
Camera VFE – MSM8994 Bayer Statistics Overview

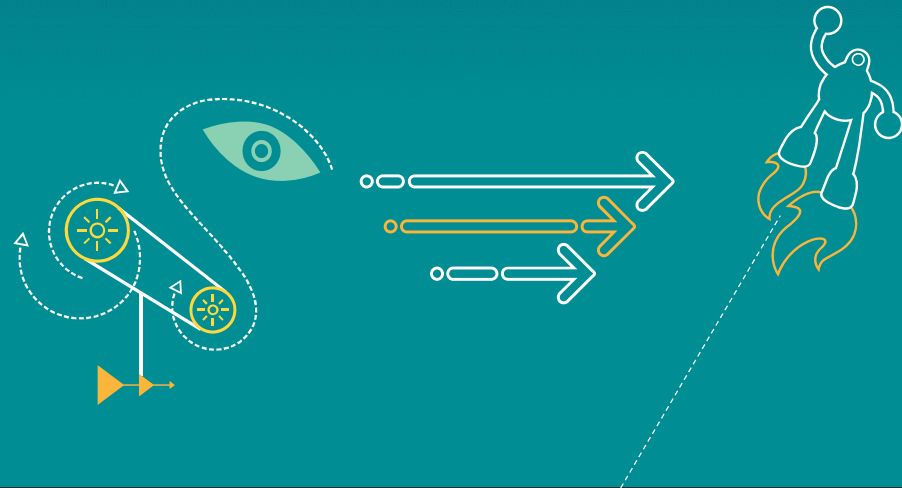


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Revision History

Revision	Date	Description
A	Aug 2014	Initial release
B	Mar 2015	Updated slide 19 and 21

Contents

- HDR Bayer Histogram Statistics
- HDR Bayer Exposure (BE) Statistics
- Dual Bayer Focus Statistics
- Bayer Grid Statistics
- Bayer Histogram Statistics
- Row/Column Sum (RS/CS) Statistics
- Image Histogram
- Skin Tone Detection
- Skin Tone Statistics
- References
- Questions?

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HDR Bayer Histogram Statistics



HDR Bayer Histogram Statistics

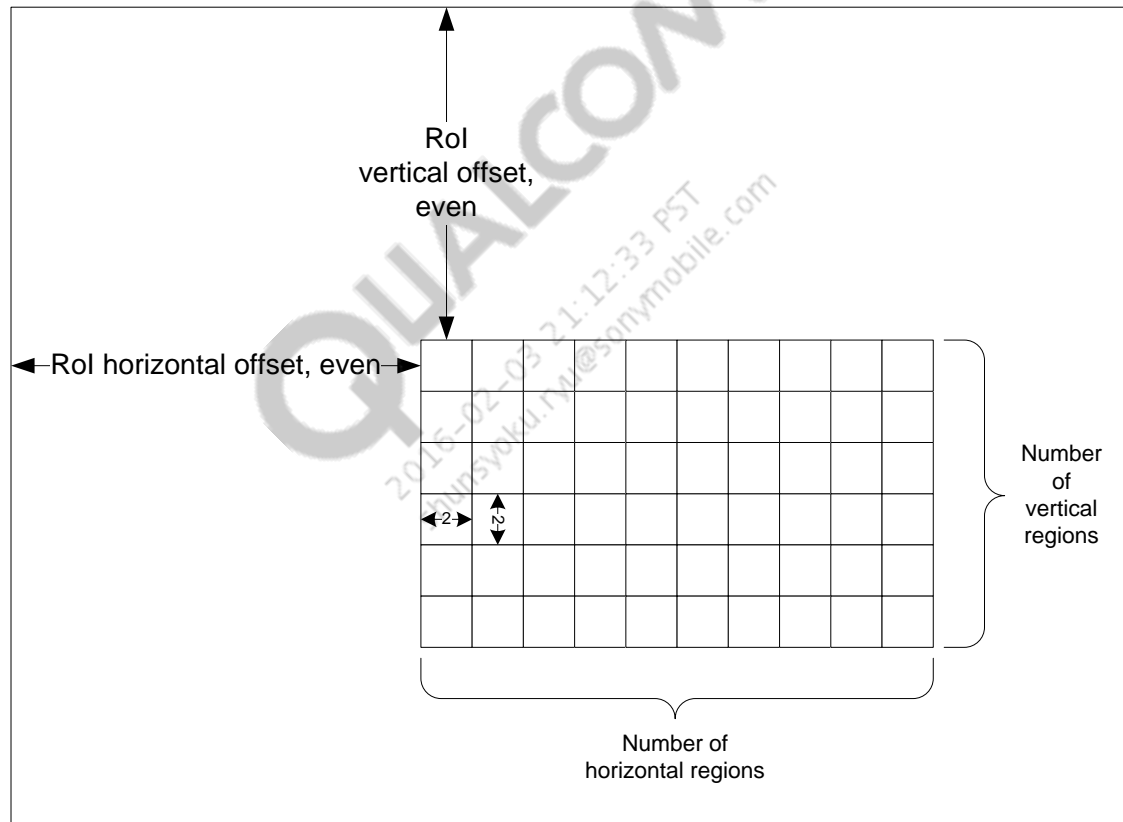
- Two independent sets of HDR bhist Generic Region Controllers (GRCs) and outputs for HDR F0 and F1 lines
- 1024-bin histogram collected for each R, Gr, Gb, B channel from Region of Interest (RoI)
- RoI is composed of regions of 2x2 pixels
- Each histogram bin is 25 bits to support 6240x16384

Name	Bits	Description	Double buffered
Enable	1	<ul style="list-style-type: none"> 0x0 – Disable histogram 0x1 – Enable histogram 	Yes
Region vertical offset	14	Vertical offset of RoI, must be multiple of 4	Yes
Region horizontal offset	13	Horizontal offset of RoI, must be even	Yes
Vertical region number	12	Vertical number of the regions of Bayer 2x2 pixels	Yes
Horizontal region number	12	Horizontal number of the regions of Bayer 2x2 pixels	Yes

31	0
31:25	R Histogram Bin 0, bits 24:0
31:25	B Histogram Bin 0, bits 24:0
31:25	Gr Histogram Bin 0, bits 24:0
31:25	Gb Histogram Bin 0, bits 24:0
31:25	R Histogram Bin 1, bits 24:0
31:25	B Histogram Bin 1, bits 24:0
31:25	Gr Histogram Bin 1, bits 24:0
31:25	Gb Histogram Bin 1, bits 24:0
31:25	...
31:25	...
31:25	...
31:25	...
31:25	R Histogram Bin 1023, bits 24:0
31:25	B Histogram Bin 1023, bits 24:0
31:25	Gr Histogram Bin 1023, bits 24:0
31:25	Gb Histogram Bin 1023, bits 24:0
31	0

4096 Entries

HDR Bayer Histogram Statistics (cont.)



HDR Bayer Histogram Statistics (cont.)

Configuration bhist_stats_reg.h

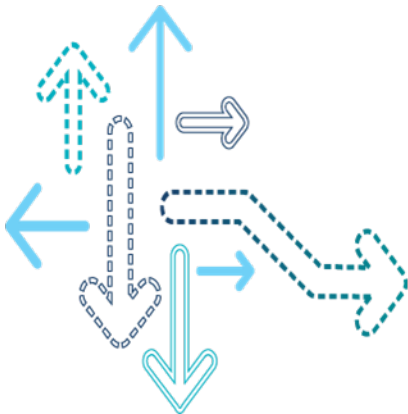
```
typedef struct ISP_StatsBhist_CfgCmdType {  
    /* VFE_STATS_BHIST_RGN_OFFSET_CFG */  
    uint32_t    rgnHOffset      : 13;  
    uint32_t    /* reserved */  : 3;  
    uint32_t    rgnVOffset      : 12;  
    uint32_t    /*reserved */   : 4;  
    /* VFE_STATS_BHIST_RGN_SIZE_CFG */  
    uint32_t    rgnHNum         : 12;  
    uint32_t    rgnVNum         : 11;  
    uint32_t    /* reserved 23:31 */ : 9;  
} __attribute__((packed, aligned(4)))  
ISP_StatsBhist_CfgCmdType;
```

Output q3a_stats_hw.h

```
typedef struct {  
    uint32_t bayer_r_hist[MAX_BHIST_STATS_NUM];  
    uint32_t bayer_b_hist[MAX_BHIST_STATS_NUM];  
    uint32_t bayer_gr_hist[MAX_BHIST_STATS_NUM];  
    uint32_t bayer_gb_hist[MAX_BHIST_STATS_NUM];  
    uint32_t num_bins;  
    stats_hdr_mode_t hdr_mode;  
} q3a_bhist_stats_t;
```


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HDR Bayer Exposure (BE) Statistics



HDR Bayer Exposure (BE) Statistics

- RoI is divided into a grid with up to 160x90 regions for 6240x16384 image size
- Collect the following statistics for each block
 - Number of saturated and nonsaturated nondark pixels
 - Sum and number of 14-bit R, B, Gr, Gb values that are within low and high thresholds

