Technical Note

MT9P012
Lens Shading Correction (LSC)

Introduction

This technical note describes the lens shading correction method and calibration procedure to automatically obtain lens corrected images with Micron's MT9P012 CMOS image sensor. Camera modules have signal degradation on sensor periphery due to optical and geometrical factors. Lens shading correction compensates the signal degradation by digitally gaining pixels on the image periphery. In the MT9P012, the lens shading correction function is performed on all four color channels—red, greenR, blue, and greenB.

Lens Shading Correction (LSC) Method

LSC is performed on Raw12 Bayer data in the datapath. In the context of the signal chain, lens shading correction is located before the Digital Gain block, as shown in Figure 1.

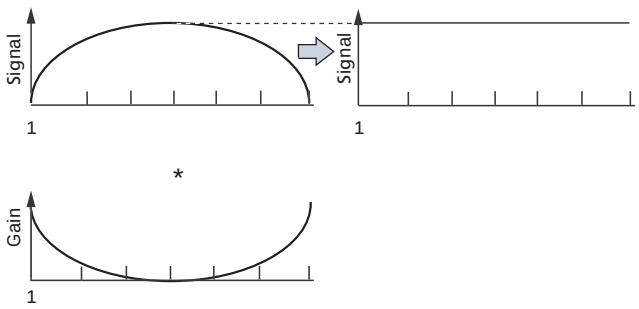
LSC can be enabled or disabled by programming data register bit field R0x3780 bit[15] to "1."

Figure 1: Lens Shading Correction in Signal Path

LSC is implemented by multiplying the value of incoming pixel data $S_i(x,y,c)$ by the value of the correction function G(x,y,c), which is calculated based upon the position and the color channel of the array sensor. The resulting output pixel data $S_o(x,y,c)$, is given in the following formula:

$$S_o(x,y,c) = S_i(x,y,c)*G(x,y,c) \quad \text{(EQ 1)}$$

Figure 2: Before and After Signal

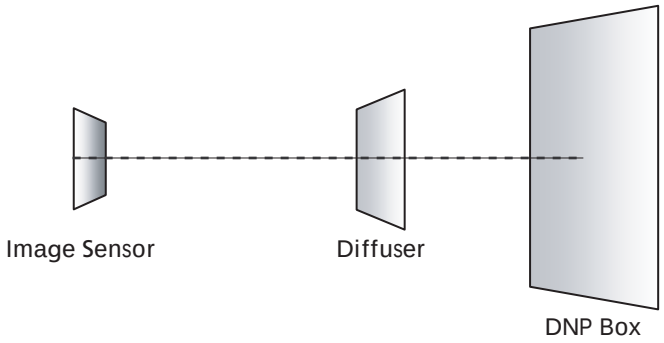


Lens Calibration Procedure

Setup

1. Start up DevWare and camera in the default state (load default register settings).
2. Point the camera at a flat and uniformly illuminated calibration target (the variation in light intensity should be no more than 2 percent over the entire FOV at a color temperature of approximately 5000K). The light source and sensor demo system should be shielded from external light sources.

Figure 3: Lens Correction Setup



Switch to Full Resolution

By default, the sensor is in full resolution mode (2592 x 1944). If the sensor is not in full resolution, return to full resolution. Use the "Zoom Out" button from the toolbar to fit the entire image within the current view.

