Hisilicon ISP

User Guide

Issue 02

Date 2015-02-10

HiSilicon Technologies Co., Ltd.

Address:	Huawei Industrial Base Bantian, Longgang Shenzhen 518129 People's Republic of China
Website:	http://www.hisilicon.com
Email:	support@hisilicon.com

About This Document

Glossary

3A	AE, AWB and AF
AE	Auto Exposure
AF	Auto Focus
AG	Analog Gain
AGC	Auto Gain Control
API	Application Programming Interface
APB	Advanced Peripheral Bus (ARM AMBA specification)
AWB	Auto White Balance Correction
AXI	Advanced eXtensible Interface (ARM AMBA specification)
BP	Black Point
CPU	Central Processing Unit
DG	Digital Gain
DIS	Digital Image Stabilization
DRC	Dynamic Range Compression
FW	Firmware
HDR	High Dynamic Range, synonymous with WDR
HW	Hardware
ISO	ISO standard 12232:2006. A measure of photographic sensitivity to light
ISP	Image Signal Processor
LED	Light-emitting Diode
LUT	Lookup Table
MV	Motion Vector
NR	Noise Reduction
ROI	Region of Interest

SoC	System on Chip
SPI	Serial Peripheral Interface
WB	White Balance
WDR	Wide Dynamic Range, synonymous with HDR
WP	White Point
YCbCr	Method of encoding RGB colorspace according to the ITU-R BT.601 or ITU- R BT.709 standards
YUV	A method of encoding RGB colorspace in practice equivalent to YCbCr

Change History

Updates between document issues are cumulative. Therefore, the latest document issue contains all updates made in previous issues.

Issue 02 (2015-02-10)

This issue is the second offcial release.

Issue 01 (2014-12-20)

This issue is the first offcial release.

Contents

About This Document i

1 Introduction 1

1.1 Main Features 1

2 Functional Overview 2

3 General Details 4

3.1 Number format 4

3.2 Bayer Pattern and Pixel Readout 4

4 Module Configuration 6

4.1 Vedeo Test Generator 6

4.1.1 Key Parameters 7

4.1.2 Register Map 8

4.2 Sensor Offset 10

4.2.1 Functional Description 10

4.2.2 Register Map 10

4.3 Gamma_FE, WDR Pre-Companding LUT 11

4.3.1 Functional Description 11

4.3.2 Key Parameter 11

4.3.3 Register Map 12

4.4 Digital Gain 12

4.4.1 Register Map 13

4.5 Green Equalization 13

4.5.1 Key Parameters 14

4.5.2 Register Map 14

4.6 Defect Pixel Correction 15

4.6.1 Dynamic Defect Pixel Correction 15

4.6.2 Dynamic Defect Pixel Detection and Relpacement 17

4.6.3 Key Parameters 17

4.6.4 Static Defect Pixel Correction 18

4.6.5 Register Map 22

4.7 Frame-Switching WDR 24

4.7.1 Functional Description 24

4.7.2 Key Parameters 25
4.7.3 Noise Reduction In Dual Exposure Mode 26
4.7.4 Register Map 26
4.8 NR 27
4.8.1 Functional Description 27
4.8.2 Key Parameters 28
4.8.3 Radial NR Strength 28
4.8.4 Key Parameters 28
4.8.5 Register Map 29
4.9 White Balance 31
4.9.1 Functional Description 31
4.9.2 Register Map 31
4.10 Lens Shading 33
4.10.1 Key Parameters 33
4.10.2 Register Map 34
4.11 Pre-DRC and Post-DRC LUT 35
4.12 DRC 36
4.12.1 Functional Description 36
4.12.2 Key Parameters 37
4.12.3 Register Map 37
4.13 Demosaic 40
4.13.1 Function Description 40
4.13.2 False Color Suppression 40
4.13.3 Directional And Un-directional Sharpening 40
4.13.4 Key Parameters 41
4.13.5 Register Map 41
4.14 3x3 Color Matix 46
4.14.1 Functional Description 46
4.14.2 Key Parameters 46
4.14.3 Register Map 46
4.15 Gamma 48
4.15.1 Functional Description 48
4.15.2 Register Map 49
4.16 Sharpening 50
4.16.1 Functional Description 50
4.16.2 Key Parameters 51
4.16.3 Register Map 51

5 2A (AE, AWB) Statistics 52

5.1 Zone Configuration 53
5.1.1 Key Parameters 54
5.1.2 Register Map 54

5.2 Zone Weighting 55
5.2.1 Key Parameters 55
5.2.2 Regsiter Map 55
5.3 AE Statistics 56
5.3.1 5 Bin Histogram 56
5.3.2 Key Parameters 57
5.3.3 Register Map 58
5.4 AE Sum Statistics 59
5.4.1 Register Map 60
5.5 256 Bin Histogram 60
5.5.1 Register Map 61
5.6 AWB Statistics 61
5.6.1 Key Parameters 62
5.6.2 AWB Zone Data 63
5.6.3 AWB Sum Statistics 64
5.6.4 Register Map 64
6 Interrupt 69
6.1 Functional Description 69
6.2 Details 69
6.2.1 Key Parameters 70
6.2.2 Interrupt Timing 70

1 Introduction

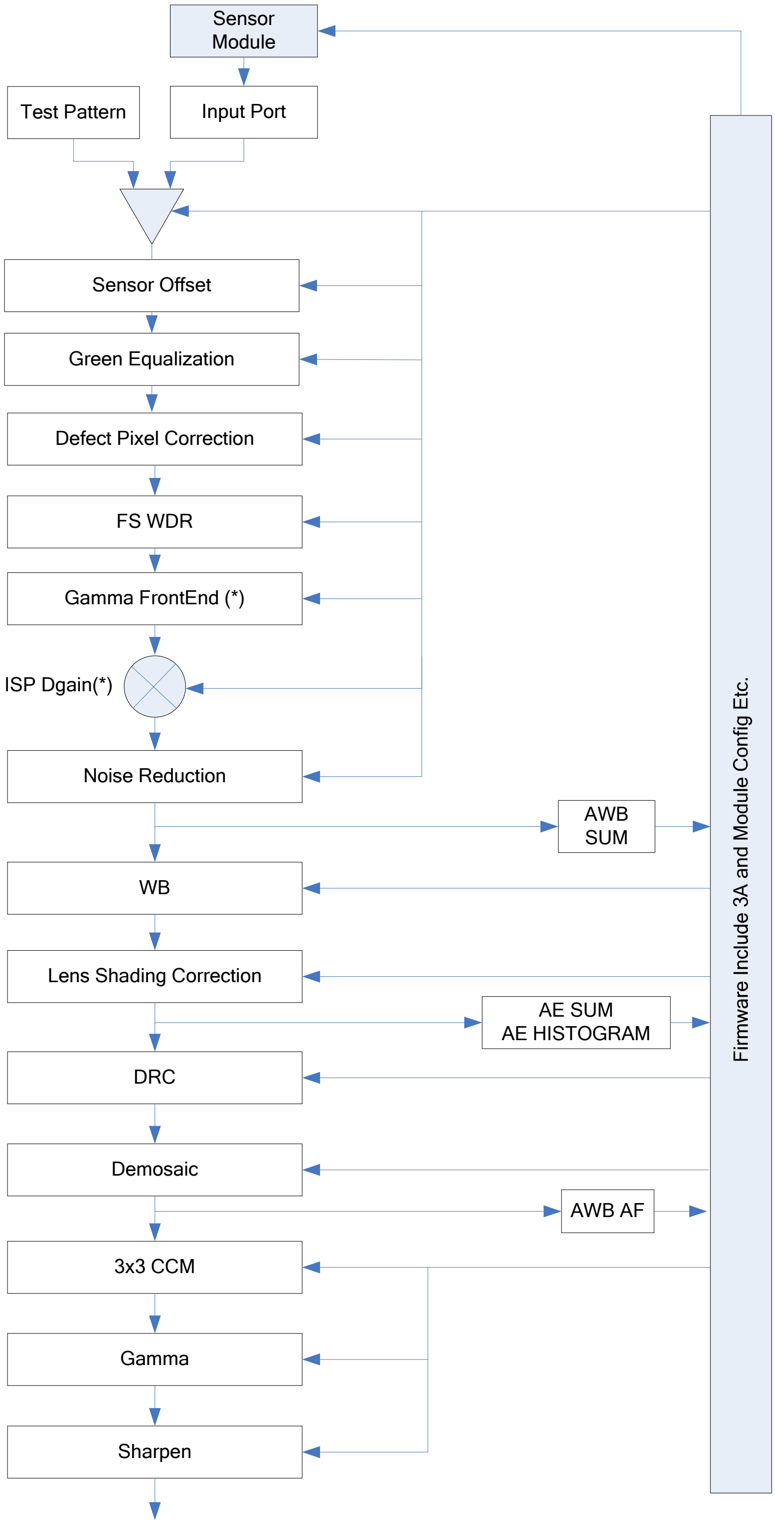
1.1 Main Features

Hisilicon's Image Signal Processor is a complete camera subsystem which includes a variety of advanced image processing technologies to address the requirements of high-performance camera designs.

Key Requirement	ISP Feature
High-throughput, Low-power pixel processing	Full hardware pixel pipeline operating at one pixel per clock. Maximal efficiency of algorithm implementation, including clock gating, and minimal use of system memory.
High image quality	Advanced demosaic, color processing, lens shading and other modules meeting DSLR/broadcast image quality requirements.
High dynamic range	HDR/WDR processing is fully embedded within the pipeline enabling high dynamic range in both still and video capture modes. Incorporates the dynamic range compression engine.

2 Functional Overview

A detailed block diagram of the ISP is shown in following Figure . The ISP includes support for standard image sensors, sensor native WDR sensors with companding curve output, and frame-switching WDR. In frame-switching WDR, short and long exposure frames are stored in external frame memory and are passed into the ISP via two input data paths. In normal operation including sensor native WDR one input is used to receive image sensor data and FS WDR is disabled. The following sections of this document will describe each of the functional blocks in the ISP.



The Top Level Block Diagram of Hisilicon ISP

Note: There are just some typical functions of HiISP in the list above

*: The Two modules Gamma_FE and digital gain locate in a selectable point of pipeline. One case is present view, another case is between sensor offset and green equalization.

3 General Details

3.1 Number format

The ISP uses a variety of number formats, including integers of various lengths from 4 bits to 32 bits, and both signed and unsigned fixed point fractions with various precisions.

There are also Boolean fields, and enumerants of various sizes. Multiple Boolean values, and other enumerants may be packed into a single register.

If the format is not specified, then the register is an 8 bit unsigned integer.

The Configuration space for the ISP is organised as a series of 32 bit registers. The layout of registers in the address map ensures that 32bit objects fit in 32bit registers.

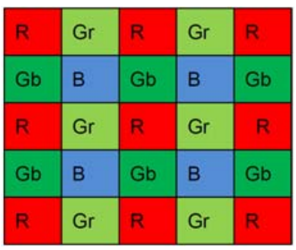
In this document, register diagrams are usually drawn 32 bits wide. Individual bytes may be read/written using Byte Enable controls, but it is expected that all I/O accesses will be performed 32 bits at a time.

If a 32 bit register contains too many fields, it may not be possible typographically to fit within the width of the page. In these cases the 32 bit register may be drawn as two sets of 16 bits, or 4 sets of 8 bits. This is only a documentation layout issue. The register is 32 bits wide, and 32 bit I/O is still the preferred method.

3.2 Bayer Pattern and Pixel Readout

The bayer pattern is split into four color planes that are represented as R, Gr, Gb, B in the ISP as in the following diagram where Gr represents the green pixels horizontally adjacent to the red pixel and Gb represents the green pixels horizontally adjacent to the blue pixels. The starting pixel in the sensor readout can be any one of the four bayer pattern pixels.

Figure 3-1 Raw Bayer pattern and pixel naming



Unless specified otherwise, the pixel coordinates in the readout start from pixel 0,0 as shown in the following diagram where pixel 0,0 is the first pixel of the first line and pixel M, N is the last pixel in the frame.

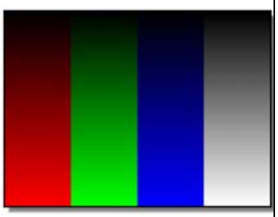
	Column 0	Column 1	Column 2	Column 3	...	Column N
Line 0	Pix 0,0	Pix 0,1	Pix 0,2	Pix 0,3	...	Pix 0,N
Line 1	Pix 1,0	Pix 1,1	Pix 1,2	Pix 1,3	...	Pix 1,N
Line 2	Pix 2,0	Pix 2,1	Pix 2,2	Pix 3,3	...	Pix 2,N
.	...	...	...	...	...	...

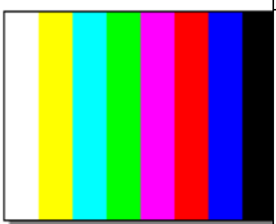
4 Module Configuration

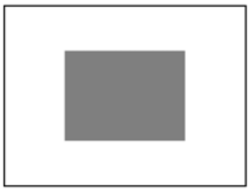
4.1 Vedeo Test Generator

This module synthesises a video test pattern. It is especially useful at the start of a project, as it enables the ISP signals to be tested and may be useful in testing for connectivity during production testing. Valid clock, and frame geometry must be present from input module. It can replace the video data with a test pattern selected from the following:

<table>
<tr><th>Flat field</th><th>All pixels set to r_backgnd, g_backgnd, b_backgnd values</th></tr>
<tr><td>Horizontal Gradient
</td><td>Lines are coloured as follows: Top 25% of lines are Red.
Next 25% of lines are Green. Next 25% of lines are Blue. Bottom 25% of lines are Grey.

