AND9244/D

KAE Sensor Family EMCCD Gain Ageing Considerations

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APPLICATION NOTE

Introduction

KAE image sensors incorporate both a conventional horizontal CCD register and a high gain EMCCD register. An intra-scene switchable gain feature samples each charge packet on a pixel-by-pixel basis, enabling the camera system to determine whether the charge will be routed through the normal gain output or the EMCCD output.

The signal threshold for routing charge through the EMCCD register is user selectable and can influence the operational lifetime of the sensor. When using the EMCCD function of the image sensor, the electron multiplication (EMCCD gain) can change with respect to the operating time (aging).

In this application note we describe how ON Semiconductor characterized this feature of the image sensor in order to provide some guidance on the expected variation of the EMCCD gain.

Root Cause of the EMCCD Aging

The cause of EMCCD gain aging is attributed to high energy electrons, originated by the charge multiplication process, becoming permanently trapped in the EMCCD gate dielectric. Therefore, to obtain the same electric field in the EMCCD, a slightly higher horizontal phase clock voltage is required to maintain a constant multiplication gain.

Characterization Test & Results

To investigate the EMCCD gain aging, sensor performance was monitored for over 3000 hours using the KAE−02150, operating at a controlled temperature of 20°C.

Each camera's EMCCD gain was controlled via the H1SEM and H2SEM clock voltage and set to 20x.

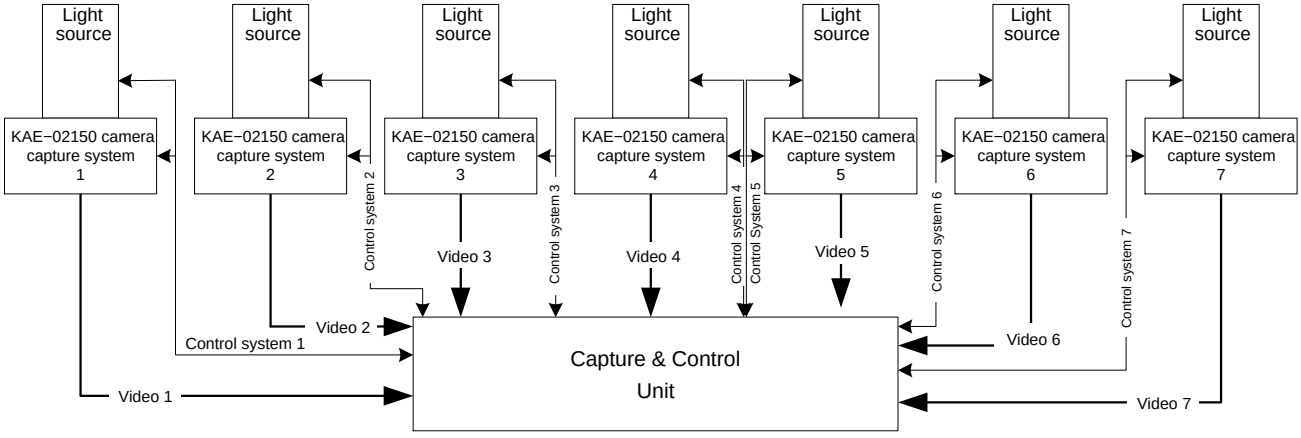

Figure 1. DUT Test Layout

For each camera, every 12 hours, the H1SEM/H2SEM clock voltage was adjusted to keep the EMCCD gain at a nominal value of 20x. The light intensity was set to provide an input signal to the EMCCD register of approximately 0 e^-, 200 e^- or 500 e^-.

A plot of the variation of the H1SEM/H2SEM clock voltages, for different signal intensities, was recorded in order to estimate the EMCCD gain aging and is presented in Figure 2 through Figure 4.

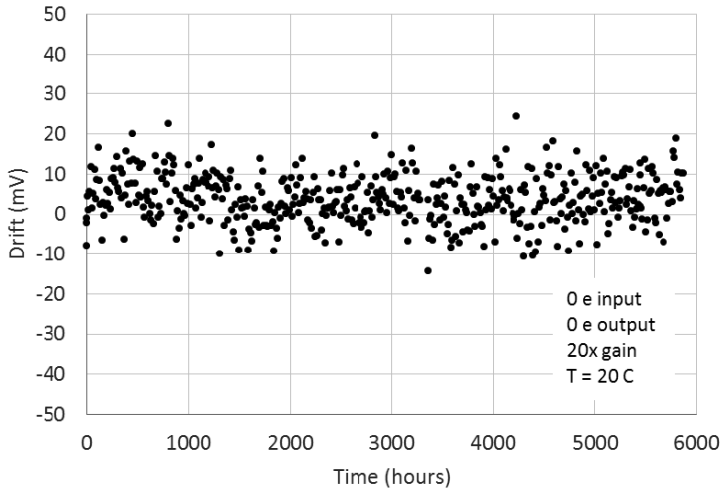

Figure 2. Drift of H1SEM/H2SEM Clock Voltage to Maintain 20x EMCCD Gain with 0 e⁻ Input Signal (Dark)