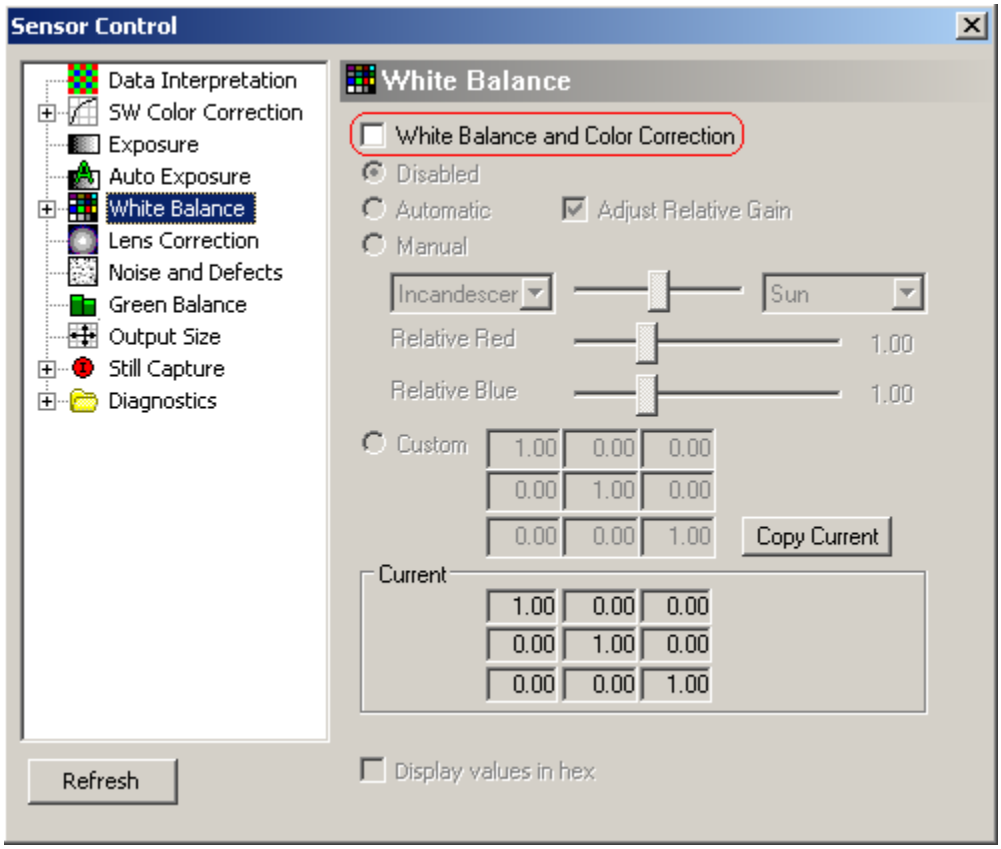
Turn Off Color Processing

From the toolbar, select "Preset," then select and load "Color Processing Off." This should disable (uncheck) the following functions:

- SW Color Correction (including Gamma and Contrast)
- Exposure
- Auto Exposure and Auto White Balance
- Color Correction

For example, Figure shows the Auto White Balance and Color Correction box is unchecked (disabled) in the Sensor Control Window.

