# Specification of

# YACBAE1SDDAC

**[Rev. 0.3]**

## 1/10” VGA Pixel CIS

### with Image Signal Processor

### [Hi-708]



**Rev 0.3 /Nov. 2013**

# Revision History

| Version | Date | Comments |
|---|---|---|
| 0.0 | 2012/02/27 | YACBAE1SDDAC Preliminary is released |
| 0.1 | 2013/03/18 | Errata for pixel size is revised |
| 0.2 | 2013/09/25 | Errata for active image size is revised |
| 0.3 | 2013/11/28 | The Temperature Characteristics is revised |

**Disclaimer**
This document is subjected to change without notice to customers.
Check for latest version of this document, contact to SK hynix FAE*(cis_ae@skhynix.com)*.

**General Precautions**
Do not disclose the document to third parties without prior permission from SK Hynix Inc.

# Contents

# Figure Contents

# Table Contents

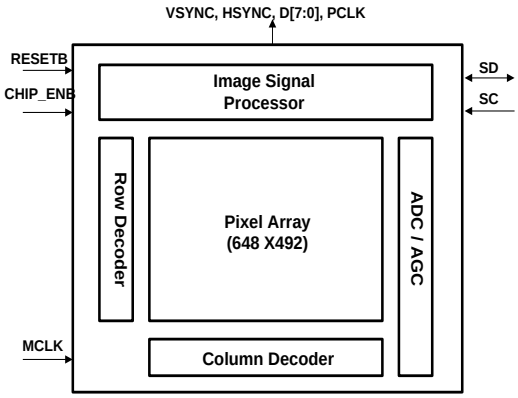
# 1. OVERVIEW

## 1.1. Description

YACBAE1SDDAC is VGA single chip CMOS image sensor for mobile phone camera applications and video conference camera products.

YACBAE1SDDAC incorporates a 648 x 492 pixel array, on-chip 10-bit ADC, and an image signal processor. Unique sensor technology enhances image quality by reducing FPN (Fixed Pattern Noise), horizontal/vertical line noise, and random noise.

<Figure 1. Block Diagram>




## 1.2. Applications

- Mobile Phone Camera
- PC Camera / Video Conference

## 1.3. Key Features

- **Pixel Size: 2.125um X 2.125um**
- **Active Image Size :**
- **1.370mm(H) X 1.040mm(V) X 1.720mm(D)**
- **Resolution: 640H X480V**
- **Color Filter: RGB Bayer**
- **Optical Format: 1/10 inch**
- **Frame Rate: 30fps@VGA, 60fps@QVGA**
- **Power Supply: 2.8V(Single voltage possible)**
  **2.8/1.8V(Dual voltage possible)**
- **Power Consumption**
  **Single - Active : 123mW@30fps(Typical)**
  **Dual - Active : 107mW@30fps(Typical)**
  **Standby: 300µW@60°C(Max)**
- **ADC: 10bit**
- **Operation Temperature: -20 ~ 60°C**
- **Fixed Frame Rate / Variable Frame Rate**
- **Master Clock: 27MHz(Max)**
- **Host Interface: two-wire serial bus interface**
- **Output Format: YUV4:2:2, RGB5:6:5, RGB4:4:4**
  **RGB Bayer 8, RGB Bayer 10**
- **Windowing: Programmable**
- **Sub-Sample: 1/4 (QVGA) , 1/16(QQVGA)**
- **Image Flip: X/Y Flip**
- **Auto Exposure**
- **Auto White Balance**
- **Anti-Flicker(50Hz / 60Hz): Auto/Manual**
- **Noise Reduction**
- **Black Level Calibration**
- **On-Chip Dead Pixel Correction**
- **Edge Enhancement**
- **Brightness**
- **Color Saturation**
- **Gamma Correction**
- **Color Correction**
- **Lens Shading Correction**
- **Image Effect: Mono, Sepia, Sketch, Negative**

