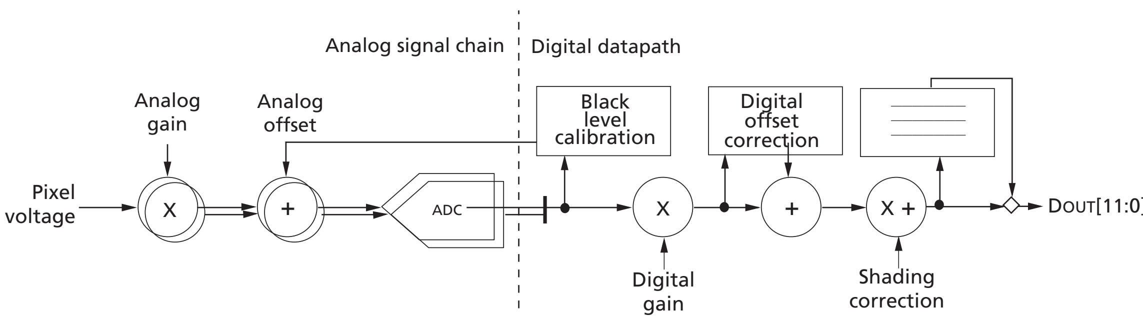
Technical Note

MT9P031
Black Level Calibration (BLC)

Introduction

This technical note discusses technical details on how Micron's MT9P031 CMOS digital image sensor uses the black level calibration (BLC) algorithm to control the black level of an image. The BLC algorithm corrects variations in the black level when the sensor integration time and gain levels are changed.

Figure 1: Data Flow Diagram



The sensor uses rows and columns of pixels that are not exposed to light to control the black level of each frame and to provide black level and dark current measurements. The BLC algorithm uses this data to compensate for analog offset, row noise, and dark current.

The BLC consists of two main algorithms to control the black level in the output image.

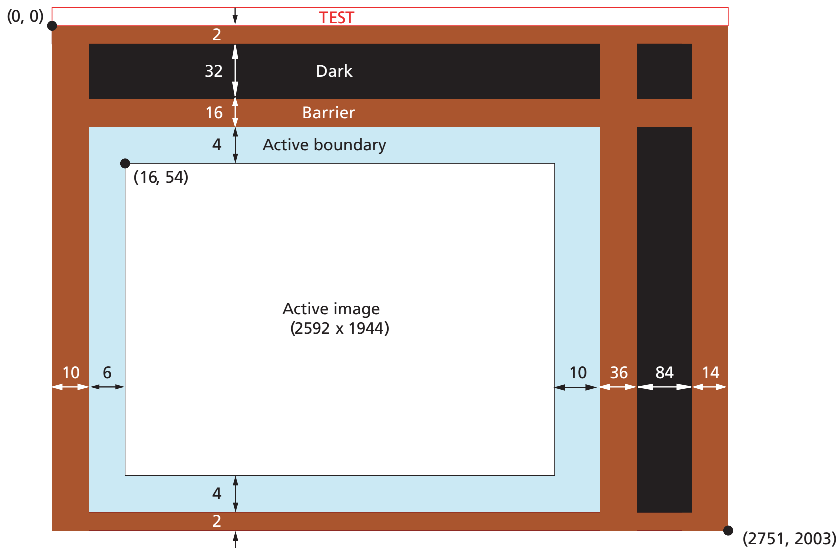
1. Analog offset calibration.
   An offset that can be applied on a color-wise basis to the pixel voltage as it enters the analog-to-digital converter (ADC). This enables adjustments for offset introduced in the pixel sampling and gain stages to be removed, centering the resulting voltage swing in the ADC's range. This offset can be automatically determined by the sensor using the automatic black level calibration circuit—a fairly coarse adjustment with step sizes ranging from 4–8 least significant bits (LSBs).
2. Digital offset correction.
   A digital offset added on a color-wise and line-wise basis to fine-tune the black level of the output image. This offset is based on an average black level taken from each dark column of the rows and is automatically determined by the digital row-wise black level calibration circuit (RBLC), which is 1 LSB resolution.

BLC Pixels

The sensor uses dark pixels to measure the black level. The dark rows are read before the readout of the active pixel array. For each row, the dark pixels in the corresponding dark column are read from left to right. The dark rows are used to measure the mean dark level for each color plane in the image.

The dark columns are used to digitally fine-tune any remaining black level errors. This also removes row fixed pattern noise (FPN). The dark row is read first, from left to right; the active pixel array is also read from left to right, starting at the sixteenth pixel.