Figure 4: White Balance

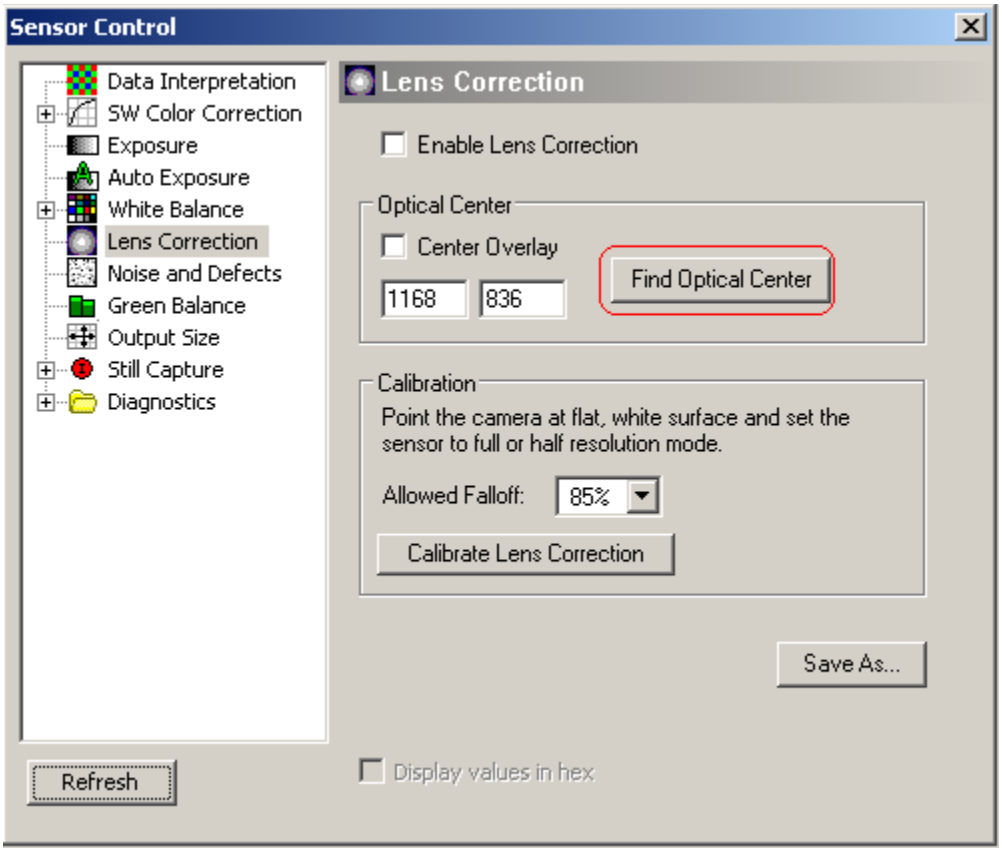


Calibration

1. Find the center of the lens by going to Sensor Control –> Lens Correction.

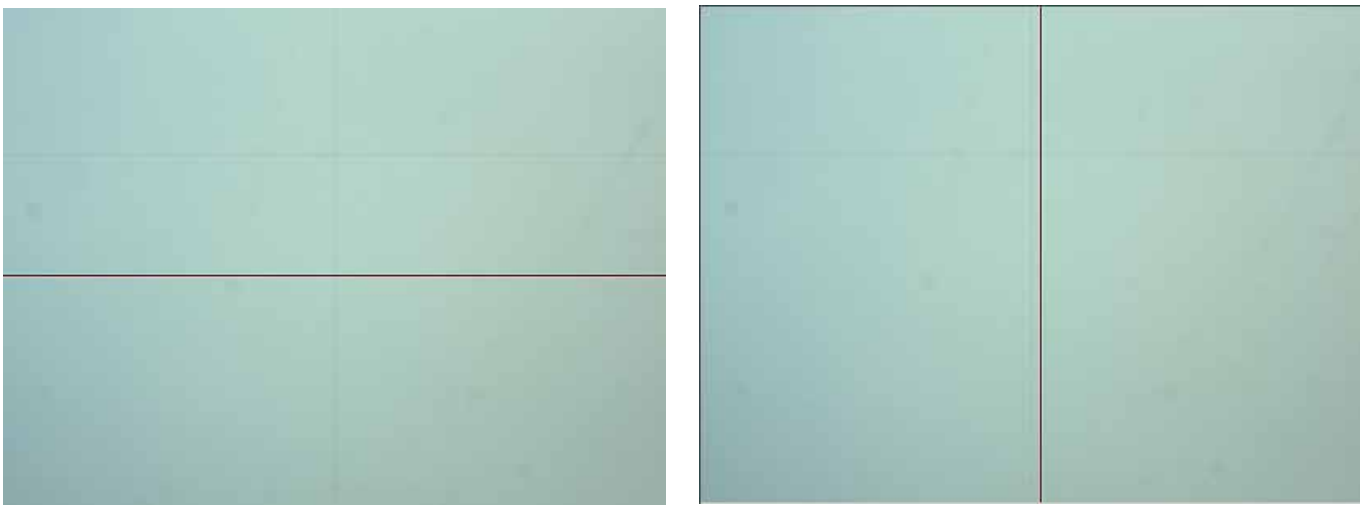
   Click on "Find Optical Center" and watch the zones readjust on the image.