# 2. ELECTRICAL CHARACTERISTICS

**[Table 1. DC Characteristics]**

Case 1) Single power supply( VDD:A =VDD:I)

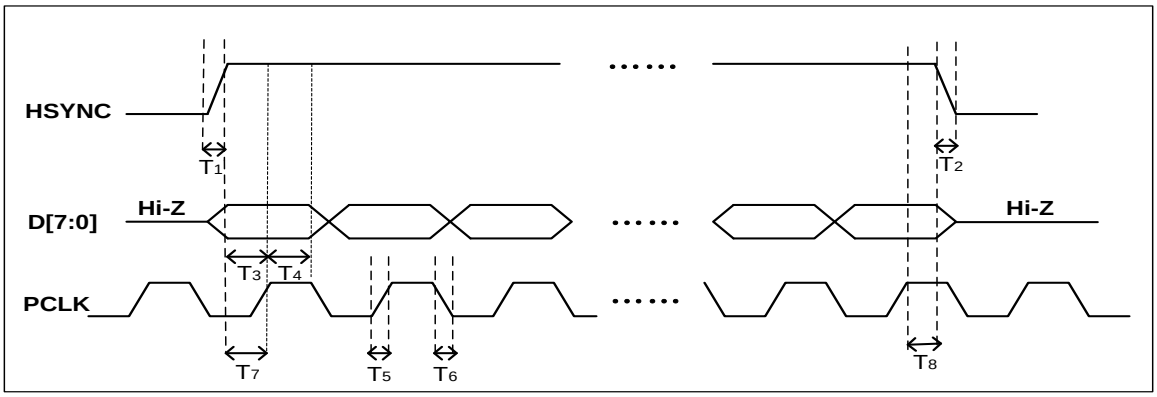
| Item | Symbol | Min | Typ | Max | Unit | Note |
|---|---|---|---|---|---|---|
| Analog Circuit Power Supply Voltage | $V_{DD:A}$ | 2.7 | 2.8 | 3.0 | V | |
| Digital I/O Circuit Power Supply Voltage | $V_{DD:I}$ | 2.7 | 2.8 | 3.0 | V | |
| H level Input Voltage | $V_{IH}$ | 0.7*$V_{DD:I}$ | | | V | |
| L level Input Voltage | $V_{IL}$ | | | 0.3*$V_{DD:I}$ | V | |
| Output High Current ($V_{DD:I}$ =2.8V, $V_{OH}$ = 2.4V) | $I_{OH}$ | | 13 | | mA | 1 |
| Output Low Current($V_{DD:I}$ =2.8V, $V_{OH}$ = 0.4V) | $I_{OL}$ | | 15 | | mA | 1 |

Case 2) Dual power supply ( VDD:A = 2.8V, VDD:I = 1.8V / 2.8V, VREF = 1.8V)

| Item | Symbol | Min | Typ | Max | Unit | Note |
|---|---|---|---|---|---|---|
| Analog Circuit Power Supply Voltage | $V_{DD:A}$ | 2.7 | 2.8 | 3.0 | V | |
| Digital I/O Circuit Power Supply Voltage | $V_{DD:I}$ | 1.7 | 1.8 / 2.8 | 3.0 | V | |
| VREF | $V_{DD:I}$ | 1.7 | 1.8 | 1.9 | V | |
| H level Input Voltage | $V_{IH}$ | 0.7*$V_{DD:I}$ | | | V | |
| L level Input Voltage | $V_{IL}$ | | | 0.3*$V_{DD:I}$ | V | |
| Output High Current ($V_{DD:I}$ =1.8V, $V_{OH}$ = 2.4V) | $I_{OH}$ | | 10 | | mA | 1 |
| Output Low Current($V_{DD:I}$ =1.8V, $V_{OH}$ = 0.4V) | $I_{OL}$ | | 13 | | mA | 1 |

Note1) User can control the amount of current by controlling bit[7:4] of PWRCTL[0x01:P0].
Above values are output current when bit[7:4] of PWRCTL[0x01:P0] is 4'b1010.
.