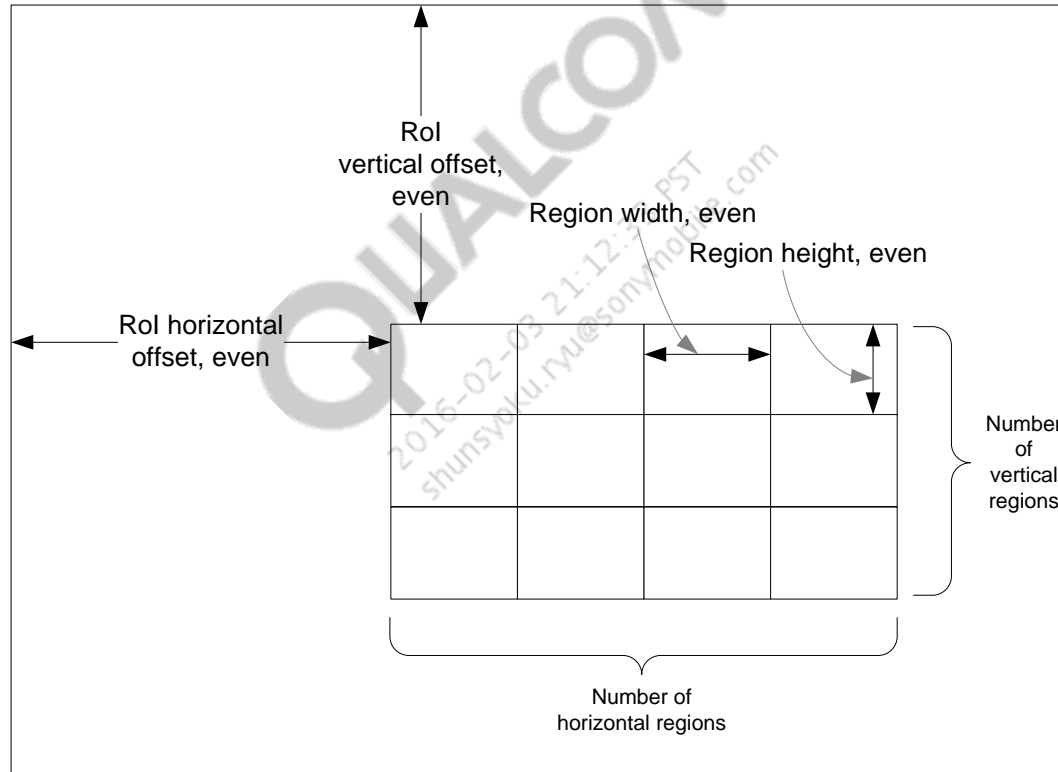
Name	Bits	Description	Double buffered
Enable	1	<ul style="list-style-type: none">▪ 0x0 – Disable grid statistics▪ 0x1 – Enable grid statistics	Yes
Site selection	1	<ul style="list-style-type: none">▪ 0x0 – Before BPC▪ 0x1 – Before HDR fusion	Yes
Input field selection	2	<ul style="list-style-type: none">▪ 0x0 – All lines▪ 0x1 – HDR F0 lines▪ 0x2 – HDR F1 lines	Yes
en_quad_sync	1	Enable quad-synchronized R/Gr/Gb/B thresholding	Yes
Region vertical offset	14	Offset from top edge of image for RoI, must be even	Yes
Region horizontal offset	13	Offset from left edge of image for RoI, must be even	Yes
Block height	10	Height of regions in pixels; must be even; range is [2, 512]	Yes
Block width	9	Width of regions in pixels; must be even; range is [4, 390]	Yes
Number of vertical blocks	7	Number of regions in vertical direction; range is [1, 90]	Yes
Number of horizontal blocks	8	Number of regions in horizontal direction; range is [1, 160]	Yes
R, B, Gr, Gb high threshold	14x4	Pixel > high threshold is counted as saturated	Yes
R, B, Gr, Gb low threshold	14x4	Pixel < low threshold is counted as dark	Yes

HDR Bayer Exposure (BE) Statistics (cont.)

- Number of dark pixels for region n = region width * region height – B cnt – R cnt – Gb cnt – Gr cnt – B sat_cnt – R sat_cnt – Gb sat_cnt – Gr sat_cnt
- Statistics are read out from left-to-right, top-to-bottom from the grid
Maximum output entries $12 * 160 * 90 = 172,800$

31		0	
12 entries per region	31:30	Region n, R Sum, (29:0)	
	31:30	Region n, B Sum, (29:0)	
	31:30	Region n, Gr Sum, (29:0)	
	31:30	Region n, Gb Sum, (29:0)	
	Region n, B Cnt, (31:16)		Region n, R Cnt, (15:0)
	Region n, Gb Cnt, (31:16)		Region n, Gr Cnt, (15:0)
	31:30	Region n, Saturated R Sum, (29:0)	
	31:30	Region n, Saturated B Sum, (29:0)	
	31:30	Region n, Saturated Gr Sum, (29:0)	
	31:30	Region n, Saturated Gb Sum, (29:0)	
	Region n, B Sat_cnt, (31:16)		Region n, R Sat_cnt, (15:0)
	Region n, Gb Sat_cnt, (31:16)		Region n, Gr Sat_cnt, (15:0)

HDR Bayer Exposure (BE) Statistics (cont.)



HDR Bayer Exposure (BE) Statistics (cont.)

Configuration `hdr_be_stats_reg46.h`

```
typedef struct ISP_StatsHdrBe_CfgCmdType {
    /* STATS_HDR_BE_RGN_OFFSET_CFG */
    uint32_t    rgnHOffset    : 13;
    uint32_t    /* reserved */ : 3;
    uint32_t    rgnVOffset    : 14;
    uint32_t    /* reserved */ : 2;
    /* STATS_HDR_BE_RGN_NUM_CFG */
    uint32_t    rgnHNum       : 8;
    uint32_t    /* reserved */ : 8;
    uint32_t    rgnVNum       : 7;
    uint32_t    /* reserved */ : 9;
    /* STATS_HDR_BE_RGN_SIZE_CFG */
    uint32_t    rgnWidth      : 9;
    uint32_t    /* reserved */ : 7;
    uint32_t    rgnHeight     : 9;
    uint32_t    /* reserved */ : 7;

    /* STATS_HDR_BE_HI_THRESHOLD_CFG_0 */
    uint32_t    rMax          : 14;
    uint32_t    /* reserved */ : 2;
    uint32_t    grMax         : 14;
    uint32_t    /* reserved */ : 2;
    /* STATS_HDR_BE_HI_THRESHOLD_CFG_1 */
    uint32_t    bMax          : 14;
    uint32_t    /* reserved */ : 2;
    uint32_t    gbMax         : 14;
    uint32_t    /* reserved */ : 2;
    /* STATS_HDR_BE_LO_THRESHOLD_CFG_0 */
    uint32_t    rMin          : 14;
    uint32_t    /* reserved */ : 2;
    uint32_t    grMin         : 14;
    uint32_t    /* reserved */ : 2;
    /* STATS_HDR_BE_LO_THRESHOLD_CFG_1 */
    uint32_t    bMin          : 14;
    uint32_t    /* reserved */ : 2;
    uint32_t    gbMin         : 14;
    uint32_t    /* reserved */ : 2;
}__attribute__((packed, aligned(4)))
ISP_StatsHdrBe_CfgCmdType;
```

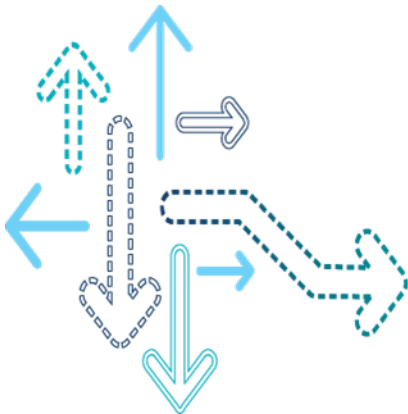
HDR Bayer Exposure (BE) Statistics (cont.)

Output q3a_stats_hw.h

```
typedef struct {  
    uint32_t be_region_h_num;  
    uint32_t be_region_v_num;  
    uint32_t be_r_sum[MAX_BE_STATS_NUM];  
    uint32_t be_b_sum[MAX_BE_STATS_NUM];  
    uint32_t be_gr_sum[MAX_BE_STATS_NUM];  
    uint32_t be_gb_sum[MAX_BE_STATS_NUM];  
    uint32_t be_r_num[MAX_BE_STATS_NUM];  
    uint32_t be_b_num[MAX_BE_STATS_NUM];  
    uint32_t be_gr_num[MAX_BE_STATS_NUM];  
    uint32_t be_gb_num[MAX_BE_STATS_NUM];  
    uint32_t be_r_sat_sum[MAX_BE_STATS_NUM];  
    uint32_t be_b_sat_sum[MAX_BE_STATS_NUM];  
    uint32_t be_gr_sat_sum[MAX_BE_STATS_NUM];  
    uint32_t be_gb_sat_sum[MAX_BE_STATS_NUM];  
    uint32_t be_r_sat_num[MAX_BE_STATS_NUM];  
    uint32_t be_b_sat_num[MAX_BE_STATS_NUM];  
    uint32_t be_gr_sat_num[MAX_BE_STATS_NUM];  
    uint32_t be_gb_sat_num[MAX_BE_STATS_NUM];  
  
    stats_hdr_mode_t hdr_mode;  
} q3a_hdr_be_stats_t;
```

