

1.3 Mega Pixel CCD Image Sensor Characteristics in Long Exposure Time at Low Temperature

Jin Murayama[*], *Seishi Ikami*[†], *Taizo Akimoto*[†]
[*] *Fujifilm Microdevices Co., Ltd.,*
1-6, Matsusakadaira, Taiwacho, Kurokawagun, Miyagi, Japan
[†] *Fuji Photo Film Co., Ltd, 798, Kaiseimachi, Ashigarakamigun, Kanagawa, Japan*

Introduction

Recently more than 1 mega pixel CCD image sensors are used in several digital still camera (DSC) systems. In them, the pixel number of CCD sensor is one of the most important parameter. It represents the resolution of the image. Another important parameter of CCD image sensor is a saturation level of each pixel. In the image capturing systems, the dynamic range is limited by saturation level and dark level.

In the case of detecting low light level seen, such as electro-luminescence, chemical luminescence images, or X-ray imaging, wide dynamic range and low dark level are very important. In them long exposure time is necessary to detect some important area detection, and some part might be brighter.

In X-ray imaging systems using the CCD camera systems, a fluorescent plate is used for the energy conversion from X-ray to visible light. So, CCD and camera system should catch visible image in low power and wide dynamic range input.

For the scientific application of a CCD image sensor, especially for the purpose of luminescence image detection, following four characteristics are quite important.

1. wide dynamic range
2. low dark level
3. high sensitivity
4. high resolution

Results and Discussion

We developed a new CCD image sensor for both scientific and industrial applications. The number of pixels of this sensor is 1384 x 922 (1.3 mega). The dynamic range is more than 57dB. The pixel size is 11um x 11um (square pixel). The detective area size is 15.2 x 10.1 mm^2. The optical format is around 1" size. It is an interline CCD, which works under interlaced mode. The configuration of this sensor is shown in Fig.1, and the feature of it is listed in table 1.

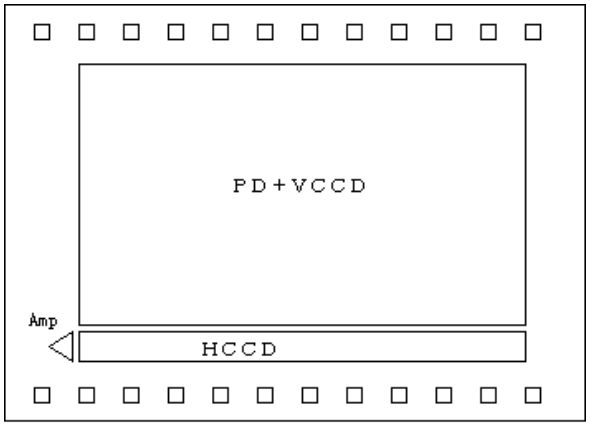

Figure 1. CCD Configuration

Table 1. CCD Feature and Characteristics

Total Pixel Number	1420H x 928V (1317760)	
Effective Pixel Number	1384H x 922V (1276048)	
Pixel Size	11.0 um ❑	
Detective Area Size	15.22 mm x 10.14 mm	
Readout Way	Interlace	
parameter	results	
sensitivity	0.33e^-/photon	blue LED
saturation	more than 140000 e^-/pixel	
dark level	0.002 e-/pixel/sec	at –30°C
linearity (γ)	~ 1.0	
S/N	larger than 50.4dB	
readout noise	less than 20 e^-	

Each pixel can accumulate more than 1 x 10^5 electrons. This value is quite larger than that of CCD image sensors used in digital still camera systems. The effective dynamic range is more than 57dB at room temperature at 12MHz as a pixel rate. Digital Still Camera (DSC) systems' exposure time range is 1/1000 to 1/4 second, as usual at room temperature. However, for luminescence image capturing, more than 10 minutes exposure is necessary. It is well known that dark current is doubled by around 8 degree up of temperature in Silicon devices. The reduction of dark signal is also important. So, a cooling chamber was prepared to keep the CCD temperature under –30°C for long exposure time.

The CCD sensor, an emitter follower transistor, and some other parts are mounted on a small print circuit board, then placed on the double stacked Peltier's devices. Including this device, peripheral circuits are built in a chamber. The atmospheric gas in the chamber was replaced to the dried Nitrogen, for keeping away from dewing the ICs and circuit boards.

In –30°C, the dark output comes smaller around 1/64 compared to that of room temperature.

Furthermore, the amplifier current on the CCD chip is suppressed during exposure period. Most power consumes in the source follower on chip amplifier in the CCD image sensors. The ampifier current is several mili-ampere of 15V. It is suppressed lower than 1 mA during long exposure time. Using these approach, we could perform lower dark level than estimation level. Fig. 4a and 4b shows a great effect of the heat reduction. In Fig.4a, sensor output near the amplifier are larger than that of other part. Fig.4b shows the result of amplifier current suppression. In these figures, black is high level signal, and white is small signal level (negative image). These are the images of 10minutes exposure under –30°C.

