Block-wise-controlled Image Sensor with Variable Resolution, Frame rate, and Exposure Time for Scene Adaptive Imaging

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Abstract This paper proposes a block-wise-controlled image sensor, which has pixel blocks with independently controllable pixel binning and exposure time. The frame rate, resolution, and dynamic range can be controlled according to the shooting scene. A 1K x 1K prototype image sensor with 16 x 17 blocks (64 x 64 pixels in each block) demonstrates the capability of block-wise control of the image sensor using a specified external feedback signal.

Keywords: Block-wise control, CMOS image sensor, High-framerate, High-resolution

1. Introduction

Tradeoffs between frame rate, resolution, noise performance, and dynamic range make it difficult to design the high pixel-rate image sensors [1] required for recent imaging systems such as 8K, VR, and 360°video [2]. To overcome these tradeoffs, we propose a scene-adaptive imaging system that locally controls the imaging parameters area-by-area according to the characteristics of the shooting scene such as object movement and brightness distribution. Thereby, imaging parameters such as resolution and framerate can be allocated according to the scene being recorded, and the subjective image quality can be expected to increase.

A key technology in this system is the proposed architecture for a block-wise-controlled image sensor. This architecture divides the pixel array into blocks in which an external feedback signal is used to control pixel binning and exposure time individually. This feedback signal is supposed to be obtained by external scene analysis and specifies appropriate imaging parameters area by area.

This paper presents a prototype block-wise-controlled image sensor and demonstrates its capability for block-wise control of resolution, framerate, and exposure time.

2. Prototype block-wise-controlled Image Sensor

Figures 1 and 2 show the die image and the pixel architecture of the prototype image sensor. The prototype image sensor consists of a 1024 × 1088 pixel array, a pixel driver, column-parallel ADCs, an output block, and a mode controller. The die's dimensions are 6.5 mm (H) × 7.7 mm (V). The pixel array is divided into 16 × 17 control blocks (64 × 64 pixels for each block). The effective pixel areas are 15×15 blocks with the other blocks being optical black. Figure 2 (c) shows that every 2×2 pixels (depicted as A, B, C, and D) share a pixel amplifier and receive readout pulses through switches provided for each pixel. These switches are independently controlled by the control signals from the mode controller. Therefore, one selected pixel signal or pixel-binned signal of the 2×2 pixels can be selectively read out according to the control signal. The mode controller can specify the control signals for each block according to externally received feedback signals.

Table 1 summarizes the four operation modes supported by the

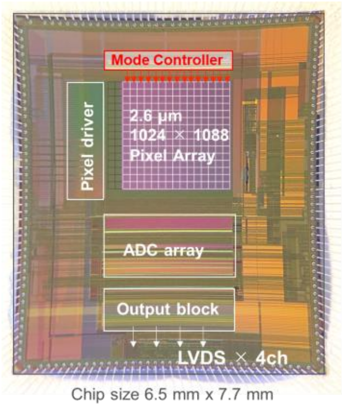

Fig. 1. Die photograph

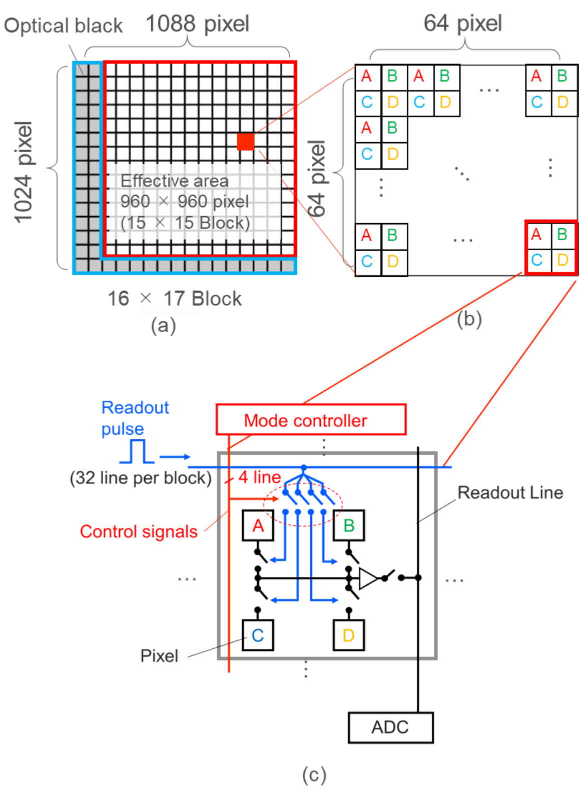

Fig. 2. Pixel architecture: (a) pixel array, (b) pixel block, and (c) pixel readout circuit for 2×2 pixels.

