Recent Progress of CMD Imaging

Tsutomu Nakamura and Kuniaki Saitoh
Olympus Optical Co., Ltd.
Tatsuno, Nagano, 399-04, Japan
Fax: +81-266-41-4868 Phone: +81-266-41-4179
E-mail: nakamura@ted.olympus.co.jp

There are two directions in image capturing. The one is toward faithful image reproduction as that with human eyes. The other is for an image recognition for industrial or medical use. In both cases, fundamental demands are grouped to three categories.

1) High resolution in space and time.

2) Wide latitude (including high sensitivity).

3) Accurate color formation.

We must realize the above three demands at the same time. This abstract presents two trial examples of CMD image sensors to achieve higher resolution and wider latitude.

To realize a high resolution in space, many pixels must be arrayed. In general, a high resolution image sensor requires a long frame-time. Therefore, the improvement in space-resolution tends to degrade a resolution in time. Increasing a data-rate avoids this compromise, but it brings many problems of designing a camera system. As a replacement scheme, a 4M pixel CMD image sensor with random readout function has been designed and evaluated[1]. This sensor enables still image capturing with 4M pixel resolution and a real time monitoring of whole and/or partial fields. This function named "Electronic Eye Motion" (EEM) was realized with newly developed scanning circuits.

Figure 1 shows a relation between a number of pixel per a frame and a frame rate. A resolution can be changed depending on a situation. Figure 2 shows a block diagram of the sensor. 2048x2048 CMD pixels are arrayed for effective imaging diagonal. The pixel size is $7.5 \times 7.5 \mu m^2$, thus making a 1-1/4 inch optical format. The VD switching circuit drives a common drain terminal of the CMD array, and is used to suppress dark current generation for a long time integration. Three modes of image readout are drawn in Fig. 3. In a full readout mode, a whole 4M pixel array is scanned sequentially. The frame rate is 2.5 frames per second with the pixel data rate of 12MHz. The skip access mode is a coarse-scanning of a full angle of view. The image sensor outputs signal from every 4th pixel in horizontal and vertical directions. The window access mode is a partial scanning of a full angle of view. The size and address of a window can be selected arbitrarily. The window size is fixed to 512x488 pixels in our evaluation camera. Therefore, a coarse full angle of view and a fine partial view can be obtained within a 1/30 second. These functions are quite useful in a digital-still-camera application. Composition is determined with the

skip access mode and a focus is adjusted with the window access mode. Both operations can be performed in real time. Photo 1 and 2 are reproduced images of the skip access mode and the window access mode, respectively. The specifications and performance of the camera are listed in Table I.

Conventional TV cameras have an exposure dynamic range of 50 - 60 dB and a silver-halide film has the range of about 80 dB. Therefore, there is a strong demand to expand a dynamic range in electronic imaging. A non-destructive-readout (NDR) mode of the CMD image sensor was used to solve this problem. A 330k pixel CMD image sensor with NDR mode has been newly devised and evaluated[2]. The sensor was scanned twice a field. Figure 4 shows a schematic of signal integration. Figure 5 represents a readout timing. The first scanning outputs signal with short exposure time in NDR mode. The second scanning outputs a long exposure signal with the conventional reset operation. The signal from an overexposed area is saturated in a long exposure period. The corresponding signal with a short exposure period is not saturated and is usable to latitude expansion. The two signals are synthesized to generate an image. The reproduced image has a dynamic range of 84dB and the example is shown in photo 3. The specifications and performance of the camera are listed in Table II.

Although some similar trials were reported by using CCDs, the NDR approach using a CMD image sensor has two advantages in comparison with the CCD approaches. The first advantage is a readout flexibility. For a progressive scanning, a CCD pixel must have one photo-diode and 8 transfer electrodes in a vertical CCD unit to handle two independent packets of carriers. This restriction degrades a full well capacity of the CCD. No change in pixel architecture is needed in a CMD image sensor. The second is related to the intervals and number of multi-scanning. In the CCD image sensor, a short exposure time is restricted within the vertical blanking period. In the CMD image sensor, a short exposure time is chosen arbitrarily and an introduction of an extra medium exposure can be arranged for further improvement of the dynamic range.

The authors have introduced that the CMDs can extend an imaging area with higher resolution and wider latitude. Now, we are developing a 4M-CMD color camera and will report its partial results at the workshop.

The authors acknowledge their directors and colleagues for their support and encouragement.

Reference:

[1] T. Nomoto et al.: "A 4M-pixel CMD Image Sensor with Block and Skip Access Capability", ISSCC Dig. of Tech. Papers, pp. 186 - 187 & 453, Feb. 1997

[2] H. Miyahara and M. Katashiro: "A Wide Dynamic Range CMD Image Sensor", Tech. Dig. of 1996 ITE Annual Convention, 2-5, pp. 15 - 16 (in Japanese).

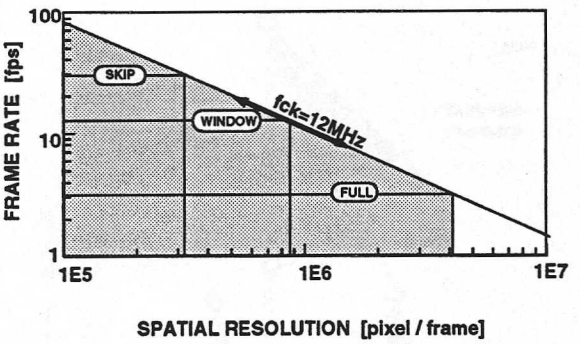

Figure 1. A sensor-resolution chart in time and space.

