Technical Note

MT9V022

## Auto Exposure Control (AEC) and Auto Gain Control (AGC) Functions

Introduction

This technical note illustrates the auto exposure control (AEC) and the auto gain control (AGC) features of the Micron® MT9V022 image sensor. These features are responsible for maintaining optimal self-adjusting exposure and analog gain settings. The auto-adjusted exposure settings ensure that the acquired image falls in a desirable region of the sensor's sensitivity range, ensuring optimal luminance of the image.

Operation Details

The integrated AEC/AGC unit (as shown in Figure 1) is responsible for ensuring that optimal auto settings of exposure and (analog) gain are computed and updated every frame.

AEC and AGC can be individually enabled or disabled by R0xAF. When AEC is disabled (R0xAF[0] = 0), the sensor uses the manual exposure value in R0x0B. When AGC is disabled (R0xAF[1] = 0), the sensor uses the manual gain value in R0x35.

Figure 1: Controllable and Observable AEC/AGC Registers
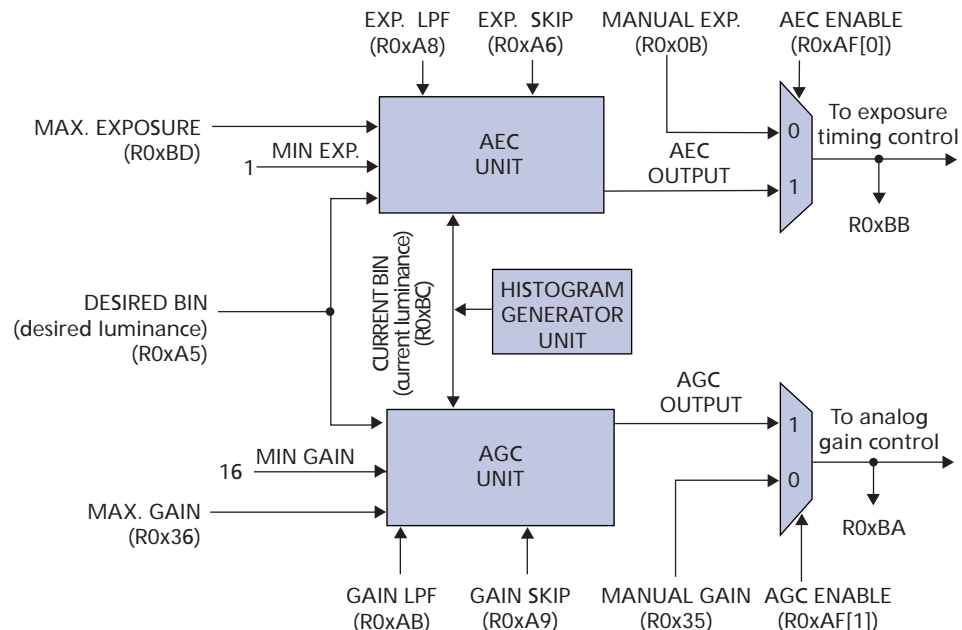
The exposure is measured in row-time by reading R0xBB. The exposure range is from 1 through 480. The gain is measured in gain-units by reading R0xBA. The gain range is from 16 through 63 (unity gain = 16 gain-units; multiply by 1/16 to get the true gain).

When AEC is enabled (R0xAF[0] = 1), the maximum auto exposure value is limited by the smaller of R0xBD or 2,047. The minimum auto exposure is fixed at 1 row-time.

When AGC is enabled (R0xAF[1] = 1), the maximum auto gain value is limited by R0x36; minimum auto gain is fixed to 16 gain-units.

The exposure control measures current scene luminance and desired output luminance by accumulating a histogram of pixel values while reading out a frame. The desired exposure and gain are then calculated from the current frame for the subsequent frame.

AEC and AGC Enabled

When both AEC and AGC are enabled, only the AEC unit is initially active with the AGC unit is static (at unity gain), as shown in Figure 2. The AGC becomes active only when AEC hits the maximum row time, causing the AEC to remain static at its maximum row-time value while the gain is increased.