For the readout of long exposure time image, the driving way is different from a standard readout way. After long time exposure, one field data is readout without transfer gate pulse, that is, VCCD dark signal is swept out without photo-diode signal. After these procedure, accumulated photo-diode signals are read out.

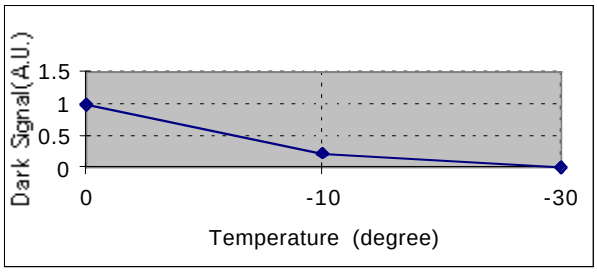

Figure 2. Dark Signal vs. Temperature

The characteristics of the CCD at low temperature is almost the same level of those at room temperature. One different characteristics is a dark output level. The dark current at –30°C is 0.0017e^-/ pixel sec. The dark signal output dependence versus temperature is shown in Fig. 2. The CCD characteristics are listed in table 1.

In Fig. 3 the dynamic range and the linearity is shown with conventional X-ray film. From this results, new CCD has good linearity and effective dynamicrange is about 10 times larger than X-ray films. The resolution is shown in Fig. 3a,b. The mega pixel CCD image sensor is quite a good resolution. These resolution is almost the same as Mega Pixel DSC.

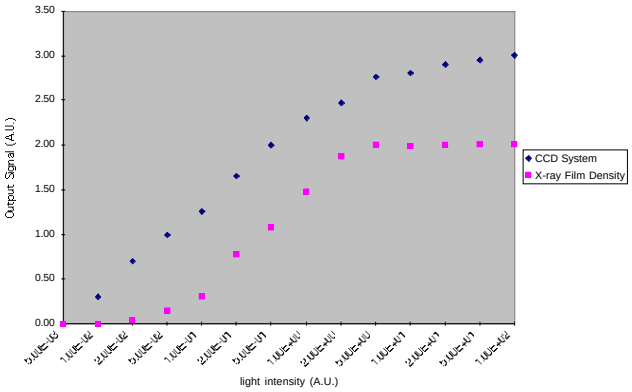

Figure 3. Dynamic Range and Linearity

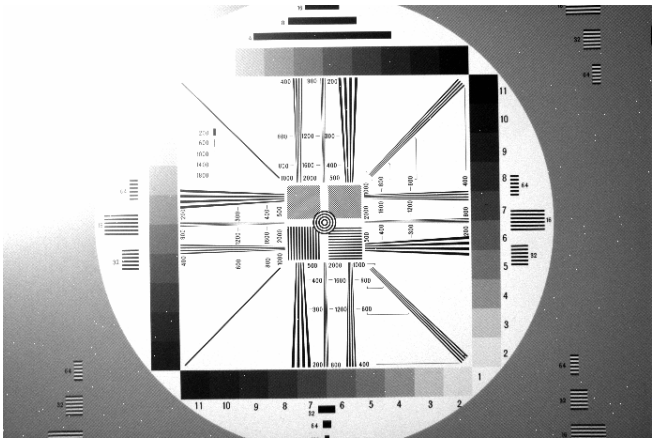

Figure 4a

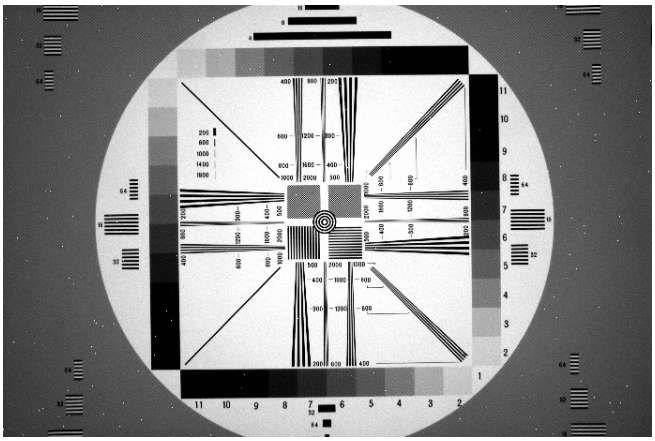

Figure 4b

Conclusion

A mega-pixel high dynamic range CCD image sensor was developed. It can be applicable for scientific applications such as chemical luminescent image detection. The CCD sensor is hold in the chamber, cooled down under –30°C. The camera system using this new sensor can catch better image than conventional Xray film for more than 10 minutes exposure time. It is hopeful for analyzing luminescent image for the purpose of DNA analysis, etc.

Acknowledgment

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References

M. L.Peri, et. Al. " A series of CCD cameras for low light-level applications" Proceedings of 'Solid State Sensor Arrays and CCD Cameras' 1996