approach, also known as super exposure, that uses very large in−pixel overflow memory to extend dynamic range many times and achieve 120 dB LED flicker free operation. With the advanced super exposure pixels, they can address the challenges of ADAS requirements and flickering LEDs.

LED lights are generated using pulse−width modulation (PWM), a digital technique commonly used to reduce power consumption in headlights, taillights, traffic signs, and vehicle messaging systems. Their on−off pulse frequency is imperceptible to the human eye, but it causes problems when trying to capture images. To prevent oversaturation from occurring in the bright area within a scene, it is often necessary to use short exposure times − thus missing LED pulses. As a result, sometimes it can appear as if a light is off, as shown on the left image in Figure 1. In a video scene, LED lights seem to be continuously turning on and off − a phenomenon referred to as LED flicker. As LEDs are commonly used in modern vehicle lighting and digital signage, the video captured may show different striped or segmented artifacts which may be very distracting for drivers and passengers.

Figure 1. LFM Samplings at 30 fps 10% Duty Cycle 10 ms Period (100 Hz)

This is a critical problem as it can distract a driver who looks at a display only to see the flickering headlights behind them and mistakes it for a first responder vehicle. It can also potentially create a problem for algorithms being used to determine the number being displayed on a digital speed sign or color of a traffic light or detect brake lights (in Figure 2), to make safety−critical decisions accurately. Automotive image sensors must address challenging scenarios, including flickering LEDs, while providing a high dynamic range (HDR) of over 140 dB and operating at high temperatures (up to +125°C junction). In this article, we briefly discuss the operation and limitations of some optical techniques commonly used for HDR and LED flicker mitigation (LFM) in automotive image sensors before presenting a new type of sensor that overcomes these limitations to provide multiple types of LFM with even better HDR.

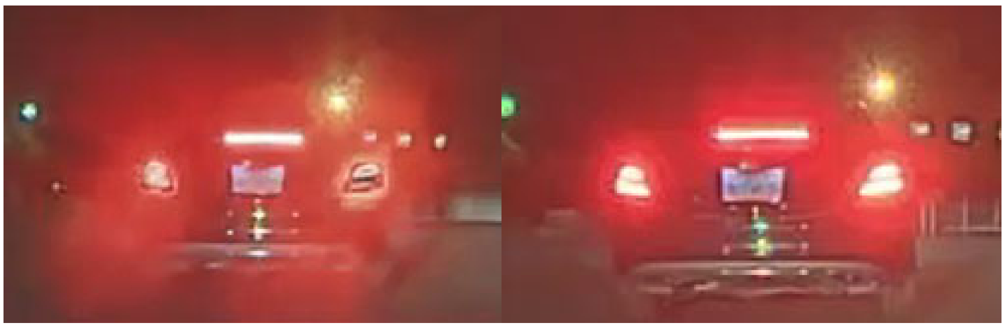

Figure 2. Flicker of LED Taillights

Traditional Multiple Exposure HDR

Capturing scenes with HDR typically requires taking multiple images, each with different exposure time settings, which are then processed and combined into a single image. Using various exposure settings allows more usable image data to be gathered from the brighter and darker areas of the scene. For example, longer exposure times will capture more image information in darker areas, while shorter exposure times capture more usable data in brighter areas. The final processed image takes the best data from each exposure and combines it into an HDR image (see Figure 3 top). While traditional multiple exposure HDR imaging is excellent for static scenes (with little to no motion), real−life dynamic scenes such as automotive applications with the camera moving at a high speed, can produce motion artifacts due to objects changing position between different exposures. This happens because each exposure takes place at different times, sequentially, and this delay causes the HDR post−processing to generate a final image with objects that appear to be distorted and with color artifacts.

Simultaneous Split−Pixel Exposure

Split−Pixel sensor technology has been used to capture images with HDR in automotive applications because it captures multiple exposures simultaneously rather than sequentially, thus reducing blurring and color artifacts caused by motion. To produce an image with HDR, raw images are captured using both large and small sub−pixels, and these are then combined in the