Left is dark, with initial value set using rgb_gradient_start
Right is light. Color increment per pixel set using rgb_gradient</td></tr>
<tr><td>Vertical Gradient
</td><td>Pixels are coloured as follows: Left 25% of pixels are Red,
Next 25% of pixels are Green,
Next 25% of pixels are Blue, Right 25% of pixels are Grey.

Top is dark, with initial value set using rgb_gradient_start
Bottom is light. Color increment per pixel set using rgb_gradient</td></tr>
<tr><td>Vertical Bars
</td><td>8 vertical bars of colour, organised from left to right as follows:
<table>
<tr><th>Color</th><th>Red</th><th>Green</th><th>Blue</th></tr>
<tr><td>White(Grey)</td><td>r_backgnd</td><td>g_backgnd</td><td>b_backgnd</td></tr>
<tr><td>Yellow</td><td>r_backgnd</td><td>g_backgnd</td><td>0</td></tr>
<tr><td>Cyan</td><td>0</td><td>g_backgnd</td><td>b_backgnd</td></tr>
<tr><td>Green</td><td>0</td><td>g_backgnd</td><td>0</td></tr>
<tr><td>Magenta</td><td>r_backgnd</td><td>0</td><td>b_backgnd</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Flat field</th><th>All pixels set to r_backgnd, g_backgnd, b_backgnd values</th></tr>
<tr><td></td><td><table>
<tr><td>Red</td><td>r_backgnd</td><td>0</td><td>0</td></tr>
<tr><td>Blue</td><td>0</td><td>0</td><td>b_backgnd</td></tr>
<tr><td>Black</td><td>0</td><td>0</td><td>0</td></tr>
</table></td></tr>
<tr><td>Arbitrary Rectangle
</td><td>Flat field background colour = (r_backgnd, g_backgnd, b_backgnd) Rectangle foreground colour = (r_foregnd,g_foregnd,b_foregnd)
Rectangle pixel geometry = (rect_top,rect_bot,rect_left, rect_right)
(first line = 1, first pixel = 1)</td></tr>
<tr><td>Default pattern
</td><td>2 pixel white(100% RGB) frame on black background (0% RGB)</td></tr>
</table>

4.1.1 Key Parameters

Parameter	Description
test_pattern_off_on	Test pattern enable. Enables test pattern when set to 1.
pattern_type	8 bit selector for test pattern: 0=Flat field 1=Horizontal gradient 2=Vertical Gradient 3=Vertical Bars 4=Arbitrary Rectangle 5-255=Default white frame on black
r_backgnd, g_backgnd, b_backgnd	Red, Green and Blue values for background in Flat field, Vertical Bars and Arbitrary Rectangle test patterns.
r_foregnd, g_foregnd, b_foregnd	Red, Green and Blue values for windowed rectangle in Arbitrary Rectangle test pattern.
rgb_gradient_start	Specifies the starting brightness value of the gradient in Vertical and Horizontal Gradient test patterns
rgb_gradient	16 bit value specifying the per pixel increment in the gradient in 4.12 fixed point format.

Parameter	Description
Rect_top, Rect_bot, Rect_left, Rect_right	Specifies the coordinates of the windowed rectangle in Arbitrary Rectangle test pattern. Note: (1, 1) corresponds to the first pixel.

4.1.2 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	**Default**
0x00C0	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
															bayer rgb o sel	**bayer rgb i sel**	**test pattern off on**	

test_pattern_off on Test pattern off-on: 0=off, 1=on
bayer_rgb_i sel Bayer or rgb select for input video: 0=bayer, 1=rgb
bayer_rgb_o sel Bayer or rgb select for output video: 0=bayer, 1=rgb

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00C4	**R/W**																									**pattern type**								**0x00000003**

pattern type [7:0] Pattern type select: 0=Flat field,1=Horizontal gradient,2=Vertical Gradient,3=Vertical Bars,4=Rectangle,5-255=Default white frame on black

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00C8	**R/W**																	**r backgnd**																**0x0000FFFF**

r backgnd [15:0] Red background value 16bit, MSB aligned to used width

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00CC	**R/W**																	**g backgnd**																**0x0000FFFF**

g backgnd [15:0] Green background value 16bit, MSB aligned to used width

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00D0	**R/W**																	**b backgnd**																**0x0000FFFF**

b backgnd [15:0] Blue background value 16bit, MSB aligned to used width

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00D4	**R/W**																	**r foregnd**																**0x00008FFF**

r foregnd [15:0] Red foreground value 16bit, MSB aligned to used width

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00D8	**R/W**																	**g foregnd**																**0x00008FFF**

g foregnd [15:0] Green foreground value 16bit, MSB aligned to used width

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00DC	**R/W**																	**b foregnd**																**0x00008FFF**

b foregnd [15:0] Blue foreground value 16bit, MSB aligned to used width

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00E0	**R/W**																	**rgb gradient**																**0x00003CAA**

rgb gradient [15:0] RGB gradient increment per pixel (0-15) Format: unsigned 4.12-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00E4	**R/W**																	**rgb gradient start**																**0x00000000**

rgb_gradient start [15:0] RGB gradient start value 16bit, MSB aligned to used width

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00E8	**R/W**																					**rect top**												**0x00000001**

rect top [11:0] Rectangle top line number 1-n

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00EC	**R/W**																					**rect bot**												**0x00000100**

rect bot [11:0] Rectangle bottom line number 1-n

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x00F0	**R/W**																					**rect left**												**0x00000001**

rect left [11:0] Rectangle left pixel number 1-n

<table>
<tr><th>Addr</th><th>Mode</th><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th><th>Default</th></tr>
<tr><td>0x00F8</td><td>R/W</td><td colspan="20"></td><td colspan="12">rect right</td><td>0x00000100</td></tr>
</table>

rect right [11:0] Rectangle right pixel number 1-n

4.2 Sensor Offset

4.2.1 Functional Description

This module provides correction for the black level from the sensor data. Separate offsets are provided for each of the 4 Bayer component color channels (R, Gr, Gb, B).

These values are typically set to 0, but may be used to adjust video raw data prior to processing.

Parameter	Description
Black_00	Black offset subtracted from the color plane corresponding to pixel (0, 0) in the readout.
Black_01	Black offset subtracted from the color plane corresponding to pixel (0, 1) in the readout.
Black_10	Black offset subtracted from the color plane corresponding to pixel (1, 0) in the readout.
Black_11	Black offset subtracted from the color plane corresponding to pixel (1, 1) in the readout.

4.2.2 Register Map

<table>
<tr><th>Addr</th><th>Mode</th><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th><th>Default</th></tr>
<tr><td>0x0140</td><td>R/W</td><td colspan="18"></td><td colspan="14">Black 00</td><td>0x00000000</td></tr>
</table>

Black 00 [13:0] Black offset for color channel 00 (R)

<table>
<tr><th>Addr</th><th>Mode</th><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th><th>Default</th></tr>
<tr><td>0x0144</td><td>R/W</td><td colspan="18"></td><td colspan="14">Black 01</td><td>0x00000000</td></tr>
</table>

Black 01 [13:0] Black offset for color channel 01 (Gr)

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0148	**R/W**																			**Black 10**														**0x00000000**

Black 10 [13:0] Black offset for color channel 10 (Gb)

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x014C	**R/W**																			**Black 11**														**0x00000000**

Black 11 [13:0] Black offset for color channel 11 (B)

4.3 Gamma_FE, WDR Pre-Companding LUT

4.3.1 Functional Description

This module is used to convert wide dynamic range data into a format that can be processed by the ISP and is used for both frame stitching WDR and sensor native WDR with companding curve.

When operating in sensor native WDR, this module provides linear expansion of the sensor compressed output followed by dynamic range compression. The lower bit-width sensor data is typically a piecewise linear compressed representation of the linear video covering up to a 20 bit number range. The Gamma_FE module functionally converts the sensor values back into a linear range and applies a global DRC to reduce the values back to 14 bits for processing in the ISP.

When operating in FSWDR, this module functionally takes the large bit width, linear stitched data from the FSWDR module and functionally applies a global DRC to reduce the values back to 14 bits for processing in the ISP.

The Gamma_FE module is implemented with two LUTs, LUT0 and LUT1, which are programmed to match the data input characteristics with a target output profile that will be compatible with the AWB algorithm in order to maintain color accuracy. Please contact Hisilicon support for reference curves, LUT generation code, and AWB reference code.

In typical configurations, LUT0 has 33 evenly spaced nodes labeled 0…32 and LUT1 has S129 evenly spaced nodes labeled 0…128 with linear interpolation applied between these nodes. Each data value is a 16 bit unsigned number. Each LUT is implemented as an array of 32 bit values where the 16 MSbits are set to 0.

NOTE

LUT sizes may vary depending on implementation.

The position of this module in the ISP pipeline is selectable with the parameter **gamma_fe_position**. For sensor native WDR the Gamma_FE module should be placed after the sensor offset module and prior to green equalization and defect pixel correction. For FS WDR the Gamma_FE module should be placed after the FS WDR module. The parameter **gamma_fe_position** should be set to 1 for FS WDR and set to 0 for sensor native WDR.

As modification of the LUT during active video will cause corrupted video, it is recommended to write the LUT during the vertical blanking period.

4.3.2 Key Parameter

Parameter	Description
Enable0, Enable1	Set to 1 enable LUTs.
gamma_fe_position	Sets position of Gamma_FE module in the pipeline. Set to 1 for FS WDR. Set to 0 for Sensor native WDR
LUT0_Data(0)…Data(32)	33, 32 bit LUT values
LUT1_Data(0)…Data(128)	129, 32 bit LUT values

4.3.3 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x0188	**R/O**																	--
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
												MCU ready1	**MCU ready0**	**MCU priority**		**Enable1**	**Enable0**	

Enable0 Frontend lookup0 enable
Enable1 Frontend lookup1 enable
MCU ready0 LUT0 is ready to receive the data from CPU
MCU ready1 LUT1 is ready to receive the data from CPU

4.4 Digital Gain

The digital gain module is located immediately after the Gamma_FE module. The digital gain module can be used to apply additional ISP digital gain to all color channels if sensor gain is insufficient. The digital gain can be set by the 12 bit **Gain** parameter. This is in 4.8 number format for a maximum gain of 16. Note that since this module is after the Gamma_FE curve, the gain may not be in linear space.

The 14 bit **Offset** parameter is used set to the black level offset such that gain is not applied to the black offset. The **Offset** value is MS bit aligned and should be scaled according to bit width. Note that the black offset is not subtracted from the resulting output and should be subtracted in the White balance module later on in the pipeline.

There are no options to scale gain or offset by color channel in this module. If offset by color is required it is expected to make slight adjustments using the Sensor Offset module.

Parameter	Description
Gain	ISP digital gain. This is in 4.8 format an

Parameter	Description
Offset	Black Offset. Set to input black level so that digital gain is not applied to black level.

4.4.1 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01A0	**R/W**																					**Gain**												**0x00000100**

Gain [11:0] Gain applied to data in 4.8 format

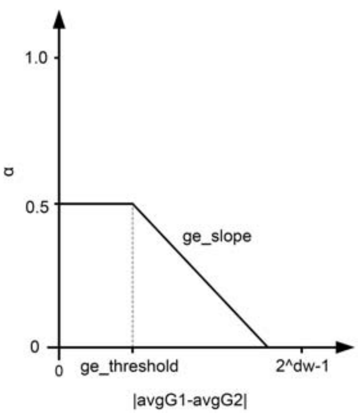
Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01A4	**R/W**																	**Offset**																**0x00000000**

Offset [15:0] Data black level

4.5 Green Equalization

This module corrects imbalances between pixels in the GR and GB colour planes, and adjusts the planes to have equal sensitivity. This correction reduces the appearance of checker patterns after demosaic and can also improve false color correction in the demosaic algorithm.

Green pixels are compared with the average of the neighbouring GR and GB values and if the differences are smaller than the **ge_threshold** the pixels are replaced with a blended value based on the raw pixel value and the neighbouring differences between the two green channels. The **ge_slope** parameter is used to define the amount of blending for differences above the **ge_threshold**. Increasing the **ge_threshold** or **ge_slope** will result in more aggressive correction. The diagram below shows a curve representing the amount of blending as a function of the difference between the two green channels.



As correction of the greens should not take place on edges an additional **ge_sens** parameter is used to adjust sensitivity of the green equalization to detected edges. A higher **ge_sens** value will result in more aggressive green equalization on edges.

4.5.1 Key Parameters

Parameter	Description
ge_enable	Set to 1 to enable green equalization
ge_strength	A parameter that is set during calibration.
ge_threshold	Controls the strength of green equalization. Higher values result in stronger green equalization.
ge_slope	Controls the strength of blending for green imbalances larger than **ge_threshold**. Higher values result in stronger green equalization
ge_sens	Controls the sensitivity of green equalization to edges. Higher values result in stronger green equalization on detected edges.

