Chapter 1 Introduction

1.1 Brief Introduction

Eyes, the one which is the most important sense organs for living, give all creatures' colorful world and sense of light. Form ancient years, human use the silver bromide exposure to get the oldest camera. As time goes by, the technology not only push photography from black image into colorful image, from stable frame into video frame stream, furthermore, the camera has been improved form chemical exposure into electron exposure. From begins of the theory, photoelectric effect which expounded by Einstein on 1905, the research and paper has been published for a long time on image topic. No matter research in photodiodes, image sensors in CCD technology or through CMOS process implementation, scientists and engineer. Cooperated with other optical devices and signal processing chips, it has been successfully leaded into commercial market in our life. Fig. 1.1-1 shows the cross-sectional view of digital camera SONY-α 100, and we could recognize that image sensor set in the most important angle which is the interface between lens and digital signal processing （DSP） circuits. The ability of the image sensor would command the frame quality and function, and it has begun the difference between CCD and CMOS technology.

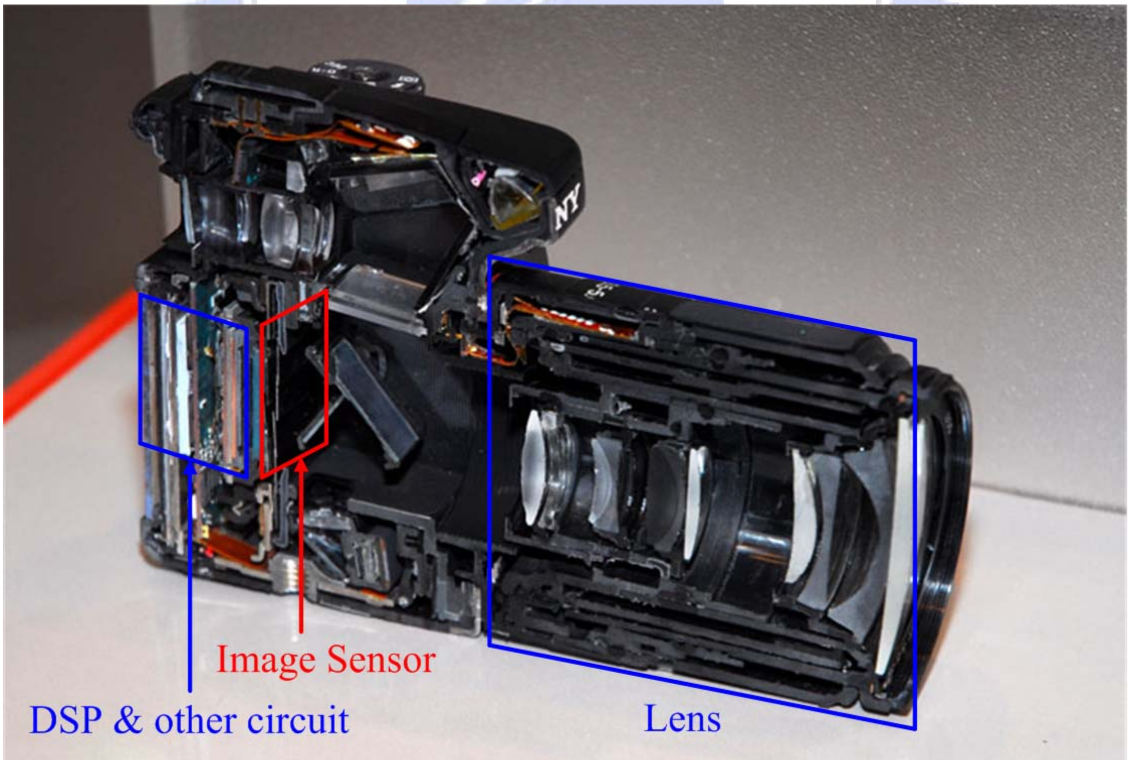

Fig. 1.1-1 The cross-sectional view of digital camera SONY-α 100
extracted from Arena Nikkeibp Report < 1 >

