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Design and implementation of interleave-integration-control image sensor

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Abstract In this study, we propose an imaging method, which can simultaneously acquire images with different characteristics by controlling the reset and readout timings in a block unit. The image sensor can control the reset and readout timings dynamically in a block unit via a threshold operation during the exposure period.

Key words: image sensor, exposure pattern control

1. Introduction

In recent years, reductions in the pixel size of an image sensor have been facilitated by the miniaturization of semiconductors [1]. Therefore, it is now possible to obtain a high-resolution image without increasing the chip size of the sensor. However, low light sensitivity and increases in the amount of readout information are typical issues caused by reducing the pixel size [2]. Thus, there is a tradeoff between spatial resolution, temporal resolution, and light sensitivity. In this study, we propose a new imaging method that improves the performance of image sensors. By controlling the exposure time pattern in a pixel block unit, sampling points are arranged appropriately in the space-time domain. It is expected that the reconstructed image quality will be improved after imaging by post-signal processing. In this paper, we describe the proposed imaging method and prototype image sensor.

2. Proposed imaging method

Figure 1 shows the proposed imaging method based on three-dimensional coordinates: the spatial-axes x and y, and time-axis t. The length of the rectangular parallelepiped along the time-axis is the exposure time length. In the conventional imaging method, all of the pixels in the focal plane are treated with the same imaging parameters. However, in the proposed imaging method, common imaging parameters are set at regular intervals in the horizontal and vertical directions. As shown in Figure 1, pixels with the same number are arranged at regular intervals, thereby obtaining an image where pixels with different number have different exposure time lengths, reset timings, and readout timings.

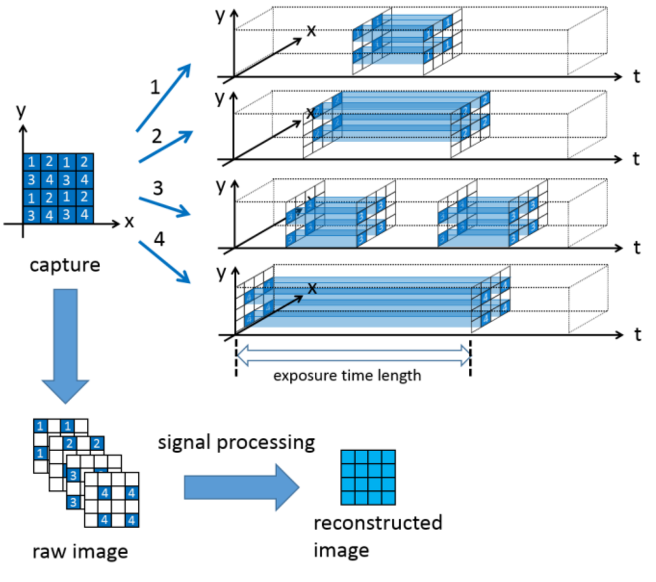

Fig.1 Proposed imaging method

Thus, high dynamic range and motion blur-free images can be obtained by capturing images with multiple different parameters in the focal plane simultaneously and by utilizing the characteristics of images with different parameters. It is expected that the quality of the reconstructed image will be improved after imaging by performing post-signal processing, such as registration with high accuracy motion estimation, removing the blur, dynamic range adjustment, and spatial and temporal interpolation.

3. Prototype image sensor

Figure 2 and Table 1 show the overall structure and the design specifications of the prototype image sensor, respectively. The image sensor comprises a pixel array (256 × 256 pixels), vertical

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shift register, row level shifter, column readout circuit, column parallel A/D converter, horizontal shift register, column level shifter, and an 8-bit binary counter. The reset operation in the image sensor can be controlled in the column and row directions. The pixel circuit comprises four transistors, as shown on the left of Figure 2. There are two reset transistors in the pixel circuit. The reset operation is performed only when the column and row reset signals are both high. The block unit size can be controlled by adding skip reset and skip readout functions to the vertical and horizontal scanning circuits.