4.5.2 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x01C0	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
										bright disable	**dark disable**			**show dynamic defect pixel**	**dp enable**		**ge enable**	

ge enable Green equalization enable: 0=off, 1=on

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01C4	**R/W**																									**ge strength**								**0x00000000**

ge strength [7:0]Controls strength of Green equalization

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01C8	**R/W**					**dp threshold**												**debug sel**																**0x00400000**

debug sel [15:0] Debug selection port
dp threshold [11:0] Controls Config of green equalization

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01CC	**R/W**																					**ge threshold**												**0x00000400**

ge threshold [11:0] Controls Config of green equalization

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01D4	**R/W**																					**ge slope**												**0x000000AA**

ge slope [11:0] Slope for GE Mask function

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01D8	**R/W**																									**ge sens**								**0x00000080**

ge sens [7:0] Controls the sensitivity of STD-DEV

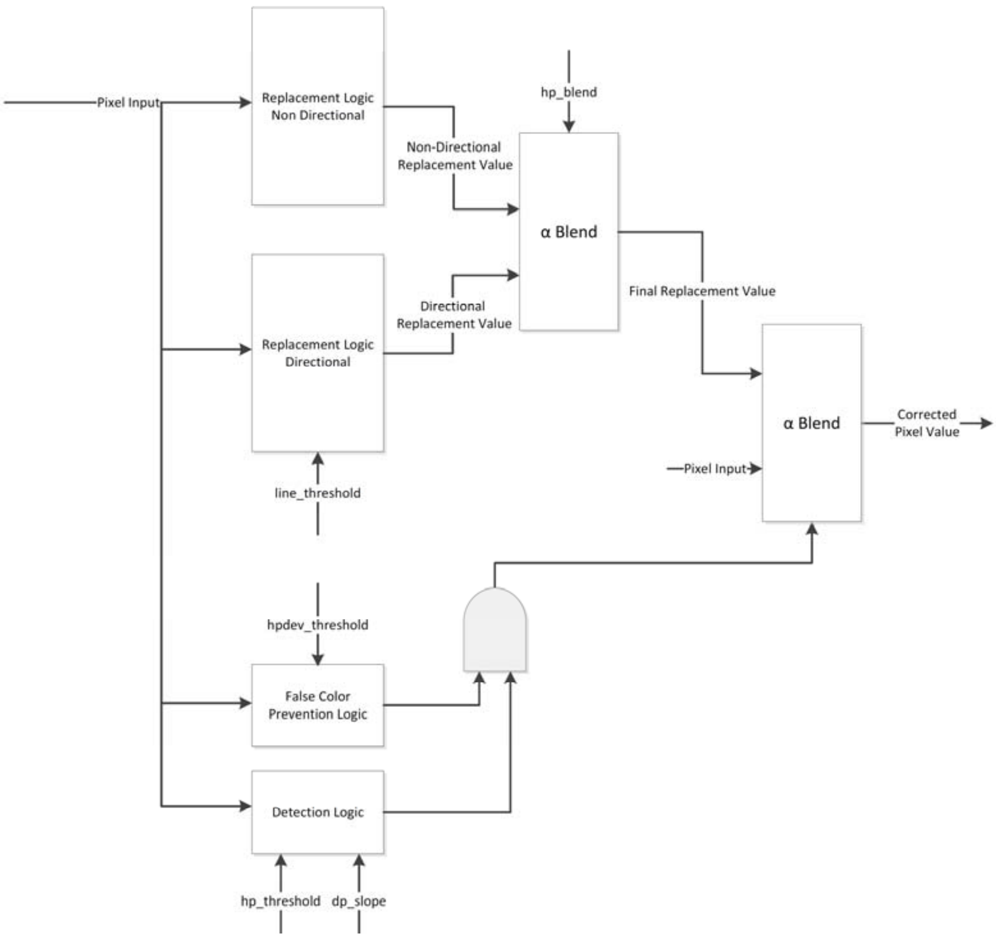
4.6 Defect Pixel Correction

Static and dynamic defect pixel correction modules can be used to correct for defective pixels in the sensor via interpolation from near neighbours. A 5x5 kernel is employed for detection and correction, enabling the correction of single defective pixels as well as small clusters. Clusters are defined as adjacent defect pixels within the same color plane and each color plane (R, Gr, Gb, and B) are treated separately. The maximum correctable size of a cluster within the same color plane is 2.

As image sensors from different process technologies and sensor manufacturers will vary there may be cases where the static defect pixel will not be able to correct all defect pixels on the sensor due to the limited memory available to store defect pixel locations. In this case, the static defect pixel correction should be used to correct the worst case defects and the dynamic defect pixel correction should be used to correct the remaining defects. As the number and characteristics of defect pixels change over temperature, it is also recommended to enable dynamic defect pixel correction if the system operating temperature range is large. Static defect pixel correction should always be calibrated and enabled to effectively correct cluster defects.

4.6.1 Dynamic Defect Pixel Correction

This module performs on-the-fly detection and correction of both bright and dark defective pixels in the raw bayer pattern domain. The dynamic defect pixel correction module will only correct single pixel defects and static defect pixel correction should be calibrated and enabled in order to correct size 2 clusters. There is no limitation on the number of single pixel defects which can be corrected. If a pixel is detected as a defect, this module replaces the raw pixel input value with a corrected pixel value. This method is generally less reliable than the static method in scenes where details approach Nyquist frequency. A functional block diagram is shown below.



4.6.1.1 Pixel Replacement Values

Both directional and non-directional replacement blocks are used to calculate intermediate directional and non-directional replacement values.

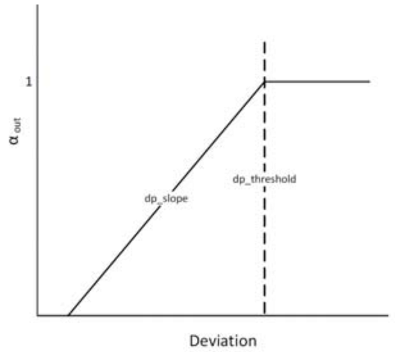
The non-directional logic block provides a non-directional replacement value based on the median (green pixels) or neighborhood average (red and blue pixels).

The directional replacement logic block provides a directional replacement value which is biased to preserve detected edges. The **line_thresh** parameter can be used to adjust the directional bias of the directional replacement value. Smaller values for the **line_thresh** will make the directional replacement values more sensitive to edges and may result in improved resolution in high spatial frequency regions.

The final replacement value is a blended result of the directional and non-directional replacement values where blending is based on the **hp_blend** parameter. Higher **hp_blend** values will bias the blending towards the directional replacement value. The blending is linear where a value of 0 would result in the final replacement value being the non-directional replacement value and a value of 255 would result in the final replacement being the directional replacement value.

4.6.2 Dynamic Defect Pixel Detection and Relpacement

The determination of whether a pixel is defective is based on the standard deviation of the neighboring pixels and the deviation of the raw pixel input from the median of its neighboring pixels of the same color. The Detection Logic block generates a mask or alpha blending parameter, αout, based on the calculated deviation and the **hp_threshold** and **dp_slope** parameters as shown in the below graph.



Pixels with deviation above the **dp_threshold** are replaced with the final replacement values while pixels with deviation below the **dp_threshold** are alpha blended with the original pixel input value and the final replacement value. The degree of blending between the original pixel value and the final replacement value depends on the **dp_slope** parameter. Higher values of **dp_slope** will increase the amount of blending between the original pixel value and the final replacement value. A value of zero for **dp_slope** would result in all pixels with deviation lower than **dp_threshold** to be uncorrected.

4.6.2.1 False Color Prevention

Additional circuitry is used to prevent overcorrection on edges which could cause false colors. A detected defect pixel would not be corrected based upon the standard deviation of the neighbouring pixels in all color planes. The **hpdev_threshold** parameter can be used to adjust the aggressiveness of the correction. Reducing **hpdev_threshold** will reduce visible coloration on edges caused by overcorrection, but may result in an increase in visible defect pixels.

NOTE

In the presence of a defective pixel, green equalization is disabled.

4.6.3 Key Parameters

Parameter	Description
dp_enable	Set to 1 to activate dynamic defect pixel correction
dp_threshold	8 bit threshold value for dynamic pixel detection. Lower values result in more aggressive correction.
dp_slope	8 bit value which controls the aggressiveness of the alpha blending between original pixel values and the filtered pixel value for pixels below the **dp_threshold.** Higher values result in more aggressive correction.

Parameter	Description
hpdev_threshold	Controls the aggressiveness of the correction to control false colors near edges. Lower values may reduce colored edges due to overcorrection, but may allow more uncorrected defect pixels.
line_thresh	Controls the directional nature of the directional replacement algorithm. Higher values reduce the directional nature of the replacement value.
hp_blend	Determines the degree of blending between the directional and non- directional replacement values.

4.6.4 Static Defect Pixel Correction

For static defect pixel correction, a map of defective pixels is generated using a self -calibration procedure. The locations specified in the defect pixel map are replaced by the median of its neighbouring pixels. The total number of defect pixels that can be corrected by the static defect pixel correction is limited to the amount of memory available to store the defect pixel locations.

4.6.4.1 Static Defect Pixel Detection

As in the dynamic defect pixel correction module, a pixel is determined to be a defect pixel based on the pixel deviation value given by the equation:

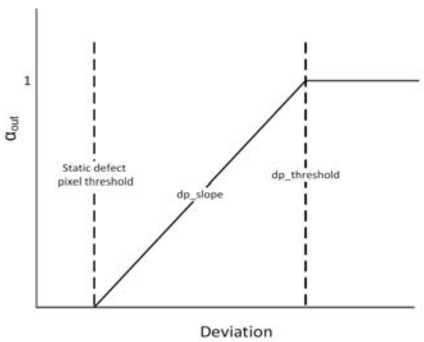
$$\text{Pixel Deviation} = \frac{|(X - median)|}{sigma_{in}}$$

Where x is the pixel value

median is the median of the neighboring pixel values, and **sigma_in** is a 12 bit adjustable parameter.

Note that larger **sigma_in** values will result in smaller pixel deviation values.

The static defect pixel threshold is shown in the below diagram where all pixels with a deviation value greater than the x-intercept are considered static defect pixels and are replaced with the median of its neighbors of the same color. The **dp_threshold** and **dp_slope** parameters are shared with the dynamic defect pixel correction block during the static defect pixel calibration procedure and do not affect static defect pixel correction during normal operation. If the pixel deviation value is larger than the static defect pixel threshold, the pixel will be replaced with the median of its neighbors. Unlike dynamic defect pixel correction, there is no alpha blending of original pixel values.



It is possible to correct both bright and dark defects using the static defect correction module. To determine locations of the bright pixels, calibration should be performed in the dark, while locations of dark pixels should be performed with an illuminated flat field. The defect pixel locations are stored in local memory during calibration and can be read back and stored in external non-volatile memory. On system power up the defect pixel map can be written back to the ISP memory.

It is also possible to disable detection of bright or dark pixels using the **bright_disable** and **dark_disable** parameters. When these single bit parameters are set to 1, detection is disabled. Note that during normal operation these bits should both to set to 0.

4.6.4.2 Defect Pixel Calibration

The calibration procedures for hot and dark pixels are described below:

Step 1 Bright pixel calibration

1. Sensor should be programmed for slow frame rate to increase exposure and intensity of hot pixel defects.
2. Analog and Digital gains should be programmed to their minimum values where sensor noise will be a minimum.
3. Iris should be closed (or cap placed over lens) such that sensor is in complete darkness
4. **Sigma_in**, **dp_threshold** and **dp_slope** should be set according to the average image sensor characteristics. The sigma _in and **dp_threshold** values should not be set to 0.
5. Enable Static defect pixel correction by setting the **Enable** bit to 1 and **Static_Marker** bit to 1.
6. Toggle the **Pointer_Reset** bit to 1 and then 0.
7. Enable the defect pixel calibration by setting **Detection_Trigger** bit to 1.
8. Wait for a minimum of 1 full frame for the defect pixel detection to complete. Waiting for multiple frames will allow for detection of flashing pixels on the sensor as defect pixel locations will accumulated over multiple frames.
9. Disable the hot pixel calibration by setting **Detection_Trigger** bit to 0. j. Wait until the current frame read out completes.
10. Read back the **Table_Start** which indicates the address in memory of the first hot pixel.
11. Read back the **Defect_Pixel_Count** which indicates the number of defect pixels. If the number of defect pixels does not meet the predetermined criteria then adjust sigma_in and go to step 6. If the number of defects meets the criteria then the calibration is complete.
12. Set **Static_Marker** bit to 0.
13. Read back the Static Defect Pixel LUT following the procedure described in section 4.8.4.4.

Step 2 Dark pixel calibration

1. Image a flat field such that the resulting raw video data is approximately 50% of full scale. Video level does not need to be extremely accurate, but lowest values of pixels in the bayer pattern (typically blue) should be above 20% of full scale.
2. Set **dp_threshold** to 0x40 and **dp_slope** to 0x200
3. Set **Sigma_in** to set the defect pixel threshold as a percentage deviation from the mean video. As a general rule of thumb the defect pixel threshold as a percent deviation from the mean can be approximated by the equation:

Defect pixel Threshold = ~ 0.3125*Sigma_in

The table below shows values of the Sigma_in and the corresponding dark defect threshold as a percent deviation from the mean video.

Sigma_in	Defect pixel Threshold (% deviation from mean)
32	10
66	20
100	30
134	40

4. Enable Static defect pixel correction by setting the Enable bit to 1 and **Static_Marker** bit to 1.
5. Toggle the **Pointer_Reset** bit to 1 and then 0.
6. Enable the defect pixel calibration by setting **Detection_Trigger** bit to 1.
7. Wait for a minimum of 1 full frame for the defect pixel detection to complete. Waiting for multiple frames will allow for detection of flashing pixels on the sensor as defect pixel locations will accumulated over multiple frames.
8. Disable the defect pixel calibration by setting **Detection_Trigger** bit to 0.
9. Wait until the current frame read out completes.
10. Read back the **Table_Start** which indicates the address in memory of the first hot pixel.
11. Read back the **Defect_Pixel_Count** which indicates the number of defect pixels. If the number of defect pixels does not meet the predetermined criteria then adjust sigma_in and go to step 6. If the number of defects meets the criteria then the calibration is complete.
12. Set Static_Marker bit to 0.
13. Read back the Static Defect Pixel LUT following the procedure described in section 4.8.4.4.

4.6.4.3 Merging Static Defect Pixel LUT

As the bright and dark defect pixel LUTs are calibrated separately the two tables should be merged. The defect pixel locations of the bright and dark defect pixel LUTs should be combined into a single table such that all locations are in raster order.