Whether image sensors were implemented in CCD process or in CMOS Technology, they have outstanding in different points of view such as frame quality or integration ability. Though CCD has become popular on the early digital camera age for the high performance on its frame quality and become a standard device in digital still camera（DSC）or digital video camera（DV）, CMOS image sensor still has its merit and market. As the pioneer scholar in CMOS Image Sensor, E. R. Fossum's paper"Active Pixel Sensors – are CCD's Dinosaurs？"[1]which published in 1993, he did not only describe the difference between CCD image sensor and CMOS image sensor, but also expound CMOS image sensor's future. He said, if CMOS image sensor can focus on certain application, consider the environment identity and build in corresponding circuit to improve image quality, even can overtake the CCD quality [1]. As Fossum's anticipation, with CMOS LSI technology to integrate other circuits IP into system on chip（SOC）, CMOS image sensor has become the powerful one with various functions. The famous example is "Camera-on-a-chip"[2], which achieve camera function in single chip such as develop images, auto focus, etc. Others function of camera instead of improving image quality, such as tracking, distance measuring, 3D image [3] , and image compression [4] etc. The research goal has no longer stay in the quality improvement and turns into smart functions for particular application.

The target focus on applications has also been started. In automotive applications, M. Schanz et al publish the paper" A High-Dynamic-Range CMOS Image Sensor for Automotive Applications" [5] started relative survey. In their research, CCD can only achieve dynamic range amount 50dB ~ 70dB （Dynamic Range, which represents the response ratio of max illumination to min illumination, we called it DR briefly in later articles.） General CMOS image sensor has only 50dB ~ 60dB, and it isn't enough to match the spec of automotive image sensor. Concerning the environment of cars, it should response the light include vivid sunlight and slight reflection light and push the limit as DR level as human being's eyes in 200dB. Though, the image system should expose under sunshine and still ensure function work over 85°C. However, their result shows that if the operation temperature raised from 65°C to 85°C, the DR will reduce amount 10db. Fig. 1.1-2 demonstrated the different temperatures' frame that we can recognize that the dpi of the sensor would decay in increasing heat environment. In order to overcome the defects from environment variation, those team announce the

CMOS image sensor which operate in four different integration time with three kinds of gain's amplifier in 2003, which is shown in Fig. 1.1-3.

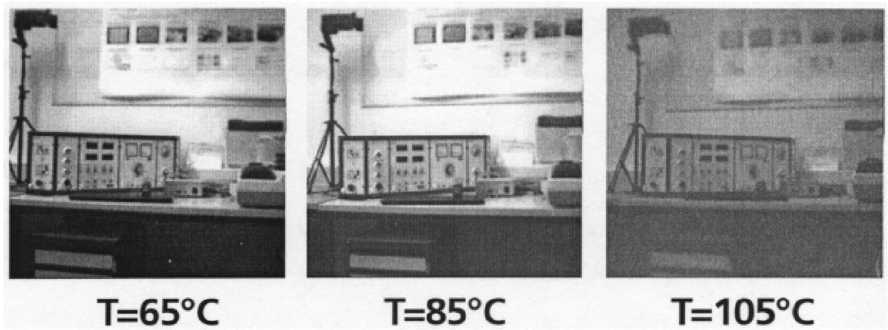

Fig. 1.1-2 Frame quality on CMOS Image Sensor which in 65˚C,85˚C and 105˚C
extracted from M. Schanz, C. Nitta, A. Bußannm, B. J. Hosticka, R. K. Wertheimer, "A High-Dynamic-Range CMOS Image Sensor for Automotive Applications", in IEEE JSSC,Vol. 35,NO.7, pp.932~938, July 2000. [5]

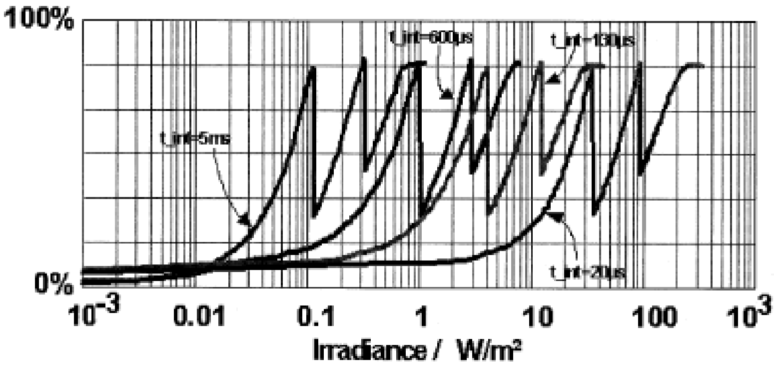

Fig. 1.1-3 Four integration time with three different gain to solve frame problem
extracted from B. J. Hosticka, W. Brockherde, A. Bußannm, T. Heimann, R. Jeremias, A. Kemna, C. Nitta, O. Schrey, "CMOS Imaging for Automotive Applications", in IEEE Trans. Electron Devices, Vol. 50, No.1, pp.173~183, January 2003. [6]