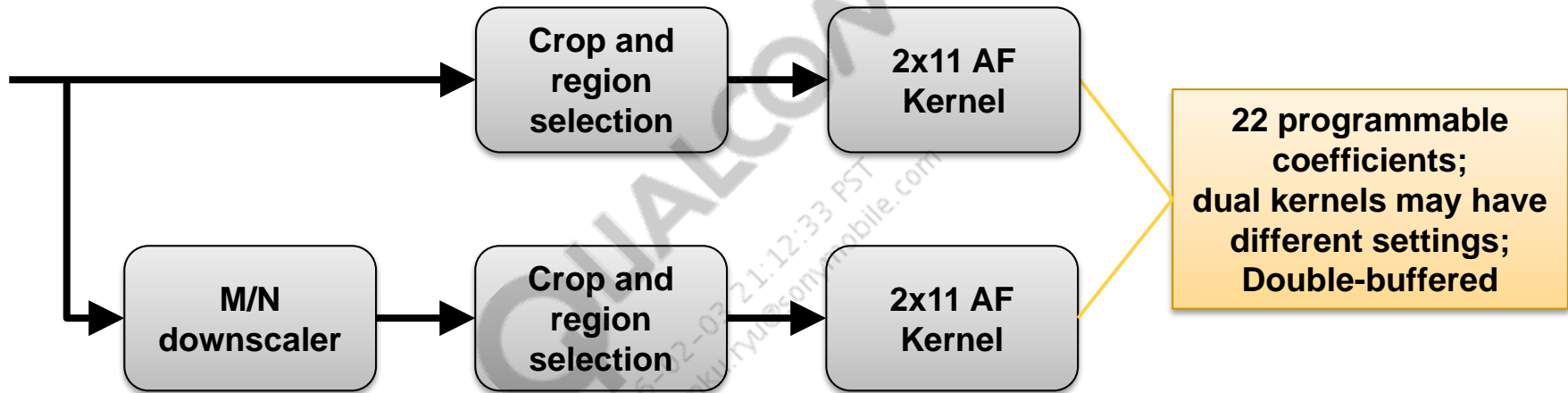
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Dual Bayer Focus Statistics



Dual Bayer Focus Statistics

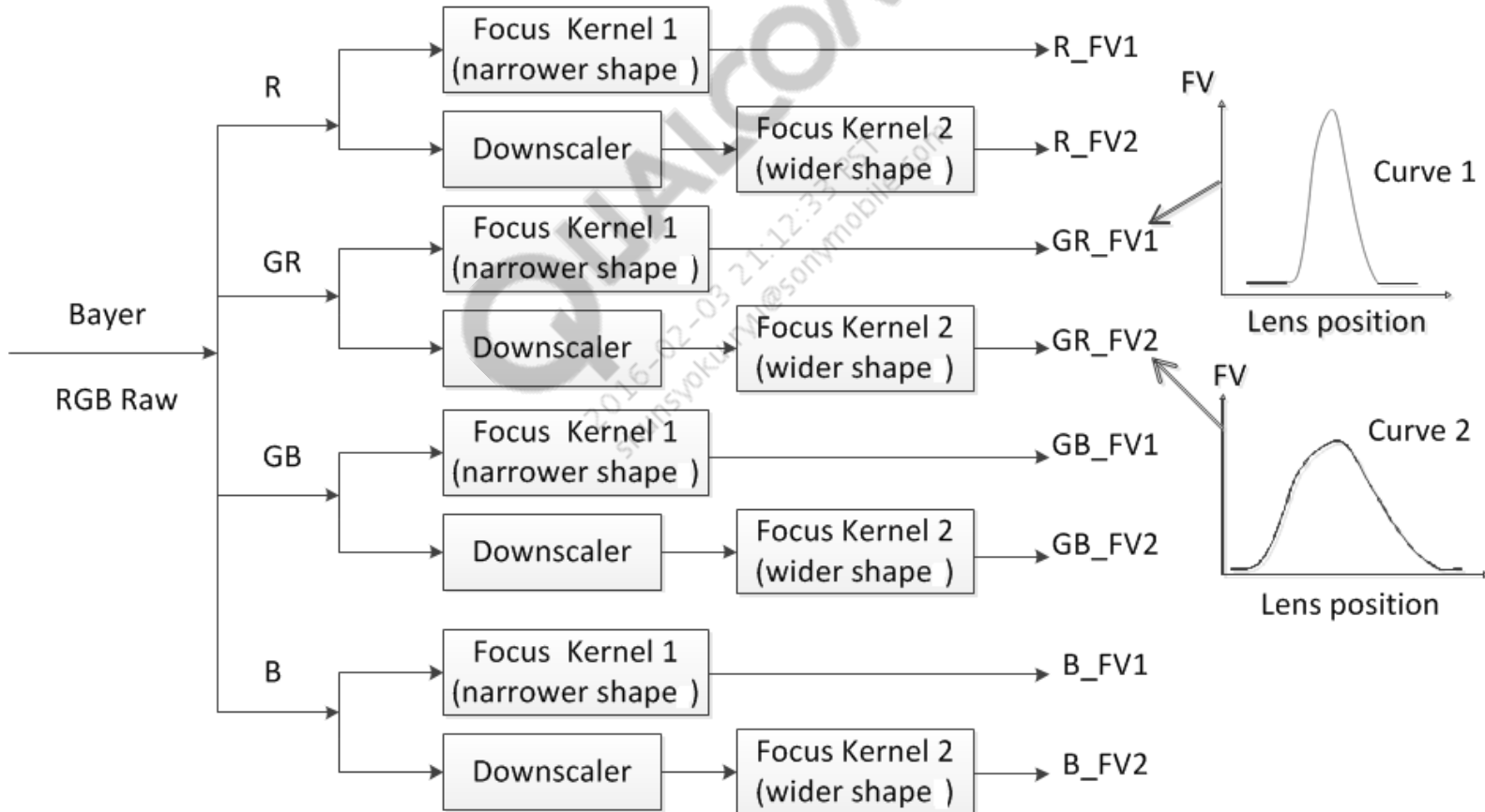
- Architecture – Add one set of Bayer focus filters with downscaler



- RoI is divided into a grid with up to 18x14 regions
- Both BF kernels before and after downscaler have the same number of horizontal and vertical regions
- Calculate the following statistics for each region
 - Sharpness for R, B, Gr, Gb channels; only the 8 Most Significant Bits (MSBs) of each pixel used in the filter
 - Sum of R, B, Gr, Gb values; only the 8 MSBs of each pixel used in the sum

Dual Bayer Focus Statistics (cont.)

- Two sets of filter coefficients for kernel 1 and kernel 2



Dual Bayer Focus Statistics (cont.)

■ BF Register Fields

Name	Bits	Description	Double-buffered
Enable	1	<ul style="list-style-type: none">0x0 – Disable focus statistics0x1 – Enable focus statistics	Yes
Site selection	2	<ul style="list-style-type: none">0x0 – Before BPC0x1 – Before HDR fusion0x2/0x3 – Before demosaic	Yes
Input field selection	2	<ul style="list-style-type: none">0x0 – All lines0x1 – HDR F0 lines0x2 – HDR F1 lines	Yes
RoI vertical offset	14	Offset from top edge of image for RoI, must be even	Yes
RoI horizontal offset	13	Offset from left edge of image for RoI, must be even	Yes
Region height	11	Height of region in pixels; must be even; range is [2, 1492]	Yes
Region width	10	Width of region in pixels; must be even; range is [6, 566]	Yes
Number of vertical regions	4	Number of regions in vertical direction before and after downscaler; range is [1, 14]	Yes
Number of horizontal regions	5	Number of regions in horizontal direction before and after downscaler; range is [1, 18]	Yes
a0, a1, ..., a10, a11, a12, ..., a21	5s x22	2x11 HPF coefficients; signed values; all 4 channels share the same filter	Yes
FV threshold before downscaler, R/Gr/Gb/B	23u x4	Minimum value of pixel sharpness that enables the region sharpness, sum, and pixel count accumulations	Yes
Downscaler H input size (N)	14	Per-channel input width, common to all 4 channels, n means n+1; stripe-related downscaler registers are all 0s	Yes
Downscaler H output size (M)	14	Per-channel output width, common to all 4 channels, n means n+1	Yes

Dual Bayer Focus Statistics (cont.)

■ BF Register Fields (cont.)

Name	Bits	Description	Double-buffered
Downscaler H phases Q2	2	<ul style="list-style-type: none"> 0x0 – $M/N=[1/69, 1/16]$ 0x1 – $M/N=(1/16, 1/8]$ 0x2 – $M/N=(1/8, 1/4]$ 0x3 – $M/N=(1/4, 1]$ 	Yes
Downscaler H multiplication factor	21	N/M in (14+Q2), unsigned	Yes
Downscaler V input size (N)	14	Per-channel input height, common to all 4 channels, n means n+1; stripe related downscaler registers are all 0s	Yes
Downscaler V output size (M)	14	Per-channel output height, common to all 4 channels, n means n+1	Yes
Downscaler V phases Q2	2	<ul style="list-style-type: none"> 0x0 – $M/N=[1/69, 1/16]$ 0x1 – $M/N=(1/16, 1/8]$ 0x2 – $M/N=(1/8, 1/4]$ 0x3 – $M/N=(1/4, 1]$ 	Yes
Downscaler V multiplication factor	21	N/M in (14+Q2), unsigned	Yes
Scaled input field selection	2	<ul style="list-style-type: none"> 0x0 – All lines 0x1 – HDR F0 lines 0x2 – HDR F1 lines 	Yes
RoI vertical offset	14	After downscaler offset from top edge of image for RoI, must be even	Yes
RoI horizontal offset	13	After downscaler offset from left edge of image for RoI, must be even	Yes
Region height	11	After downscaler height of region in pixels; must be even; range is [2, 1492]	Yes
Region width	10	After downscaler width of region in pixels; must be even; range is [8, 566]	Yes
b0, b1, ..., b10, b11, b12, ..., b21	5s x22	After downscaler 2x11 HPF coefficients; signed values for all 4 channels	Yes
FV threshold after downscaler, R/Gr/Gb/B	23u x4	Minimum value of pixel sharpness that enables the region sharpness, sum, and pixel count accumulations	Yes

Dual Bayer Focus Statistics (cont.)