**<Figure 2. AC Timing of output PAD>**



**[Table 2. AC Characteristics]**

| Item | Symbol | Min | Typ | Max | Unit | Note |
|---|---|---|---|---|---|---|
| MCLK | Frequency | 12 | | 27 | MHz | |
| MCLK | Duty Cycle | 45 | 50 | 55 | % | |
| PCLK | Frequency | | | 27 | MHz | |
| PCLK | Duty Cycle | 40 | 50 | 60 | % | |
| SC | Frequency | | | 400 | KHz | |
| HSYNC(VSYNC) rising time | $T_1$ | 3.5 | 4.55 | 5.5 | ns | 2 |
| HSYNC(VSYNC) falling time | $T_2$ | 3.2 | 3.92 | 5.2 | ns | 2 |
| PCLK rising time | $T_5$ | 3.5 | 4.48 | 5.5 | ns | 2 |
| PCLK falling time | $T_6$ | 3.2 | 3.9 | 5.2 | ns | 2 |
| HSYNC(VSYNC) rising time | $T_1$ | 5.2 | 6.39 | 8.5 | ns | 3 |
| HSYNC(VSYNC) falling time | $T_2$ | 3.8 | 5.25 | 7.7 | ns | 3 |
| PCLK rising time | $T_5$ | 5.2 | 6.54 | 8.5 | ns | 3 |
| PCLK falling time | $T_6$ | 3.8 | 5.05 | 7.7 | ns | 3 |
| Setup time of PCLK – HSYNC | $T_7$ | 2 | | | ns | |
| Hold time of PCLK – HSYNC | $T_8$ | 2 | | | ns | |
| Setup time of PCLK – D[7:0] | $T_3$ | 2 | | | ns | |
| Hold time of PCLK – D[7:0] | $T_4$ | 2 | | | ns | |

Note2) Output load capacitance = 60pF, VDD:A =2.8V, VDD:I =2.8V, VOH =2.4V, VOL =0.4V

User can control the rising(falling) time by controlling bit[7:4] of PWRCTL[0x01:P0].

Above values are rising time when bit[7:4] of PWRCTL[0x01:P0] is 4'b1111.

Note3) Output load capacitance = 60pF, VDD:A =2.8V, VREF =1.8V, VDD:I =1.8V, VOH =1.4V, VOL =0.4V

User can control the rising(falling) time by controlling bit[7:4] of PWRCTL[0x01:P0].

Above values are rising time when bit[7:4] of PWRCTL[0x01:P0] is 4'b1111.

**[Table 3. Temperature Characteristics]**

| Item | Symbol | Rating | Unit | Note |
|---|---|---|---|---|
| Storage Temperature | $T_{STR}$ | -40 ~ 80 | °C | |
| Operating Temperature | $T_{FUN}$ | -20 ~ 60 | °C | 4 |

Note4) Recommended sensor operating temperature is from -20~40C. Image can be degraded above 40C.

**[Table 4. Power Consumption]**

Case 1) VDD:I = VDD:A = 2.8V

| Item | Condition | Min | Typ | Max | Unit | Note |
|---|---|---|---|---|---|---|
| VGA @30fps | VDD:A =2.8V | | 18 | | mA | 5 |
| | VDD:I =2.8V | | 22 | | mA | 6 |
| Stand by Current | | | | 100 | uA | 7 |

Case 2) VDD:I = 1.8V, VDD:A = 2.8V, VREF = 1.8V

| Item | Condition | Min | Typ | Max | Unit | Note |
|---|---|---|---|---|---|---|
| VGA @30fps | VDD:A =2.8V | | 18 | | mA | 5 |
| | VDD:I =1.8V | | 6 | | mA | 6 |
| | VREF =1.8V | | 13 | | mA | |
| Stand by Current | | | | 100 | uA | 7 |

Note5) Because current of analog circuit depends on the registers' values, it is measured at specific register's value .