4.6.4.4 Reading From Static Defect Pixel LUT

The hot pixel locations are stored in the LUT in raster order and the order must be maintained when writing these locations back to the defect pixel map.

The read procedure is as follows:

1. Write the address to the **Table_LUT_Addr** register. The value read back from **Table_Start** register during calibration corresponds to the address of the first defect pixel in the LUT.
2. Wait two configuration clock cycles.

3. Read back the hot pixel location from the **Table_LUT_Read_Data** register.
4. Continue to read back Defect pixel LUT by incrementing the address and repeating steps 1-3 until the number of defect pixels matches the number read back from the Defect_Pixel_Count register. Note that depending on the starting address, the number of defect pixels, and the size of the LUT, the address can wrap around to 0.

4.6.4.5 Writing To Static Defect Pixel LUT

When writing to the defect pixel LUT the first defect pixel location should be written in address 0. The write procedure is as follows:

1. Write the address to the **Table_LUT_Addr** register. The starting address should be 0.
2. Write the 24 bit hot pixel location to the **Table_LUT_Write_Data** register.
3. Continue writing all defect pixel locations by incrementing the address and the repeating steps 1-2.
4. After the entire defect pixel map is written to the LUT write the defect pixel count to the **Defect_Pixel_Count_In** register.
5. Toggle the **Pointer_Reset** bit to 1 and then 0.

4.6.4.6 Key Parameters

Parameter	Description
Enable	Set to 1 to enable static defect pixel correction. Contents of defect pixel LUT must be valid values.
Show_Reference	Displays reference image which are compared with actual values to detect bad pixels. This should be viewed with the iris closed or with the lens capped. Note that the reference image will continue to be processed unless the subsequent ISP blocks are bypassed.
Show_Static_Defect-pixels	Shows detected static pixels by setting the detected pixel location to the maximum intensity. This may be seen as colored pixels if the subsequent ISP blocks are not bypassed.
Bright_Disable	When set to 1, disables detection and correction of bright pixels. This should be set to 0 during normal operation.
Dark_Disable	When set to 1, disables detection and correction of dark pixels. This should be set to 0 during normal operation.
Static_Marker	Sets defect pixel correction to use absolute threshold based on (pixel – median)/sigma_in
Sigma_in	Value used to determine pixel deviation for static defect pixel detection.
Detection_Trigger	Setting this bit to 1 starts the hot pixel calibration procedure. This must be set back to 0 to stop the calibration.
Pointer_Reset	Resets the defect pixel table pointer every frame. This should be toggled to 1 then 0 when the defect pixel LUT is written.

Parameter	Description
dp_threshold	8 bit threshold value used for static defect pixel calibration. This register is shared with dynamic defect pixel correction and is only used during the static defect pixel calibration
dp_slope	8 bit value which used for static defect pixel calibration. This register is shared with dynamic defect pixel correction and is only used during the static defect pixel calibration procedure.
Defect_Pixel_Count	Read only value indicating the number of static hot pixels.
Defect_Pixel_Count _In	The number of static hot pixels to be written after writing to the defect pixel LUT.
Table_LUT_Addr	Defect pixel LUT address used to access hot pixel locations stored in the defect pixel LUT
Table_LUT_Read_ Data	Read only register which returns the hot pixel location from the defect pixel LUT from the address indicated by **Table_LUT_Addr**
Table_LUT_Write_ Data	Register used to write the hot pixel location to the defect pixel LUT at the address indicated by **Table_LUT_Addr**.

4.6.5 Register Map

Detection and processing of defect-pixels

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x01E8	**R/O**																	--
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
											Overflow		**Detection Trigger**	**Show Static Defect-Pixels**	**Enable**	**Show Reference**	**Pointer Reset**	

Pointer Reset Reset defect-pixel table pointer each frame - set this when defect-pixel table has been written from mcu
Show Reference Show reference values which are compared with actual values to detect bad pixels
Enable Correction enable: 0=off 1=on
Show Static Defect-Pixels Show which pixels have been detected as bad
Detection Trigger Starts detection on 0-1 transition
Overflow Table overflow flag

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01EC	**R/O**																					**Defect Pixel Count**												--

Defect Pixel Count [11:0] Number of defect-pixels detected

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01F0	**R/O**																					**Table Start**												--

Table Start [11:0] Address of first defect-pixel in defect-pixel store

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x01F4	**R/W**																					**Defect Pixel Count In**												**0x00000000**

Defect Pixel Count In [11:0] Number of defect-pixels in the written table

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0850	**R/W**																					**Table LUT Addr**												**0x00000000**
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0854	**R/W**									**Table LUT Write Data**																								**0x00000000**
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0858	**R/O**									**Table LUT Read Data**																								--

Static defect-pixel table.

Table LUT Addr Lut address register (range 0 - 4095)
Table LUT Write Data Data format: [23:12] = pixel line, [11:0] = pixel column.
Table LUT Read Data Data format: [23:12] = pixel line, [11:0] = pixel column.

These registers provide indirect read-write access to the look-up-table. The table consists of 4096 nodes of 24-bit data.

To write a value to the nth element of the table:

1. Write n to the LUT address register.
2. Write 24-bit data value to the LUT write data register - this triggers the update of the internal LUT value.

To read a value from the nth element of the table:

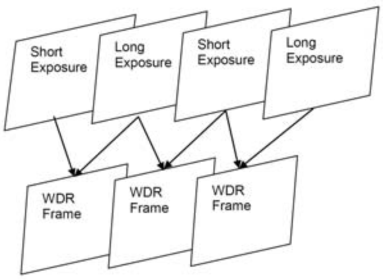
1. Write n to the LUT address register - this triggers the internal LUT read.
2. Wait for at least 2 configuration clock cycles.
3. Read value from the LUT read data register.

4.7 Frame-Switching WDR

4.7.1 Functional Description

This module provides WDR support using Frame-Switching. This is a method for creating WDR images by combining together long and short exposure frames which alternate in time. It is expected that frames are stored in external frame memory and that the long and short exposure data are available at the two input ports of the ISP at the same time. The data from the two frames should be synchronous at the inputs where the same pixel in the short and long exposure is available during the same clock cycle.

The sensor should be dynamically programmed (switched) to produce alternate short and long exposure frames. The FS WDR module combines the long and short exposure frames to generate a wide (or high) dynamic range 16 bit output.



Pixels in highlights are typically gathered from the short exposure, thereby avoiding oversaturation, while pixels in shadows are typically gathered from the long exposure, thereby minimizing noise.

The algorithm suppresses ghosting due to object motion between frames as far as possible.

The main control for this module is **Exposure_Ratio** which defines the ratio between short and long exposures. This value must match the real exposure ratio in the sensor.

The parameters **Short_Thresh** and **Long_Thresh** determine whether an output pixel is based on the long exposure, the short exposure, or a blend of the two.

The parameter **Stitch_Error_Thresh** controls the sensitivity of the component which evaluates the stitching error due to local motion and decides if short exposure data should be used in image reconstruction in such areas. The higher the value of this register, the less sensitive the error detector becomes. This parameter needs to be adjusted when analog or digital gains are applied. As the gain is increased, the value of **Stitch_Error_Thresh** should be increased. Optimal values should be determined experimentally.

The parameter **Stitch_Correct** can be used for fine adjustment of the exposure ratio used for data stitching.

The parameter **Stitch_Error_Limit** should not be modified.

The input black level is subtracted prior to stitching. The black level of the short and long exposures should be entered in the **Black_level_Short** and **Black_level_Long** parameters respectively.

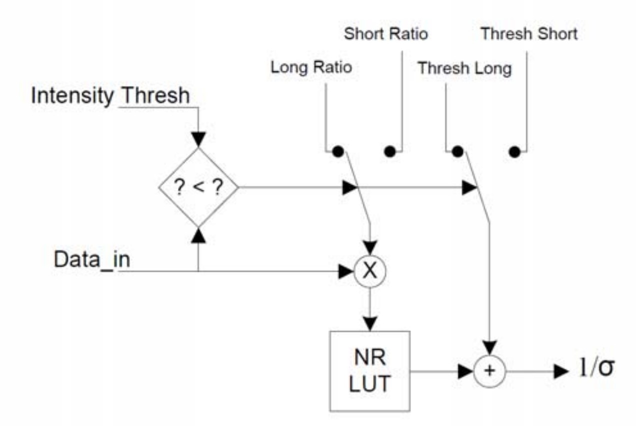
The video offset at the output of the FS WDR block can be set using the **Black_level_Out** parameter.

4.7.2 Key Parameters

Parameter	Description
WDR_Mode	Selects WDR mode: 0: No WDR image reconstruction is performed 1: Frame Switching WDR is enabled
Exposure_Ratio	Sets the ratio between long and short exposures. This must match the sensor exposure ratio. 12 bit number in 6.6 format.
Short_Thresh	Data above this threshold will be taken from short exposure only. This value is normally not changed and should be left at the default value.
Long_Thresh	Data below this threshold will be taken from long exposure only. This value is normally not changed and should be left at the default value.
Stitch_Correct	Allows adjustment for error in sensor exposure ratio in the stitching area. 8 bit value in 1.7 format.
Stitch_Error_Thresh	Sets level for detection of stitching errors due to motion.
Stitch_Error_Limit	Sets intensity level for long exposure, below which stitching error detection is disabled. This value is normally not changed and should be left at the default value.
Black_level_Short, Black_level_Long	Black level input for the short and long exposures. 14 bit values.
Black_level_Out	Black level output. 16 bit value.

4.7.3 Noise Reduction In Dual Exposure Mode

Figure 4-1 Noise Reduction in WDR mode



4.7.4 Register Map

Dual-exposure wide-dynamic-range blending

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x0150	**R/W**					**Short Thresh**												**0x0F00C001**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
		Rsvd	**Rsvd**	**Rsvd**							**WDR Mode**	**Rsvd**				**Rsvd**	**Rsvd**	

WDR Mode Selects WDR mode
0 = WDR Disabled
1 = Frame-Switching

Short Thresh [11:0] Data above this threshold will be taken from short exposure only

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0154	**R/W**																					**Long Thresh**												**0x00000C00**

Long Thresh [11:0] Data below this threshold will be taken from long exposure only

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0158	**R/W**					**Exposure Ratio**																												**0x01000000**

Exposure Ratio [11:0] Sets ratio between long and short exposures - this must match the actual exposure ratio on the sensor
Format: unsigned 6.6-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0160	**R/W**																									**Stitch Correct**								**0x00000080**

Stitch Correct [7:0] Allows adjustment for error in sensor exposure ratio for stitching area
Format: unsigned 1.7-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x015C	**R/W**																	**Stitch Error Thresh**																**0x00000040**

Stitch Error Thresh [15:0] Sets level for detection of stitching errors due to motion

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x016C	**R/W**	**Stitch Error Limit**																																**0x02000000**

Stitch Error Limit [15:0] Sets intensity level for long exposure below which stitching error detection is disabled

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0170	**R/W**																					**Black level Long**												**0x00000000**

Black level Long [11:0] Black level for long exposure input

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0174	**R/W**																					**Black level Short**												**0x00000000**

Black level Short [11:0] Black level for short exposure input

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0178	**R/W**																	**Black level Out**																**0x00000000**

Black level Out [15:0] Black level for module output

4.8 NR

4.8.1 Functional Description

This module is an advanced spatial noise reduction module combining a set of algorithms to suppress sensor noise while preserving edges and image textures.

It is a complex design which contains numerous control parameters. However, practical use of the module is made straightforward via the use of an externally-generated sensor **Noise Profile** LUT.

When this LUT is correctly programmed, the module is controllable via a reduced set of intuitive parameters. In most cases only the NR threshold is modified to adjust noise filter strength. **Thresh_Long** and **Thresh_Short** parameters corresponding to the long and short exposures respectively are used in WDR mode. When the exposure ratio is 1 or when WDR is disabled **Thresh_Long** and **Thresh_Short** should be set to the same value. The threshold values are determined during a standard calibration procedure using images captured at various ISO values and are modulated with system gain. If the image has been created using Frame-switching, these values should be set accordingly based on the exposure ratio.

Larger values for **Thresh_Short** and **Thresh_Long** increase the strength of the noise reduction.

4.8.2 Key Parameters

Parameter	Description
Enable	Set to 1 to enable NR
Thresh_Short	Master noise threshold adjustment for long exposure in WDR mode.
Thresh_Long	Master noise threshold adjustment for short exposure in WDR mode.

4.8.3 Radial NR Strength

In cases where lens shading correction is used (see section 4.11 for information on lens shading) it is possible to vary NR thresholds radially to match the gain correction from the lens shading correction block. A 33 node LUT is used to store 8 bit NR threshold offset values based on the square of the distance from the calculated center. This allows a more dense distribution of nodes closer to the edge of the image. NR threshold offsets are linearly interpolated for distances between LUT nodes. Please contact Hisilicon support for NR radial shading table generation.

rm_center_x and **rm_center_y** specify the x and y center coordinates and **rm_off_center_mult** specifies the scaling factor that can be calculated based on the furthest distance from the center to the edge of the image. **rm_off_center_mult** is calculated as $2^{31}/r^2$ where r is the furthest distance, in pixels, from the center to the edge of the image.

4.8.4 Key Parameters

Parameter	Description
rm_enable	Set to 1 to enable radial modulation of NR
rm_center_x	Center x coordinate used in radial NR
rm_center_y	Center y coordinate used in radial NR
rm_off_center_mult	Scaling factor which maps the internal precision to the frame resolution. Based on distance from the center to the farthest edge of the frame.
rm_shading_lut(0..32)	33 node NR radial shading table. 8 bits per node.