Figure 5: Lens Regions



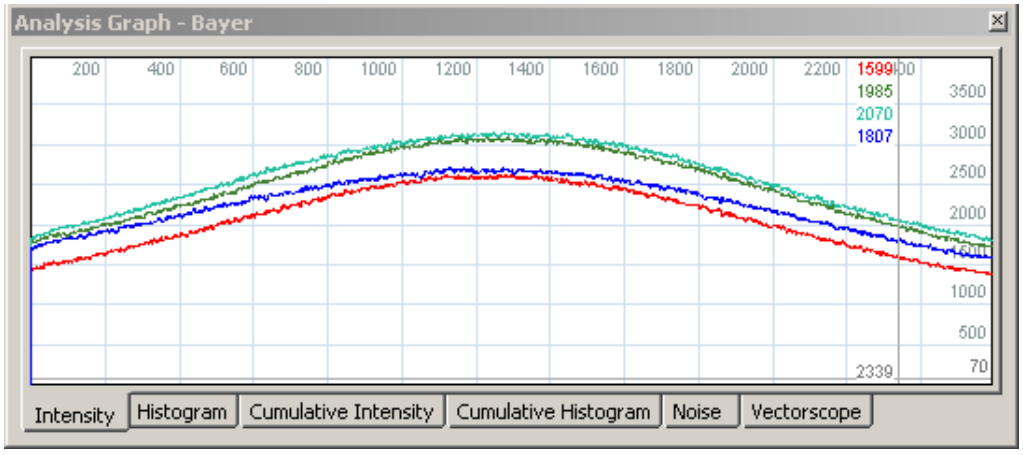
2. Set the row and column line at the middle row/column of the image. In full resolution mode, the row line is set at 1296 with column line at 972. The mouse cursor position can be read from the "Info" panel on the left side of the screen.

Figure 6: Sensor Array Row and Column Selection



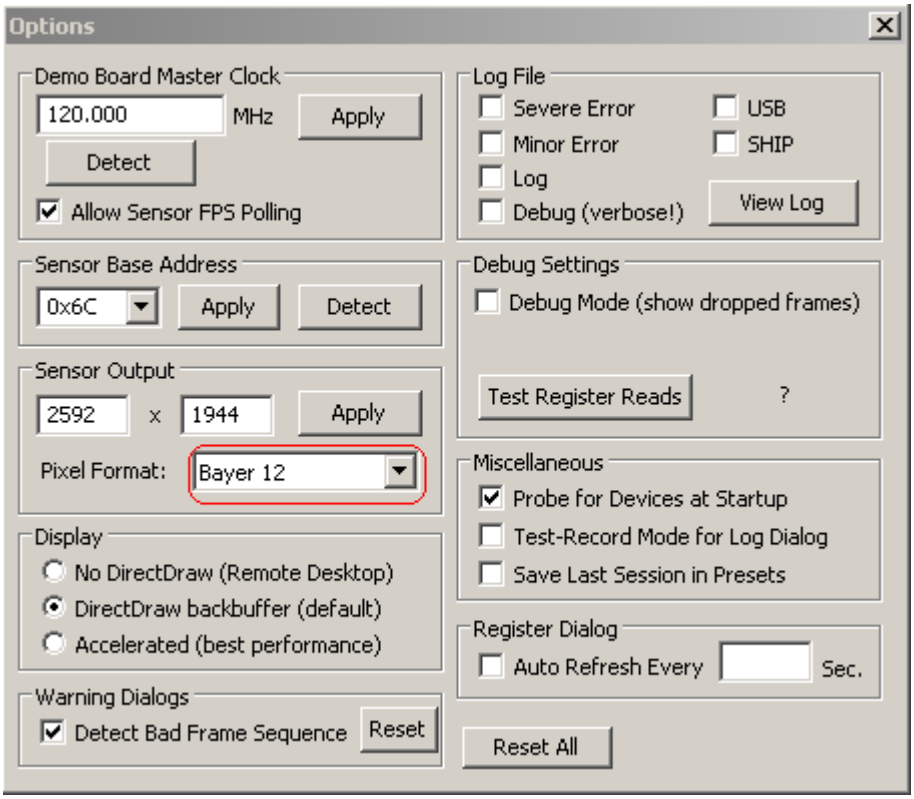
3. Open Analysis Graph and view the Intensity plot of the middle row/column of the image—the graph should be similar to Figure . Right-click on the Analysis Graph window and select “Plot Bayer Data.” This will show both the greenR and greenB channels.