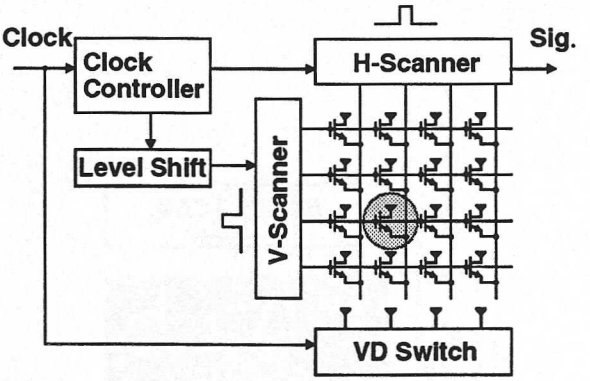

Figure 2. A block diagram of a 4M pixel CMD.

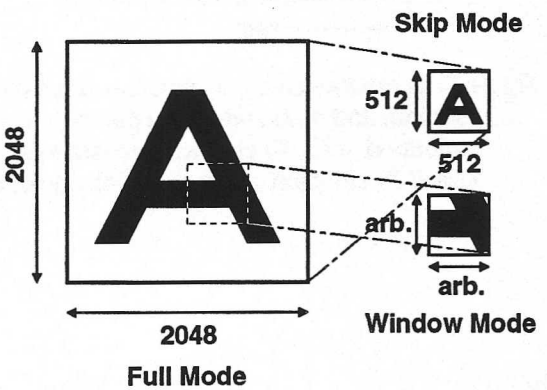

Figure 3. Three modes of image readout

Table I Specifications and performance of HRC*
(*HRC: High-resolution Random-access Camera)

Pixel size	7.5 μm × 7.5 μm
No. of pixel	2048 × 2048
Cam. out	(1) analog video (RS-170A)
	(2) 8-bits digital(RS-422)
Sensitivity	F4 / 1000 lx
S/N	> 46 dB
Size	80 mm[H] × 80mm[W] × 165mm[D]

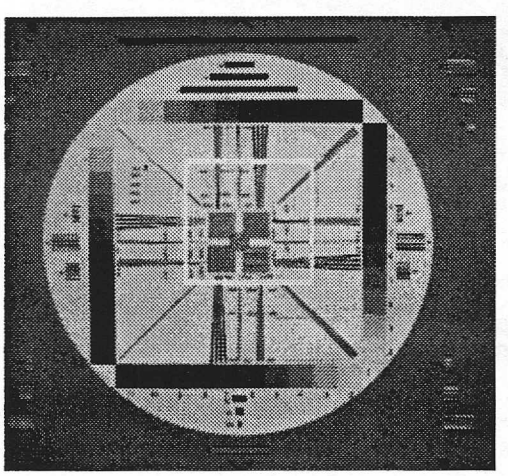

Photo 1. Reproduced image of the skip access mode. A bright frame denotes the scanning area of the window access mode at Photo 2.

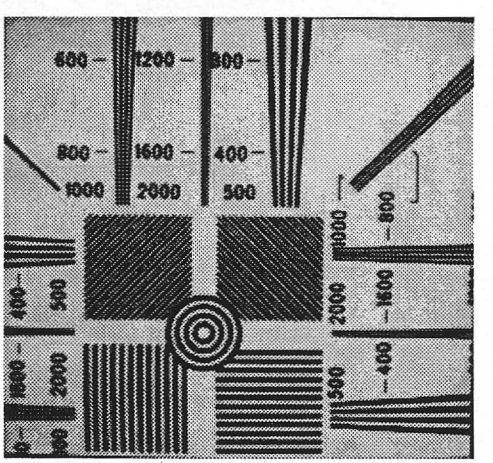

Photo 2. Reproduced image of the window access mode.

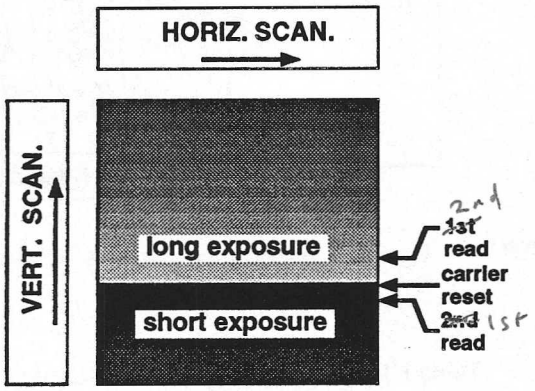

Figure 4. An integration image and signal readout.

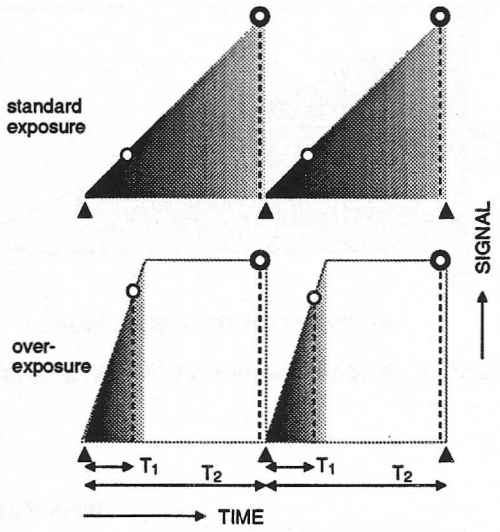

Figure 5. A readout timing of dynamic range expansion.
1st read, 2nd read and reset operations are performed at ○, ◎ and ▲, respectively.
T_1 and T_2 are short and long exposure periods, respectively.

Photo 3. Reproduced image of the wide D-R camera (a).
(b) is a normal image for reference.

Table II Specifications and performance of the wide D-R color camera.

Pixel size	9.8 μm × 9.8 μm
No. of pixel	660 × 494
Sensitivity	F5.6 / 2000 lx
S/N	> 54 dB
Imaging D-R	84 dB