4.8.5 Register Map

Spatial noise reduction

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x0200	**R/W**																	**0x0000041C**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
						int config				**rm enable**	**Int select**	**Filter select**	**Enable**	**Rsvd**	**Rsvd**	**Rsvd**	**Rsvd**	

Enable NR enable: 0=off 1=on
Filter select NR filter fine tuning
Int select Select intensity filter
rm_enable Lens shading correction enable: 0=off, 1=on
int config [3:0] Intensity blending with mosaic raw

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0210	**R/W**																	**rm center x**																**0x00000280**

rm_center_x [15:0] x coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0214	**R/W**																	**rm center y**																**0x00000168**

rm_center_y [15:0] y coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0218	**R/W**																	**rm off center mult**																**0x00000100**

rm_off_center_mult [15:0] normalizing factor for sum of squares

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x021C	**R/W**	**Thresh 4h**								**Thresh 2h**								**Thresh 1h**								**Thresh 0h**								**0x00000000**

Thresh 0h [7:0] Unused - no effect
Thresh 1h [7:0] Noise threshold for high horizontal spatial frequencies
Thresh 2h [7:0] Unused - no effect
Thresh 4h [7:0] Noise threshold for low horizontal spatial frequencies

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0220	**R/W**	**Thresh 4v**								**Thresh 2v**								**Thresh 1v**								**Thresh 0v**								**0x00000000**

Thresh 0v [7:0] Unused - no effect

Thresh 1v [7:0] Noise threshold for high vertical spatial frequencies
Thresh 2v [7:0] Unused - no effect
Thresh 4v [7:0] Noise threshold for low vertical spatial frequencies

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0224	R/W																									Thresh Short								0x00000000

Thresh Short [7:0] Noise threshold adjustment for short exposure data

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0228	R/W																									Thresh Long								0x00000030

Thresh Long [7:0] Noise threshold adjustment for long exposure data

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x022C	R/W																									Strength 0								0x000000FF

Strength 0 [7:0] Unused - no effect

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0230	R/W																									Strength 1								0x000000FF

Strength 1 [7:0] Noise reduction effect for high spatial frequencies

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0234	R/W																									Strength 2								0x000000FF

Strength 2 [7:0] Unused - no effect

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0238	R/W																									Strength 4								0x000000FF

Strength 4 [7:0] Noise reduction effect for low spatial frequencies

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0980	R/W	rm shading lut(3)								rm shading lut(2)								rm shading lut(1)								rm shading lut(0)								--
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0984	R/W	rm shading lut(7)								rm shading lut(6)								rm shading lut(5)								rm shading lut(4)								--

... repeated until ...																																		
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x099C	**R/W**	**rm shading lut(31)**								**rm shading lut(30)**								**rm shading lut(29)**								**rm shading lut(28)**								--
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x09A0	**R/W**																									**rm shading lut(32)**								--

rm_shading_lut [7:0] Radial LUT
This is an array of 33 8-bit registers. The address for element (i) is: 0x0980 + 4 * int(i / 4).

4.9 White Balance

4.9.1 Functional Description

This module provides a gain correction for the 4 Bayer component colors (R, Gr, Gb, B) separately. This block is typically used to perform a global ISP digital gain on all color channels and to apply white balance gains.

Offset or Black level subtraction per color channel can also applied in this block. The Offsets for each color channel should be set to match the sensor black offset.

Parameter	Description
Gain_00, Gain_01, Gain_10, Gain_11	12 bit gain multipliers for each color channel in 4.8 number format
Black_00, Black_01, Black_10, Black_11	12 bit integer offsets for each color channel

4.9.2 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02C0	**R/W**																					**Gain 00**												**0x00000100**

Gain 00 [11:0] Multiplier for color channel 00 (R) Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02C4	**R/W**																					**Gain 01**												**0x00000100**

Gain 01 [11:0] Multiplier for color channel 01 (Gr) Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02C8	**R/W**																					**Gain 10**												**0x00000100**

Gain 10 [11:0] Multiplier for color channel 10 (Gb) Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02CC	**R/W**																					**Gain 11**												**0x00000100**

Gain 11 [11:0] Multiplier for color channel 11 (B) Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02D0	**R/W**																					**Black 00**												**0x00000000**

Black 00 [11:0] Black offset for color channel 00 (R)

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02D4	**R/W**																					**Black 01**												**0x00000000**

Black 01 [11:0] Black offset for color channel 01 (Gr)

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02D8	**R/W**																					**Black 10**												**0x00000000**

Black 10 [11:0] Black offset for color channel 10 (Gb)

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x02DC	**R/W**																					**Black 11**												**0x00000000**

Black 11 [11:0] Black offset for color channel 11 (B)

4.10 Lens Shading

This module optionally applies an intensity correction for lens shading. A separate correction may be applied to each of the R, G, and B components. The lens shading is corrected via a radial model wherein the position of the shading function for each color channel can be independently set and radial shading correction coefficients are provided via independent 129-element LUTs. This assumes symmetric lens shading based on the distance from the calculated center. The node positions are based on the square of the distance from the center which allows a more dense distribution of nodes closer to the edge of the image.

centerR_x, **centerG_x**, and **centerB_x** specify the x center coordinates for the R, G and B color planes. **centerR_y**, **centerG_y**, and **centerB_y** specify the y center coordinates for the R, G and B color planes. **off_center_multR**, **off_center_multG**, and off_center_multB specify the scaling.

factor that is calculated based on the farthest distance from the center to the edge of the image for each color plane. **Off_center_mult** values for each color plane are calculated as $2^{31}/r^2$ where r is the furthest distance, in pixels, from the center to the edge of the image.

The radial shading coefficients are stored in a 32 bit, 643 entry LUT. Coefficients in 4.12 format where the lower 12 bits are fractional values. The coefficients are stored starting from center to outer edge for each color plane where red coefficients are stored in entries 0 to 128, green are stored in entries 256 to 384, and blue coefficients are stored in entries 512 to 640.

4.10.1 Key Parameters

Parameter	Description
Enable	Set to 1 to enable Radial Shading correction
centerR_x, centerG_x, centerB_x	Center x coordinates for red, green and blue color planes.
centerR_y, centerG_y, centerB_y	Center y coordinates for red, green and blue color planes.
off_center_multR, off_center_multG, off_center_multB	Scale factor for shading correction for each color plane. Calculated from the center coordinate to the edge of image.
Radial_Shading_Mem (0..642)	3x129 node radial shading LUT for each color plane. Each node takes one 32 bit entry in the LUT with R starting address at base address + 0, G starting address at base address + 256 and B starting address at base address + 512.

4.10.2 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x0300	**R/O**																	--

		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
															MCU ready	**MCU priority**	**Enable**	

Enable Lens shading correction enable: 0=off, 1=on
MCU priority Priority of CPU port 0=low, 1=high
MCU ready LUT is ready to receive the data from CPU

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0304	**R/W**																	**centerR x**																**0x000003C0**

centerR x [15:0] Rx coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0308	**R/W**																	**centerR y**																**0x0000021C**

centerR y [15:0] Ry coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x030C	**R/W**																	**centerG x**																**0x000003C0**

centerG x [15:0] Gx coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0310	**R/W**																	**centerG y**																**0x0000021C**

centerG y [15:0] Gy coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0314	**R/W**																	**centerB x**																**0x000003C0**

centerB x [15:0] Bx coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0318	**R/W**																	**centerB y**																**0x0000021C**

centerB y [15:0] By coordinates of shading map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default

0x031C	**R/W**																	**off center multR**																**0x000006EA**

off center multR [15:0] normalizing factor for sum of squares

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0320	**R/W**																	**off center multG**																**0x000006EA**

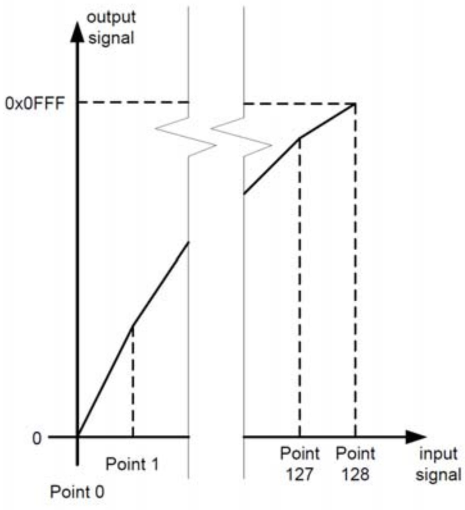
off center multG [15:0] normalizing factor for sum of squares

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0324	**R/W**																	**off center multB**																**0x000006EA**

off center multB [15:0] normalizing factor for sum of squares

4.11 Pre-DRC and Post-DRC LUT

These modules apply adaptive or fixed gamma immediately before and after DRC. DRC IP works in a perceptually uniform space and thus when linear data is presented to the IP it needs to be processed with special perceptual functions. These are implemented as two perceptual LUTs namely: Pre-DRC and Post-DRC LUTs.



This module applies a LUT separately for each of the three color channels. For typical configurations, these LUTs have 129 evenly spaced nodes labeled 0…128 and the hardware applies linear interpolation between these nodes.

Each data value is a 16bit unsigned number, so it is expected that Data[0]=0 and Data[128]=0xFFFF, with the other 127 values defining the curve.

It is not recommended to change the default values of these LUTs.

4.12 DRC

4.12.1 Functional Description

This module is an advanced local tone mapping (space-variant dynamic range compression) engine based on the performance of the human visual system. It adjusts the tonal range of the input image so that it is optimised for viewing on standard output devices.

Within the ISP, the primary function of this module is to transfer up to 16-bit WDR data into standard

10-bit output suitable for post-processing by the latter part of the pipeline.

As DRC adjusts image content based on previous frame content, it is possible that flicker may be noticeable during extreme scene changes. The 12 bit **drc_collection_correction** paramter can be used to adjust the DRC statistics based on changes in the exposure and gain. The ratio between the current exposure and previous exposure should be written to this register each frame. The drc_collection_correction parameter is in 4.8 number format. It is important to note that the value of this register must be updated at the time the corresponding sensor exposure and gains and ISP gains are updated. These updates should be carefully timed to match the actual frame update as there are typically frame latencies when updating sensor registers.

4.12.2 Key Parameters

Parameter	Description
Enable	Set to 1 to enable DRC
Strength	Strength of dynamic range compression. Higher values lead to higher differential gain between shadows and highlights
Variance_space	Degree of spatial sensitivity of the DRC algorithm.
Variance_intensity	Degree of intensity sensitivity of the DRC algorithm
Slope_Max	Restricts the maximum slope (gain) which can be generated by the adaptive algorithm
Slope_Min	Restricts the minimum slope (gain) which can be generated by the adaptive algorithm
Black_Level	DRC black level. Values below this are not processed and remain linear.
White_Level	DRC White level. Values above this are not processed and remain linear.
drc_collection_correction	Ratio of current exposure/previous exposure. This is in 4.8 format and should be written each frame as part of the auto exposure algorithm.

4.12.3 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	Default
0x0380	**R/W**									**0x00004629**
		23	22	21	20	19	18	17	16	
		15	14	13	12	11	10	9	8	
		Reserved	**Reserved**	**Reserved**	**Reserved**	**Reserved**	**Reserved**	**Reserved**	**Reserved**	
		7	6	5	4	3	2	1	0	
		Reserved	**Reserved**	**Reserved**	**Reserved**	**Reserved**	**Reserved**	**Reserved**	**Enable**	

Enable DRC enable: 0=off 1=on

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0384	**R/W**																									**Strength**								**0x00000080**

Strength [7:0] Strength of dynamic range compression. With other parameters at defaults, increases visibility of shadows

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x0388	**R/W**									**Slope Min**								**0x00408012**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
		Slope Max								**Variance Intensity**				**Variance Space**				

Variance Space [3:0] Sets the degree of spatial sensitivity of the algorithm
Variance Intensity [3:0] Sets the degree of luminance sensitivity of the algorithm
Slope Max [7:0] Restricts the maximum slope (gain) which can be generated by the adaptive algorithm
Slope Min [7:0] Restricts the minimum slope (gain) which can be generated by the adaptive algorithm

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x03C8	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
																Rev Percept Enable		

Rev Percept Enable DRC lookup 1 enable: 0=off 1=on

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x0820	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	

											Rev Percept LUT Addr							
Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
0x0824	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
		Rev Percept LUT Write Data																

Rev Percept Lut Addr [6:0] Lut Address register(range 0 - 64)
Rev Percept Lut Write Data[11:0] Lut Write data register

These registers provide indirect write-only access to the look-up-table. The table consists of 65 nodes of 12-bit data.

To write a value to the nth element of the table:

1. Write n to the LUT address register.
2. Write 12-bit data value to the LUT write data register - this triggers the update of the internal LUT value.

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x03E8	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
																Fwd Percept Enable		

Fwd Percept Enable DRC lookup 2 enable: 0=off 1=on

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x0830	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
											Fwd Percept LUT Addr							
Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
0x0834	**R/W**																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
						Fwd Percept LUT Write Data												

Fwd Percept Lut Addr [6:0] Lut Address register(range 0 - 64)
Fwd Percept Lut Write Data[11:0] Lut Write data register

These registers provide indirect write-only access to the look-up-table. The table consists of 65 nodes of 12-bit data.

To write a value to the nth element of the table:

1. Write n to the LUT address register.
2. Write 12-bit data value to the LUT write data register - this triggers the update of the internal LUT value.

4.13 Demosaic

4.13.1 Function Description

This module implements the conversion from Bayer to RGB color-space using a proprietary anisotropic non-linear color interpolation algorithm.

The algorithm applies both isotropic and anisotropic interpolation based on the detection of gradients. The resulting resolution can be modified by adjusting various parameters during the calibration procedure, but these are typically not adjusted during normal operation.

The demosaic block includes false color suppression and edge-adaptive sharpening.

4.13.2 False Color Suppression

False color suppression is useful for systems which may not have an OLPF. In this case color aliasing and Moire patterns may be reduced by adjusting the **FC_Slope** parameter. Increasing this value will reduce visible Moire patterns in fine details, however higher values may result in overcorrection of colors.