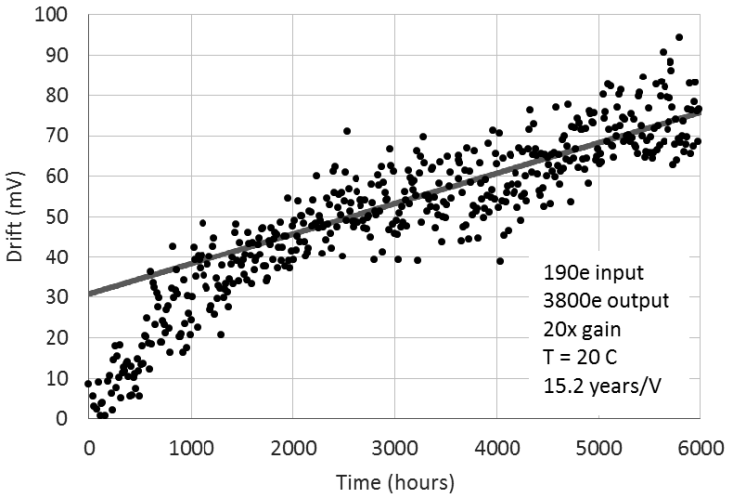

Figure 3. Drift of H1SEM/H2SEM Clock Voltage to Maintain 20x EMCCD Gain with 190 e⁻ Input Signal. The Long Term Trend is 15.2 Years to Drift 1 V.

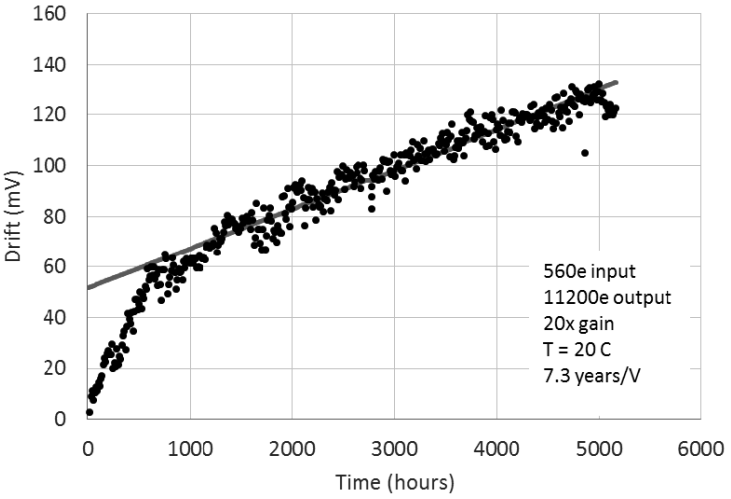

Figure 4. Drift of H1SEM/H2SEM Clock Voltage to Maintain 20x EMCCD Gain with 560 e⁻ Input Signal. The Long Term Trend is 7.3 Years to Drift 1 V.

Figure 2 through Figure 4 clearly demonstrates that gain aging is very dependent on the signal intensity.

- The camera with no light illumination (0 e^-) exhibits no measurable drift over time
- The camera with the highest EMCCD signal (560 e^-) exhibits the largest drift rate
- The long term ‘steady state’ gain aging rate exhibits a dependence on the signal level, although much less compared to the differences in first 1000 hours.

The expected lifetime is greater than 10 years for the EMCCD under normal operating conditions of 20x gain and limiting the charge input to the EMCCD register to 200 electrons. If the EMCCD output is greater than 4000 electrons, then the lifetime will be reduced. If the typical image has less than 4000 electrons per pixel at the EMCCD output or the EMCCD is not operated 24 hours per day, then the lifetime will be increased.

The data after 1000 hours was used to estimate the life time of the EMCCD assuming a failure when the H1SEM/H2SEM clock variation was equal or higher to 1.0 V. A straight line fitting from 1000 hours to the end of available collected data was used for the estimation of the EMCCD lifetime.

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