- BF output buffer format
- Average R, B, Gr, Gb calculated by:
 - avg R = R sum / (R number)
 - avg B = B sum / (B number)
 - avg Gr = Gr sum / (Gr number)
 - avg Gb = Gb sum / (Gb number)
- Statistics are read out from left-to-right, top-to-bottom from the grids
Maximum output entries, $20 * 18 * 14 = 5,040$ 64-bit buffers for both sets of BF filters

63		0	
10 entries per region	Region n, B Sum, (63:32)		Region n, R Sum, (31:0)
	Region n, Gb Sum, (63:32)		Region n, Gr Sum, (31:0)
	63:41		Region n, R Sharpness, (40:0)
	63:41		Region n, B Sharpness, (40:0)
	63:41		Region n, Gr Sharpness, (40:0)
	63:41		Region n, Gb Sharpness, (40:0)
	63:58	Region n, R Cnt, (57:40)	39:33 Region n, R Max, (32:0)
	63:58	Region n, B Cnt, (57:40)	39:33 Region n, B Max, (32:0)
	63:58	Region n, Gr Cnt, (57:40)	39:33 Region n, Gr Max, (32:0)
	63:58	Region n, Gb Cnt, (57:40)	39:33 Region n, Gb Max, (32:0)
10 entries per region	Scaled Region n, B Sum, (63:32)		Scaled Region n, R Sum, (31:0)
	Scaled Region n, Gb Sum, (63:32)		Scaled Region n, Gr Sum, (31:0)
	63:41		Downscaled Region n, R Sharpness, (40:0)
	63:41		Downscaled Region n, B Sharpness, (40:0)
	63:41		Downscaled Region n, Gr Sharpness, (40:0)
	63:41		Downscaled Region n, Gb Sharpness, (40:0)
	63:58	Scaled Region n, R Cnt, (57:40)	39:33 Downscaled Region n, R Max, (32:0)
	63:58	Scaled Region n, B Cnt, (57:40)	39:33 Downscaled Region n, B Max, (32:0)
	63:58	Scaled Region n, Gr Cnt, (57:40)	39:33 Downscaled Region n, Gr Max, (32:0)
	63:58	Scaled Region n, Gb Cnt, (57:40)	39:33 Downscaled Region n, Gb Max, (32:0)

Dual Bayer Focus Statistics (cont.)

- Maximum 18 (H) x 14 (V) regions
- Pad of 2 rows/columns required on all four sides
- Height of a region must be >2
- Width of a region must be > 8

- For the region highlighted in yellow:

$$\text{R Sharpness} = \lambda(R_{0,4}) + \lambda(R_{0,6}) + \lambda(R_{2,4}) + \lambda(R_{2,6})$$

$$\text{Gr Sharpness} = \lambda(Gr_{0,5}) + \lambda(Gr_{0,7}) + \lambda(Gr_{2,5}) + \lambda(Gr_{2,7})$$

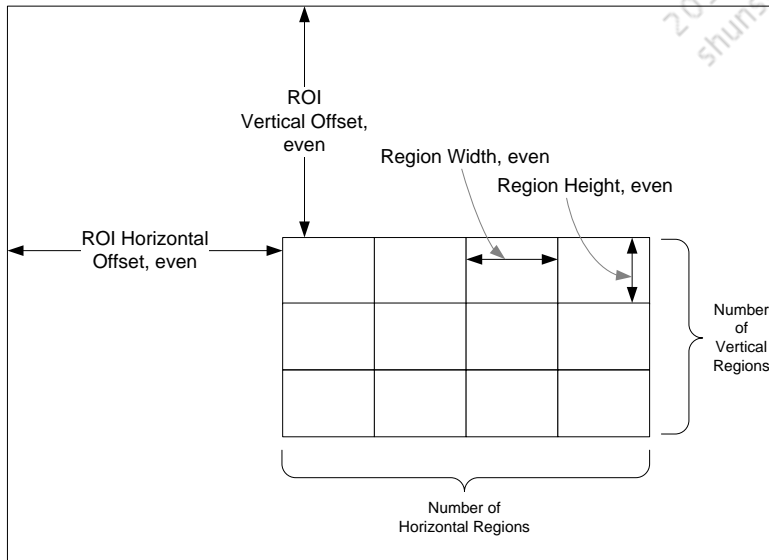
$$\text{Gb Sharpness} = \lambda(Gb_{1,4}) + \lambda(Gb_{1,6}) + \lambda(Gb_{3,4}) + \lambda(Gb_{3,6})$$

$$\text{B Sharpness} = \lambda(B_{1,5}) + \lambda(B_{1,7}) + \lambda(B_{3,5}) + \lambda(B_{3,7})$$

$$\text{Filter Definition : } \lambda(X_{i,j}) =$$

$$\text{ABS}(a_0 \cdot X_{i,j-10} + \dots + a_5 \cdot X_{i,j} + \dots + a_{10} \cdot X_{i,j+10} +$$

$$a_{11} \cdot X_{i+2,j-10} + \dots + a_{16} \cdot X_{i+2,j} + \dots + a_{21} \cdot X_{i+2,j+10})$$



R00	Gr01	R02	Gr03	R04	Gr05	R06	Gr07	R08	Gr09	...
Gb10	B11	Gb12	B13	Gb14	B15	Gb16	B17	Gb18	B19	...
R20	Gr21	R22	Gr23	R24	Gr25	R26	Gr27	R28	Gr29	...
Gb30	B31	Gb32	B33	Gb34	B35	Gb36	B37	Gb38	B39	...
R40	Gr41	R42	Gr43	R44	Gr45	R46	Gr47	R48	Gr49	...
Gb50	B51	Gb52	B53	Gb54	B55	Gb56	B57	Gb58	B59	...
R60	Gr61	R62	Gr63	R64	Gr65	R66	Gr67	R68	Gr69	...
Gb70	B71	Gb72	B73	Gb74	B75	Gb76	B77	Gb78	B79	...
...

Dual Bayer Focus Statistics (cont.)

Configuration bf_stats_reg.h

```
typedef struct ISP_StatsBf_CfgCmdType {
    /* VFE_STATS_BF_RGN_OFFSET_CFG */
    uint32_t    rgnHOffset      : 13;
    uint32_t    /* reserved */  : 3;
    uint32_t    rgnVOffset      : 14;
    uint32_t    /*reserved */   : 2;
    /* VFE_STATS_BF_RGN_NUM_CFG */
    uint32_t    rgnHNum         : 5;
    uint32_t    /* reserved */  : 11;
    uint32_t    rgnVNum         : 4;
    uint32_t    /* reserved */  : 12;
    /* VFE_STATS_BF_RGN_SIZE_CFG */
    uint32_t    rgnWidth        : 10;
    uint32_t    /* reserved */  : 6;
    uint32_t    rgnHeight       : 11;
    uint32_t    /* reserved */  : 5;
    /* VFE_STATS_BF_FILTER_CFG_0 */
    uint32_t    r_fv_min        : 23;
    uint32_t    /* reserved 23:31 */ : 9;
    /* VFE_STATS_BF_FILTER_CFG_1 */
    uint32_t    gr_fv_min       : 23;
    uint32_t    /* reserved 23:31 */ : 9;

    /* VFE_STATS_BF_FILTER_CFG_2 */
    uint32_t    b_fv_min        : 23;
    uint32_t    /* reserved 23:31 */ : 9;
    /* VFE_STATS_BF_FILTER_CFG_3 */
    uint32_t    gb_fv_min       : 23;
    uint32_t    /* reserved 23:31 */ : 9;
    /* VFE_STATS_BF_FILTER_COEFF_0 */
    int32_t     a00              : 5;
    int32_t     a01              : 5;
    int32_t     a02              : 5;
    int32_t     a03              : 5;
    int32_t     a04              : 5;
    uint32_t    /* reserved 25 */ : 1;
    int32_t     a05              : 5;
    uint32_t    /* reserved 31 */ : 1;
    /* VFE_STATS_BF_FILTER_COEFF_1 */
    int32_t     a06              : 5;
    int32_t     a07              : 5;
    int32_t     a08              : 5;
    uint32_t    /* reserved */   : 1;
    int32_t     a09              : 5;
    uint32_t    /* reserved 21:23 */ : 3;
    int32_t     a10              : 5;
    uint32_t    /* reserved 29:31 */ : 3;
```

Dual Bayer Focus Statistics (cont.)