Figure 7: Intensity Graph



4. Open the “Options” window under the View tab. Under “Pixel Format,” set the pixel format to “Bayer 12.”

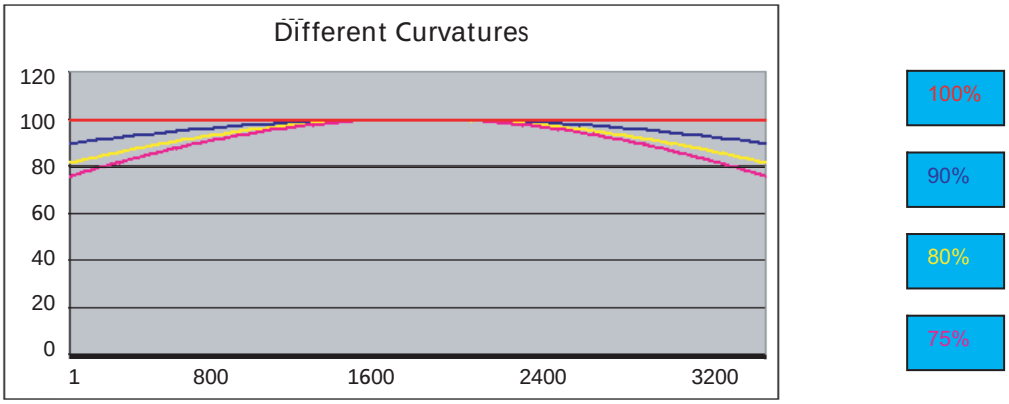
Figure 8: Change Pixel Format to 12-bit



5. Adjust peak intensity to approximately 3000. From the Register window (click on the "Register" icon in the toolbar), adjust the coarse_integration_time register (R0x3012) such that the peak intensity of the green curves is not or around 2800–3000. The red and blue curve should not clip in this condition; the intensity value should not exceed 4095. If clipping occurs, try using a different uniform light source or manually lowering the analog gains—R0x3056 for greenR, R0x3058 for blue, R0x3052 for red, and R0x305C for greenB.

6. Return to the “Lens Correction” window. Choose the allowed “Percentage Fallout” for the LSC. One hundred percent corresponds to a completely flat curve. However, the percentage of the lens correction can be reduced by selecting lower percentage for curvature. Click on “Calibrate Lens Correction.” DevWare will calculate the LSC based on the flat field image it is viewing. Then choose “Enable Lens Correction” to view the corrected flat field image.

Figure 9: Curve Percentage



7. Use the “Save As” button to save the new register settings.

Results

Figures through show a set of data images before and after the lens correction calibration procedure. The intensity graphs are plotted in horizontal, vertical, and diagonal profiles.

Figure 10: Before LSC Image

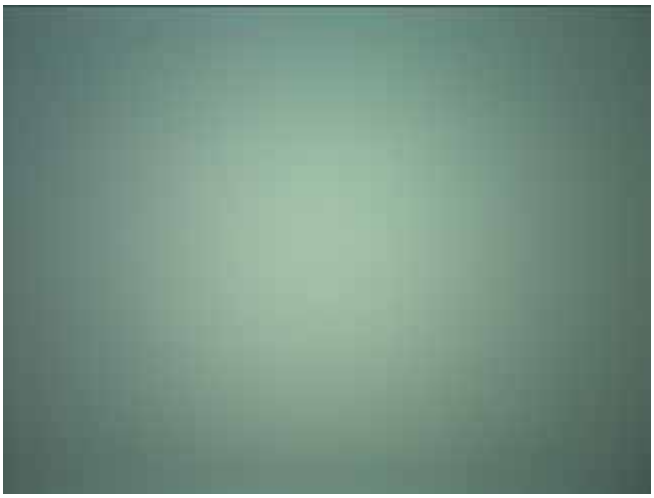
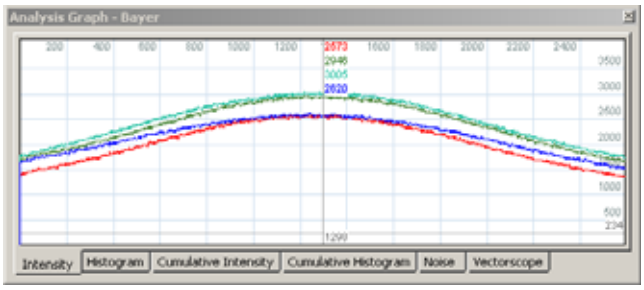
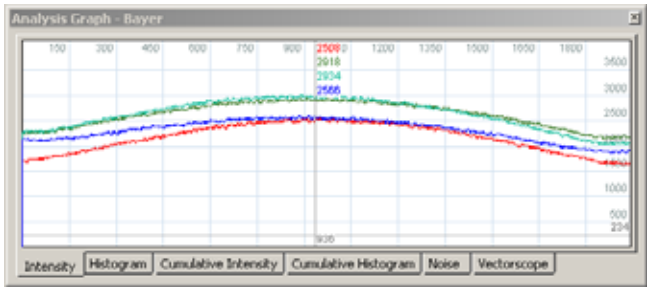


