A Dual Pixel CMOS CCD Image Sensor

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Abstract

A dual pixel progressive-scan CMOS CCD image sensor has been developed. This device has on-chip CMOS driving circuits to simplify a camera system. It has dual pixel unit cell to get high resolution with high fidelity color. Each square cell has two color pixels of green and red, or green and blue. The number of pixel is 320(H) x 480(V). Reproduced image is 320(H) x 240(V)(QVGA). Sensitivity of 400mV(1/30sec, 1200nt, F8.0), saturation voltage of 500mV and smear ratio of -97dB have been achieved.

Introduction

In the beginning of the PC camera development era, those cameras used interlace CCDs, which was designed for camcorder. Format translation, which degrades image quality, was required at such system. Recently, the most of digital still cameras employed square pixel image sensor that has RGB color filter array on it. Even in such cameras, number of pixel at reproduced image is the same as that of image sensor. It is difficult to say that picture quality of such camera have been optimized. Considering video communication applications such as video conference or video phone, picture quality is the most important point, because data transfer rate is limited by bandwidth of signal line. In order to get high quality image, 3CCD camera is the best solution, but such camera will be too expensive. So, the picture quality under the same image file size is very important.

A dual pixel progressive-scan CCD image sensor has been developed to improve the picture quality for the PC camera. A pixel of this CCD has two sub-pixels, and read out each signal independently at one scanning period. CMOS driving circuits have been integrated on CCD chip. Analog Signal Processor (ASP) and Digital Signal Processor (DSP) have also been co-developed. By using this chipset, high image quality PC camera working up to 30fps can be developed easily.

Dual Pixel Image Sensor

Square pixel sensors are used in many digital cameras. In them, the number of pixel in the image file is the same as that of the image sensor. Fig. 1 shows an example of conventional color filter arrangement. Half of the pixels are covered with Green filter, quarter of them is covered with Red, and the rest of the pixels are covered with Blue. As is well known, Green pixel commits the resolution of the image much more than Red or Blue. So, this sensor can't realize maximum resolution.

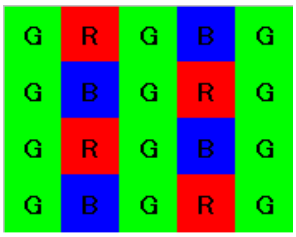

Figure 1. An example of color filter arrangement for conventional sensor

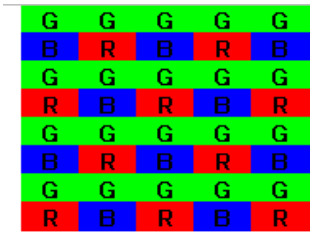

Figure 2. An example of color filter arrangement for dual pixel sensor

Fig. 2 shows an example of color filter arrangement for the dual pixel image sensor. Each pixel is consisted with two sub-pixels. The one of each pixel is green and the other is red or blue. Every pixel has a green sub-pixel. So maximum resolution will be realized using this pixel configuration. The sampling frequency of red and blue is two times higher compared with conventional sensor. Fig. 3 shows the image of CZP chart captured by conventional sensor and Fig. 4 shows the image captured by dual pixel sensor. Dual pixel sensor has achieved higher resolution and less false colors imaging on the same picture format in compared with conventional sensor.

Fig. 5 shows the image of foods chart captured by the QVGA dual pixel CCD. The picture quality is the best grade in this format of image sensors.