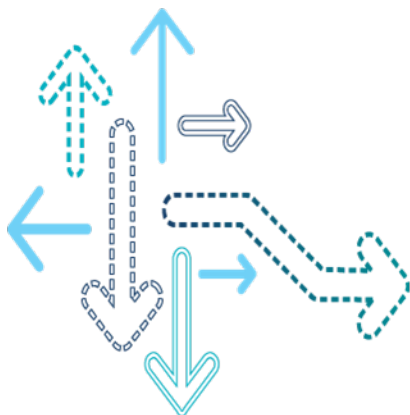
```
/* VFE_STATS_BF_FILTER_COEFF_2 */
int32_t    a11        : 5;
int32_t    a12        : 5;
int32_t    a13        : 5;
uint32_t    /* reserved */ : 1;
int32_t    a14        : 5;
int32_t    a15        : 5;
int32_t    a16        : 5;
uint32_t    /* reserved */ : 1;
/* VFE_STATS_BF_FILTER_COEFF_3 */
int32_t    a17        : 5;
int32_t    a18        : 5;
int32_t    a19        : 5;
uint32_t    /* reserved */ : 1;
int32_t    a20        : 5;
int32_t    a21        : 5;
uint32_t    /* reserved 26:31 */ : 6;
}__attribute__((packed, aligned(4))) ISP_StatsBf_CfgCmdType;
```

Output q3a_stats_hw.h

```
typedef struct {
    uint32_t config_id;
    uint32_t bf_region_h_num;
    uint32_t bf_region_v_num;
    uint8_t use_max_fv;
    uint32_t bf_r_sum[MAX_BF_STATS_NUM];
    uint32_t bf_b_sum[MAX_BF_STATS_NUM];
    uint32_t bf_gr_sum[MAX_BF_STATS_NUM];
    uint32_t bf_gb_sum[MAX_BF_STATS_NUM];
    uint64_t bf_r_sharp[MAX_BF_STATS_NUM];
    uint64_t bf_b_sharp[MAX_BF_STATS_NUM];
    uint64_t bf_gr_sharp[MAX_BF_STATS_NUM];
    uint64_t bf_gb_sharp[MAX_BF_STATS_NUM];
    uint32_t bf_r_num[MAX_BF_STATS_NUM];
    uint32_t bf_b_num[MAX_BF_STATS_NUM];
    uint32_t bf_gr_num[MAX_BF_STATS_NUM];
    uint32_t bf_gb_num[MAX_BF_STATS_NUM];
    uint64_t bf_r_max_fv[MAX_BF_STATS_NUM];
    uint64_t bf_b_max_fv[MAX_BF_STATS_NUM];
    uint64_t bf_gr_max_fv[MAX_BF_STATS_NUM];
    uint64_t bf_gb_max_fv[MAX_BF_STATS_NUM];
} q3a_bf_stats_t;
```

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Bayer Grid Statistics



Bayer Grid Statistics

- RoI is divided into a grid with up to 160x90 regions for 6240x16384 image size
- Collect the following statistics for each block
 - Number of saturated and nonsaturated nondark pixels
 - Sum and number of 14-bit R, B, Gr, Gb values that are within low and high thresholds

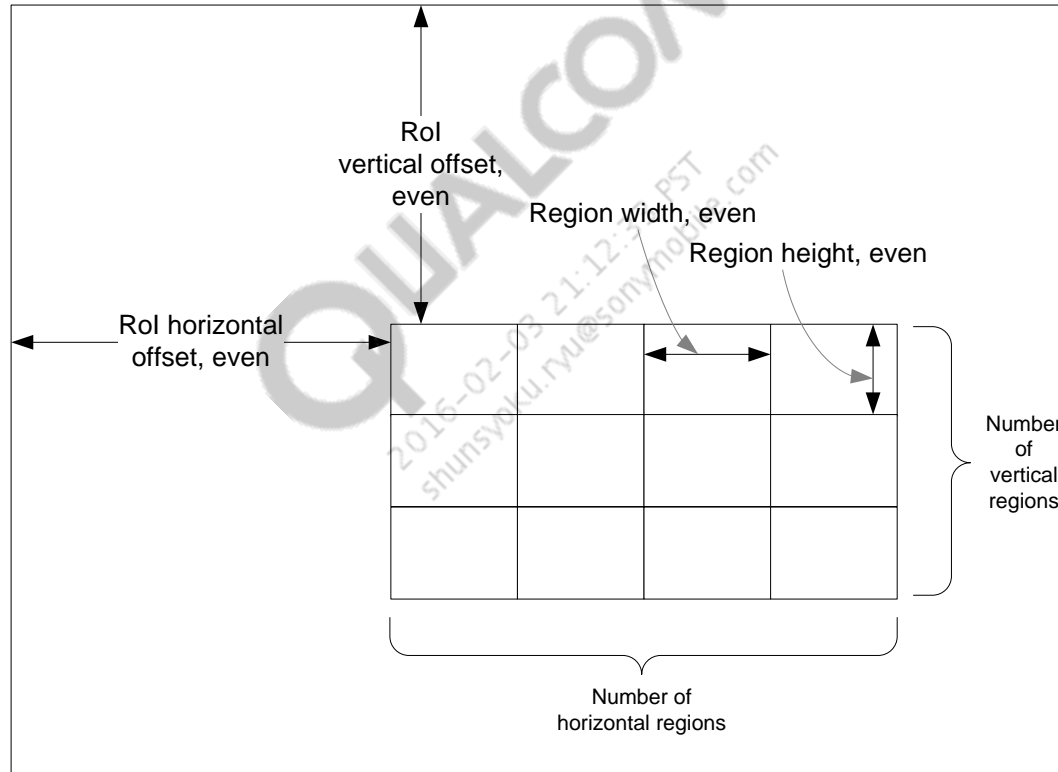
Name	Bits	Description	Double-buffered
Enable	1	0x0 – Disable grid statistics 0x1 – Enable grid statistics	Yes
en_quad_sync	1	Enable quad-synchronized R/Gr/Gb/B thresholding	Yes
Region vertical offset	14	Offset from top edge of image for RoI, must be even	Yes
Region horizontal offset	13	Offset from left edge of image for RoI, must be even	Yes
Block height	10	Height of regions in pixels; must be even; range is [2, 512]	Yes
Block width	9	Width of regions in pixels; must be even; range is [4, 390]	Yes
Number of vertical blocks	7	Number of regions in vertical direction; range is [1, 90]	Yes
Number of horizontal blocks	8	Number of regions in horizontal direction; range is [1, 160]	Yes
R, B, Gr, Gb high threshold	14x4	Pixel > high threshold is counted as saturated	Yes
R, B, Gr, Gb low threshold	14x4	Pixel < low threshold is counted as dark	Yes

Bayer Grid Statistics (cont.)

- Number of dark pixels for region n = region width * region height – B cnt – R cnt – Gb cnt – Gr cnt – B sat_cnt – R sat_cnt – Gb sat_cnt – Gr sat_cnt
- Statistics are read out from left-to-right, top-to-bottom from the grid
Maximum output entries, $12 * 160 * 90 = 172,800$

31		0	
12 entries per region	31:30	Region n, R Sum, (29:0)	
	31:30	Region n, B Sum, (29:0)	
	31:30	Region n, Gr Sum, (29:0)	
	31:30	Region n, Gb Sum, (29:0)	
	Region n, B Cnt, (31:16)		Region n, R Cnt, (15:0)
	Region n, Gb Cnt, (31:16)		Region n, Gr Cnt, (15:0)
	31:30	Region n, Saturated R Sum, (29:0)	
	31:30	Region n, Saturated B Sum, (29:0)	
	31:30	Region n, Saturated Gr Sum, (29:0)	
	31:30	Region n, Saturated Gb Sum, (29:0)	
	Region n, B Sat_cnt, (31:16)		Region n, R Sat_cnt, (15:0)
	Region n, Gb Sat_cnt, (31:16)		Region n, Gr Sat_cnt, (15:0)

Bayer Grid Statistics (cont.)



Bayer Grid Statistics (cont.)

Configuration bg_stats_reg46.h

```
typedef struct ISP_StatsBg_CfgCmdType {
    /* VFE_STATS_BG_RGN_OFFSET_CFG */
    uint32_t    rgnHOffset      : 13;
    uint32_t    /* reserved */  : 3;
    uint32_t    rgnVOffset      : 14;
    uint32_t    /* reserved */  : 2;
    /* VFE_STATS_BG_RGN_NUM_CFG */
    uint32_t    rgnHNum         : 8;
    uint32_t    /* reserved */  : 8;
    uint32_t    rgnVNum         : 7;
    uint32_t    /* reserved */  : 9;
    /* VFE_STATS_BG_RGN_SIZE_CFG */
    uint32_t    rgnWidth        : 9;
    uint32_t    /* reserved */  : 7;
    uint32_t    rgnHeight       : 10;
    uint32_t    /* reserved */  : 6;
    /* VFE_STATS_BG_HI_THRESHOLD_CFG_0 */
    uint32_t    rMax            : 14;
    uint32_t    /*reserved */   : 2;
    uint32_t    grMax           : 14;
    uint32_t    /*reserved */   : 2;

    /* VFE_STATS_BG_HI_THRESHOLD_CFG_1 */
    uint32_t    bMax            : 14;
    uint32_t    /*reserved */   : 2;
    uint32_t    gbMax           : 14;
    uint32_t    /*reserved */   : 2;
    /* VFE_STATS_BG_LO_THRESHOLD_CFG_0 */
    uint32_t    rMin            : 14;
    uint32_t    /*reserved */   : 2;
    uint32_t    grMin           : 14;
    uint32_t    /*reserved */   : 2;
    /* VFE_STATS_BG_LO_THRESHOLD_CFG_1 */
    uint32_t    bMin            : 14;
    uint32_t    /*reserved */   : 2;
    uint32_t    gbMin           : 14;
    uint32_t    /*reserved */   : 2;
} __attribute__((packed, aligned(4)))
ISP_StatsBg_CfgCmdType;
```

Bayer Grid Statistics (cont.)