Figure 2:   Operation When AEC and AGC Both Enabled
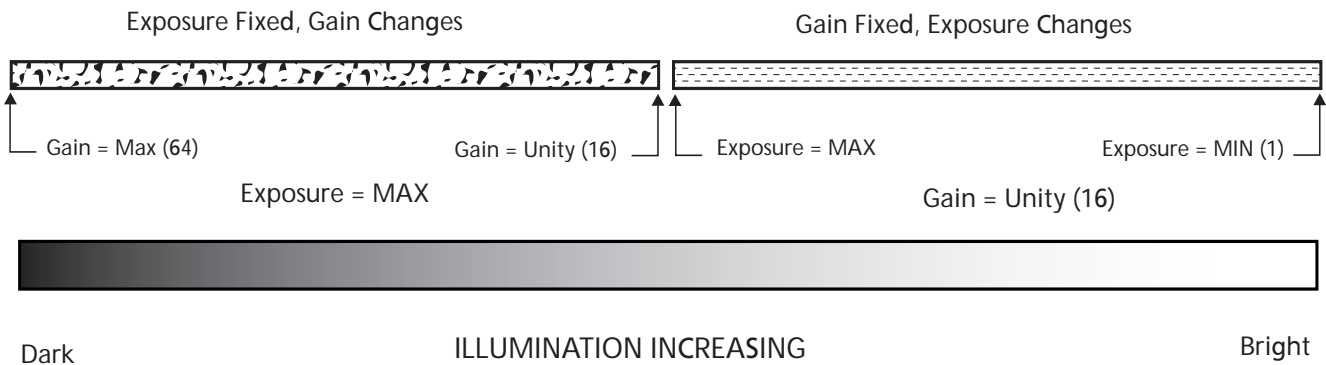
Each histogram bin accumulates 16 pixel intensities. Bin 1 is a collection of all pixels intensities from 0 through 15; Bin 2 is a collection of all pixel intensities from 16 through 31 and so forth. Since the auto exposure and auto gain controls are histogram-based, the bin number represents a saturation percentile. The total count of the pixels in this percentile is user-definable through R0xB0. The user controls the desired luminance of the image by setting a desired bin using R0xA5. This value can range from 1 through 64.

The current luminance of the image is available in R0xBC. It ranges from 1 through 64 and is termed the current bin. For a given image frame, when the total of all pixels in bin 64 + bin 63... + bin n is equal to or greater than the saturation percentile (pixel-count value in R0xB0), then bin n is the value of the current bin.

From the current bin and desired bin values, the automatic exposure correction algorithm calculates the next image's exposure time. When the current image is underexposed and the current bin is less than 7, the next exposure is approximately double the current exposure (all exposure times are rounded to the nearest whole number row time increment.) When the image is overexposed and the current bin is at 64, the next exposure is approximately 3/4 of the current exposure. For all other current bin values, the

next exposure is calculated by multiplying the current exposure by the ratio of the desired bin to the current bin. The automatic gain correction algorithm follows similar logic.

To maximize the auto exposure/auto gain response and minimize the settling time (oscillation dying down), the user may need to adjust the low pass filter (LPF) and skip-frame values. The register table in the MT9V022 data sheet describes these controls in R0xA6, R0xA8, R0xA9, and R0xAB. An LPF value of "0" indicates that the next update will be the newly computed exposure or gain value. An LPF value of "1" indicates that the next update will be the newly computed exposure or gain value only if the ratio of the difference of the calculated value to the current value is more than 1/4. If not, only 1/2 the total change is put into effect. An LPF value of "2" indicates that the next update will be the newly computed exposure or gain value only if the ratio of the difference of the calculated value to the current value is more than 1/4. If not, only 1/4 the total change is put into effect.

The skip-frame value conveys how many frames to skip before updating the exposure or gain. If the skip-frame value is equal to "0," it implies skipping zero frames before update. If the skip-frame value is equal to "1," it implies skipping one frame before update. The maximum skip-frame value is 15.

Computing Current Luminance

Figure 3 shows graphically how the current bin (current luminance) of an image is calculated.

Figure 3:   Computing the Current Bin (Current Luminance) of an Image Frame
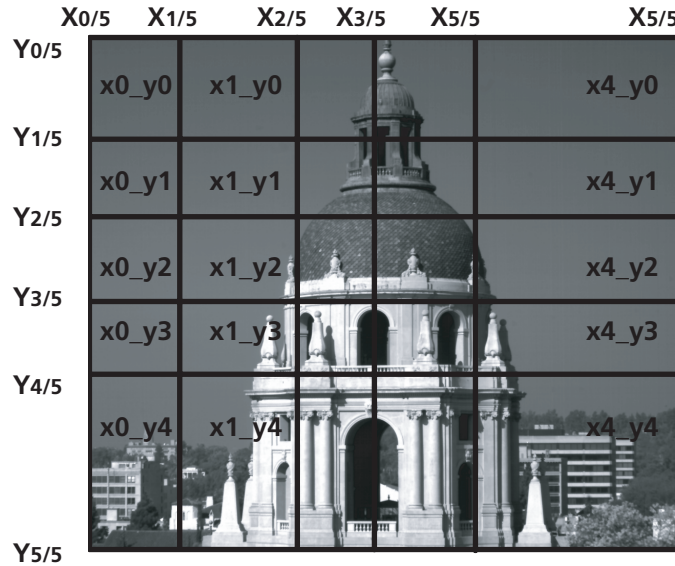
3
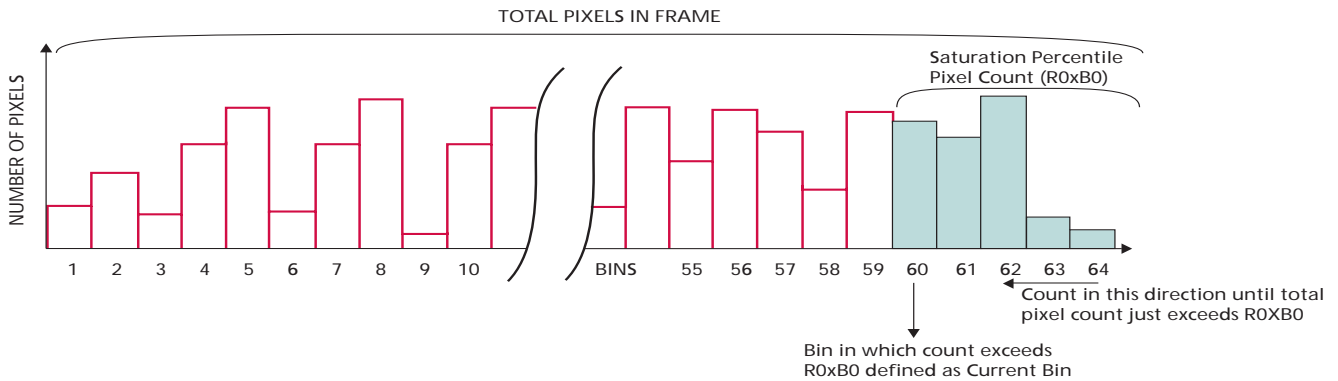
Using Regions of an Image to Set Exposure and Gain

