

Memo Title: SU256LSB Signal Conditioning Analysis
Memo Number: 0016
Revision: Revision 1.3

Parameter		Symbol	Typical	Unit
Saturation output voltage				
Readout noise	High Gain (CAP = LOW)	Nr	800	e ⁻ rms
	Low Gain (CAP = HIGH)		10000	
node sensitivity	High Gain	Sv	400	nV / e ⁻
	Low Gain		15.4	
Dark Current	-10° C	DS	100,000	e ⁻ /pixel/s

Table 1: Electrical Characteristics.

(T_a = 25° C, unless otherwise noted)

The above table shows the electrical characteristics of the SU 256LSB InGaAs sensor. The Readout Noise Level can be estimated using the following equation:

$$\begin{aligned} \text{High Gain Readout Noise Level} &= Nr * Sv = 800 \text{ e}^- \text{ rms} * 400 \text{ nV} / \text{e}^- \\ &= 320 \text{ uV rms} \end{aligned}$$

$$\begin{aligned} \text{Low Gain Readout Noise Level} &= Nr * Sv = 10000 \text{ e}^- \text{ rms} * 15.4 \text{ nV} / \text{e}^- \\ &= 154 \text{ uV rms} \end{aligned}$$

The total gain through the amplifier circuitry is 22.5. The 16-bit Analog to Digital converter (ADC) has an absolute range of 8.19 V and a resolution of $8.19\text{V} / 65536 = 125 \text{ uV}$ per ADC count. Therefore, the resolution of the ADC at the input is:

$$\text{ADC Resolution} = 125 \text{ uV per ADC count} / 22.5 = 5.56 \text{ uV per ADC count}$$

The node sensitivity in terms of e⁻ per ADC count can now be determined:

High Gain:

$$\begin{aligned} \text{Node sensitivity (e}^- \text{ per ADC count)} &= 5.56 \text{ uV} / Sv = 5.56 \text{ uV} / 400 \text{ nV per e}^- \\ &= 13.90 \text{ e}^- \text{ per ADC count} \end{aligned}$$

Low Gain:

$$\begin{aligned} \text{Node sensitivity (e}^- \text{ per ADC count)} &= 5.56 \text{ uV} / Sv = 5.56 \text{ uV} / 15.4 \text{ nV per e}^- \\ &= 361.04 \text{ e}^- \text{ per ADC count} \end{aligned}$$

Given that the node sensitivity is 13.9 e⁻ per ADC count at the high gain and 361.04 e⁻ per ADC count at the low gain, the ADC saturation levels can be calculated in terms of e⁻. The gain in the low setting can be factory adjusted (special order) to allow the ADC saturation level to match the horizontal summing register saturation levels. In most circumstances, this will not provide optimum performance.

High Gain:

$$\begin{aligned}\text{ADC Saturation (e}^{-}\text{)} &= 13.9 \text{ e}^{-} \text{ per ADC count} * 65536 \\ &= 910.95 \text{ ke}^{-}\end{aligned}$$

Low Gain:

$$\begin{aligned}\text{ADC Saturation (e}^{-}\text{)} &= 361.04 \text{ e}^{-} \text{ per ADC count} * 65536 \\ &= 23661.12 \text{ ke}^{-}\end{aligned}$$

When performing noise calculations, the three contributions to noise across the camera are considered:

- Sensor readout noise
- Electronics
- Shot noise from dark current

The theoretical readout noise level due to the sensor on-chip amplifier in terms of ADC counts is calculated using the following equation:

$$\text{Readout Noise Level (counts rms)} = \text{Readout Noise Level} / \text{ADC input resolution}$$

High Gain:

$$\begin{aligned}\text{Readout Noise Level (counts rms)} &= 320 \text{ uV rms} / 5.56 \text{ uV per ADC count} \\ &= 57.55 \text{ ADC counts rms}\end{aligned}$$

Low Gain:

$$\begin{aligned}\text{Readout Noise Level (counts rms)} &= 154 \text{ uV rms} / 5.56 \text{ uV per ADC count} \\ &= 27.70 \text{ ADC counts rms}\end{aligned}$$

The shot noise due to dark current is approximately the square root of the number of electrons detected. The number of electrons detected is a function of the sensor temperature as well as the exposure time.

Typically, the sensor temperature during normal operation is cooled down to around -10° C and the dark current at -10° C is approximately 100,000 e⁻/pixel/s. The shot noise level due to dark current over 10 second can then be calculated.

For Area Readout, where every pixel is read out individually, the shot noise for each pixel is:

$$\begin{aligned}\text{Dark Current} &= 100,000 \text{ e}^{-}/\text{s} * 10\text{s} = 1,000,000 \text{ e}^{-} \\ \text{Shot Noise} &= \sqrt{1,000,000 \text{ e}^{-}} = 1000 \text{ e}^{-} \text{ rms}\end{aligned}$$

High Gain:

$$\begin{aligned}\text{Shot Noise} &= 1000 \text{ e}^{-} \text{ rms} / 13.90 \text{ e}^{-} \text{ per ADC count} \\ &= 71.94 \text{ ADC count rms}\end{aligned}$$

Low Gain:

$$\begin{aligned}\text{Shot Noise} &= 1000 \text{ e}^{-} \text{ rms} / 361.04 \text{ e}^{-} \text{ per ADC count} \\ &= 2.77 \text{ ADC count rms}\end{aligned}$$

The three sources of noise come into play differently, depending on the application.

For short exposures (even up to several seconds), the shot noise of the dark current should be significantly below the signal level. If signal levels are very low, however, readout noise (the sum of the inherent sensor readout noise and the electronics noise) can be a source of poor images. Longer exposures will generally improve the signal-to-readout noise ratio very quickly. For each doubling of the exposure time, the signal to readout noise ratio will improve by 1.5dB. Because readout noise is only added when the data is read out of the sensor.

Because the shot noise increases as the square-root of the signal (dark current or actual signal), longer exposures will produce better signal-to-noise ratios, in spite of the increase in dark current. The dark current represents a fixed-pattern noise, and is mostly deterministic. Subtraction of the average dark current at a given exposure setting can remove a very significant source of what would appear to be noise. This procedure leaves only the shot noise of the dark current, the shot noise of the signal, and the combined readout noise, in the image.