Output q3a_stats_hw.h

```
typedef struct {
    uint32_t bg_region_h_num; /* 64, max 72 */
    uint32_t bg_region_v_num; /* 48, max 54 */
    uint32_t region_pixel_cnt;
    uint32_t bg_region_height;
    uint32_t bg_region_width;
    uint16_t rMax, bMax, grMax, gbMax;
    uint32_t bg_r_sum[MAX_BG_STATS_NUM];
    uint32_t bg_b_sum[MAX_BG_STATS_NUM];
    uint32_t bg_gr_sum[MAX_BG_STATS_NUM];
    uint32_t bg_gb_sum[MAX_BG_STATS_NUM];
    uint32_t bg_r_num[MAX_BG_STATS_NUM];
    uint32_t bg_b_num[MAX_BG_STATS_NUM];
    uint32_t bg_gr_num[MAX_BG_STATS_NUM];
    uint32_t bg_gb_num[MAX_BG_STATS_NUM];

    /* this section is valid only when BG_EXTENDED_SATURATED
    is set */
    uint32_t bg_r_sat_sum[MAX_BG_STATS_NUM];
    uint32_t bg_b_sat_sum[MAX_BG_STATS_NUM];
    uint32_t bg_gr_sat_sum[MAX_BG_STATS_NUM];
    uint32_t bg_gb_sat_sum[MAX_BG_STATS_NUM];
    uint32_t bg_r_sat_num[MAX_BG_STATS_NUM];
    uint32_t bg_b_sat_num[MAX_BG_STATS_NUM];
    uint32_t bg_gr_sat_num[MAX_BG_STATS_NUM];
    uint32_t bg_gb_sat_num[MAX_BG_STATS_NUM];

    uint32_t ex_fields;
} q3a_bg_stats_t;
```



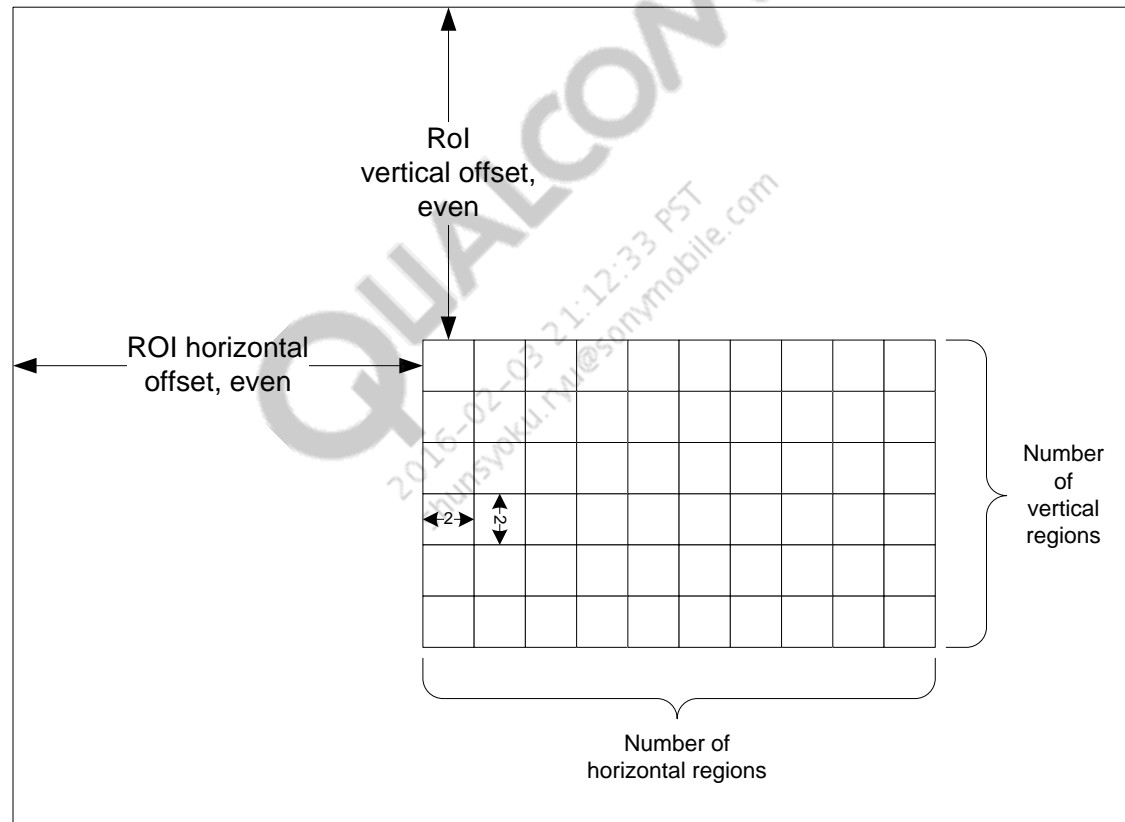
Bayer Histogram Statistics

- 4096-bin histogram collected for each R, Gr, Gb, B channel from RoI
- RoI is composed of regions of 2x2 pixels
- Each histogram bin is 25 bits to support 6240x16384

Name	Bits	Description	Double-buffered
Enable	1	<ul style="list-style-type: none"> 0x0 – Disable histogram 0x1 – Enable histogram 	Yes
Region vertical offset	14	Offset from top edge of image for RoI, must be even	Yes
Region horizontal offset	13	Offset from left edge of image for RoI, must be even	Yes
Vertical region number	13	Vertical number of the regions of 2x2 pixels	Yes
Horizontal region number	12	Horizontal number of the regions of 2x2 pixels	Yes

31	0
31:25	R Histogram Bin 0, bits 24:0
31:25	B Histogram Bin 0, bits 24:0
31:25	Gr Histogram Bin 0, bits 24:0
31:25	Gb Histogram Bin 0, bits 24:0
31:25	R Histogram Bin 1, bits 24:0
31:25	B Histogram Bin 1, bits 24:0
31:25	Gr Histogram Bin 1, bits 24:0
31:25	Gb Histogram Bin 1, bits 24:0
31:25	...
31:25	...
31:25	...
31:25	...
31:25	R Histogram Bin 4095, bits 24:0
31:25	B Histogram Bin 4095, bits 24:0
31:25	Gr Histogram Bin 4095, bits 24:0
31:25	Gb Histogram Bin 4095, bits 24:0

Bayer Histogram Statistics (cont.)



Bayer Histogram Statistics (cont.)

Configuration bhist_stats_reg.h

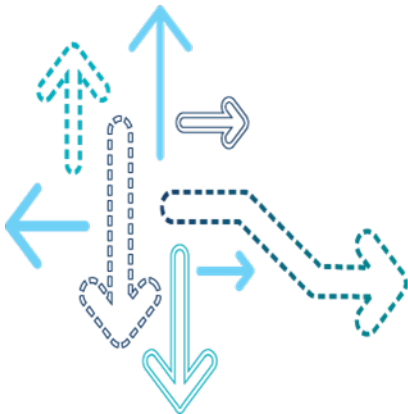
```
typedef struct ISP_StatsBhist_CfgCmdType {  
    /* VFE_STATS_BHIST_RGN_OFFSET_CFG */  
    uint32_t    rgnHOffset      : 13;  
    uint32_t    /* reserved */  : 3;  
    uint32_t    rgnVOffset      : 12;  
    uint32_t    /*reserved */   : 4;  
    /* VFE_STATS_BHIST_RGN_SIZE_CFG */  
    uint32_t    rgnHNum         : 12;  
    uint32_t    rgnVNum         : 11;  
    uint32_t    /* reserved 23:31 */ : 9;  
} __attribute__((packed, aligned(4)))  
ISP_StatsBhist_CfgCmdType;
```

Output q3a_stats_hw.h

```
typedef struct {  
    uint32_t bayer_r_hist[MAX_BHIST_STATS_NUM];  
    uint32_t bayer_b_hist[MAX_BHIST_STATS_NUM];  
    uint32_t bayer_gr_hist[MAX_BHIST_STATS_NUM];  
    uint32_t bayer_gb_hist[MAX_BHIST_STATS_NUM];  
    uint32_t num_bins;  
    stats_hdr_mode_t hdr_mode;  
} q3a_bhist_stats_t;
```

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Row/Column Sum (RS/CS) Statistics

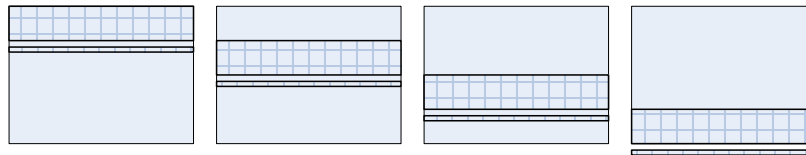


Row/Column Sum (RS/CS) Statistics

- Statistics color conversion outputs 12-bit Y for RS/CS statistics
- Legacy post-demosaic AWB statistics to be removed
- Row sums (RS) / column sums (CS) v.2
 - 4 sets of Row Sums of 1/4 image/RoI width



- One set of Column Sums of 1/4 image/RoI height are reused four times



- Different software combinations for full width RS / full height CS or regional RS/CS for frame registration

Row/Column Sum (RS/CS) Statistics (cont.)

- Operates on viewfinder and continuous snapshot modes up to 6240x16384
- RoI is divided to up to four equal width/height chunks for RS/CS respectively
- Accumulate Y for every row, no more than 4,096 row sums
- Accumulate Y for every other column, no more than 1,560 column sums
- Accumulator clamping at the maximum value
- Output rowsums[.] and colsums[.]