HDR output (see Figure 3 middle). To extend the dynamic range, a large sub−pixel is used for darker parts of image and a small sub−pixel is used for mid to high light parts of image captures. The big sub−pixel collects more light, and therefore saturates in brighter conditions. Conversely, the small sub−pixel can be exposed for a longer time but will not saturate easily because less light is collected. The overall effect of having the large sub−pixel working in low−light conditions and the small sub−pixel in bright conditions is extended dynamic range. The relative size of the photosensitive area of the pixel (fill factor) plays a very significant role in the image quality. A disadvantage of split−pixel is that less pixel area is available for image capture in low−light conditions as significant part of the pixel is occupied by small sub−pixel. Even less area is available for small sub−pixel thus generating order of magnitude smaller signal and consequently lower signal−to−noise ratios. When viewing an identical scene, the output image will be different, depending on whether large or small sub−pixels are used. Also, significant color artifacts and shifts can occur because of the incident angle of light rays from the lens interacting differently with the two−sized sub−pixels in the array. Removing these artifacts requires special sensor calibration and elaborate on−sensor corrections. This is the reason of generally higher power consumption of split−pixel sensors. Furthermore, the performance of image sensors based on this technique can degrade at ambient temperatures exceeding +100°C and often even +80°C, with SNR transition dropping much below 25 dB.

Super−Exposure Pixel

onsemi has developed image sensors with a unique set of features that cater to both sensing and viewing camera applications. From one side, they provide a mode of operation to capture 120 dB HDR images with LED flicker mitigation (good for surround view and e−mirror applications). On the other side, a classical multiple exposure operation extends the total dynamic range to 140 dB and beyond to address even the most challenging scenes for front and surround sensing. They also feature a third pulsing LFM mode which covers the extreme case of the brightest flickering headlights. In all cases, these sensors keep all signal−to−noise ratio (SNR) transitions at 30 dB and above, even for high temperatures (up to +125°C junction). These sensors deliver the performance needed for ADAS safety and autonomous driving system designs that may rely on the image sensor, especially on hot sunny days when sensors within tightly packed front cameras heat up to scorching temperatures.