4.13.3 Directional And Un-directional Sharpening

Both directional and un-directional sharpening can be adjusted using the **sharp_alt_d** and **sharp_alt_ud** parameters in the demosaic module respectively. Increasing the **sharp_alt_d** parameter will increase directional sharpening on defined edges and increasing the **sharp_alt_ud** parameter will increase un-directional sharpening on textures and fine details. The directional and unidirectional sharpening values are determined during a standard calibration procedure using images captured at various ISO values and are modulated with system gain. Note that increased sharpening strength could result in higher noise and unnatural edges in fine details. The sharpening values in the demosaic module should be set to maintain a natural look in fine details while a separate sharpening module located after the gamma module should be used to increase or decrease overall sharpening.

4.13.4 Key Parameters

Parameter	Description
FC_slope	Sets the strength of false color correction. Higher values will reduce color aliasing and Moire artifacts, but may overcorrect colors.
sharp_alt_d	Strength of directional sharpening. Higher values increase sharpening effect for defined edges.
sharp_alt_ud	Strength of un-directional sharpening. Higher values increase sharpening effect in texture and fine details.

4.13.5 Register Map

Bayer Demosaic

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0400	**R/W**																									**VH Slope**								**0x000000C0**

VH Slope [7:0] Slope of vertical/horizontal blending threshold in 4.4 logarithmic format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0404	**R/W**																									**AA Slope**								**0x000000C0**

AA Slope [7:0] Slope of angular blending threshold in 4.4 logarithmic format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0408	**R/W**																									**VA Slope**								**0x000000AA**

VA Slope [7:0] Slope of VH-AA (VA) blending threshold in 4.4 logarithmic format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x040C	**R/W**																									**UU Slope**								**0x000000AD**

UU Slope [7:0] Slope of undefined blending threshold in 4.4 logarithmic format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0410	**R/W**																									**Sat Slope**								**0x0000005D**

Sat Slope [7:0] Slope of saturation blending threshold in linear format 2.6

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0414	**R/W**																					**VH Thresh**												**0x00000131**

VH Thresh [11:0] Threshold for the range of vertical/horizontal blending

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0418	**R/W**																					**AA Thresh**												**0x000000A0**

AA Thresh [11:0] Threshold for the range of angular blending

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default

0x041C	**R/W**																				**VA Thresh**												**0x00000070**

VA Thresh [11:0] Threshold for the range of VA blending

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0420	**R/W**																				**UU Thresh**												**0x00000171**

UU Thresh [11:0] Threshold for the range of undefined blending

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0424	**R/W**																				**Sat Thresh**												**0x00000171**

Sat Thresh [11:0] Threshold for the range of saturation blending in signed 2.9 format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0428	**R/W**																				**VH Offset**												**0x00000800**

VH Offset [11:0] Offset for vertical/horizontal blending threshold

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x042C	**R/W**																				**AA Offset**												**0x00000800**

AA Offset [11:0]Offset for angular blending threshold

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0430	**R/W**																				**VA Offset**												**0x00000800**

VA Offset [11:0]Offset for VA blending threshold

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0434	**R/W**																				**UU Offset**												**0x00000000**

UU Offset [11:0]Offset for undefined blending threshold

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0438	**R/W**																				**Sat Offset**												**0x00000000**

Sat Offset [11:0]Offset for saturation blending threshold in signed 2.9 format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x043C	**R/W**																									**sharp alt d**								**0x00000030**

sharp_alt_d [7:0] Directional sharp mask strength in signed 4.4 format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0440	**R/W**																									**sharp alt ud**								**0x00000020**

sharp_alt_ud [7:0] Non-directional sharp mask strength in signed 4.4 format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0444	**R/W**																					**lum thresh**												**0x00000060**

lum_thresh [11:0] Luminance threshold for directional sharpening

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0448	**R/W**																									**np offset**								**0x00000000**

np_offset [7:0] Noise profile offset in logarithmic 4.4 format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x044C	**R/W**																									**Dmsc config**								**0x00000000**

Dmsc config [7:0] Debug output select. Set to 0x00 for normal operation.

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0450	**R/W**																					**AC Thresh**												**0x000001B3**

AC Thresh [11:0] Threshold for the range of AC blending in signed 2.9 format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0454	**R/W**																									**AC Slope**								**0x000000CF**

AC Slope [7:0] Slope of AC blending threshold in linear format 2.6

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default

0x0458	**R/W**																					**AC Offset**												**0x00000000**

AC Offset [11:0]Offset for AC blending threshold in signed 2.9 format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x045C	**R/W**																									**FC Slope**								**0x00000080**

FC Slope [7:0] Slope (strength) of false color correction

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0460	**R/W**																									**FC Alias Slope**								**0x00000055**

FC Alias Slope [7:0] Slope (strength) of false colour correction after blending with saturation value in 2.6 unsigned format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0464	**R/W**																									**FC Alias Thresh**								**0x00000000**

FC Alias Thresh [7:0]Threshold of false colour correction after blending with saturation valuet in in 0.8 unsigned format

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0C00	**R/W**	**Weight lut(3)**								**Weight lut(2)**								**Weight lut(1)**								**Weight lut(0)**								--
Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0C04	**R/W**	**Weight lut(7)**								**Weight lut(6)**								**Weight lut(5)**								**Weight lut(4)**								--
... repeated until ...																																		

		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0C7C	**R/W**	**Weight lut(127)**								**Weight lut(126)**								**Weight lut(125)**								**Weight lut(124)**								--

Weight lut [7:0] Noise profile LUT
This is an array of 128 8-bit registers. The address for element (i) is: 0x0C00 + 4 * int(i / 4).

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default

0x046C	R/W																	**0x00000000**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
										NP off reflect	**NP off**							

NP off [6:0] Black level offset for noise profile table

NP off reflect 0=replicate noise profile for data below black level; 1=reflect the noise profile for data below black

4.14 3x3 Color Matix

4.14.1 Functional Description

This module applies linear color correction to input {R, G, B} pixel values. The Matrix coefficients are usually calculated dynamically by firmware in order to implement color saturation adjustments and color-correction under various lighting conditions.

$$\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{pmatrix} m_{RR} & m_{RG} & m_{RB} \\ m_{GR} & m_{GG} & m_{GB} \\ m_{BR} & m_{BG} & m_{BB} \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

R, G, and B are the inputs and mRR to mBB are configurable matrix coefficients. The coefficients are stored as 16 bit values in 8.8 number format, where the MSbit is used as a sign bit. Negative values have the MSbit set to 1.

4.14.2 Key Parameters

Parameter	Description
Enable	Set to 1 to enable the CCM. Note that disabling the CCM will also disable color saturation adjustments.
Coefft_R-R, Coefft_R-G, Coefft_R-B, Coefft_G-R, Coefft_G-G, Coefft_G-B, Coefft_B-R, Coefft_B-G, Coefft_B-B	16 bit coefficients in the 3x3 matrix. Numbers are in 8.8 format with the MSbit being a sign bit (1 for negative numbers).

4.14.3 Register Map

Color correction on RGB data using a 3x3 color matrix

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x04A4	**R/W**																	**0x00000001**
		15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
																	Enable	

Enable Color matrix enable: 0=off 1=on

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0480	**R/W**																	**Coefft R-R**																**0x00000100**

Coefft R-R [15:0] Matrix coefficient for red-red multiplier
Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0484	**R/W**																	**Coefft R-G**																**0x00000000**

Coefft R-G [15:0] Matrix coefficient for red-green multiplier
Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0488	**R/W**																	**Coefft R-B**																**0x00000000**

Coefft R-B [15:0] Matrix coefficient for red-blue multiplier
Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x048C	**R/W**																	**Coefft G-R**																**0x00000000**

Coefft G-R [15:0] Matrix coefficient for green-red multiplier
Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0490	**R/W**																	**Coefft G-G**																**0x00000100**

Coefft G-G [15:0] Matrix coefficient for green-green multiplier
Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0494	**R/W**																	**Coefft G-B**																**0x00000000**

Coefft G-B [15:0] Matrix coefficient for green-blue multiplier

Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0498	**R/W**																	**Coefft B-R**																**0x00000000**

Coefft B-R [15:0] Matrix coefficient for blue-red multiplier
Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x049C	**R/W**																	**Coefft B-G**																**0x00000000**

Coefft B-G [15:0] Matrix coefficient for blue-green multiplier
Format: sign/magnitude 8.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x04A0	**R/W**																	**Coefft B-B**																**0x00000100**

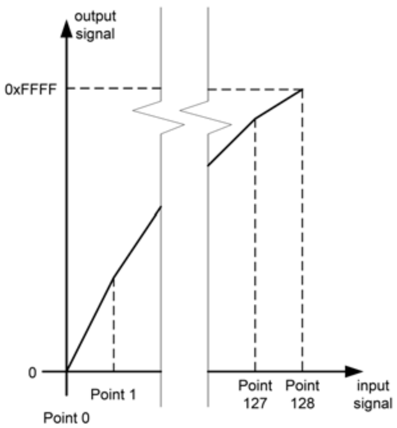
Coefft B-B [15:0] Matrix coefficient for blue-blue multiplier
Format: sign/magnitude 8.8-bit fixed-point

4.15 Gamma

4.15.1 Functional Description

This module encodes the output gamma and is typically set to match BT.709 or sRGB gamma curves.

Figure 4-2 Gamma LUT



This module applies a gamma LUT separately for each of the three (R,G,B) color channels.

NOTE

LUT sizes may vary depending on implementation.

In typical configurations, the LUT has 129 evenly spaced nodes labeled 0…128 and the hardware applies linear interpolation between these nodes.

Each data value is a 16bit unsigned number, so it is expected that Gamma[0]=0 and Gamma[128]=0xFFFF, with the other 127 values defining the Gamma correction curve.

NOTE

The adaptive contrast enhancement is performed dynamically by the DRC module. This LUT should be programmed statically based on the desired output gamma characteristics

4.15.2 Register Map

Gamma correction

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x04C0	**R/O**																	--
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
															MCU ready	**MCU priority**	**Enable**	

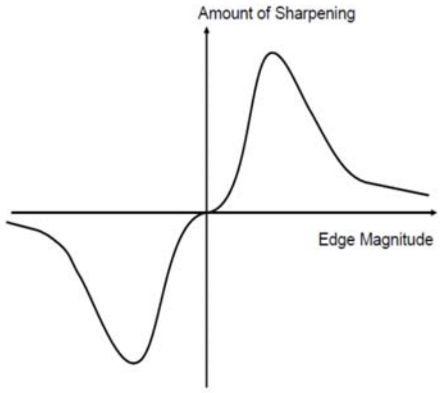
Enable Gamma enable: 0=off 1=on
MCU priority Priority of CPU port 0=low, 1=high
MCU ready LUT is ready to receive the data from CPU

4.16 Sharpening

4.16.1 Functional Description

This module implements a non-linear 2D sharpening filter. A single parameter, **strength**, controls the strength of edge enhancement. The sharpening is applied equally in both the horizontal and vertical directions.

The sharpening effect is determined by a curve defined in the sharpening LUT defining the sharpening values vs the magnitude of the edge. A typical curve is shown below. Note that a value of 128 corresponds to a value of 0.



The 8 bit unsigned sharpening LUT values are stored in 256, 32bit LUT entries where the MSbits are set to 0 as shown in the following table. There are two sharpening LUTs available and the 2 bit **coring** parameter can be used to select between them. This allows programming of one sharpening LUT as the other is being used during normal operation. This also allow for seamless switching between two the sharpening LUTs. When the **coring** parameter is set to 0 LUT0 is used, when the **coring** parameter is set to 1 LUT1 is used.

LUT	Entry	31:28	27:24	23:20	19:16	15:12	11:8	7:4	3:0
0	1							Sharpen_Coeff0	
0	2							Sharpen_Coeff1	
... repeated until ...									
0	256							Sharpen_Coeff255	
1	257							Sharpen_Coeff0	
1	258							Sharpen_Coeff1	
... repeated until ...									
1	512							Sharpen_Coeff255	

The equation below can be used to generate typical LUT values where core, magnitude and strength variables can be used to adjust the curve.

xx = ((0:255)-128)/127;

lut = (abs(xx.^core).* xx .* exp(-abs(xx*magnitude))*128);

lut = 128 + round(lut .* strength .* 127./(max(abs(lut))));

lut = min(255, max(0, lut));

The default LUT in hardware is most closely represented by the following parameter values:

core = 2.0 magnitude = 8.0 strength = 1.0

4.16.2 Key Parameters

Parameter	Description
Enable	Set to 1 to enable Sharpening
Coring	Two bit value to select sharpening LUT. Set to 0 to use LUT0, set to 1 to use LUT1.
Strength	8 bit value which controls the overall strength of the sharpening. Higher values result in stronger sharpening.

4.16.3 Register Map

Non-linear sharpening algorithm

Addr	Mode	31	30	29	28	27	26	25	24	23	2	21	20	19	18	17	16	Default
0x04D0	**R/W**																	**0x00000004**
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
														Coring			**Enable**	

Enable Sharpening enable: 0=off, 1=on

Coring [1:0] Selects LUT memory bank, value 00 connects bank 0 to sharpening and bank 1 to programming, value 01 swap banks

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x04D4	**R/W**																									**Strength**								**0x00000030**

Strength [7:0] Controls strength of sharpening effect

5 2A (AE, AWB) Statistics

The statistics modules collect raw statistics from the image. Three categories of statistics are produced:

- Histogram statistics for use by AE algorithms
- Color ratio statistics for use by AWB algorithms

All statistics are calculated on a zone-by-zone basis and are provided as a global average. Per zone weighting is available on histogram statistics and it is expected that zone weighting for AWB statistics be performed in firmware.

