OMNIVISION®

A New Era for Single-Exposure HDR

White Paper

OMNIVISION®

TheiaCel™

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Introduction

CMOS image sensors, long employed for myriad end uses, face HDR performance challenges in many applications. OMNIVISION's new TheiaCel™ family of easy-to-implement solutions combines OMNIVISION's proprietary HDR technologies and LOFIC technology to address these challenges. This paper describes the first application of TheiaCel™ technology: mitigating LED flicker in 2.1µm pixel-generation automotive applications to enhance the HDR image and eliminate LED flicker in virtually any lighting condition.

Executive Summary

Makers of complementary metal oxide semiconductor (CMOS) image sensors for the automotive market face growing challenges with respect to achieving high-dynamic-range (HDR) imaging that delivers improved flicker mitigation and enhanced performance in low-light conditions. Implementing lateral overflow integration capacitor (LOFIC) technology in single-exposure LED flicker mitigation (LFM) sensors can help optimize dynamic range and reduce image flicker. OMNIVISION's TheiaCel™ technology harnesses the capabilities of LOFIC, together with the company's DCG™ HDR technology, to enable superior image quality regardless of lighting condition.

Automotive HDR Imaging Challenges

CMOS image sensors convert photons to electrons to create digital images in still and video cameras. As light enters the camera, the CMOS image sensor causes the photodetector on each of the pixels housed in the chip to accumulate an electrical charge based on the amount of light detected. The camera's analog-to-digital converter processes the electrical signals to yield a digital image. This established technology has continued to evolve with emerging technology requirements – mostly notably, the need for HDR capabilities that enable the sensor to achieve crisp image capture, even in areas with extremes of bright and dark light in a single scene.

Existing HDR imaging techniques often struggle to provide consistent performance in terms of dynamic range, flicker mitigation, and low-light performance. Pulse-width modulation (PWM) in LED light sources creates issues in short exposure time conditions. If that short exposure timing falls in between the LED pulses, the sensor misses detecting the LED light. Video stream flicker is created by frames missing the "on" pulse when the sensor tries to capture bright LED light with short exposure time; however, increasing exposure time to capture the LED pulse causes excess pixel saturation.

In the automotive market, flicker from LED traffic lights or traffic signs poses a serious challenge for HDR solutions (Figure 1), preventing driver-assistance and autonomous driving systems from being able to correctly detect lighted traffic signs. Mitigating this challenge requires an approach that can be easily integrated into a CMOS image sensor. Some solutions that have achieved good LFM capabilities have resulted in reduced image quality, especially for low-light signal-to-noise ratio (SNR), high temperature performance, etc.

Figure 1. LED image flicker can create a problem in HDR camera systems for traffic lights, as shown in the close-up.

The goal is not only to achieve HDR performance, but also to prevent a drop in signal-to-noise ratio (SNR) at the signal transition point or knee point of the SNR curve. This improves sensing accuracy over a wide range of illumination conditions, preventing under- or overexposure.

For single-exposure HDR, several technologies have been explored for LFM applications, including dual conversion gain (DCG), split-diode (large/small photodiode) architecture with attenuation in the small photodiode, or a combination of these. Together, these approaches can achieve a dynamic range of around 100dB, making them useful for such automotive applications as in-vehicle cameras. Introducing another technology – LOFIC – enables creation of 2.1µm LFM sensors with higher total dynamic range, enabling them to achieve optimal object detection in vehicle driver assistance and autonomous driving systems.

What Is LOFIC?

LOFIC technology is key to realizing low noise, high sensitivity, and good linear response because it can achieve a wide dynamic range in a single exposure. By harnessing LOFIC's unique capabilities, HDR imaging can be effectively enhanced, allowing for superior image quality across a wide range of lighting conditions.

In DCG pixels, a photodiode's photoelectrons are read out twice in different gains: low-conversion gain (LCG) and high-conversion gain (HCG). A sensor that utilizes LOFIC stores more signal electrons by collecting overflow electrons in the large capacitor within each pixel. This is essential to achieving the desired dynamic range.

Combining DCG with LOFIC or DCG and split-diode with LOFIC significantly improves LFM range for single-exposure HDR. A split-diode LOFIC sensor achieves the ultimate LFM range, while a single-photodiode LOFIC sensor enables a good balance between low-light SNR and dynamic range in a small-pixel product. The key to automotive image sensor success is to achieve the best performance in the parameters of greatest importance to CMOS image sensor developers.

Next-Generation Solution

Makers of CMOS image sensors for automotive applications seek superior LFM sensor performance in the areas of:

- Low-light image quality
- High device temperature
- LFM/HDR range

OMNIVISION's new 2.1µm single-pixel TheiaCel™ LFM sensor technology is the first automotive solution to deliver high LFM dynamic range without sacrificing image quality, offering the best-balanced performance of any solution on the market. TheiaCel™ technology combines next-generation LOFIC capabilities with the strengths of OMNIVISION's proprietary HDR technology (patented DCG and split-diode technology), which captures extremely high-contrast scenes for optimum content and image quality.