Figure 11: Before LSC Intensity Graphs



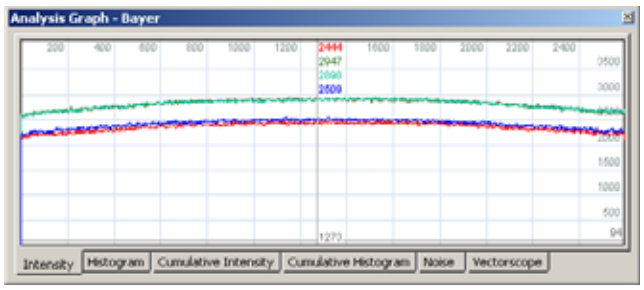
Before LSC Intensity Graph (horizontal)



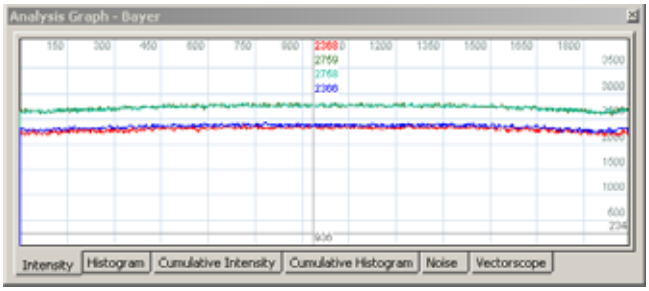
Before LSC Intensity Graph (vertical)

Figure 12: After LSC Image

Figure 13: After LSC Intensity Graphs



After LSC Intensity Graph (horizontal)



After LSC Intensity Graph (vertical)

Verification

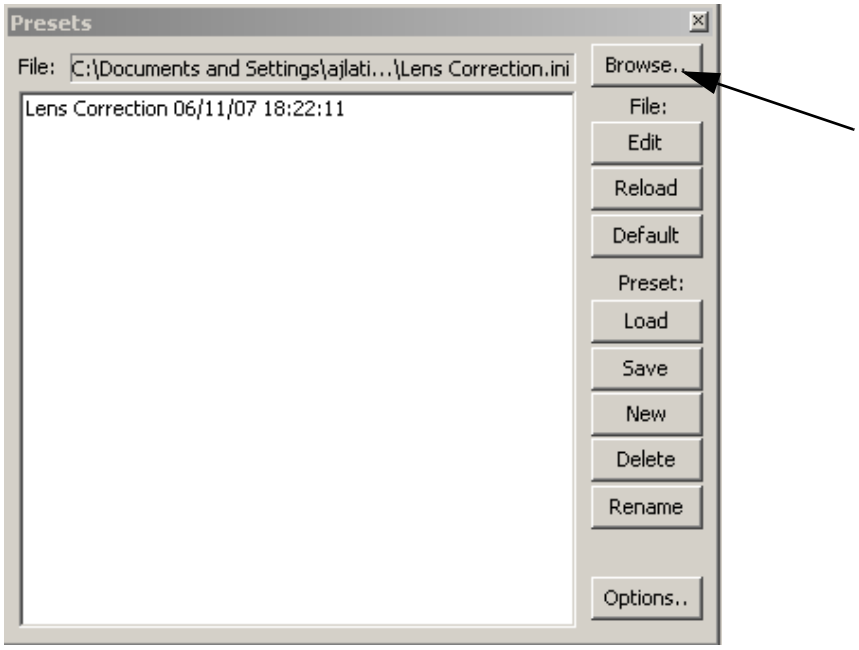
For a thorough verification of lens corrected image results, the following steps are recommended:

1. Place the MT9P012 camera module in front of flat and uniformly illuminated targets for inspection. The following scenarios are suggested: daylight (6500K), incandescent (2850K), cool white florescent (4150K).
2. Load DevWare and reset all registers.

Figure 14: DevWare

3. Open Preset window, click on "Browse…" and locate the load lens correction .ini file. Enable LSC by setting R0x3780 bit[15] to “1.”

Figure 15: Lens Correction Preset



4. For each of the scenarios, look at the picture for visual artifacts and the intensity graph to see if a flat curve is obtained for each color (R,G,B).
5. Point the camera module at a well-lit scene and inspect the picture as a last check on image quality.

Register List and Default Values

The coefficients used in the lens shading correction algorithm of the MT9P012 are read in the wrong order when the sensor enables flip or mirror. This issue does not arise when mirror and flip are both enabled.

The workaround is to change the coefficient order in the LSC applied for mirror and flip modes, from red-greenR-blue-greenB (normal) to blue-greenB-red-greenR.

Table 1: Register List and Default Values

Register # (Hex)	Register Description	Data Format (Binary)	Default Value Dec (Hex)
R0x3600	Reserved	–	0 (0x0000)
R0x3602	Reserved	–	0 (0x0000)
R0x3604	Reserved	–	0 (0x0000)
R0x3606	Reserved	–	0 (0x0000)
R0x3608	Reserved	–	0 (0x0000)
R0x360A	Reserved	–	0 (0x0000)
Rx360C	Reserved	–	0 (0x0000)
Rx360E	Reserved	–	0 (0x0000)
R0x3610	Reserved	–	0 (0x0000)
R0x3612	Reserved	–	0 (0x0000)
R0x3614	Reserved	–	0 (0x0000)
R0x3616	Reserved	–	0 (0x0000)
R0x3618	Reserved	–	0 (0x0000)
R0x361A	Reserved	–	0 (0x0000)
R0x361C	Reserved	–	0 (0x0000)
R0x361E	Reserved	–	0 (0x0000)
R0x3620	Reserved	–	0 (0x0000)
R0x3622	Reserved	–	0 (0x0000)
R0x3624	Reserved	–	0 (0x0000)
R0x3626	Reserved	–	0 (0x0000)
R0x3640	Reserved	–	0 (0x0000)
R0x3642	Reserved	–	0 (0x0000)
R0x3644	Reserved	–	0 (0x0000)
R0x3646	Reserved	–	0 (0x0000)
R0x3648	Reserved	–	0 (0x0000)
R0x364A	Reserved	–	0 (0x0000)
R0x364C	Reserved	–	0 (0x0000)
R0x364E	Reserved	–	0 (0x0000)
R0x3650	Reserved	–	0 (0x0000)
R0x3652	Reserved	–	0 (0x0000)
R0x3654	Reserved	–	0 (0x0000)
R0x3656	Reserved	–	0 (0x0000)

Table 1: Register List and Default Values (continued)