Individual zone values are not directly available using the register interface. However the full set of information per zone is available to the CPU which uses an indirect addressing system to extract values from the statistics core.

NOTE

Interface functions to access this data are provided as part of the firmware deliverable.These interface functions are the recommended method by which the data should be accessed.

The locations of the statistics blocks within the pipeline are configurable via ISP registers. The table below lists the possible locations and the associated ISP parameters for each of the statistics blocks.

Statistics Module	Parameter Name	Register Value	Location
AE, AE Sum	AE_Switch, AESum_Switch	0	After static WB
		1	Immediately from Sensor, Channel 1(for WDR mode)
		2	After Shading
		3	After Gamma FE.
		4	After DRC
		5	Immediately from Sensor, Channel 2(for WDR mode)
		6	After WDR stitch

Statistics Module	Parameter Name	Register Value	Location
		7	After BLC, channel 2 (for WDR modes), only when GammaFE is after BLC of channel 1.
AE histogram (256 bins)	Histogram_ Switch	0	Same as AE
		1	Immediately from Sensor, Channel 1(for WDR mode)
		2	After Shading
		3	After GammaFE
		4	After DRC
		5	Immediately from Sensor, Channel 2(for WDR mode)
		6	After WDR Stitch
		7	After BLC, channel 2 (for WDR modes), only when GammaFE is after BLC of channel 1
AWB	AWB_Switch	0	Immediately before Color Matrix
		1	Immediately after Color Matrix
AWB Sum			After NR

5.1 Zone Configuration

The entire image area is split into a grid with equal size zones in the horizontal and vertical direction. The number of zones in each direction is fully configurable and the AE and AWB can be configured to have different zone configurations.The maximum number of allowable zones is specified during build time for each of the statistics modules.

The minimum size of each zone is 12 pixels in each direction and the maximum zone size is limited by bit depth of internal accumulators.

The zones are numbered in raster order where the first zone corresponds to the top left corner of the image and the last zone corresponds to the bottom right corner of the image. An example zone configuration for mxn zones is shown below where m is the number of zones horizontally and n is the number of zones vertically.

Z1	Z2	Z3	…	…	…	Zm-2	Zm-1	Zm
Zm+1	Zm+2	Zm+3	…	…	…	Z2m-2	Z2m-1	Z2m
Z2m+1	Z2m+2	Z2m+3				Z3m-2	Z3m-1	Z3m
…	…	…				…	…	…

Z1	Z2	Z3	…	…	…	Zm-2	Zm-1	Zm
…	…	…				…	…	…
Zm(n-2)+1	Zm(n-2)+2	Zm(n-2)+3				Zm(n-1)-2	Zm(n-1)-1	Zm(n-1)
Zm(n-1)+1	Zm(n-1)+2	Zm(n-1)+3				Zmn-2	Zmn-1	Zmn

5.1.1 Key Parameters

The table below shows the key parameters used for zone configuration for the statistics modules.

Statistics Module	Parameter	Description
AE	AEXP_Nodes_Used_Horiz	Sets the number of zones in the horizontal direction.
	AEXP_Nodes_Used_Vert	Sets the number of zones in the vertical direction.
AWB	AWB_Nodes_Used_Horiz	Sets the number of zones in the horizontal direction.
	AWB_Nodes_Used_Vert	Sets the number of zones in the vertical direction.

5.1.2 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0630	**R/W**																	**AEXP Nodes Used Vert**								**AEXP Nodes Used Horiz**								**0x00000F11**

AEXP Nodes Used Horiz [7:0] Number of active zones horizontally

AEXP Nodes Used Vert [7:0] Number of active zones vertically

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x066C	**R/W**																	**AWB Nodes Used Vert**								**AWB Nodes Used Horiz**								**0x00000F11**

AWB Nodes Used Horiz [7:0] Number of active zones horizontally

AWB Nodes Used Vert Number of active zones vertically

[7:0]

5.2 Zone Weighting

An array of weighting coefficients is supplied for each zone for the AE statistics module.

Weighting coefficients can be set to equal values for all zones so that all parts of the image contribute equally to the relevant statistics. Alternatively, the specific zone(s) can be emphasized by applying a greater weighting coefficient for those zones. Zones may be excluded by setting their weighting coefficients to zero.

The weighting coefficient is a 4 bit value where each increment corresponding to a weighting of 1/16, with the exception of a value of 15 which corresponds to a weighting of 1.

Weighting coefficients are also in raster order following the zone configuration.

W1	W2	W3	…	…	…	Wm-2	Wm-1	Wm
Wm+1	Wm+2	Wm+3	…	…	…	W2m-2	W2m-1	W2m
W2m+1	W2m+2	W2m+3				W3m-2	W3m-1	W3m
…	…	…				…	…	…
…	…	…				…	…	…
Wm(n-2) +1	Wm(n-2) +2	Wm(n-2) +3				Wm(n-1) -2	Wm(n-1) -1	Wm(n-1)
Wm(n-1) +1	Wm(n-1) +2	Wm(n-1) +3				Wmn-2	Wmn-1	Wmn

NOTE

Depending on deliverables, the AWB statistics module may have weighting coefficients.

5.2.1 Key Parameters

Statistics Module	Parameter	Description
AE	AEXP_Weight(0,1,2,…,mn)	Array of weights for mxn AE zones in raster order. (0,0) corresponds to top left corner of image.

5.2.2 Regsiter Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Defaul t
0x0A00	**R/W**					**AEXP Weight(0,3)**								**AEXP Weight(0,2)**								**AEXP Weight(0,1)**								**AEXP Weight(0,0)**				--

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0A04	**R/W**					**AEXP Weight(0,7)**								**AEXP Weight(0,6)**								**AEXP Weight(0,5)**								**AEXP Weight(0,4)**				--
... repeated until ...																																		
Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0AF8	**R/W**					**AEXP Weight(16,11)**								**AEXP Weight(16,10)**								**AEXP Weight(16,9)**								**AEXP Weight(16,8)**				--
Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x0AF C	**R/W**													**AEXP Weight(16,14)**								**AEXP Weight(16,13)**								**AEXP Weight(16,12)**				--

AEXP Weight [3:0] Sets zone weighting for auto exposure. Index is (row,col) where (0,0) is top-left zone
This is an array of 255 4-bit registers, arranged as 17x15. The address for element (i,j) is: 0x0A00 + 4 * int((15i + j) / 4).

5.3 AE Statistics

AE statistics can be collected in several locations with the default being immediately after the white balance module. Two histogram types are available for metering:

1. 5 bin local and global histogram
2. 256 bin global histogram.

5.3.1 5 Bin Histogram

A 5 bin normalized histogram is generated for each zone and for the entire image with adjustable histogram bin boundaries. The parameters **Hist_Thresh [i] [j]** are set to define the threshold intensity values between each bin i and j.

The registers **Hist [i]** provide the global normalized pixel counts for each bin i. The total sum is normalized to 0xFFFF.

The center bin of the histogram is not available and can be calculated in firmware by subtracting the values of Hist0, Hist1, Hist3, and Hist4 from 0xFFFF as in the following equation:

$$Hist_2 = 0xFFFF - \sum_i Hist_i$$

where i = 0,1,3, and 4

5.3.2 Key Parameters

Parameter	Description
Hist_Thresh_0_1	8 bit value specifying the bin 0/1 boundary
Hist_Thresh_1_2	8 bit value specifying the bin 1/2 boundary
Hist_Thresh_3_4	8 bit value specifying the bin 2/3 boundary
Hist_Thresh_4_5	8 bit value specifying the bin 3/4 boundary
Hist_0	Normalized, weighted global histogram results for bin 0
Hist_1	Normalized, weighted global histogram results for bin 1
Hist_3	Normalized, weighted global histogram results for bin 3
Hist_4	Normalized, weighted global histogram results for bin 4

5.3.2.1 AE Zone Data: 5 Bin Histogram

The zone by zone data collected by the AE statistics module is not directly available in the register space. Indirect access to all of the "metering data" statistics is available in firmware.

NOTE

The zone statistics values are stored in internal memory, and are updated by the ISP hardware. This memory is read only.

An internal table with Histx data gives the normalised values of the histograms for each of the zones as shown in the table below for mxn zones. The order of the zones is in raster order starting from the top left corner of the image. The sum of the histogram data is normalized to 0xFFFF for each zone. Note that as in the global histogram, the Hist2 value is not available but can be calculated based on the normalized sum and the values of Hist0, Hist1, Hist3 and Hist4 for each zone.

Table Index	Zone	31:16	15:0
0	1	Hist1	Hist0

Table Index	Zone	31:16	15:0
1	1	Hist4	Hist3
2	2	Hist1	Hist0
3	2	Hist4	Hist3
... repeated until ...			
2mn-2	mn	Hist1	Hist0
2mn-1	mn	Hist4	Hist 3

5.3.3 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0600	**R/W**																									**Hist Thresh 0 1**								**0x00000010**

Hist Thresh 0 1 [7:0] Histogram threshold for bin 0/1 boundary

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0604	**R/W**																									**Hist Thresh 1 2**								**0x00000020**

Hist Thresh 1 2 [7:0] Histogram threshold for bin 1/2 boundary

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0608	**R/W**																									**Hist Thresh 3 4**								**0x000000D0**

Hist Thresh 3 4 [7:0] Histogram threshold for bin 2/3 boundary

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x060C	**R/W**																									**Hist Thresh 4 5**								**0x000000E0**

Hist Thresh 4 5 [7:0] Histogram threshold for bin 3/4 boundary

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default

0x0620	**R/O**																	**Hist 0**																--

Hist 0 [15:0] Normalized histogram results for bin 0

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0624	**R/O**																	**Hist 1**																--

Hist 1 [15:0] Normalized histogram results for bin 1

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0628	**R/O**																	**Hist 3**																

Hist 3 [15:0] Normalized histogram results for bin 3

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x062C	**R/O**																	**Hist 4**																

Hist 4 [15:0] Normalized histogram results for bin 4

5.4 AE Sum Statistics

The AE Sum statistics module provides additional zone statistics for the average R, Gr, Gb, and B pixels in the bayer pattern. A normalized global average for R, Gr, Gb and B values can be read from ISP registers **SUM_R, SUM_RG, SUM_BG, SUM_B** respectively. Averages are scaled to 16 bit such that 50% gray corresponds to a value of 32768.

All of the AE Sum statistics values are also available by zone and can be accessed indirectly via firmware. The table below shows the internal memory organization for mxn zones.

Table 5-1 AE Sum Statistics by Zone

Table Index	Zone	31:16	15:0
0	0	Average Gr	Average R
1	0	Average B	Average Gb
2	1	Average Gr	Average R
3	1	Average B	Average Gb
... repeated until ...			

Table Index	Zone	31:16	15:0
2mn-2	mn	Average Gr	Average R
2mn-1	mn	Average B	Average Gb

5.4.1 Register Map

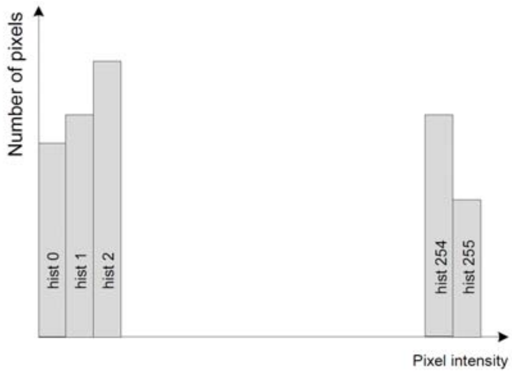
Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x9800	**R/O**	**Average Gr**																**Average R**																--
		Average B																**Average Gb**																--

The table address range of AE Sum is from 0x9800 to 0x9800 +(2mn-1)*4.

5.5 256 Bin Histogram

A separate global 256 bin histogram is built for the entire image as shown in the figure below. The global histogram data is not directly available in register space but can be indirectly accessed in firmware. The values are double buffered and remain stable for the duration of the entire frame after the one from which they were derived. The global histogram can also be weighted by zone if the location is set to be the same as the AE statistics block.

Figure 5-1 256 bin Auto Exposure Histogram



Histogram values are 16 bit floating point and are log base 2 values. This can be converted to linear values using the following pseudo-code:

e = F >> 12;

m = F & 0x4095;

if e == 0 :

L = m

else

L = (4096+m) << (e-1)

where F is the 16 bit histogram value.

Histogram data is available to the firmware as a consecutive array of 256x32 bit unsigned integers where the upper 16 MSbits are zeroes.

Table 5-2 AE 256 Bin Histogram Data

Table Index	31:16	15:0
0		Hist0
1		Hist1
2		Hist2
... repeated until ...		
254		Hist254
255		Hits255

5.5.1 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x3C00	**R/W**	**Data(0)**																																--
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x3C04	**R/W**	**Data(1)**																																--
... repeated until ...																																		
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x3FFC	**R/W**	**Data(255)**																																--

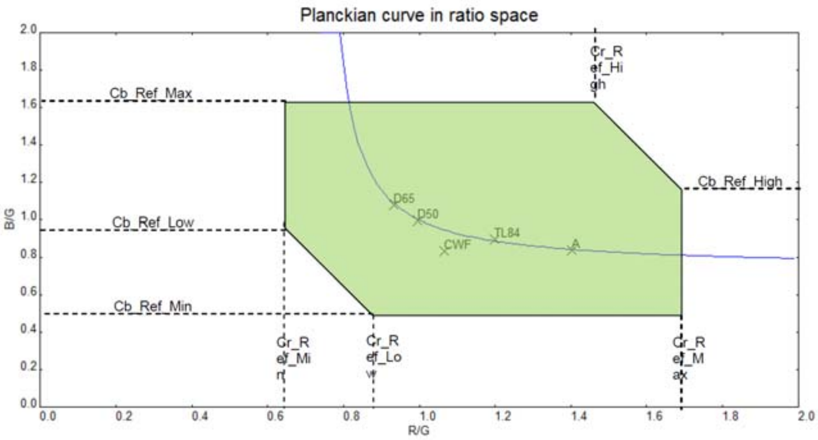
Data [31:0] Please see other documentation for a description of the contents of this array.
This is an array of 256 32-bit registers. The address for element (i) is: 0x3C00 + 4i.