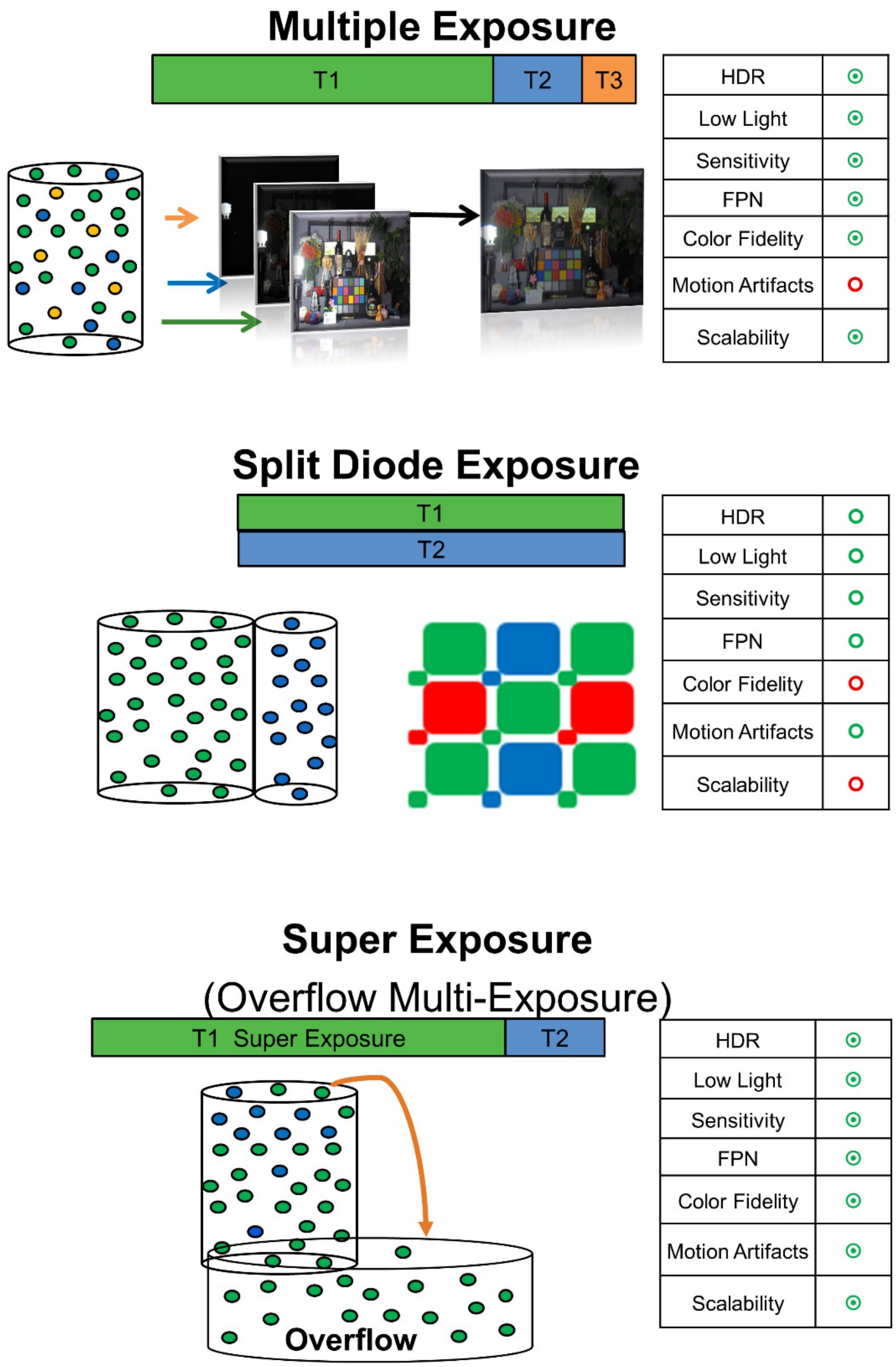

Figure 3. Different Exposure Techniques

onsemi’s latest automotive HDR image sensors are built with super exposure technology. These sensors implement a set of operations for effective, across entire automotive temperature range:

- Super−exposure with 150 dB HDR LFM
- Pulsed LED flicker mitigation (pLFM)
- Multiple exposure 140 dB and beyond HDR image capture

These modes cover the full range of typical automotive scenarios and enable effective mitigation of flickering LEDs and other lights. The HDR performance of image sensors combined with high conversion gain (HCG) signal readout provides a cinematographic image quality with sharp, high color fidelity captures as a result of excellent pixel linearity from very low to very bright light levels. Some sensors provide an additional mode of operation in conjunction with two photodiodes (PDs) covered by a single μlens enabled distance extraction and a color image using in−pixel phase−detect. Characterizing 4−exposure HDR mode at room temperature shows a 140 dB dynamic range and all total SNR transitions at or above 30 dB with the first T1 exposure readout using HCG.

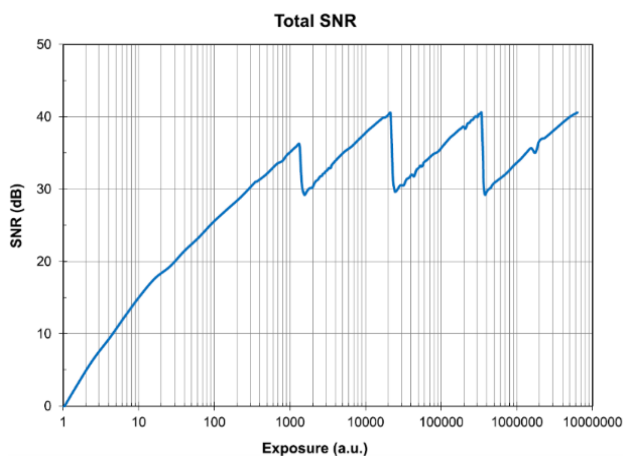

Figure 4. 4−exposure Room Temperature 140 dB Dynamic Range Total SNR

These super−exposure HDR LFM image sensors better captured bright flickering LEDs and eliminated motion artifacts compared to conventional multi−exposure image sensors, as shown in Figure 5.

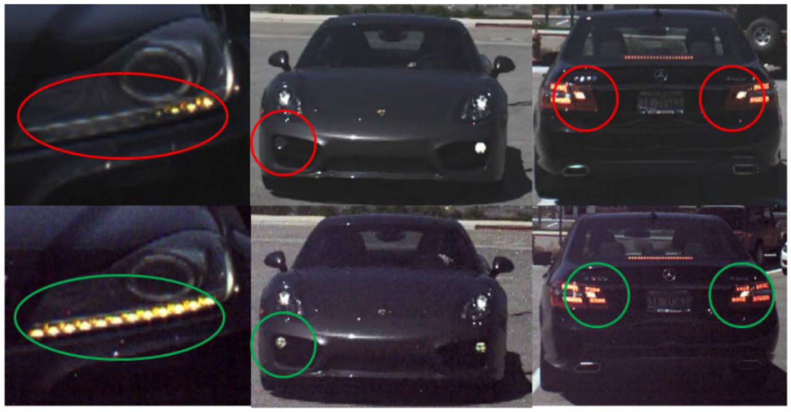

Figure 5. Multi-exposure HDR (top) vs. LFM HDR (bottom) Image Captures of Flickering LED Lights

Superior Performance

The super-exposure pixel HDR image sensors provide greater HDR and superior LFM across the entire automotive temperature range and are used for safety and other applications in the most demanding lighting and temperature environments. Our second-generation super exposure technology is based on the same architecture principals to enable even smaller and better performing HDR LFM pixels.

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