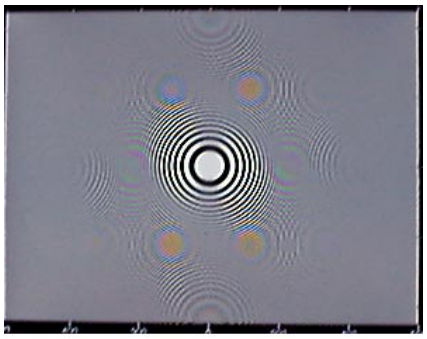

Figure 3. QVGA Image of CZP chart by Conventional Sensor

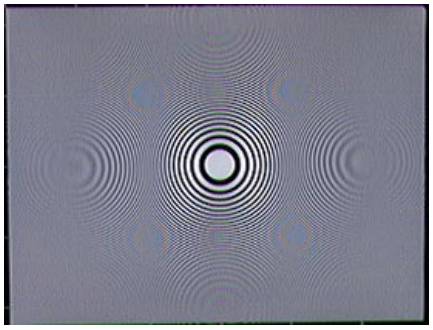

Figure 4. QVGA Image of CZP chart by Dual Pixel Sensor

Figure 5. Quarter VGA Image by Dual Pixel CCD Sensor

Progressive-scan CCD for dual pixel

Fig. 6 shows pixel configuration of the dual pixel CCD sensor. Two vertical CCDs are arranged in both side of pixel. Each CCD in a pixel has one stage of 4-phase CCD. Generated charge in the photodiode-1 is transferred to right side CCD, and generated charge at photodiode-2 is transferred to left side CCD. Two sub pixel image signals are carried to the adjacent bit of the HCCD at the same timing. These image data are read out continually. 4-phase CCD has advantage in the point of charge transfer capacitance.[1] And progressive-scan CCD has been realized by 2-layer poly silicon technology, which can simplify a manufacturing process of progressive-scan CCD.[2,3] The Two vertical 4-phase CCD is appropriate configuration for dual pixel CCD image sensor.

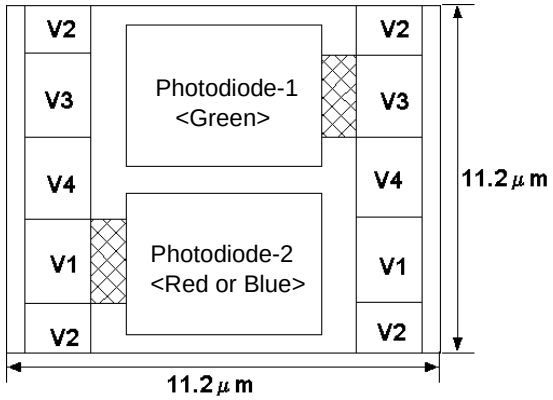

Figure 6. Pixel Layout of Dual Pixel CCD

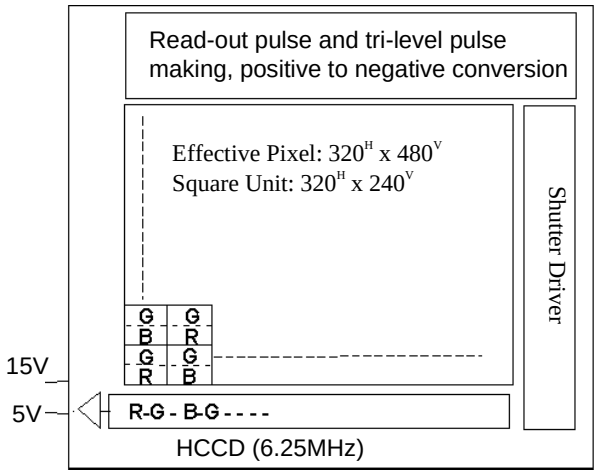

Figure 7. Block Diagram of Dual Pixel CCD

Specification

Fig. 7 shows the block diagram of this new CCD image sensor, which has adopted dual pixel technology. Table 1 shows the device specifications. The effective number of sub-pixel is 320(H)x480(V). The pixel size is 11.2 micrometer square and sub-pixel size is 11.2um (H) x 5.6 um (V). The number of pixel is 320(H)x240(V), which is quarter size of VGA. Optical format fit to quarter inch. Driving frequency of HCCD is 6.25MHz, which achieves frame rate of 30fps. The Vertical Overflow Drain (VOD) structure of photo-diode has been adopted to control the exposure time and to suppress blooming. The electronic shutter driver, frame shift driver and tri-level pulse

generator have been integrated on CCD chip. Usually these circuits are located outside of CCD chip. High level clipping circuits are also integrated in this CCD, which convert positive pulse to negative pulse. So, negative power supply is unnecessary for this CCD. Required supply voltages are 5V and 15V. 15V pulses are needed for read out of photo-diode and VOD shutter control.