Note6) Because power consumption of VDD:I depends on the output load and system environment, user should supply enough current to sensor for stable operation. It is measured when output load is floated.

Note7) Stand by current is measured at CHIP_ENB = HI and MCLK = LO.
We recommend that power should be turned off, when low standby power consumption is required.

**[Table 5. Absolute Maximum Ratings]**

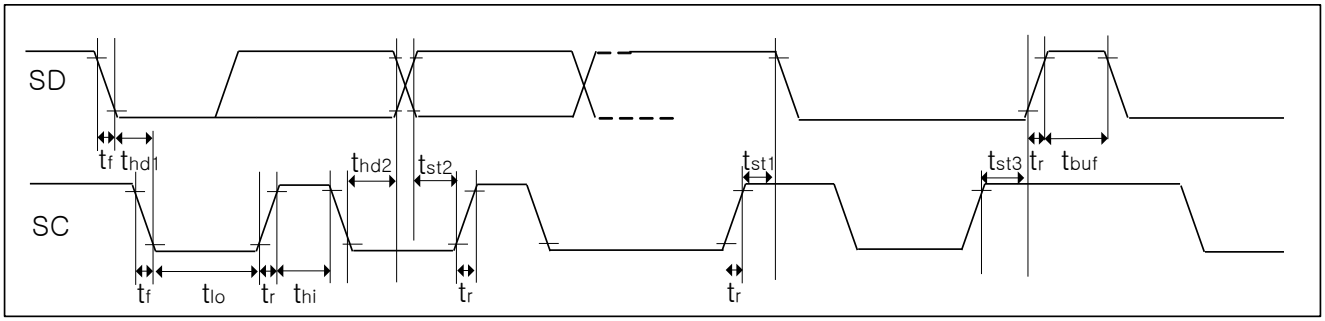
| Item | Symbol | Min | Max | Note |
|---|---|---|---|---|
| Analog and Pixel Power | VDD:A | -0.3V | 3.3V | 8 |
| Digital I/O Power | VDD:I | -0.3V | 3.3V | 8 |
| Input Pin Voltage | VIN | -0.2V | VDD:I | 8 |
| Output Pin Voltage | VOUT | -0.2V | VDD:I | 8 |

Note8) Exposure to absolute maximum rating conditions for extended periods may affect reliability.

# 3. TWO-WIRE SERIAL BUS INTERFACE

## 3.1. Timing Specifications

<Figure 3. AC Timing of Two Wire Serial Bus>




[Table 6. AC Characteristics of Two Wire Serial Bus]

| Parameter | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| SC frequency | $f_{sck}$ | | | 400 | KHz |
| SC low period | $t_{lo}$ | 1.2 | | - | us |
| SC high period | $t_{hi}$ | 0.6 | | - | us |
| SC setup time for START condition | $t_{st1}$ | 0.6 | | - | us |
| SC setup time for STOP condition | $t_{st3}$ | 0.6 | | - | us |
| SC hold time for START condition | $t_{hd1}$ | 0.6 | | - | us |
| SD setup time | $t_{st2}$ | 0.6 | | - | us |
| SD hold time | $t_{hd2}$ | 1*MCLK's period | | - | us |
| Bus free time Between a STOP and START condition | $t_{buf}$ | 0.6 | | - | us |
| Rising time of both SD and SC | $t_r$ | - | | 0.3 | us |
| Falling time of both SD and SC | $t_f$ | - | | 0.3 | us |
| Capacitive load of SC/SD | $C_b$ | - | | 100 | pF |
| Pull-up resistor on SC and SD | | | 4.7 | | kΩ |

