

## 52 Mega-pixel APS-H-size CMOS Image Sensor for Super High Resolution Image Capturing

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### Abstract

**We have developed a new CMOS image sensor having pixels of more than 52M in APS-H size. The CMOS image sensor has the most number of pixels known to date without stitching. The sensitivity of the monochromatic image sensor is  $39000\text{e}^-/\text{lx}\cdot\text{s}$ . The sensitivity of the color image sensor (green pixel) is  $16600\text{e}^-/\text{lx}\cdot\text{s}$ . Pixel size is  $3.2\mu\text{m} \times 3.2\mu\text{m}$ . Random noise is  $5.5\text{e}^-$  with a saturation level of  $24000\text{e}^-$ . The CMOS image sensor has  $5 \times 5$  random block readout mode and  $4(2 \times 2)$  adjacent pixels averaging mode. The reproduced image shows splendid high resolution.**

### 1. Introduction

The number of pixels in image sensors used for digital cameras and camcorders is growing year by year. In addition, demand for high resolution image capture in machine vision and security cameras is becoming stronger. We have already reported small pixel CMOS image sensor for full high-definition camcorders [1] and large format image sensor chip for digital SLRs [2]. The both technologies have been merged to realize a 52 Mega-pixel CMOS image sensor in APS-H film size. The CMOS image sensor has the most number of pixels known to date without stitching [3].

### 2. Pixel Architecture

Figure 1 shows schematic cross section of pixel. Shallow trench isolation (STI) is employed for the pixel isolation. The buried photodiode is surrounded by the potential barrier of p type regions. These structures contribute to low cross talk, high sensitivity and high saturation. The pixel pitch is  $3.2\mu\text{m} \times 3.2\mu\text{m}$  with high conversion gain using 2-shared pixel

architecture. M1, M3, M4 and FD represent transfer gate, reset MOS transistor, source-follower amplifier and floating diffusion, respectively.

We have experimentally fabricated both monochromatic image sensor and color image sensor. The monochromatic image sensor has micro lenses and colorless interlayer that has same thickness as the color filter of the color image sensor.

### 3. Circuit Structure

Figure 2 shows readout equivalent circuit with pixel unit. Two buried photodiodes (PD1, PD2) and two transfer gates (M1, M2) share one FD, reset MOS transistor (M3) and source-follower amplifier (M4) in the pixel unit [1].

The signal on the output line is amplified by a column amplifier to suppress random noise [4]. The column amplifier consists of a CMOS operational amplifier, an input capacitor ( $C_0$ ), a feedback capacitor ( $C_{FB}$ ) and a switch MOS transistor. The amplifier gain is set by the ratio of  $C_0$  to  $C_{FB}$ . Gain settings of  $\times 1.5$ ,  $\times 3$ ,  $\times 6$ ,  $\times 12$  and  $\times 24$  are employed.

The noise cancellers, consisting of line memories ( $C_{TN}$  and  $C_{TS}$ ), remove the vertical offset stripes caused by the column amplifiers. Each line memory stores the reset level of the column amplifier ( $N$ ) and photo signal level ( $N + S$ ), individually. Output amplifier subtracts voltages stored on  $C_{TN}$  from the voltage on  $C_{TS}$  and output the amplified signals.

Figure 3 shows a block diagram of the CMOS image sensor. The image signals are read-out in 8ch with 20MHz clock input. Vertical shift register and horizontal shift register (represented by  $V1, \dots, V5$  and  $H1, \dots, H5$ ) are divided into 5 blocks in order to achieve arbitrary block group readout. Decoders control these divided shift registers.

#### 4. Specification and characteristics

Specifications and characteristics are summarized in Figure 4. The sensitivity of the monochromatic image sensor is  $39000e^-/lx \cdot s$ . The sensitivity of the color image sensor (green pixel) is  $16600e^-/lx \cdot s$ . Random noise is  $5.5e^-$  with a saturation level of  $24000e^-$ . Dark current is  $56.4e^-/s(@60^\circ C)$  per pixel.