Figure 4 shows how an image can be divided into 25 regions or tiles. Each tile can have an individual gain or weighting when used in the AEC/AGC algorithm.

Figure 4: **Tiled Image Grid**

Scene Grid for Region of Interest

The MT9V022 has a scene grid allowing the user to identify tiles of interest upon which the AEC/AGC unit will perform its computations. The user can select the sampling weight for each tile. If a tile has a sampling weight of 15, then all the pixels in that tile will be used in the computation of exposure and gain. A sampling weight of "0" implies that no pixels in that tile should be used for the computation. The sampling weight algorithm works by first dividing each row of each tile into 16 pixel segments. Then, the algorithm selects the first number of pixels from each row according to the number stored in each tile's sampling weight register, as shown in Table 1 on page 5. These selected pixels are used in the automatic exposure and gain algorithms.

Table 1:   Number of Pixels Used Per Segment in AEC/AGC Algorithm

Sample Weight Register Setting	Number of Pixels Used per Segment
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	9
9	10
10	11
11	12
12	13
13	14
14	15
15	16

Pixel Weighting

In Figure 5, pixels identified in blue are the specific ones used in the sampling weight algorithm for a 20-column x 4-row tile with the tile weight set to a value of "2."

Figure 5:   Example Locations of Pixels Used in AEC/AGC Algorithm

The resulting exposure and gain values are applied uniformly to the entire scene. The user can therefore force the AEC/AGC unit into using pixels from a region of interest. A region of interest in the scene can be selected by choosing the appropriate tiles for optimal tile luminance (at the expense of the remainder of the image). If the user changes the sampling weight of any tile from the default value of 15, it may be necessary to make an adjustment to the pixel-count value to keep a saturation percentile at the empirically determined optimal value of 12 percent (Note: $44,000/(752 \times 480) \times 100$ is approximately 12 percent). The region of interest is fully flexible (grid coordinates can be arbitrarily changed) and each tile can be given an arbitrary weight (even "0" to null its influence). R0x99 through R0x9E provide the user the means to change the locations of the vertical grid lines. R0x9F through R0xA4 provide the user the means to change the locations of the horizontal grid lines.

The unit also supports digital gain and attenuation for each individual tile. This feature can only be controlled manually (and is completely decoupled from the AEC/AGC units). Bits [3:0] of R0x80 to R0x98 control the digital gain/attenuation of each individual tile.

AEC and Digital Gain Tile Coordinate Settings

The AEC and digital gain tile coordinate settings behave differently for the X (R0x99–R0x9E) and Y (R0x9F–R0xA4) coordinates when binning is enabled. In general, the tile coordinates settings are equal to the column or row number in the binned image. However, for the 4X column binning mode, a value that is double the actual X coordinate must be entered into the appropriate register.

Table 2 summarizes the tile coordinate ranges for each binning condition.

Table 2: Tile Coordinate Ranges

Column Bin Setting	R0x0D[3:2]	X Tile Coordinate Range (R0x99–R0x9E)
Normal operation	00	0 to 752
Bin by 2	01	0 to 376
Bin by 4	10	0 to 376
Row Bin Setting	**R0x0D[1:0]**	**Y Tile Coordinate Range (R0x9F–R0xA4)**
Normal operation	00	0 to 480
Bin by 2	01	0 to 240
Bin by 4	10	0 to 120

Conclusion

The automatic exposure and gain controls are designed into the MT9V022 sensor to ensure optimal luminance of the scene without manual intervention. This greatly simplifies the task of maintaining good image quality from frame to frame as the light intensity changes.

Revision History

- Minor edits and format updates.

- Initial release.