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Spec No: 001-16628

Spec Title: COLOR RECONSTRUCTION WITH HIGH DYNAMIC RANGE MODES-AN4082

Sunset Owner: Evelyn Beard (EYB)

Replaced by: None

Color Reconstruction with High Dynamic Range Modes

AN4082

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Introduction

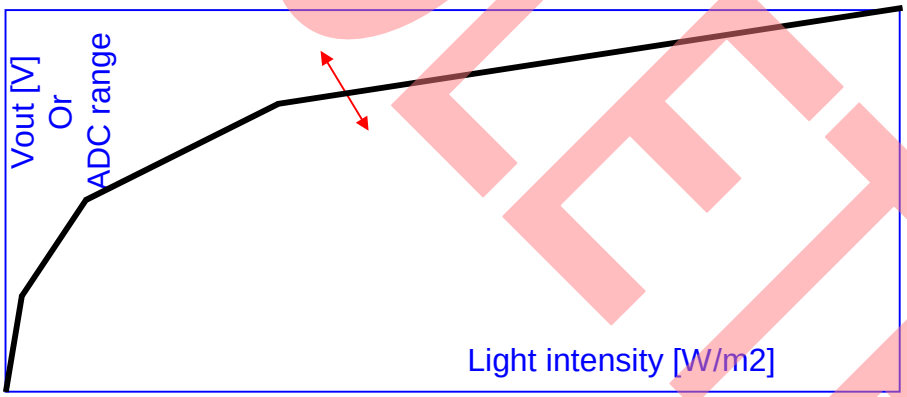
This document applies to the IBIS4-C and IBIS5-C families, and most other color sensors with double or multiple slopes having on-chip FPN correction.

The method of multiple slope integration is used to compress a wide optical dynamic range on a limited voltage output range. This method is implemented in several Cypress image sensors. Essentially, the light power [W/m2] to voltage [V] relation is made piece-wise linear. Both the relative slopes and knee points (the voltages at which the slopes change) are programmable, although they may be fixed in certain image sensors. Figure 1 is an example of a 4-slope power-voltage relationship.

A specific problem arises when such an image sensor is used with a mosaic color filter array (CFA). If the color reconstruction is done as usual, that is, in the output voltage domain (or ADC domain), three kinds of artifacts occur.

- Discontinuity of color saturation over the kneepoints. Just below a knee point, the pixel contrast is high; just beyond it is lower. As color saturation is calculated from the RGB differences, color saturation is high just before a knee point, and low just beyond it.
- Unnatural colors, more specifically unnatural hues, occur across knee points if a certain color scene has one of its components, R, G, or B, at the other side of a knee point as the other components. The unnatural hue occurs due to the different amplification of the color components.
- Unnatural colors apply a classical white balance to the image. Classic (simple, voltage domain, ADC domain) white balance equalizes each raw color channel R, G, or B referred to each other by applying a different gain per color channel. As a result the knee points differ in amplitude for each color; the same physical hue thus receives a different hue across knee points. Even gray tones appear colored.

Figure 1. Multiple Slope Response



Generic Solution

Cypress recommends a generic solution to this problem, which involves extracting the image color information from a software linearized version of the multiple slope function and maintaining the luminance information because it results from the multiple slope relation. In this way, natural colors are obtained, while maintaining the dynamic range advantage of the multiple slope.

In this perspective, do the color reconstruction as follows:

1. Acquire the image in multiple slope
2. Linearize the nonlinear light-ADC relation
3. Perform color reconstruction on the linearized image
4. Transform the reconstructed RGB pixels to the H.S.I. representation (hue – saturation – intensity). Maintain H (hue) and saturation (S)
5. Perform the inverse of the linearization function on the Intensity (I) (or any other function for which you have a good reason)
6. Retransform the resulting H.S.I to an RGB representation, which is what you want.

All steps are obvious for the person skilled in the art. Yet a good linearization formula may be difficult to define.

How to Define a Good but Simple Linearization Formula?

Figure 2. Linearization of Multiple Slope Response

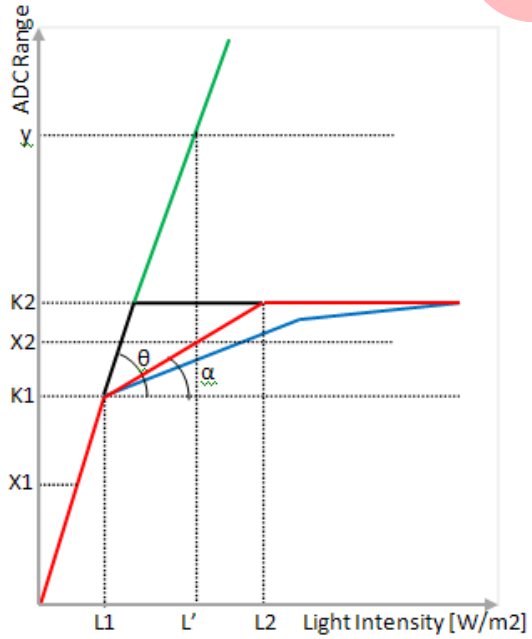


Figure 2 represents an idealized multiple slope and its linearization. Note that in reality the lines are not ideal piece-wise linear, but smoothed at the corners and not perfectly linear pieces. Yet the approximation is sufficient for the purpose: namely the reconstruction of the color saturation and hue, and not intensity (luminance).

The linarization function can be written in c-code as follows. Assume that x is the raw pixel data, y is the linearized pixels data, for three slopes

if(x < k1)y = x ;

else if(x < k2)y = k1 + (x – k1)/r1;

else y = k1 + (k2 – k1)/r1 + (x – k2)/r2;

wherein

- k1 is the first knee point (in ADC units)
- k2 is the second knee point
- r1 is the ratio of the second and first slope, smaller than 1
- r2 is the ratio of the third and first slope, smaller than r1.

How to Obtain Values for k1, k2, r1, r2?

- r1 is the ratio of the slopes. Due to the nature of the multiple slope implementation it is also related to the underlying partial integration times that enable the pixels to operate in multiple slope mode. R1 is then the ratio between the longest and second longest integration underlying time.
- r2, in a similar fashion, is the ration between the longest and the third longest underlying integration time.
- K1 is an ADC value that should be calibrated or estimated. Some experimentation may be necessary. Cypress recommends the following to obtain a knee point k1: make the ratio r1 extreme, resulting in the grey second slopes in Figure 2. With such a response, it suffices to moderately saturate the image during calibration and measure the saturation ADC reading (blue arrow in the above graph). That is a good approximation of k1.
- K2 and any other knee points may be obtained in a similar way. Make r1 close to 1 and r2 extreme. Moderately saturate the image during calibration and measure the ADC reading (purple arrow in the above graph). That is an approximation of k2,

Note that the solution discussed in this application note is not yet tested in real applications. Feedback form real-world implementation is necessary to improve, if necessary, the given solution.

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Document History Page

Document Title: Color Reconstruction with High Dynamic Range Modes - AN4082
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Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	1200303	YIS	See ECN	New application note
*A	3161299	NPA	02/03/11	Updated Figure 2. Added Document History Table
*B	4112285	MTA	09/04/13	Obsolete specs.

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In March of 2007, Cypress recataloged all of its Application Notes using a new documentation number and revision code. This new documentation number and revision code (001-xxxxx, beginning with rev. **), located in the footer of the document, will be used in all subsequent revisions.

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