Figure 5 shows input referred noise versus actual column amplifier gain of the image sensor. Up to  $\times 3$  gain setting (actual gain is 2.93), the signal can be read out without losing pixel saturation.

Figure 6 shows spectral characteristic of the color image sensor. High sensitivity and low cross talk have been realized.

Figure 7 shows reproduced image of 52M-Pixel taken by the image sensor with full readout mode. With 52M-pixels, splendid high resolution is achieved. Figure 8 is another reproduced image with full readout mode.

Figure 9 shows reproduced image with  $5 \times 5$  random block readout mode. With this mode, any partial  $25(=5 \times 5)$  blocks can be read. The readout of

arbitrary combined blocks is possible. In addition, the monochromatic image sensor has  $4(2 \times 2)$  adjacent pixels averaging mode. In this mode, the signals in vertical adjacent pixel are averaged in FD of 2-shared pixel, thus can be readout faster than a 52M full readout mode.

Figure 10 shows a chip micrograph. of the CMOS image sensor.

#### 5. Conclusion

Super high resolution image capturing is archived with the APS-H size 52M-pixel CMOS image sensor. The CMOS image sensor has small random noise and high saturation. The reproduced image shows splendid high resolution. The CMOS image sensor has random block cropping mode. The monochromatic CMOS image sensor has  $4(2 \times 2)$  adjacent pixels averaging mode.

#### Acknowledgement

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#### References:

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- [2] S. Inoue, et al., "A 3.25M-pixel APS-C Size CMOS image sensor," *IEEE Workshop on CCDs and Advanced Image Sensors*, pp.16-19, 2001.
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- [4] S. Kawahito, et al., "A Column-Based Pixel-Gain-Adaptive CMOS Image Sensor for Low-Light-Level Imaging," *ISSCC Dig. Tech. Papers*, pp. 224-225 Feb., 2003.

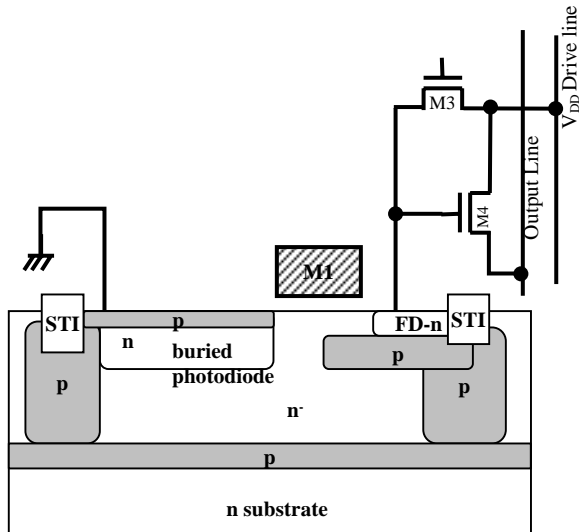


Figure 1 Schematic cross section of pixel.

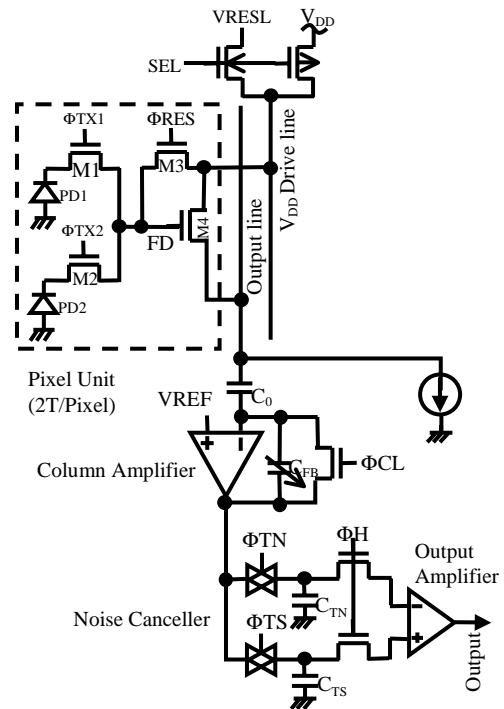


Figure 2 Readout equivalent circuit with pixel unit.

