TrueSNAP Shutter Freezes Fast-Moving Objects

An Electronic Global Shutter Architecture in Micron's CMOS Image Sensors

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Objects in Motion

Clear digital images can be difficult to capture, especially when the subject of the picture is moving. If the camera's exposure time is not aligned precisely with the movement of the object, the image blurs. The edges of a blurred image are nearly impossible to detect, rendering certain image-processing algorithms unusable. To ensure crisp, accurate image capture, even with fast-moving subjects, Micron has developed TrueSNAP™ technology—an electronic shutter imager architecture for CMOS image sensors that is capable of providing freeze-frame images. This architecture, sometimes referred to as global shutter, offers precise control over an image sensor's exposure time, which enables the camera to freeze the image and minimize blur.

How Global Shutter Works

TrueSNAP—true shutter node active pixel—refers to the design of the pixels. Each pixel contains not only a photodiode for photon-to-electron conversion and collection but also an analog pixel memory (shutter node) where signal charge may be stored prior to readout. It is the inclusion of this analog pixel memory that distinguishes this pixel design from that of the more common electronic rolling shutter image sensors.

Because of this pixel memory, the image sensor's exposure time can be controlled, at both the start and end of an exposure. Exposure starts after the photodiode is released from its reset or zero signal charge state. The photodiode then integrates the incident photoelectric charge and the signal charge is transferred from the photodiode into the analog pixel memory. This transfer of signal charge to the memory ends the exposure. Once the signal charge is in the analog memory, it becomes isolated from any new incident photoelectric signals—thus the analog memory acts like a shuttering mechanism.

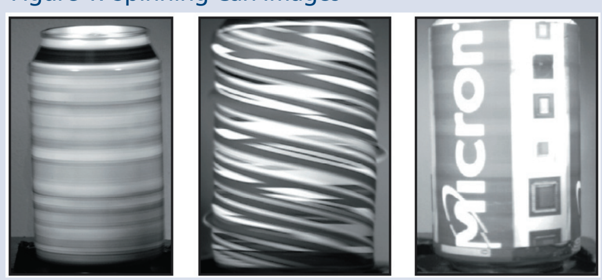
Unlike electronic rolling shutter architectures, TrueSNAP architecture controls all pixels simultaneously. All photodiodes share the same exposure time. They all start and stop exposing at simultaneously. This common, or global, exposure time enables a short exposure that effectively freezes the image motion (minimizes motion blur).

Accurate Machine Vision

Machine vision or automated inspection systems need to accurately capture images of fast-moving objects. In these systems, an object passes through the camera's field of view as a conveyor belt or other mechanism moves it along. To demonstrate the advantage of a TrueSNAP shutter in machine vision applications, we placed a can on a spinning platform and photographed it. We used a camera with a global shutter, one with an electronic rolling shutter, and one with a standard shutter.

The spinning can test simulates a quality control machine-vision application, where a product such as a wine bottle is rotated in front of the camera to be inspected for manufacturing defects. This setup is also functionally equivalent to a barcode reading system where packages or documents are passed quickly by a camera. The resulting image is analyzed to detect and read the barcode.

Figure 1: Spinning Can Images



Naked eye | *Sensor with rolling shutter* | *TrueSNAP global shutter*

Blurred movement dominates the first image capture. It happens because the exposure time is too long relative to the object in motion. The left-most edge of the letter "M" in the Micron logo has moved across all pixels in the imaging area during the exposure time. This has caused this left-most edge to blur across all pixels, making it impossible for an image processing system to determine the precise location of this edge.

The image captured using an electronic rolling shutter is also distorted. Here, all the rows of the image sensor begin and end their exposures at different times. The image appears to tear, inducing a "Christmas tree" effect. Once again, it is impossible to precisely locate the left-most edge of the letter "M" in the Micron logo.

The last image shows how a TrueSNAP image sensor freezes the spinning can. Not only has image tearing been avoided due to the simultaneous exposure of all pixels, but the motion blur has been minimized by the short exposure. In this image, the left-most edge of the "M" can be precisely detected. Therefore, this image is usable for image analysis, edge-detection, or optical character recognition systems.

Freeze Frame for Sequence Capture

Many industrial machines need to capture frame-by-frame sequences to analyze products or processes. We tested the freeze-frame capabilities of our TrueSNAP-enabled imagers by photographing a golf swing. In our golf swing analysis, as in machine-vision applications, the camera needed to operate in a super slow motion mode. This means that the image sensor must be capable of capturing images very quickly with very short exposures. The TrueSNAP architecture enables this high speed operation. All pixels share the same exposure time, which enables the camera to freeze the image. By transferring the photodiode charge into the analog memory, the image sensor can be designed with multiple output taps, so the image data can be read out quickly, which enables frame rates up to 500 frames per second.

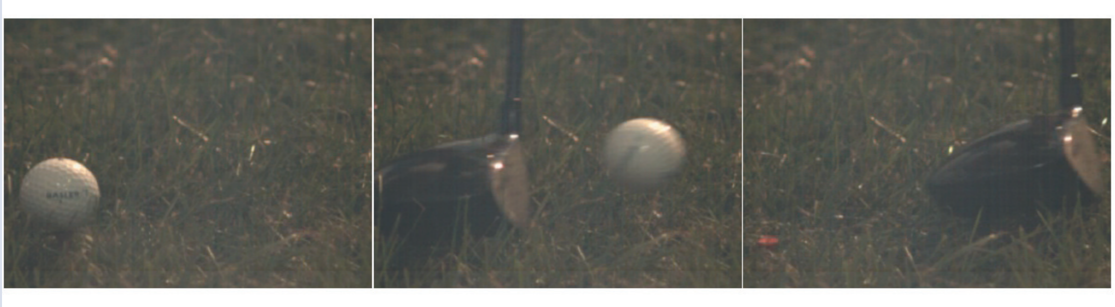
This sequence of images shows the path the golf club head takes as it strikes the ball. The first image is prior to contact, the second image is during contact, and the last image is after contact. Examining the ball in the second image, one can see the start of motion blur in the image. Electronic rolling shutter or standard shutter versions of this sequence of images would be blurry and would suffer from the sloping Christmas tree effect.

Motion Blur Predictions

With a TrueSNAP image sensor, the amount of motion blur in the system is predictable. The object of interest moves a certain distance in a given time. The magnification of the lens converts the distance the object travels to an equivalent number of pixels at the image sensor. This number of pixels is the motion blur of the object in the image. Given the needed edge detection accuracy of the image processing algorithms, it can be determined if the motion blur in the image is acceptable.

The amount of motion blur can be minimized by shortening the exposure time. However, to maintain the same signal level, the power of the imaging system's light source must be proportionally increased.

Figure 2: Golf Swing Images



(Images provided courtesy of Basler AG, Ahrensburg, Germany)

Global Shutter for Automotive

Beyond machine vision and industrial applications, CMOS imagers are designed for the automotive market. They are in demand for their, size, cost, durability, and ease of design. In vehicles, imagers need to process scenes and capture images at highway speeds. They require a global shutter for applications such as lane-departure warning, adaptive cruise control, forward crash mitigation, and bending headlights.

Conclusion

The TrueSNAP architecture freezes digital images. This is necessary when a camera capturing a fast moving object needs to detect the edges in the resulting image. Optical character recognition, motion analysis, laser profiling, automotive safety, and ballistics analysis are all made possible or simplified with TrueSNAP image sensors.

For more information on TrueSNAP technology or for more information on these features, refer to the MT9V022 or MT9M413 data sheets on Micron's Web site at www.micron.com/imaging.