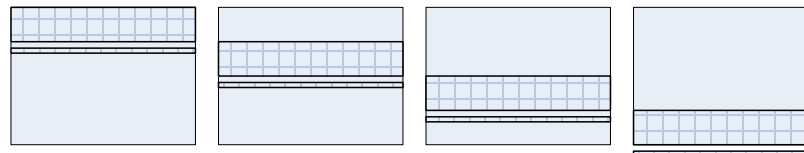
Row/Column Sum (RS/CS) Statistics – RS Hardware Interface

Register name	Bits	Description	Programming frequency
RS_EN	1	<ul style="list-style-type: none"> 0x0 – Disable flicker detection row sum 0x1 – Enable flicker detection row sum 	Initialization, double buffered
rs_rgn_h_offset	13	Programmable offset of the starting pixel for row sum	Every couple frames, double buffered
rs_rgn_v_offset	14	Programmable offset of the starting line for row sum	Every couple frames, double buffered
rs_rgn_h_num	2	(Number of horizontal chunks, c) – 1, $1 \leq c \leq 4$, default c is 1	Every couple frames, double buffered
rs_rgn_v_num	12	(RoI height)/n – 1, must be less than 4096	Every couple frames, double buffered
rs_rgn_width	13	Number of columns per region, (RoI width)/c – 1	Every couple frames, double buffered
rs_rgn_height	2	(Number of rows per region, n) – 1, $1 \leq n \leq 4$, default n is 1	Every couple frames, double buffered
RS_SHIFT_BITS	4	Number of bits to be right shifted for row sum; range is 0~10	Every couple frames, double buffered



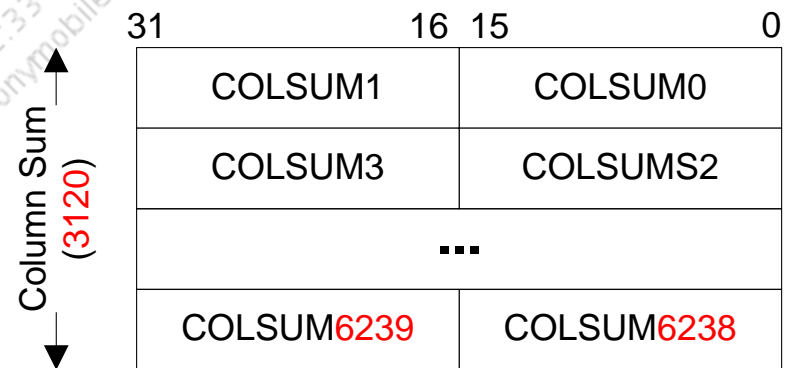
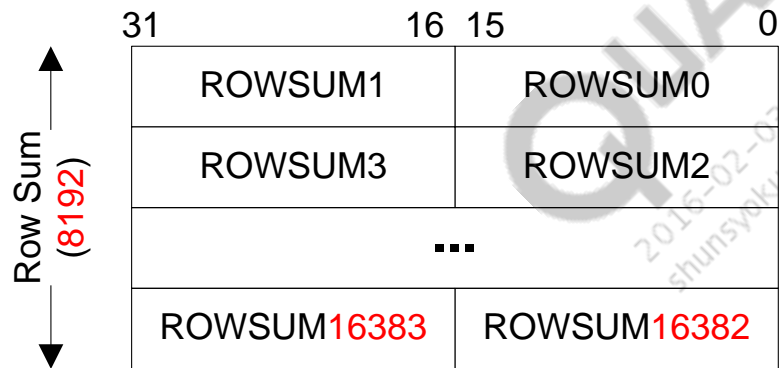
Row/Column Sum (RS/CS) Statistics – CS Hardware Interface

Register name	Bits	Description	Programming frequency
CS_EN	1	<ul style="list-style-type: none"> 0x0 – Disable column sum 0x1 – Enable column sum 	Initialization, double buffered
cs_rgn_h_offset	13	Programmable offset of the starting pixel for column sum	Every couple frames, double buffered
cs_rgn_v_offset	14	Programmable offset of the starting line for column sum	Every couple frames, double buffered
cs_rgn_h_num	11	$(\text{RoI width})/n - 1$, must be less than 1560 and $(\text{cs_rgn_h_num} \% 8)$ must be in [4, 7]	Every couple frames, double buffered
cs_rgn_v_num	2	$(\text{Number of vertical chunks, } c) - 1$, $1 \leq c \leq 4$, default c is 1	Every couple frames, double buffered
cs_rgn_width	2	$(\text{Number of columns per region, } n) - 1$, $2 \leq n \leq 4$, default n is 2	Every couple frames, double buffered
cs_rgn_height	14	Number of rows per region, $(\text{RoI height})/c - 1$	Every couple frames, double buffered
CS_SHIFT_BITS	4	Number of bits to be right shifted for column sum; range is 0~10	Every couple frames, double buffered



Row/Column Sum (RS/CS) Statistics – Statistics Output

Register name	Bits	Description	Reporting frequency
Rowsum[4x4096]	16	Row sum outputs for the frame	When row sums are requested
Colsum[4x1560]	16	Column sum outputs for the frame	When column sums are requested



Row/Column Sum (RS/CS) Statistics

Configuration rs_stats_reg46.h

```
typedef struct ISP_StatsRs_CfgType {
    /* VFE_STATS_RS_RGN_OFFSET_CFG */
    uint32_t    rgnHOffset    : 13;
    uint32_t    /* reserved */ : 3;
    uint32_t    rgnVOffset    : 13;
    uint32_t    /* reserved */ : 3;

    /* VFE_STATS_RS_RGN_NUM_CFG */
    uint32_t    rgnHNum       : 2;
    uint32_t    /* reserved */ : 14;
    uint32_t    rgnVNum       : 12;
    uint32_t    /* reserved */ : 4;

    /* VFE_STATS_RS_RGN_SIZE_CFG */
    uint32_t    rgnWidth      : 13;
    uint32_t    /* reserved */ : 3;
    uint32_t    rgnHeight     : 2;
    uint32_t    /* reserved */ : 14;
}__attribute__((packed, aligned(4))) ISP_StatsRs_CfgType;
```

Configuration cs_stats_reg46.h

```
typedef struct ISP_StatsCs_CfgType {
    /* VFE_STATS_CS_RGN_OFFSET_CFG */
    uint32_t    rgnHOffset    : 13;
    uint32_t    /* reserved */ : 3;
    uint32_t    rgnVOffset    : 14;
    uint32_t    /* reserved */ : 2;

    /* VFE_STATS_CS_RGN_NUM_CFG */
    uint32_t    rgnHNum       : 11;
    uint32_t    /* reserved */ : 5;
    uint32_t    rgnVNum       : 2;
    uint32_t    /* reserved */ : 14;

    /* VFE_STATS_CS_RGN_SIZE_CFG */
    uint32_t    rgnWidth      : 2;
    uint32_t    /* reserved */ : 14;
    uint32_t    rgnHeight     : 14;
    uint32_t    /* reserved */ : 2;
}__attribute__((packed, aligned(4))) ISP_StatsCs_CfgType;
```


Row/Column Sum (RS/CS) Statistics (cont.)

Output q3a_stats_hw.h

```
typedef struct {  
    uint32_t num_col_sum;  
    uint32_t col_sum[MAX_CS_STATS_NUM * 4];  
} q3a_cs_stats_t;  
  
typedef struct {  
    uint32_t num_row_sum;  
    uint32_t row_sum[MAX_RS_H_REGIONS][MAX_RS_STATS_NUM];  
    uint32_t num_h_regions;  
    uint32_t num_v_regions;  
} q3a_rs_stats_t;
```

Image Histogram

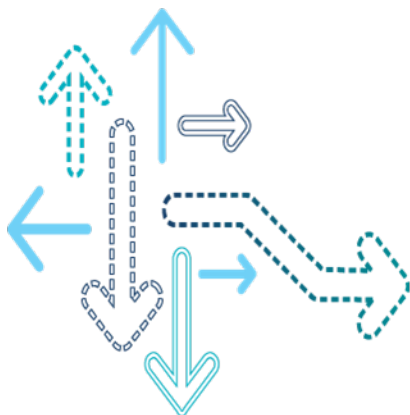


Image Histogram

- Histogram collections of the Y/Cb/Cr, G, B, R channels
 - For LA, display, and other features
 - Advanced AEC
 - Simultaneous Y/Cb/Cr, G, B, and R image histogram outputs
 - Bin value clamping at the maximum value ($2^{24} - 1$) and truncated and clamped to 16 bits

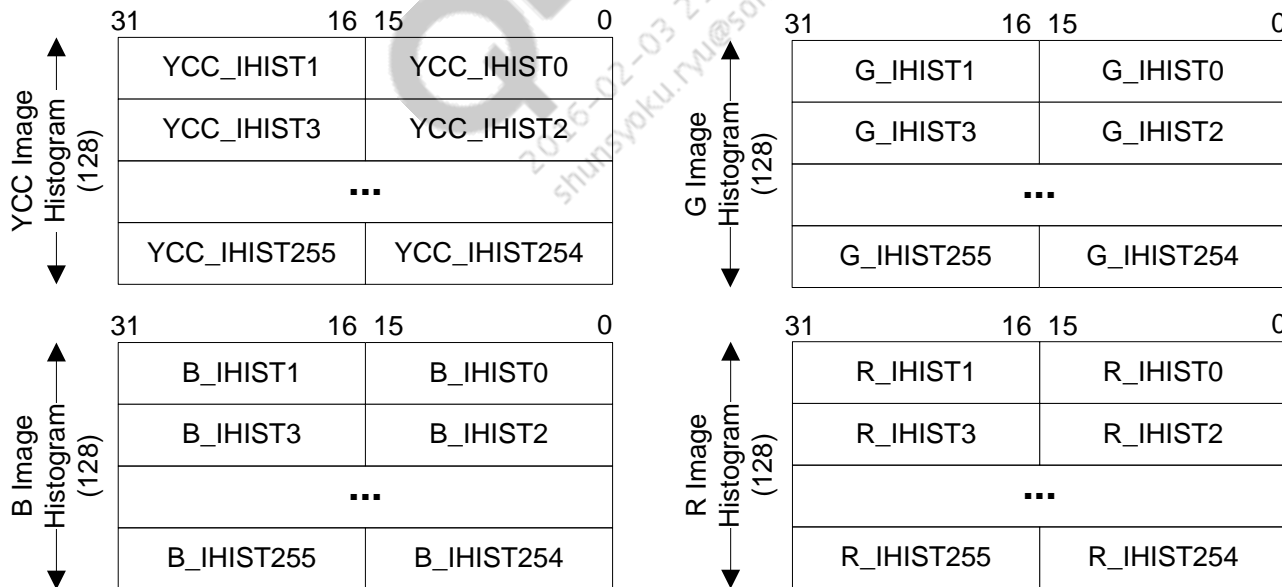


Image Histogram (cont.)