Register # (Hex)	Register Description	Data Format (Binary)	Default Value Dec (Hex)
R0x3658	Reserved	–	0 (0x0000)
R0x365A	Reserved	–	0 (0x0000)
R0x365C	Reserved	–	0 (0x0000)
R0x365E	Reserved	–	0 (0x0000)
R0x3660	Reserved	–	0 (0x0000)
R0x3662	Reserved	–	0 (0x0000)
R0x3664	Reserved	–	0 (0x0000)
R0x3666	Reserved	–	0 (0x0000)
R0x3680	Reserved	–	0 (0x0000)
R0x3682	Reserved	–	0 (0x0000)
R0x3684	Reserved	–	0 (0x0000)
R0x3686	Reserved	–	0 (0x0000)
R0x3688	Reserved	–	0 (0x0000)
R0x368A	Reserved	–	0 (0x0000)
R0x368C	Reserved	–	0 (0x0000)
R0x368E	Reserved	–	0 (0x0000)
R0x3690	Reserved	–	0 (0x0000)
R0x3692	Reserved	–	0 (0x0000)
R0x3694	Reserved	–	0 (0x0000)
R0x3696	Reserved	–	0 (0x0000)
R0x3698	Reserved	–	0 (0x0000)
R0x369A	Reserved	–	0 (0x0000)
R0x369C	Reserved	–	0 (0x0000)
R0x369E	Reserved	–	0 (0x0000)
R0x36A0	Reserved	–	0 (0x0000)
R0x36A2	Reserved	–	0 (0x0000)
R0x36A4	Reserved	–	0 (0x0000)
R0x36A6	Reserved	–	0 (0x0000)
R0x36C0	Reserved	–	0 (0x0000)
R0x36C2	Reserved	–	0 (0x0000)
R0x36C4	Reserved	–	0 (0x0000)
R0x36C6	Reserved	–	0 (0x0000)
R0x36C8	Reserved	–	0 (0x0000)
R0x36CA	Reserved	–	0 (0x0000)
R0x36CC	Reserved	–	0 (0x0000)
R0x36CE	Reserved	–	0 (0x0000)
R0x36D0	Reserved	–	0 (0x0000)
R0x36D2	Reserved	–	0 (0x0000)
R0x36D4	Reserved	–	0 (0x0000)
R0x36D6	Reserved	–	0 (0x0000)

Table 1: Register List and Default Values (continued)

Register # (Hex)	Register Description	Data Format (Binary)	Default Value Dec (Hex)
R0x36D8	Reserved	–	0 (0x0000)
R0x36DA	Reserved	–	0 (0x0000)
R0x36DC	Reserved	–	0 (0x0000)
R0x36DE	Reserved	–	0 (0x0000)
R0x36E0	Reserved	–	0 (0x0000)
R0x36E2	Reserved	–	0 (0x0000)
R0x36E4	Reserved	–	0 (0x0000)
R0x36E6	Reserved	–	0 (0x0000)
R0x3700	Reserved	–	0 (0x0000)
R0x3702	Reserved	–	0 (0x0000)
R0x3704	Reserved	–	0 (0x0000)
R0x3706	Reserved	–	0 (0x0000)
R0x3708	Reserved	–	0 (0x0000)
R0x370A	Reserved	–	0 (0x0000)
R0x370C	Reserved	–	0 (0x0000)
R0x370E	Reserved	–	0 (0x0000)
R0x3710	Reserved	–	0 (0x0000)
R0x3712	Reserved	–	0 (0x0000)
R0x3714	Reserved	–	0 (0x0000)
R0x3716	Reserved	–	0 (0x0000)
R0x3718	Reserved	–	0 (0x0000)
R0x371A	Reserved	–	0 (0x0000)
R0x371C	Reserved	–	0 (0x0000)
R0x371E	Reserved	–	0 (0x0000)
R0x3720	Reserved	–	0 (0x0000)
R0x3722	Reserved	–	0 (0x0000)
R0x3724	Reserved	–	0 (0x0000)
R0x3726	Reserved	–	0 (0x0000)
R0x3780	Reserved	–	0 (0x0000)
R0x3782	Reserved	–	0 (0x0000)
R0x3784	Reserved	–	0 (0x0000)

Conclusion

For additional information on lens shading correction, or for more information on other features, refer to the MT9P012 data sheet on Micron's Web site at www.micon.com/imaging.

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Revision History

Rev A. 07/10/2007

- Initial release