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Image Sensor ISO Measurement

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TECHNICAL NOTE

ISO Measurement

There are many ways to describe the sensitivity of an imaging system to light. It is traditional for the sensitivity of a digital image sensor to be specified in terms of its quantum efficiency − the number of electrons generated for each incident photon. It is also common to measure responsivity, or the output in volts generated during an exposure ($\mu J/cm^2$). In some cases the exposure is defined in photometric units (lux × seconds).

Traditionally, film sensitivity has been specified in terms of speed or “ISO”. ISO gives the exposure index at which specified image quality parameters are achieved. Exposure index is given by:

$$EI = \frac{10}{H} \qquad \text{(eq. 1)}$$

where ‘H’ is the exposure in lux × s.

Because it is often useful to compare digital imaging systems to conventional silver-halide based photographic systems, standards have been developed that allow the measurement of ISO for digital imaging systems. Using a particular ISO speed value as the exposure index on an electronic still camera should result in the same focal plane exposure as would be obtained using that exposure index on a film camera.

There are two basic types of ISO: saturation-based and noise-based. The saturation-based ISO is also referred to as the ‘base ISO’. The type of ISO of interest depends on the application at hand. In applications where the lighting conditions are controlled, like studio photography, exposure index settings are selected to give the best possible image, with the image highlights falling just below the saturation level. This exposure situation is described by the saturation-based ISO.

When lower than ideal lighting conditions are expected, a noise−based ISO is more useful. In this calculation the signal to noise ratio (SNR) that gives a reasonable image for the application of interest is used to calculate the ISO. This ISO corresponds to the maximum EI setting to achieve that SNR. It is common in photography to designate SNR = 40 as an ‘excellent image’ and SNR = 10 as an ‘acceptable image’ and calculate a corresponding noise-based ISO for each.

The ISO of ON Semiconductor image sensors is determined through direct measurement and application of the following formula:

$$ISO = \frac{15.4 \times f\#^2}{L \times t} \qquad \text{(eq. 2)}$$

where ‘ISO’ represents the base or saturation−based ISO, ‘f#’ is the effective f number of the camera lens used in the measurement, ‘L’ is the luminance of an 18% reflector in the scene (cd/m^2) and ‘t’ is the length of the exposure in seconds.

The choice of an 18% reflector is somewhat arbitrary, but generally an 18% gray patch is available in the laboratory so this is a convenient choice. The constant in the front is determined by making some assumptions about a typical imaging system − 90% lens transmission, a vignetting factor of 0.98, and an image point that is 10° off axis, which folds into the $\cos^4 \theta$ part of the calculation of the actual exposure on the image plane.

To measure the scene luminance, the lighting is varied until the camera outputs an average value equal to 18/106 of full scale when imaging the 18% reflecting surface. During this adjustment the exposure time is held constant. Full scale is either where the imager saturates or where the camera’s ADC reaches its maximum value, whichever happens first.

The use of the number 106 is not arbitrary − it means that we want to accommodate a reflectance of up to 106% for image highlights. Very demanding applications might need more headroom for highlights, and so might use a higher number when calculating base ISO.

The scene luminance is measured with a light meter in cd/m^2 and entered into the equation with the f number and integration time. For a color imaging system, the ISO measurement is performed on the highest speed channel − green for an RGB imager.

This measurement depends on just about everything − lenses, IR cut filters, camera gain and offset settings, mapping of the output voltage to the ADC, just to name a few. So take care that the camera system is set up exactly as it will be used in the end application.

The KAF-16801 Image Sensor, a 16 megapixel full−frame CCD image sensor with 9 micron pixels, a Red−Green−Blue color filter array, and no microlenses has a base ISO just over 100 assuming a demanding 170% reflectance tolerance for highlights or base ISO around 62 assuming 106%. This ISO is more than adequate for the studio lighting conditions under which this sensor is typically used.

Reference

International Organization for Standardization standard 12232, Photography – Electronic Still Picture Cameras – Determination of ISO Speed. (See International Organization for Standardization, www.iso.ch)

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