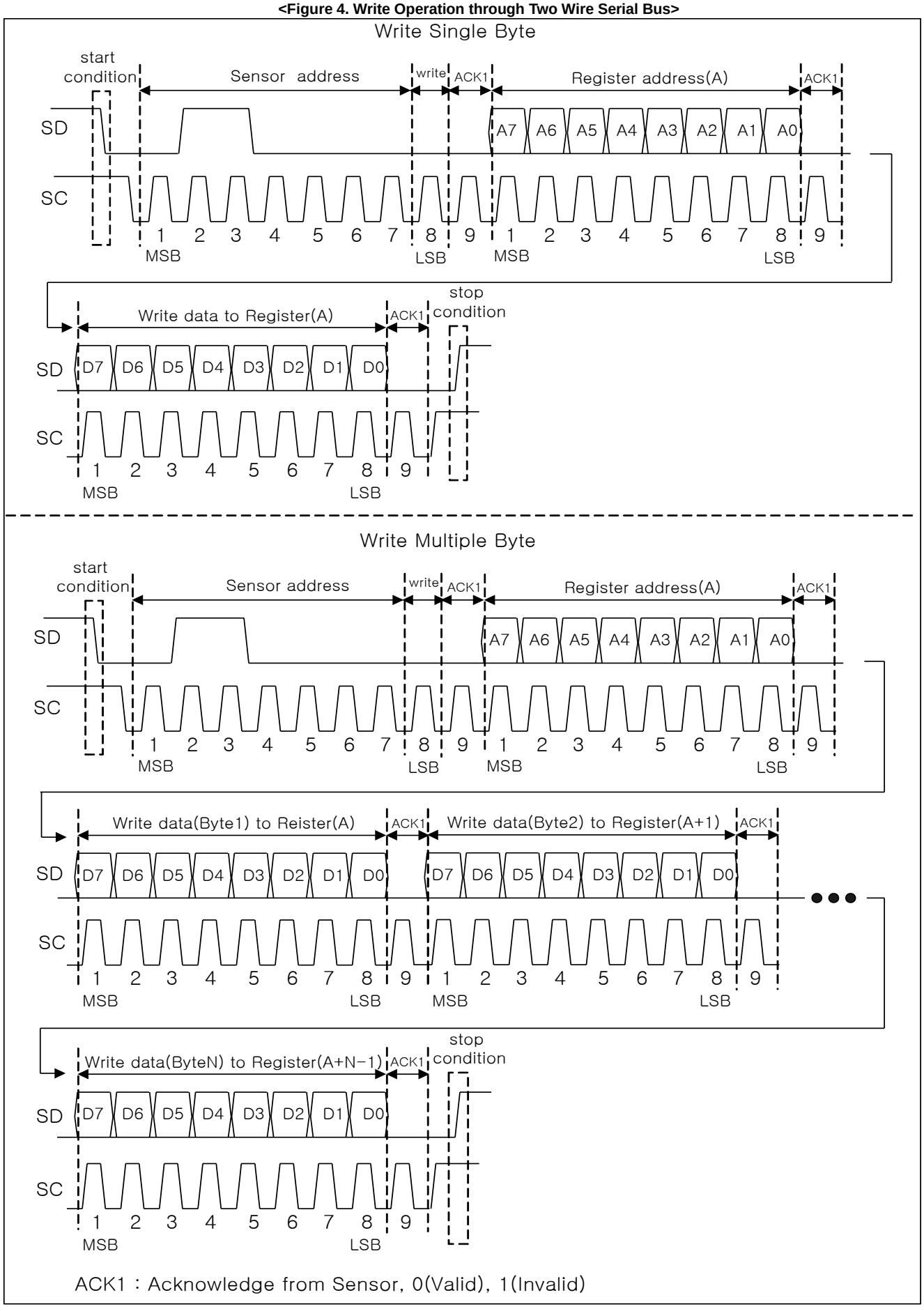
## 3.2. Bus Operation

The two-wire serial bus interface is used to write and read the required data into registers in this sensor. Sensor can operate as a slave device only. The two-wire serial bus interface is controlled by SD (serial data) and SC (serial clock). SD is bidirectional bus. Operation has single byte programming and multiple byte programming. User doesn't need to set continuously register address on programming multiple byte because sensor increases register address automatically. This will reduce time to program registers.