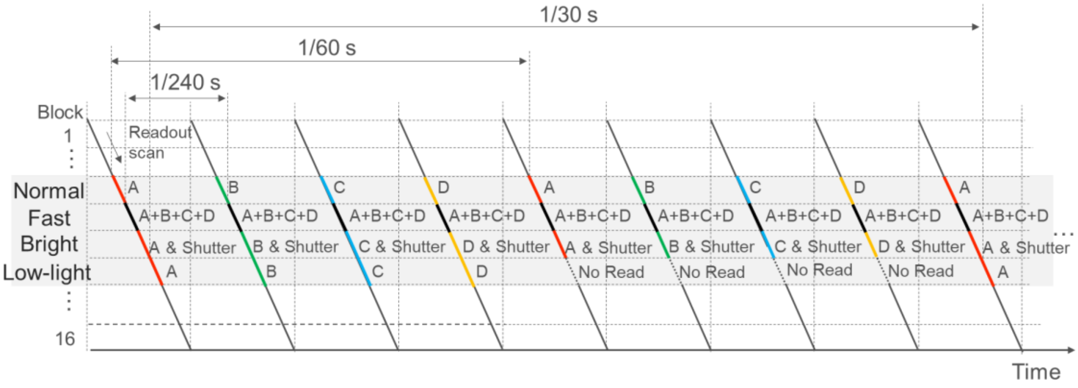

Fig. 3. Readout scan method

image sensor, and Fig. 3 shows the readout scanning method for these modes. The readout scan period is 1/240 s for all modes. The scanning method for each mode is (a) Normal mode: One selected pixel signal is read out for each scan. This enables subframe readouts with 1/240 s periods in the order of A, B, C, and D. The exposure time is 1/60 s. and the resolution is 64 ×64 pixels per block. (b) Fast mode: A pixel-binning readout is performed for each scan. This enables high-speed readouts with a 240 fps framerate, but the resolution deteriorates to 1/4 (32 × 32 pixels per block). (c) Bright mode: The subframe readout is performed similarly to the normal mode, but the exposure time is limited to 1/240 s by the electronic shutter. (d) Low-light mode: The subframe readout and 4-frame readout pauses are performed alternately. This extends the exposure time to 1/30 s.

Table 1. Operation modes

Mode	Resolution	Frame rate	Exposure time
Normal	64 × 64	60 fps	1/60 s
Fast	32 × 32	240 fps	1/240 s
Bright	64 × 64	60 fps	1/240 s
Low-light	64 × 64	30 fps	1/30 s

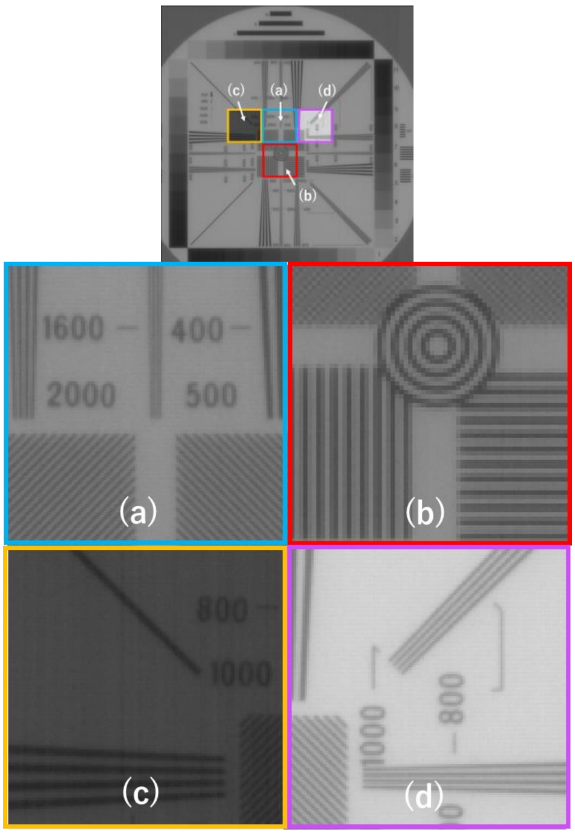

Fig. 4. Acquisition images: (a) normal mode, (b) fast mode, (c) bright mode, and (d) low-light mode.

3. Experimental results

The acquisition images are shown in Fig.4. To verify the block-wise control function, the operation modes are set by the specified external feedback signal. The images in each mode correspond to their imaging parameters: In fast mode, pixel binning results in an image with 1/4 the resolution compared to normal mode. In bright mode, the signal value is 1/4 due to the exposure control of 1/240 s. In low-light mode, the signal value is twice that of normal mode because the exposure time is extended to 1/30 s.

Figure 5 shows the comparative motion blur between the normal and fast modes. The left half is set to fast mode and the right is set to normal mode. Compared to normal mode, fast mode reduces motion blur.

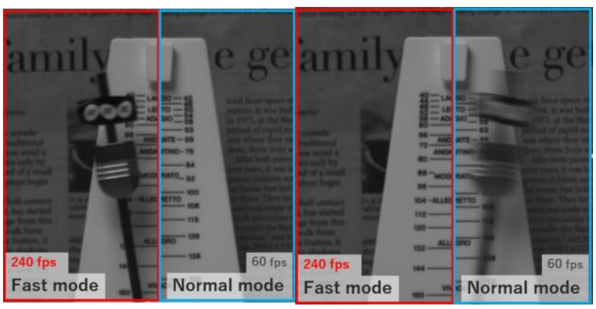

Fig. 5. Comparison of motion blur in normal mode and fast mode.

4. Conclusion

The prototype block-wise-controlled image sensor demonstrates the block-wise control of resolution, framerate, and exposure time using the specified external feedback signal. This result indicates that the architecture of the prototype image sensor is suitable for realizing scene-adaptive imaging.

References

[1] S. Kawahito, "Column-Parallel ADCs for CMOS Image Sensors and Their FoM-Based Evaluations," IEICE Trans. Electron., vol. E101-C, no. 7, pp. 444-458, 2018.

[2] Recommendation ITU-R BT. 2123: "Video Parameter Values for Advanced Immersive Audio-Visual Systems for Production and International Programme Exchange in Broadcasting," 2019.