■ Hardware interface – Each region is 2x2 pixels

Name	Bits	Description	Programming frequency
Image Histogram Enable	1	<ul style="list-style-type: none"> 0 – Disable image histogram collection 1 – Enable image histogram collection 	Initialization, double buffered
Histogram Site Select	2	Specify site to collect image histogram <ul style="list-style-type: none"> 0x0 – Before LTM 0x1 – After LTM 0x2 – Before Gamma LUT 	Every frame, double buffered
Channel Select	2	Input select for YCC image histogram <ul style="list-style-type: none"> 0x0 – Y 0x1 – Cb 0x2 – Cr 	Every frame, double buffered
hist_rgn_h_offset	13	Horizontal offset of image histogram collection regions	Every frame, double buffered
hist_rgn_v_offset	14	Vertical offset of image histogram collection regions	Every frame, double buffered
hist_rgn_h_num	12	Horizontal number of regions for image histogram collection minus 1, and $\text{hist_rgn_h_offset} + (\text{hist_rgn_h_num} + 1) * 2 \leq \text{image_width}$	Every frame, double buffered
hist_rgn_v_num	13	Vertical number of regions for image histogram collection minus 1, and $\text{hist_rgn_v_offset} + (\text{hist_rgn_v_num} + 1) * 2 \leq \text{image_height}$	Every frame, double buffered
HIST_SHIFT_BITS	4	Right shift bits for image histogram count; range is 0~8	Every frame, double buffered

■ Statistics output

Name	Bits	Description
YCC_iHist[256]	16	Y/Cb/Cr image histogram, 256 entries of 16μ
G_iHist[256]	16	G image histogram, 256 entries of 16μ
B_iHist[256]	16	B image histogram, 256 entries of 16μ
R_iHist[256]	16	R image histogram, 256 entries of 16μ

Image Histogram (cont.)

Configuration ihist_stats_reg46.h

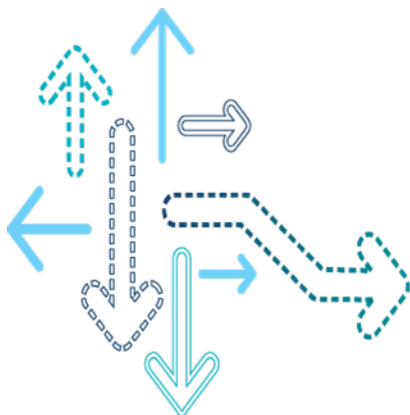
```
typedef struct ISP_StatsIhist_CfgType {  
    /* VFE_STATS_IHIST_RGN_OFFSET_CFG */  
    uint32_t    rgnHOffset        : 13;  
    uint32_t    /* reserved */    : 3;  
    uint32_t    rgnVOffset        : 14;  
    uint32_t    /* reserved */    : 2;  
  
    /* VFE_STATS_IHIST_RGN_NUM_CFG */  
    uint32_t    rgnHNum           : 12;  
    uint32_t    /* reserved */    : 3;  
    uint32_t    rgnVNum           : 14;  
    uint32_t    /* reserved */    : 3;
```

```
}__attribute__((packed, aligned(4)))  
ISP_StatsIhist_CfgType;
```

Output q3a_stats_hw.h

```
typedef struct {  
    union {  
        uint32_t histogram[MAX_HIST_STATS_NUM];  
        uint32_t r[MAX_HIST_STATS_NUM];  
    };  
    uint32_t g[MAX_HIST_STATS_NUM];  
    uint32_t b[MAX_HIST_STATS_NUM];  
    uint32_t ycc[MAX_HIST_STATS_NUM];  
    uint32_t num_bins;  
    uint32_t valid_fields;  
} q3a_ihist_stats_t;
```

Skin Tone Detection

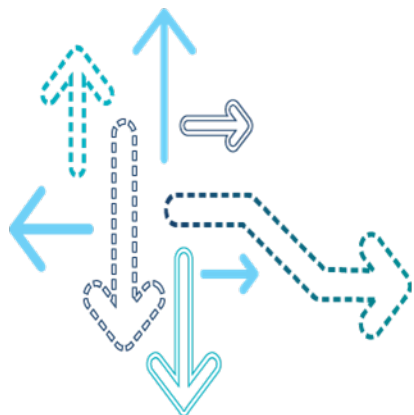


Skin Tone Detection

- Input data
 - 8 bit Y, Cb, Cr after gamma, tone mapping, and color conversion
 - Up to 6240x16384
- Skin tone map
 - Regions defined by generic region controller
 - Number of regions – From 8x8 of skin tone prioritized AEC and AF to 128x96
 - Maximum bits of map – 12,288 (3 MP on regions of 16x16 pixels → 128x96 regions)
 - Maximum number of accumulators per row is 128, clamping bitwidth = 19 ($[0, 399360 = 6240 * 16384 / 256]$)
 - Minimum 16x16 pixels per region
 - Maximum 390x1024 pixels per region
 - For 3 MP or less, 8x8, 9x9, 16x16 regions are supported
 - For more than 3 MP, region number has to be 16x16 or 18x18; software then needs to combine them into 8x8 or 9x9

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Skin Tone Statistics



Skin Tone Statistics – Hardware Interface

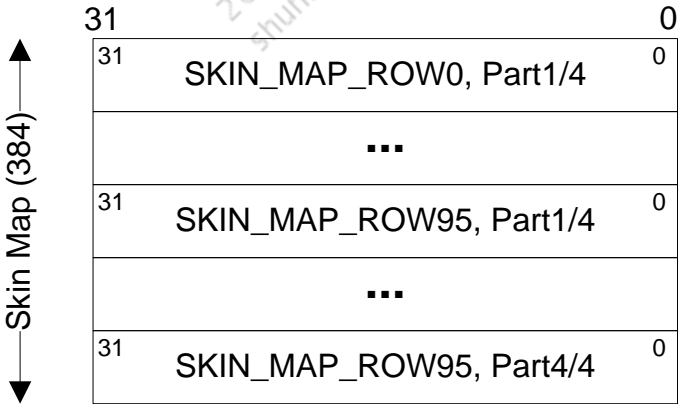
- GRC settings are to match AEC and/or AF on Viewfinder mode upon skin tone priority

Name	Bits	Description	Programming frequency
Enable	1	<ul style="list-style-type: none">▪ 0x1 – Enable▪ 0x0 – Disable	Every frame (double-buffered)
Hmin, Hmax	10, 8	Min and max values of H range (Q8)	Every frame (double-buffered)
Ymin, Ymax	8	Min and max values of Y range (Q8)	Every frame (double-buffered)
ShY_min, ShY_max	8	Min and max values of S on Ymax level (Q8)	Every frame (double-buffered)
Smin_para, Smax_para	8	Parameters used to calculate Smin and Smax for each Y level (Q8)	Every frame (double-buffered)
skin_rgn_h_offset	13	Horizontal offset of the upper left corner of the skin tone regions	Every frame (double-buffered)
skin_rgn_v_offset	14	Vertical offset of the upper left corner of the skin tone regions	Every frame (double-buffered)
skin_rgn_width	9	Width of the skin tone regions in the map minus 1; range is [16, 390] – 1	Every frame (double-buffered)
skin_rgn_height	10	Height of the skin tone regions in the map minus 1; range is [16, 1024] – 1	Every frame (double-buffered)
skin_rgn_h_num	7	Number of horizontal regions in the skin tone map minus 1	Every frame (double-buffered)
skin_rgn_v_num	7	Number of vertical regions in the skin tone map minus 1	Every frame (double-buffered)
Threshold	19	Output skin region is set to 1 if the number of skin pixels in the region > Threshold	Every frame (double-buffered)

Skin Tone Statistics – Output

- The skin tone map is packed to 32-bit words from LSB line-by-line.
- MSB bits in the last 32-bit word of a line are skipped if the number of bits in the line is not the magnitude of 32.

Name	Bits	Description	Programming frequency
Skin	12, 288	Skin tone map based on regional decision	Every frame



References

Acronyms	
Term	Definition
BE	Bayer Exposure
GRC	Generic Region Controllers
Rol	Region of Interest
RS/CS	Row/Column Sum

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Questions?

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