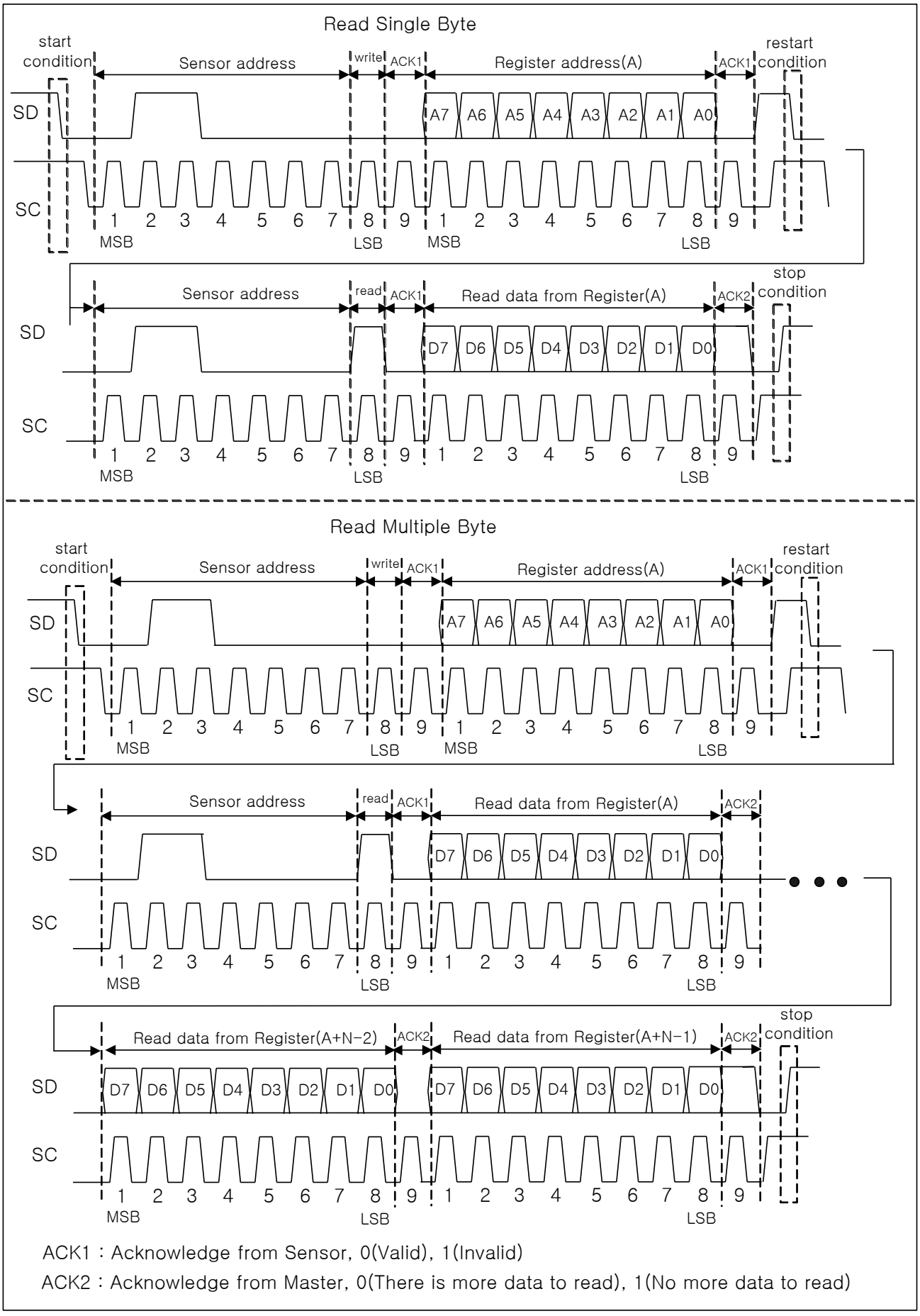
Following figures show write and read operations.

