Improving the dynamic range of CMOS image sensor using feedback reset mechanism

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Abstract In this paper, we proposed a novel image sensor using a feedback reset mechanism. To extend the dynamic range, an additional feedback circuit which is composed of a comparator and a voltage converter is needed. The floating diffusion node in the APS is reset to the medium voltage at high illumination. The proposed image sensor is based on the 3-transistor active pixel sensor (APS). It is possible to switch back and forth between normal mode and feedback reset mode, and to control both feedback reset time and voltage values. The proposed image sensor was designed and fabricated with a 0.35 μm 2-poly 4-metal CMOS process.

Keywords: CMOS image sensor, wide dynamic range, feedback reset,

1. Introduction

Recently, wide dynamic range (WDR) CMOS image sensors (CISs) have wide applications ranging from digital cameras, security systems and automobiles [1-2]. CISs have main issues of high sensitivity, low noise, WDR. As CMOS technology scales down and CIS resolution increases, pixel size decreases, making the chip design needed to attain high performance more difficult.

Conventional CISs have a dynamic range of 1 to 10^3 lux. The image sensors with narrow dynamic ranges are unable to distinguish a signal in bright or dark conditions, leading to captured images with poor contrast. Methods for improving dynamic range include multiple sampling, logarithmic response, and the use of lateral overflow integration capacitors. [2-4] However, multiple sampling consumes more power because signals must be read several times. Because of its use of capacitors, lateral overflow integration technology has an increased pixel size. Logarithmic image sensors have high noise and poor image quality owing to their low signal-to-noise ratio (SNR).

In this paper, a CIS with a feedback reset mechanism for improving dynamic range is proposed. This higher dynamic range image sensor can detect a wider range of scene illuminations and produce images with more detail. The proposed sensor operates using a linear-type sensor that extends its dynamic range through mid-level resetting before the end of the exposure time. Although the proposed image sensor design requires additional circuitry, it significantly extends and allows for the control of the dynamic range through the use of the feedback reset mechanism.

2. Operating principle

To achieve WDR performance, the output voltage of the APS must increase as illumination increases without saturating the signal. In our proposed mechanism, this is accomplished by sampling the signal prior to the end of the exposure time and applying it to the input of the comparator in order to obtain feedback reset. The signal is below the reference voltage at high illumination and the output signal, which is initially high, is reduced to a medium level by the voltage converter. Finally, the APS is feedback-reset at high illumination and its output signal for processing image is sampled at the end of the exposure time. The proposed image sensor can detect signal at high illumination. The operation for feedback reset does not occur at low illumination because the output of the comparator is low.

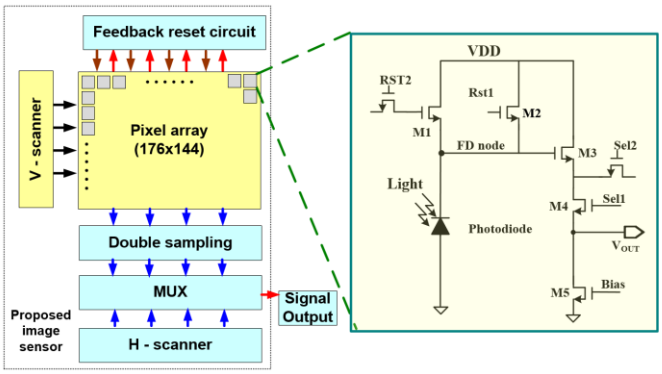

Fig. 1. Schematic diagram of the proposed image sensor.

The proto-type image sensor chip is composed of a 176 x 144 pixel array using the proposed APS, a vertical scanner, a feedback reset circuit, and a readout circuit. The proto-type image sensor chip was designed and measured using 0.35-μm 2-poly 4-metal CMOS process.

3. Measurement Results

Figure 2 shows timing diagram of the proposed image sensor. The output voltage of the proposed image sensor was measured at an exposure time of 33 ms at 30 frames per seconds (fps). In the measurements, the reset and feedback reset voltages were 3.3 and 2.5 V. It shows the output voltage of active pixel sensor (APS) when illuminating the same light. The output voltage is changes according to the feedback reset time.

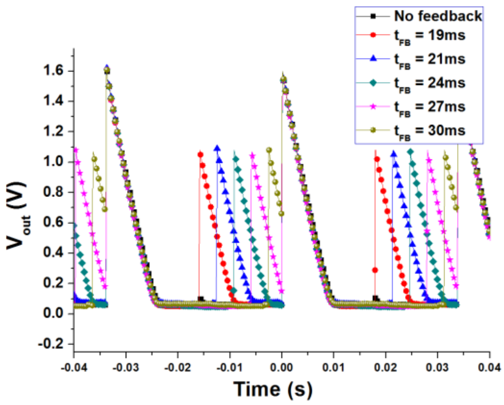

Fig. 2. The timing diagram of the proposed image sensor. (measurement results).

Measurement results showing variation of the output voltage with the light intensity as a function of feedback reset time is shown figure 3. Measurement results in which the output voltage is varied from 1.6 to 0 V by changing the light intensity. The slope of the output voltage of the proposed image sensor remains unchanged at low illumination, indicating that sensitivity is maintained under these conditions. However, as the reset time increases the slope following feedback reset decreases, indicating that the output signal is not saturated because the saturation time has been delayed. Maximum dynamic range is achieved at a feedback reset time of 30 ms, at which point the dynamic range is increased to 19.5 dB.

The overall performance characteristics of the proposed image sensor are summarized in Table I.

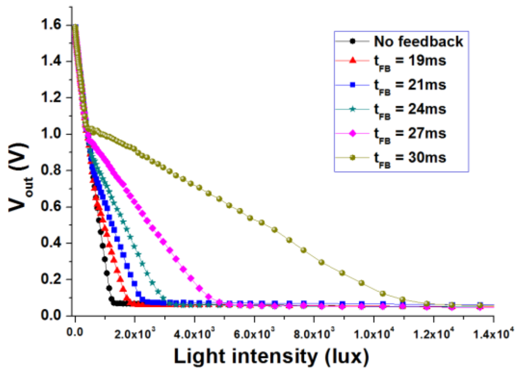

Fig. 3. Measurement results showing variation of the output voltage with the light intensity as a function of feedback reset time.

Table. 1. Characteristics of the proposed image sensor.

Process	CMOS 2-poly 4-metal 0.35 μm
Pixel size	13 μm × 13 μm
Fill factor	31%
Resolution	176 × 144
Supply voltage	3.3 for analog and digital
Dynamic range	61.5 dB (No feedback reset) ~ 81 dB (Feedback reset) ; 19.5 dB extended

4. Conclusions

Proposed image sensor can vary the dynamic range by using feedback resetting mechanism. The schematic of the proposed image sensor is slightly larger than that of conventional 3-transistor image sensor due to an additional circuit which is composed of a comparator and a voltage converter. However, the dynamic range control is easier than other reported methods and the dynamic range of the proposed image sensor using feedback reset mechanism can be increased to 19.5dB.

We presented the image sensor which can be switched between normal mode and WDR mode during expose time. Therefore, the proposed sensor might be useful for wide dynamic range image sensor applications.

Acknowledgments

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