Figure 2: Dark Pixel Geometry of the MT9P031 Sensor



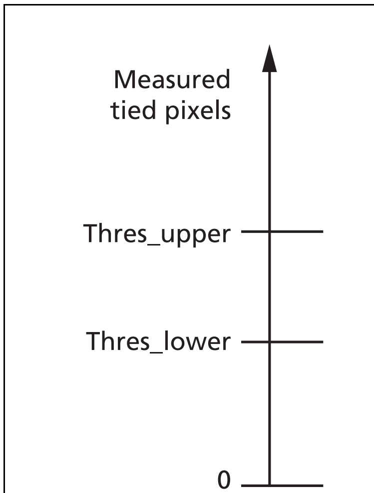
Analog Offset Calibration

This algorithm compensates for analog offset and ensures that the ADC range is optimally utilized. This is accomplished by injecting an analog voltage into the analog signal chain in front of the ADC. This algorithm uses the data measured from the dark rows to cancel out analog offset which would erroneously alter the output black level.

Algorithm

The goal of the analog offset calibration is to move the dark value into a predefined range, using the values read from the dark rows and adjusting the injected analog offset within the frame.

Figure 3: Black Level Range of First Algorithm



Two algorithms set the digital-to-analog converter (DAC) value used to automatically adjust the black level. The first algorithm is a fast-sample algorithm which is used to adjust the black level in large scenarios where there could be a large change in the dark offset (for example, a change in the gain registers). The fast-sample algorithm will read a smaller portion of the dark rows and is capable of correcting large positive or negative dark level offsets, and designed to converge within one frame.

The second algorithm, frame sampling, is used on an on-going basis when all conditions causing the fast-sample algorithm are satisfied. The frame sampling will read the entire set of dark rows and adjust the dark value in small increments.

Fast-Sample Conditions

This fast-sample algorithm is used under the following conditions:

- The frame is the first frame following a sensor reset.
- The sensor is in snapshot mode.
- The fast-sample algorithm has not yet converged.
- The dark value is outside of the upper and lower threshold values.

Digital Offset Correction

Digital BLC is the final calculation applied to pixel data before it is output. It provides a precise black level to complement the coarser grained analog black level calibration, and corrects for black level shift introduced by digital gain. This correction applies to the active columns for all rows.

The amount of shift necessary is determined by sampling the dark pixels on either side of the array (always read before reading the active pixels). A separate value is calculated for each color. These pixel values are then averaged together to form the black level for the row (RBL). Each active pixel in the output image is then adjusted with respect to the predefined RBL.

Enabling Dark Column and Dark Row Readout

The entire array, including dark pixels, can be read out without digital processing or automatic black level adjustments. This is accomplished with the register set shown in Table 1 and Table 2.

Table 1: Full-Resolution Black Rows and Columns

Register	Value	Description
0x01	0x0	Row start
0x02	0x0	Column start
0x03	0x7D3	Row size
0x04	0xABF	Column size
0x20	0x0	Reserved
0x4B	0x0	Reserved
0x62	0x1	Reserved

Table 2: Automate Analog and Disable Digital Processing

Register	Value	Description
0x01	0xC	Row start
0x03	0x7C9	Row size
0x62	0x0	Reserved

BLC Measured Performance

Figure 4 shows noise measured from a full-resolution dark frame image with the BLC features enabled.

Figure 4: Noise vs. Gain Dark Frame Full-Resolution Measurement

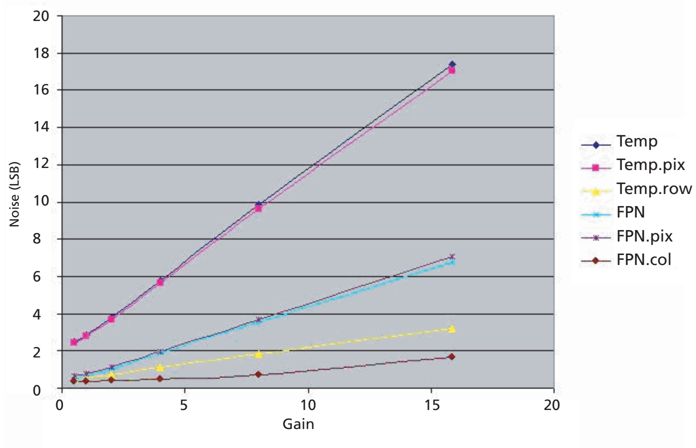
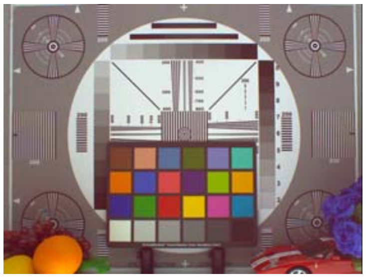


Figure 5 illustrates color images and dark frame taken at 15 fps.

Figure 5: Color Images Taken at Different Light Levels

10 Lux



30 Lux

100 Lux

Conclusion

This technical note describes how black level calibration algorithms are used to correct variations in the black level of an image when the sensor integration times and gain levels are changed. For more information on black level calibration, refer to Micron's Web site at www.micron.com/imaging.

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Revision History

Rev. A 10/18/07

- Initial release.