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Design and Analysis CMOS Image Sensor

Monika Rani Jha[1], Nisha Charaya[2], Sonal Dahiya[3]
[1]*Student M.Tech. VLSI, Amity University Haryana*
[2]*Assistant Professor, Amity University Haryana*
[3]*Assistant Professor, Amity University Haryana*

Abstract: *An image sensor or imaging sensor is a device that converts an optical image to an electric signal. It is used mostly in digital cameras and other imaging devices.*
This paper presents a high speed simulation methodology to reduce the long simulation time problem of traditional CMOS image sensor. A method based on spice model in cadence design platform is proposed to reduce the simulation time. This results simulation time reduced from 16ms to 0.225microsecond.
Keyword: *CMOS image sensor, High speed simulation matrix, Cadence design platform.*

I. Image Sensing

An image sensor or imaging sensor is a device that converts an optical image to an electric signal [5]. It is done by converting the variable attenuation of waves (as they pass through or reflect off objects) into signals, the small current is introduced that convey the information. The waves can be light or other electromagnetic radiation. Image sensors are used in electronic imaging devices of both analog and digital types, which include digital cameras, camera modules, medical imaging equipment, night vision equipment such as thermal imaging devices, radar, sonar, and others. As technology changes, digital imaging tends to replace analog imaging.

II. Types Of Image Sensor

2.1 CCD Image Sensor

A charge-coupled device (CCD) is a device used for the movement of electrical charge, usually within the device to an area where the charge can be manipulated, for example conversion into a digital value. This is achieved by shifting the signals between stages within the device one at a time. CCD moves charge between capacitive bins in the device, with the shift allowing for the transfer of charge between bins[8].
The CCD is a major piece of technology in digital imaging. In a CCD image sensor, pixels are represented by p-doped MOS capacitors. These capacitors are biased above the threshold for inversion when image acquisition begins, allowing the conversion of incoming photons into electron charges at the semiconductor-oxide interface .CCD is then used to read out these charges[7]. Although CCDs are not the only technology to allow for light detection, CCD image sensors are widely used in professional, medical, and scientific applications where high-quality image data is required[8].

Advantage of CCD image sensor[7]

- Conversion takes place in the chip without distortion
- CCDs have very high uniformity – Technique for HD quality images (not videos)
- These sensors are more sensitive – Produce Better Images in Low Light
- CCD sensors produce cleaner and less grainy Images – low-noise images
- CCD sensors is produced for longer period of time

Disadvantage of CCD image sensor[7]

- CCD sensors Consume much more power
- CCDs are interlaced
- Inferior HD Video – Less pixel rates
- CCDs are expensive as they require special manufacturing.

2.2 CMOS Image Sensor

A CMOS imaging chip is a type of active pixel sensor made using the CMOS semiconductor process[8]. Each pixel on a CMOS sensor has several transistors located next to each photo sensor converts the light energy to a voltage[8]. This cause additional circuitry on the chip may be included to convert the voltage to digital data[8]. In fig2. The arrangement of photodiodes are shown . In CCD a dense matrix of CCD is used due to which it is more sensitive to light, where in CMOS image sensor a less amount of photodiodes are used due to which it is less sensitive to light.

Advantage of CMOS image sensor [7]

- CMOS consumes less power
- CMOS sensors are cheaper
- These Sensors produce better HD videos
- CMOS cameras are used on Phones, Tablets, etc
- CMOS imager clearly has better performance

Disadvantage of CMOS image sensor[7]

- CMOS sensors are also more susceptible – sometimes images are grainy
- CMOS sensors need more light for better image

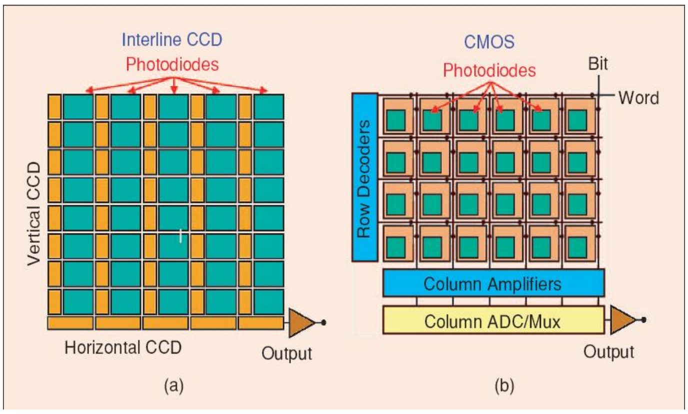


fig.1 [7]

III. Working Principle Of CMOS Image Sensor

In fig2 working of CMOS image sensor is shown. when light incident on a photodiode in CMOS image sensor is directed by the micro lens (a tiny lens placed over the pixel to increase its effective size and thereby fill factor) onto the photo-sensitive area of each pixel where it is converted into electrons that collect in a semiconductor bucket[7].

These are the following phenomena occurring in this process.

Charge accumulation

As more light enters, more electrons accumulate into the bucket[7].

Transfer

Accumulated charge must be transferred to the signal conditioning and processing circuitry[7].

Charge-to-voltage conversion

The accumulated charge must be output as the voltage signal[7].