In 2003, N. V. Loukianova et al. present the paper "Leakage Current Modeling of Test Structures for Characterization of Dark Current in CMOS Image Sensors" [7], which declares relationship between temperature and the dark current of photo detector. The temperature dependence of the thermal generation current and diffusion current is mainly determined by the intrinsic concentration of silicon, which is of the first order in the generation term and of the second order in the diffusion term. The leakage current J_R of a p-n junction consists of diffusion current from the quasi-neutral areas and generation current from the depletion area as Eq.（1）shown.

$$J_R \cong q\sqrt{\frac{D_n}{\tau_n}}\frac{n_i^2}{N_A} + q\frac{n_i}{\tau_{gen}}W, \qquad (1)$$

Where D_n is the electron diffusivity, τ_n is the electron life time, N_A is the doping level of the p-type region assumed to be the lower concentration part of the junction, n_i is the intrinsic concentration of silicon, τ_{gen} is the generation lifetime, and W is the depletion width. The intrinsic concentration of silicon depends on the temperature in the following way:

$$n_i = \sqrt{N_C N_V}\exp\left[-\frac{E_g}{2kT}\right] = A\left(\frac{T}{300}\right)^{3/2}\exp\left[-\frac{E_g}{2kT}\right], \qquad (2)$$

Where N_C and N_V are carrier densities and E_g is the energy bandgap. Fig. 1.1-4 demonstrates the leakage current to temperature on different voltage. It can clearly explain the reason why dynamic range would decay in heating environment.

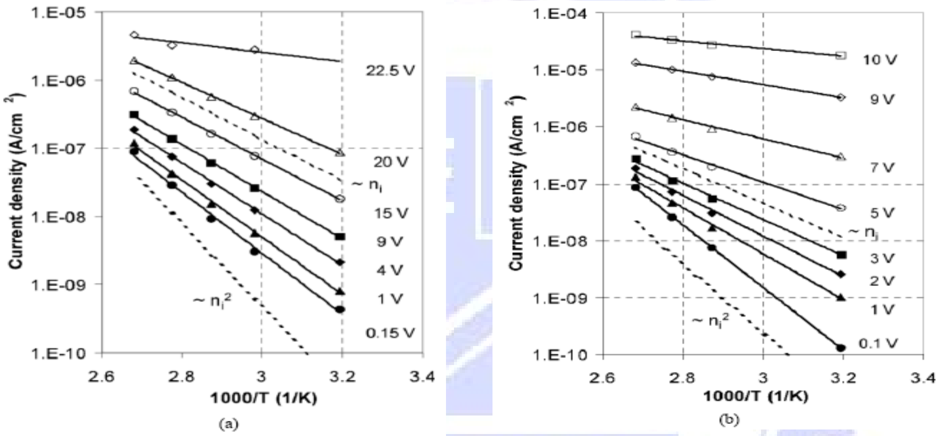

Fig. 1.1-4 Leakage current on difference voltage（a）在 n+/n-well/psb（b）n+/p-well ,1000/T versus n_i and n_i^2 variation（n_i : intrinsic concentration ）

extracted from N. V. Loukianova, H. O. Folkerts, J. P. V. Maas, D. W. E. Verburgt, A. J. Mierop, W. Hoekstra, E. Roks, A. J. P. Theuwissen, "Leakage Current Modeling of Test Structures for Characterization of Dark Current in CMOS Image Sensors", in IEEE Trans. Electron Devices, Vol. 50, No.1, pp.77~83, January 2003. [7]

1.2 Organization of the Thesis

In this thesis, we have a brief introduction for CMOS image sensor and architecture analysis of this thesis on chapter 1. Chapter 2 would introduce the history of image sensor's and other theorems, or circuits which related with this research, including the theory of "Photoelectric Effect," the one which built up by Albert Einstein. The consideration for this design and chip implementation would be described on chapter 3. Chapter 4 demonstrated the layout of each component; two stage test platforms and its result. Finally, we would have conclusion of this thesis and future sight in associated research on chapter 5.