4. Function of prototype image sensor

The image sensor can be controlled using a 4 × 4 pixel block as the maximum size. Figure 3 shows the circuit configuration for 4 × 4 pixel block control. Using 4 × 4 pixel block control, it is possible to assign the reset timing and exposure time length for each of the 16 pixels in the red block. Because the pixel block is repeated in the horizontal and vertical directions, pixels with the same number are controlled by the same imaging parameters. There are four reference voltages (Vref0–Vref3) in the single slope A/D converter. It is possible to input the ramp waveforms with different characteristics for each of Vref0–Vref3. The dynamic range is increased by changing the upper and lower limits of the ramp waveforms according to the incident light intensity. When inputting a constant voltage into Vref0–Vref3, the threshold operation of a pixel signal during exposure can be performed using a comparator. The result is determined from a 1-bit flag signal. Appropriate imaging parameters are determined by performing the threshold operation and estimating the incident light intensity.

5. Conclusion

Our proposed imaging method can acquire images with different characteristics simultaneously in a focal plane. We also designed and fabricated a prototype image sensor chip. In future research, we will consider further post-signal processing and implementation in an FPGA to facilitate real-time processing.

References

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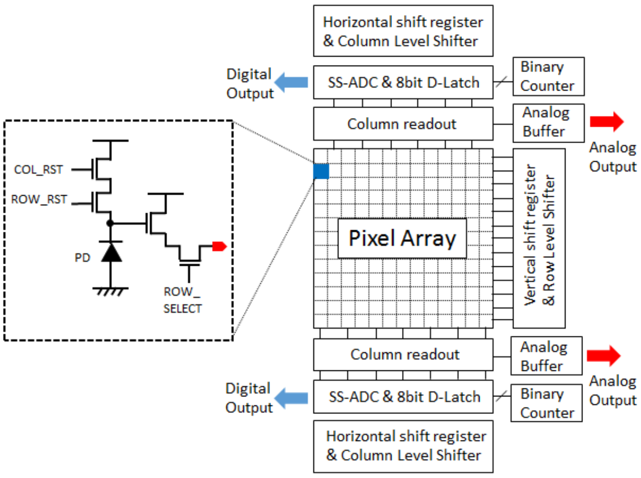

Fig.2 Overall structure of image sensor

Table.1 Design specifications

Process	0.18μm CMOS (1poly-5metal)
Power Supply [V]	3.3, 4.2
Die Size [mm^2]	2.52 × 5.18
Number of Pixels [pixels]	256 × 256
Pixel Size [μm^2]	7 × 7
Fill Factor [%]	30
Number of Transistor [Tr./pixel]	4

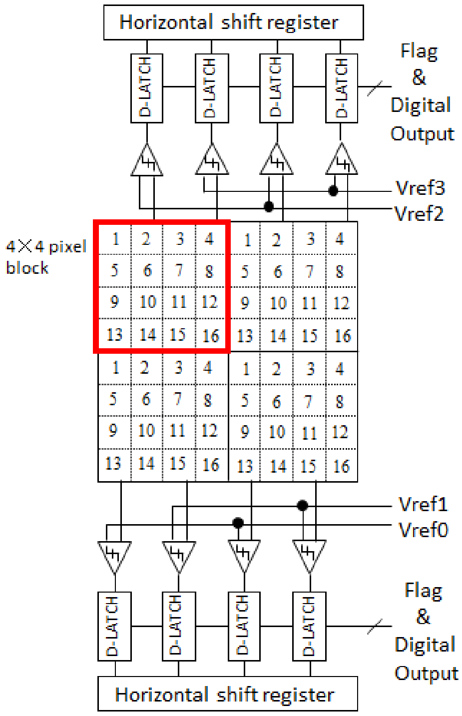

Fig.3 4✕4 pixel block control