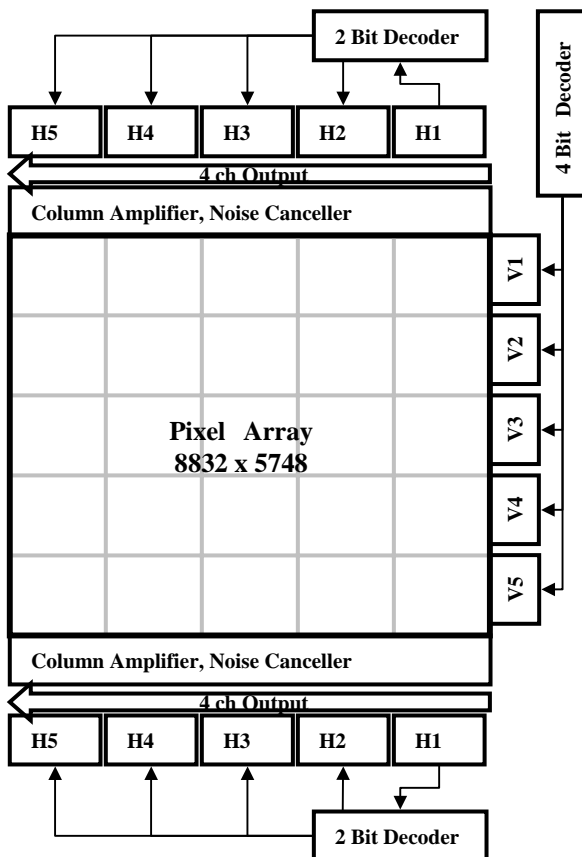
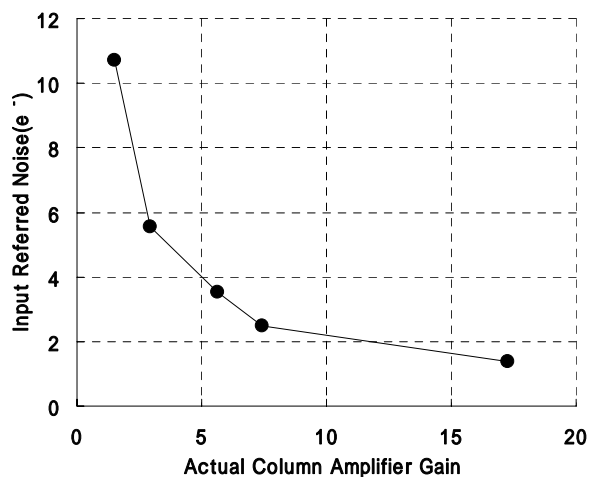


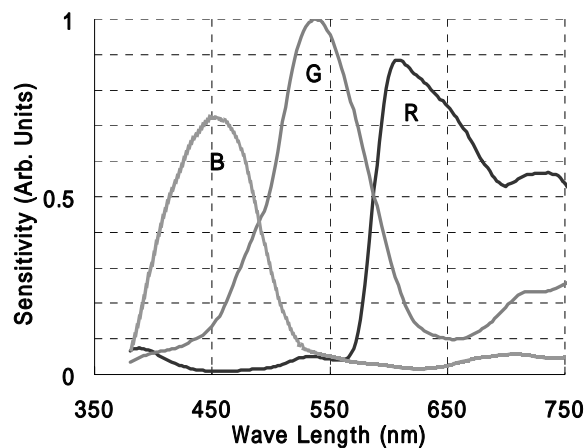
Figure 3 Block diagram.