Table.1 Device Specifications

Item	Specification
Number of Effective Sub-pixel	320^H x $(240x2)^V$
Total Number of Sub-pixel	340^H x $(248x2)^V$
Number of pixel	320^H x 240^V
Sub-pixel Size	11.2^H x 5.6^V um^2
Pixel Size	11.2^H x 11.2^V um^2
Chip Size	5.0^H x 4.4^V mm^2
Optical Forma t	1/4 inch
Color Filter Layout	G/R, G/B mosaic
CCD Type	Progressive-scan CCD
Data Rate	6.25MHz
Frame Rate	30fps
Driving Voltage	5V (HCCD, VCCD)
On Chip Circuit	CMOS
Electric Shutter	1/30 ~ 1/15,000 sec.

CMOS Structure

On chip circuits are made using CMOS technology. Fig. 8 shows the cross section of CMOS structure. When the electric shutter of Vertical Overflow Drain (VOD) is closed, substrate voltage is about 25V, n-well voltage is maximum 15V and drain voltage of p-MOS transistor is minimum –5V in this device. In order to suppress punch through, impurity profiles of this CMOS have been optimized well.

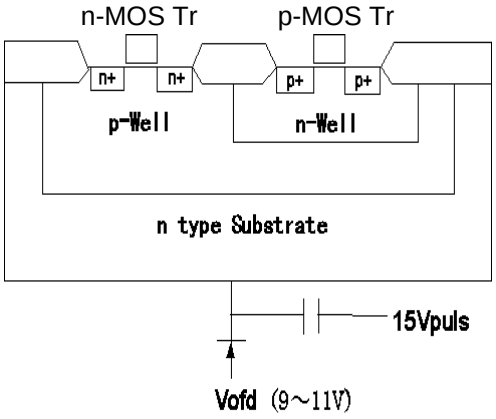

Figure 8. Cross section of CMOS

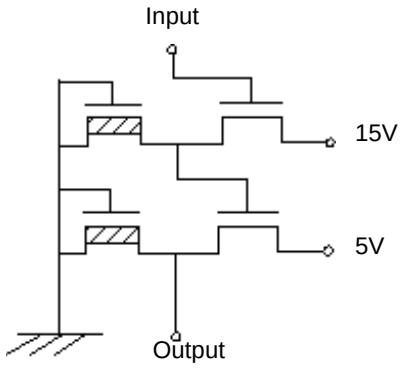

Figure 9. Source follower amplifier

Decrease of Power Dissipation

Fig. 9 shows circuit diagram of the on-chip amplifier. This amplifier has two stage of source follower. Generally, the largest power consuming position is the last stage of source follower. In this CCD, output drain voltage at last stage of source follower has been reduced from 15V to 5V. Power dissipation of the amplifier has been decreased to 50% of that of conventional one.

Sensor Characteristics

Characteristics of this CCD image sensor are shown at Table 2. The green sensitivity is 400mV, the red sensitivity is 300mV, and the blue sensitivity is 180mV. The smear ratio of –97dB, the saturation voltage of 500mV and the blooming suppression of over 400 times have been achieved respectively.

Table 2. Device Characteristics

Item	Characteristic
Sensitivity of Green Sensitivity of Red Sensitivity of Blue	400mV (F8.0, 1200nt 300mV 5100K, 1/30Sec, 180mV CM500S-0.7mm)
Smear	-97dB (F2.8)
Saturation Voltage	500mV
Blooming Suppression	Over 400 times
Dark Signal	0.5mV at 50degree C

Chip Set Performance

We have also developed the ASP(MA1101) and the DSP(MD2310) at the same time. To simplify the camera system in which this CCD sensor has been adopted, the analog signal processor (ASP) and the digital signal processor (DSP) have been co-developed. In the ASP, sample hold circuits, three channels gain control amplifier and 10bit analog to digital converter have been integrated. The DSP works as not only color signal processor but also the JPEG encoder and the Timing Generator for this dual

pixel CCD. This JPEG encoder works up to 30 frame per second.

Conclusion

A dual pixel CMOS CCD image sensor suitable for PC camera system has been developed. The dual pixel unit realized high resolution and high fidelity color. CMOS driver circuits are integrated on CCD for easy driving. High sensitivity of 400mV, low smear of –97dB, goof blooming suppression of over 400 times at saturation output voltage of 500mV, have been achieved. ASP (MA1101) and DSP (MD2310) have also been developed as a chipset. This chipset makes it possible to develop a PC camera working up to 30fps easily.

Acknowledgment

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References

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