OMNIVISION's TheiaCel™ DCG + LOFIC solution achieves a wider dynamic range than earlier single-exposure HDR architectures. The first TheiaCel™ product is the OX08D10 CMOS image sensor, with 8-megapixel (MP) resolution to enable HDR image capture at up to 200 meters. This range, optimal for automotive applications, is the sweet spot for delivering the best balance between SNR1 and dynamic range.

Compared to its non-LOFIC-based predecessor, the new X8D device exhibits overall superior performance in several key areas: 3.3x higher LFM dynamic range, nearly 3x higher total dynamic range, and more than 50% higher sensitivity (see Figure 2). This will enable the new TheiaCel™ device to overcome excess brightness and dark/cloudy conditions to provide consistent, flicker-free imaging for high-performance LFM sensors.

Item	OX08B40	OX08D10
Read Data	HCG / LCG / aSPD / VS	HCG / LCG / LOFIC (12b) / VS
PD Configuration	4-Cell Split Diode	Single PD
Full Well Capacity	1x	32x
Effective SPD Attenuation	11x	- - -
LPD Sensitivity	1x	1.7x
SNR1 @ 30 fps	1x	0.47x
Brightest LFM @ 12 ms	1x	2.1x
LFM D-Range	1x	3.3x
Total D-Range	1x	2.9x

Figure 2. OMNIVISION's TheiaCel™ OX08D10 8-MP 2.1 µm a-CSP-packaged CMOS image sensor compared to the previous-generation OX08B40 image sensor.

The OX08D10 leverages TheiaCel™'s single-photodiode LOFIC architecture with its large capacitor – key for achieving high dynamic range – to deliver industry-leading wide LFM range, low power and lowlight performance. Housed in OMNIVISION's a-CSP™ package technology, the OX08D10 is 50% smaller than other exterior cabin sensors on the market (Figure 3). Products based on the new architecture overcome excess brightness and dark/cloudy conditions to provide consistent, flicker-free imaging. The OX08D10 will enter mass production in the second half of 2024.

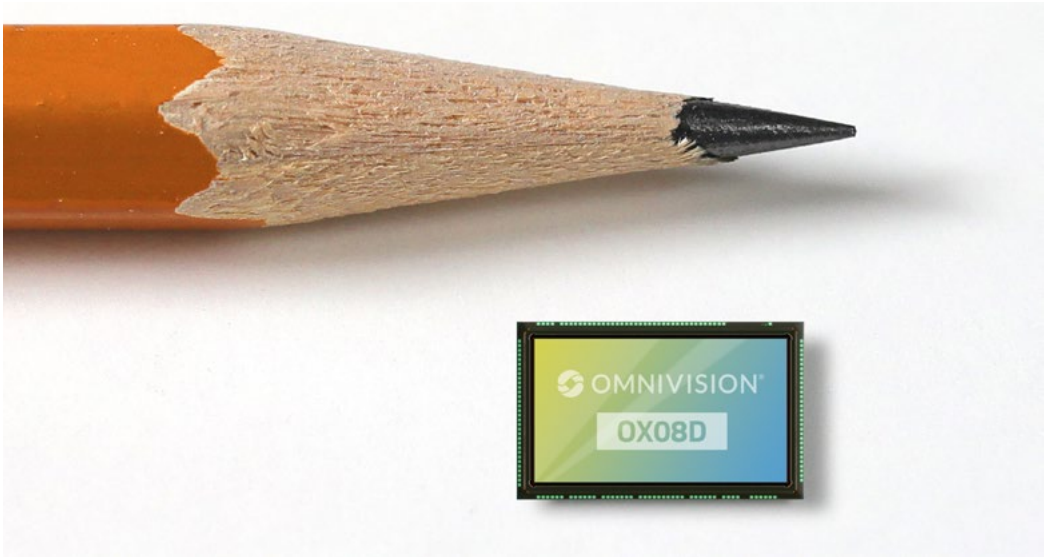

Figure 3. OMNIVISION's TheiaCel™ OX08D10 8-MP 2.1 µm a-CSP™-packaged CMOS image sensor is 50% smaller than other currently available automotive exterior cabin sensors.

Summary

HDR imaging has entered an era in which existing solutions cannot address some key requirements. Recent advances enable LOFIC technology to solve challenges that existing solutions can't. As the leading provider of CMOS image sensors for the automotive market, OMNIVISION is building on its proven solution portfolio with the new TheiaCel™ LFM sensor family. The technology's advanced LFM range will enable HDR imaging to address not only challenging sensor scenarios, eliminating LED flicker regardless of lighting conditions, but also key on-vehicle automotive applications such as mirrors and front-view cameras.

About OMNIVISION

OMNIVISION is a global fabless semiconductor organization that develops advanced digital imaging, analog, and touch & display solutions for multiple applications and industries, including mobile phones; security and surveillance; automotive; computing; medical; and emerging applications. Its award-winning innovative technologies enable a smoother human/machine interface in many of today's commercial devices.

For more information, visit: https://www.ovt.com/applications/automotive/

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