Technology	0.18μm 1P 3M CMOS
Chip size	31.6mm(H)x23.1mm(V)
Pixel size	3.2μm(H)x3.2μm(V)
Number of total pixels	8984(H)x5792(V)
Number of effective pixels	8832(H)x5748(V)
Pixel rate	160MHz (20MHz × 8ch)
Column gain stage	× 1.5, × 3, × 6, × 12, × 24
Readout Mode	<ul style="list-style-type: none"> <li>• 52M full readout</li> <li>• 5 × 5 random block readout</li> <li>• Adjacent 4 pixels addition readout (the monochrome image sensor only)</li> <li>• Rolling shutter</li> </ul>
Conversion gain	50.2 μV/ e <sup>-</sup>
Sensitivity of the monochrome image sensor	39000 e <sup>-</sup> /lx s (2856k light source with IR cut filter)
Sensitivity of the color image sensor (Green pixel)	16600 e <sup>-</sup> /lx s (2856k light source with IR cut filter)
Saturation full well	24000e <sup>-</sup>
Dark current(per pixel)	56.4e <sup>-</sup> /s (@60 °)
RMS random noise	5.5e <sup>-</sup> (@column gain stage= 3)
Power supply	5 V
Power consumption	430mW

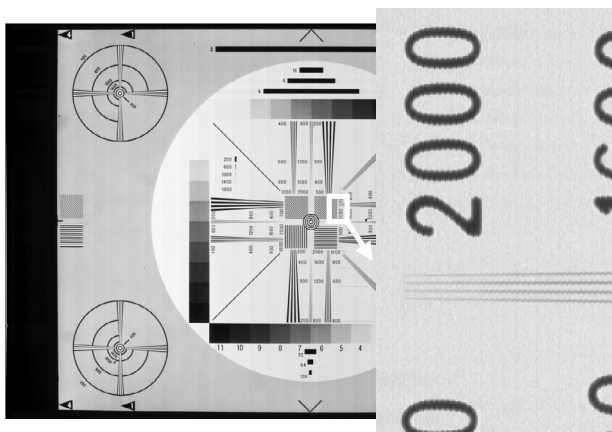
Figure 4 Specification and characteristics.



**Figure 5** Input Referred noise vs. Actual column gain.



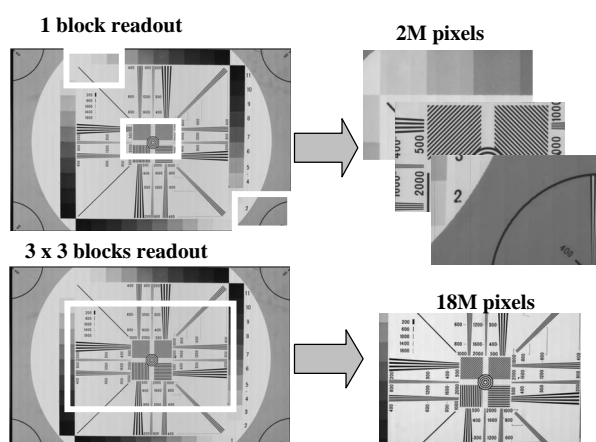
**Figure 6** Spectral characteristic of the color image sensor.



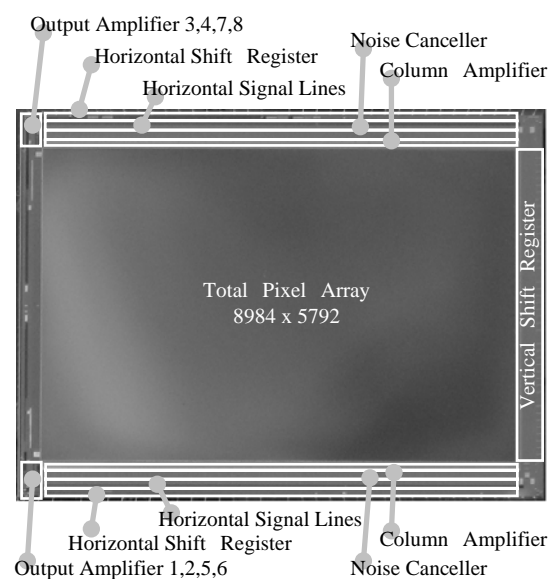
**Figure 7** Reproduced image of the resolution chart captured by the monochromatic image sensor.



**Figure 8** Another reproduced image captured by the monochromatic image sensor.



**Figure 9** 5 x 5 random block readout .



**Figure 10** Chip micrograph.