Amplification

Voltage signal is then amplified before it is fed to the camera[7].

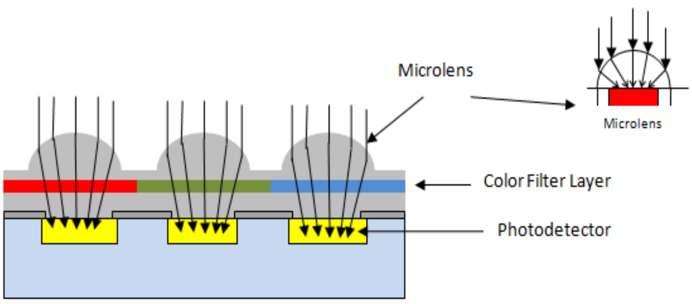


fig.2 [7]

The bigger the pixel, the more light is collected[7]. Thus, big pixel sensors work better under low-light conditions. For the same number of pixels, bigger pixels results in bigger chip, this means higher cost[8]. Conversely, smaller pixels enable smaller chip sizes and lower chip prices, as well as lower lens costs. But there are limitations on pixel size reduction. Smaller pixels are less sensitive to light, the optics required to resolve the pixels becomes expensive and requires expensive fabrication possesses[7].

IV. 3T CMOS Image Sensor

The 3T-APS consists of three NMOS transistors and a photodiode[2]. Typical signal readout procedure can be roughly divided into three phases, such as reset, integration and readout. During the reset operation, the sense node full well capacitor Cpd which comprise the photodiode inner capacitor[2], reset transistor MN1 source capacitor, and the MN2 gate parasitic capacitor will be reset to a voltage Vpd[2]. The charges will be accumulated on the sense nodes and it can gain maximum charge Qmax which depends on the full well capacitance of the photodiode[2]. After resetting, the capacitor Cpd will be discharged by the photocurrent (Iph) and dark current (Idark), the former is proportional to the light intensity during the integration time and Idark is the leakage current flowing through the photodiode when no photons enter the image pixel, the main part of the total dark current is coming from the depletion of the photodiode edge at the surface , the slope of discharge curve is determined by the sum of Iph and Idark and it also determine by the Cpd. The bigger the Iph is, the faster the Cpd discharges. For example, using three different light intensities as input to the simulation.

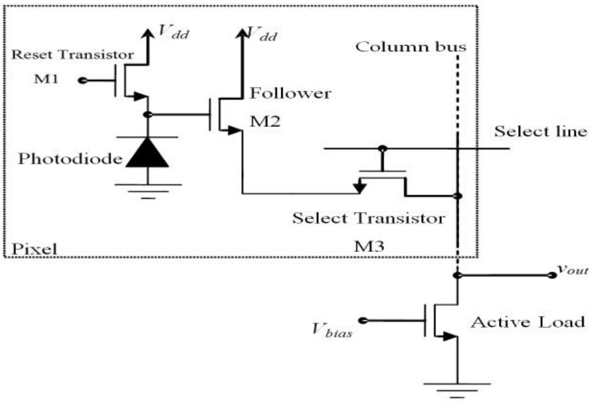
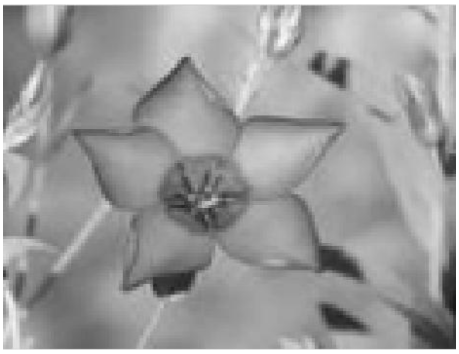
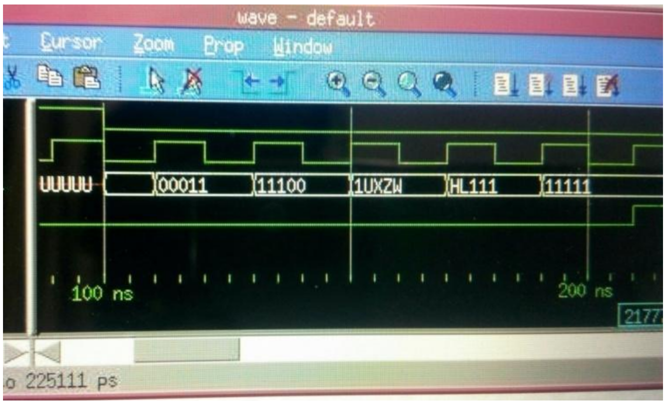


fig.3 3T image sensor[1]

V. Simulation Result





1. First read the image using MATLAB.
2. Convert the particular image in grayscale image using MATLAB.
3. Then convert it into .csv form which is read by spice simulation toolbox.
4. Then give the .csv file as input on 3T CMOS image sensor in cadence simulation toolbox.

VI. Conclusion

In this project spice simulation toolbox is used for image simulation. This method is less time consuming and easy to implement as high level language model like vhdl,verilog model is not needed. We get result in 0.225 microsecond for pixel 169*127. Earlier it was 16 millisecond for the same[9].

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