5.6 AWB Statistics

AWB statistics are collected immediately after the Demosaic block. After color interpolation in the demosaic block each pixel will have a red, green and blue value. AWB statistics can be provided as the zone weighted average of color ratios for the entire image. The **AWB_stats_mode** parameter can be used to select AWB stats to be presented as either Red/Green and Blue/Green ratios or Green/Red and Green/Blue ratios. These ratios are in unsigned 4.8 number format and can be read back through registers **AWB_RG** and **AWB_BG.**

Additional adjustments can be made to exclude pixels in the statistics based on color ratiol. Only pixels with valid color ratios bounded by the **Cr_Ref_Min**, **Cr_Ref_Max**, **Cb_Ref_Min**, **Cb_Ref_Max**, parameters are used in the statistics. These parameters set the minimum and maximum red/green and blue/green ratios. The below diagram shows the Plankian locus and the region bounded by these parameters in color ratio space (note that plot is B/G vs R/G).

Figure 5-2 Boundaries for Statistics in Color Ratio Space



Additional parameters, **White_Level_AWB** and **Black_Level_AWB**, set the upper and lower intensity boundaries within which pixels contribute to the statistics. The total number of pixels used in for the AWB statistics can be read from the **AWB_SUM** register.

5.6.1 Key Parameters

Parameter	Description
AWB_stats_mode	0: Statistics collected as Green/Red and Green/Blue ratios 1: Statistics collected as Red/Green and Blue/Green ratios
AWB_RG	Green/Red or Red/Green color ratio from zone weighted average in unsigned 4.8 fixed point format. Read only.
AWB_BG	Green/Blue or Blue/Green color ratio from zone weighted average in unsigned 4.8 fixed point format. Read only.
AWB_SUM	Read only parameter indicating the total number of pixels used in the AWB statististics.
Cr_Ref_Min	Specifies the minimum Red/Green color ratio of a pixel in 4.8 format that will be included in AWB statistics
Cr_Ref_Max	Specifies the maximum Red/Green color ratio of a pixel in 4.8 format that will be included in AWB statistics
Cr_Ref_Low	Specifies the Red/Green ratio in 4.8 format that forms a vertex of the polygon shape which encapsulates the pixels used in AWB statistics. See Figure 20.

Parameter	Description
Cr_Ref_High	Specifies the Red/Green ratio in 4.8 format that forms a vertex of the polygon shape which encapsulates the pixels used in AWB statistics. See Figure 20.
Cb_Ref_Min	Specifies the minimum Blue/Green color ratio of a pixel in 4.8 format that will be included in AWB statistics
Cb_Ref_Max	Specifies the maximum Blue/Green color ratio of a pixel in 4.8 format that will be included in AWB statistics
Cb_Ref_Low	Specifies the Blue/Green ratio in 4.8 format that forms a vertex of the polygon shape which encapsulates the pixels used in AWB statistics. See Figure 20.
Cb_Ref_High	Specifies the Blue/Green ratio in 4.8 format that forms a vertex of the polygon shape which encapsulates the pixels used in AWB statistics. See Figure 20.
White_Level_AWB	Specifies the maximum pixel intensity value that will be included in the AWB statistics.
Black_Level_AWB	Specifies the minimum pixel intensity value that will be included in the AWB statistics.

5.6.2 AWB Zone Data

AWB statistics for each zone can also be indirectly accessed in firmware. As in the global case, the average Green/Blue or Blue/Green, average Green/Red or Red/Green values, and the number of pixels used in the AWB statistics can be read back on a per zone basis. Color ratios are in unsigned 4.8 format while the total number of pixels is in integer format. The table below illustrates the data structure in internal memory for mxn zones.

Table 5-3 Auto White Balance G/B G/R Zone Data

Table Index	Zone	31:28	27:24	23:20	19:16	15:12	11:8	7:4	3:0
0	1		Average Green/Blue [27:16]				Average Green/Red [11:0]		
1	1	Number of pixels used for AWB							
2	2		Average Green/Blue [27:16]				Average Green/Red [11:0]		
3	2	Number of pixels used for AWB							
... repeated until ...									
2mn-2	mn		Average Green/Blue [27:16]				Average Green/Red [11:0]		
2mn-1	mn	Number of pixels used for AWB							

Table Index	Zone	31:28	27:24	23:20	19:16	15:12	11:8	7:4	3:0

5.6.3 AWB Sum Statistics

A simple bilinear demosaic block is used after NR to accumulate additional AWB statistics prior to the white balance block. The AWB Sum statistics module collects the global average of Red, Green, Blue and Y values which can be read back from the **Avg_R**, **Avg_G**, **Avg_B**, and **Avg_Y** registers respectively. Averages are scaled to 16 bit such that 50% gray corresponds to a value of 32768. Note that the Y average is calculated as Y = 0.3R+0.6G+0.1B.

In addition to the averages, the number of pixels above the **White_Level_AWB threshold** and below the **Black_Level_AWB** threshold are counted. These values can be read back from the **Count_Max** and **Count_Min** registers respectively. These values are normalized to the total pixels counted.

All of the AWB Sum statistics are also available by zone and can be accessed indirectly via firmware. The table below shows the internal memory organization for mxn zones.

Table 5-4 AWB Sum Statistics by Zone

Table Index	Zone	31:16	15:0
0	0	Average G	Average R
1	0	Average Y	Average B
2	0	Count Max	Count Min
3	1	Average G	Average R
... repeated until ...			
3mn-3	mn	Average G	Average R
3mn-2	mn	Average Y	Average B
3mn-1	mn	Count Max	Count Min

5.6.4 Register Map

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0640	**R/W**																							**White Level AWB**										**0x000003FF**

White Level AWB [9:0] Upper limit of valid data for AWB

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0644	**R/W**																							**Black Level AWB**										**0x00000000**

Black Level AWB [9:0] Lower limit of valid data for AWB

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0648	**R/W**																					**Cr Ref Max AWB**												**0x000001FF**

Cr Ref Max AWB [11:0] Maximum value of R/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x064C	**R/W**																					**Cr Ref Min AWB**												**0x00000040**

Cr Ref Min AWB [11:0] Minimum value of R/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0650	**R/W**																					**Cb Ref Max AWB**												**0x000001FF**

Cb Ref Max AWB [11:0] Maximum value of B/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0654	**R/W**																					**Cb Ref Min AWB**												**0x00000040**

Cb Ref Min AWB [11:0] Minimum value of B/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0658	**R/O**																					**AWB RG**												--

AWB RG [11:0] AWB output R/G
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x065C	**R/O**																					**AWB BG**												--

AWB BG [11:0] AWB output B/G
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0660	**R/O**	**AWB SUM**																																--

AWB SUM [31:0] AWB output population
Format: unsigned 32-bit integer

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0670	**R/W**																					**Cr Ref High AWB**												**0x00000FFF**

Cr Ref High AWB [11:0] Maximum value of R/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0674	**R/W**																					**Cr Ref Low AWB**												**0x00000000**

Cr Ref Low AWB [11:0] Minimum value of R/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0678	**R/W**																					**Cb Ref High AWB**												**0x00000FFF**

Cb Ref High AWB [11:0] Maximum value of B/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x067C	**R/W**																					**Cb Ref Low AWB**												**0x00000000**

Cb Ref Low AWB [11:0] Minimum value of B/G for white region
Format: unsigned 4.8-bit fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0740	**R/O**																	**Avg R**																--

Avg R [15:0] Normalized sum of Red component

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0744	**R/O**																	**Avg G**																--

Avg G [15:0] Normalized sum of Green component

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0748	**R/O**																	**Avg B**																--

Avg B [15:0] Normalized sum of Blue component

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x074C	**R/O**																	**Count All**																--

Count All [15:0] Normalized count of pixels which were averaged in Avg R, Avg G and Avg B

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0750	**R/O**																	**Count Min**																--

Count Min [15:0] Normalized count of pixels below min threshold

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0754	**R/O**																	**Count Max**																--

Count Max [15:0] Normalized count of pixels above max threshold

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0764	**R/W**																					**Min threshold**												**0x00000010**

Min threshold [11:0] Minimal threshold for AWB sums

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0768	**R/W**																					**Max threshold**												**0x00000FF0**

Max threshold [11:0] Maximal threshold for AWB sums

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	Default
0x076C	**R/W**																	**0x00000000**
		15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
																Max clip	**Min clip**	

Min clip Clip pixels below minimal threshold for AWB sums
Max clip Clip pixels ablove maximal threshold for AWB sums

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0770	**R/W**					**Cr Ref Min AWB Sum**																**Cr Ref Max AWB Sum**												**0x004001FF**

Cr Ref Max AWB Sum[11:0] Maximum value of R/G for white region unsigned 4.8 fixed-point
Cr Ref Min AWB Sum[11:0] Minimum value of R/G for white region unsigned 4.8 fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0774	**R/W**					**Cb Ref Min AWB Sum**																**Cb Ref Max AWB Sum**												**0x004001FF**

Cb Ref Max AWB Sum[11:0] Maximum value of B/G for white region unsigned 4.8 fixed-point
Cb Ref Min AWB Sum[11:0] Minimum value of B/G for white region unsigned 4.8 fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x0778	**R/W**					**Cr Ref Low AWB Sum**																**Cr Ref High AWB Sum**												**0x00000FFF**

Cr Ref High AWB Sum[11:0] Maximum value of R/G for white region unsigned 4.8 fixed-point
Cr Ref Low AWB Sum[11:0] Minimum value of R/G for white region unsigned 4.8 fixed-point

Addr	Mode	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default
0x077C	**R/W**					**Cb Ref Low AWB Sum**																**Cb Ref High AWB Sum**												**0x00000FFF**

Cb Ref High AWB Sum[11:0] Maximum value of B/G for white region unsigned 4.8 fixed-point
Cb Ref Low AWB Sum[11:0] Minimum value of B/G for white region unsigned 4.8 fixed-point

6 Interrupt

6.1 Functional Description

The ISP supports up to 8 separate hardware interrupts, Interrupt0 through Interrupt7, selectable from 24 internal ISP interrupt events.

6.2 Details

Currently there are 24 events within the ISP that may be used to generate an external interrupt signal. The table below lists the available interrupt events.

Each configured interrupt is triggered by a single event and any of the 24 possible events may be configured to trigger any of the 8 interrupts. Four bit registers **Interrupt0_source** through **Interrupt7_source** are programmed to the event number (between 8 and 31) to select the event which triggers the interrupt. Each configured interrupt/event is signalled as a positive pulse of duration of 1 pixel clock.

Table 6-1 Interrupt Events

Event Type	Event Details	Event Number
Statistics ready from	Auto-exposure 5 bin histogram	8
	AWB color ratios	9
	All	10
	Auto-exposure256 bin histogram	11
	AE sums	13
	AWB sums	14
Frame End at	Input formatter	16
	FS WDR	17
	Defect pixel	18
	NR	19

Event Type	Event Details	Event Number
	Lens Shading	20
	DRC	21
	Demosaic	22
	ISP output	23
Frame Start at	Input formatter	24
	FS WDR	25
	Defect pixel	26
	NR	27
	Lens Shading	28
	DRC	29
	Demosaic	30
	ISP output	31
UNUSED	UNUSED	0-7, 12, 15

It is expected that an interrupt controller be implemented externally for interrupt status tracking, enable/disable, masking and configuration.

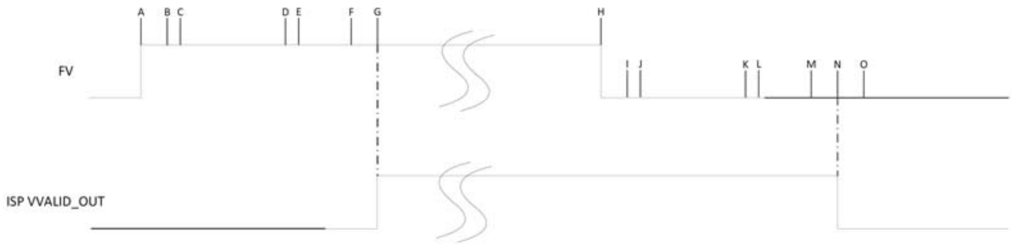
6.2.1 Key Parameters

Parameter	Description
Interrupt0_source- Interrupt7_souce	4 bit values used to set the source event for the 8 available hardware interrupts (0 through 7). Should be programmed between 8 and 31 based on events described in Interrupt Events table.

6.2.2 Interrupt Timing

There are many different combinations of interrupt timing sequences depending on location of the statistics blocks and whether ISP blocks are bypassed. The approximate interrupt timing with the default configuration is shown in the following figure and table. Note that the diagram shows interrupts occurring based on increments of line times. Although some interrupts are shown to occur at the same line they may occur during different times during the line. The order in which the interrupt event is listed in the table shows the order in which the interrupts occur within the line.

Figure 6-1 Interrupt Event Timing Diagram



Parameter	Number of lines from FV rising edge	Number of lines from FV falling edge	Interrupt Events
A	0	NA	24
B	2	NA	26
C	3	NA	25
D	11	NA	27, 28
E	12	NA	29
F	16	NA	30
G	18	NA	31
H	NA	0	16
I	NA	2	18
J	NA	3	17
K	NA	11	19, 20, 8, 11,13,14
L	NA	12	21
M	NA	16	22
N	NA	18	23, 9, 12
O	NA	20	10