Note) Before programming the two-wire serial bus interface, MCLK should be supplied.

**<Figure 4. Write Operation through Two Wire Serial Bus>**



**<Figure 5. Read Operation through Two Wire Serial Bus >**



# 4. FUNCTION DESCRIPTION

**[Table 7. Functional Description]**

| Function | Page Mode | Address | Description |
|---|---|---|---|
| Power control | P0(0x00) | 0x01 | Power sleep(Software power down) |
| Page mode | Common | 0x03 | User should change the this register before controlling functions in other page. |
| Device ID | P0(0x00) | 0x04 | To find version of SENSOR, read this register. |
| Image Size | P0(0x00) | 0x10, 0x11 | Sub-sampling, X/Y-flip, Bad Frame Skip. For X-Flip, user control VDOCCTL1[0x11:P0] |
| Windowing | P0(0x00) | 0x20~ 0x27 | Control image size by controlling windowing |
| H/VSYNC | P0(0x00) | 0x12,<br>0x40 ~ 0x47 | Control VSYNC/HSYNC<br>Horizontal Synchronization / Vertical Synchronization[Type1]<br>Vertical Synchronization[Type2] |
| Black Level Calibration | P0(0x00) | 0x80~0xA0 | Calculate black level and calibrate it automatically. |
| Output Data Format | P10(0x10) | 0x10 | YUV4:2:2, RGB5:6:5, RGB4:4:4 |
| Image Effect | P10(0x10) | 0x11 ~ 0x50 | Chrominance Offset/Constant, Negative, Mono, Sepia etc |
| Color Saturation | P10(0x10) | 0x60 ~ 0x63 | Control the gain of U/V chrominance to get vivid color reproduction. |
| Noise Reduction | P11(0x11) | 0x10 ~ 0x64 | Control the Z- LPF, for noise reduction |
| | P11(0x12) | 0x40 ~0x50 | Control the YC-LPF for noise reduction |
| | P11(0x12) | 0x70 ~0x75 | Control the B-LPF for noise reduction |
| Edge Enhancement | P13(0x13) | 0x10~0x29 | Control the edge enhancement. |
| | | 0x80~0x94 | Control the 2nd edge enhancement |
| Lens Shading Correction | P14(0x14) | 0x10~0x26 | Control the coefficient of lens shading correction |
| Color Correction | P15(0x15) | 0x10 ~ 0x48 | Control the color correction |
| Gamma Correction | P16(0x16) | 0x10 ~ 0x3E | Control the piecewise linear lines for Gamma Correction |
| Auto Flicker Cancellation | P17(0x17) | 0xC0 ~ 0xC7 | To detect 100Hz / 120Hz, control the coefficient of auto flicker cancellation. |
| Auto Exposure | P20(0x20) | 0x10~0xD3 | Control the method of auto exposure. |
| Auto White Balance | P22(0x22) | 0x10~0xD3 | Control the method of auto white balance. |

## 4.1. Black Level Calibration(BLC)

Black level is caused from pixel characteristics and analog channel offset. It makes poor image quality in dark condition and misleads color balance. To reduce these phenomenon, sensor automatically calibrates the black level every frame. The masked pixels in pixel array is used to calculate the black level.

## 4.2. Lens Shading Correction(LSC)

The circumstance area of pixel array does not have enough quantity of light due to optical characteristics of lens. It causes reduction of signal near peripheral of pixel array. The reduction of signal depends on both pixel' s location and color. To compensate the problem,

shading correction is done by controlling the correction gain, which depends on pixel's location and color.

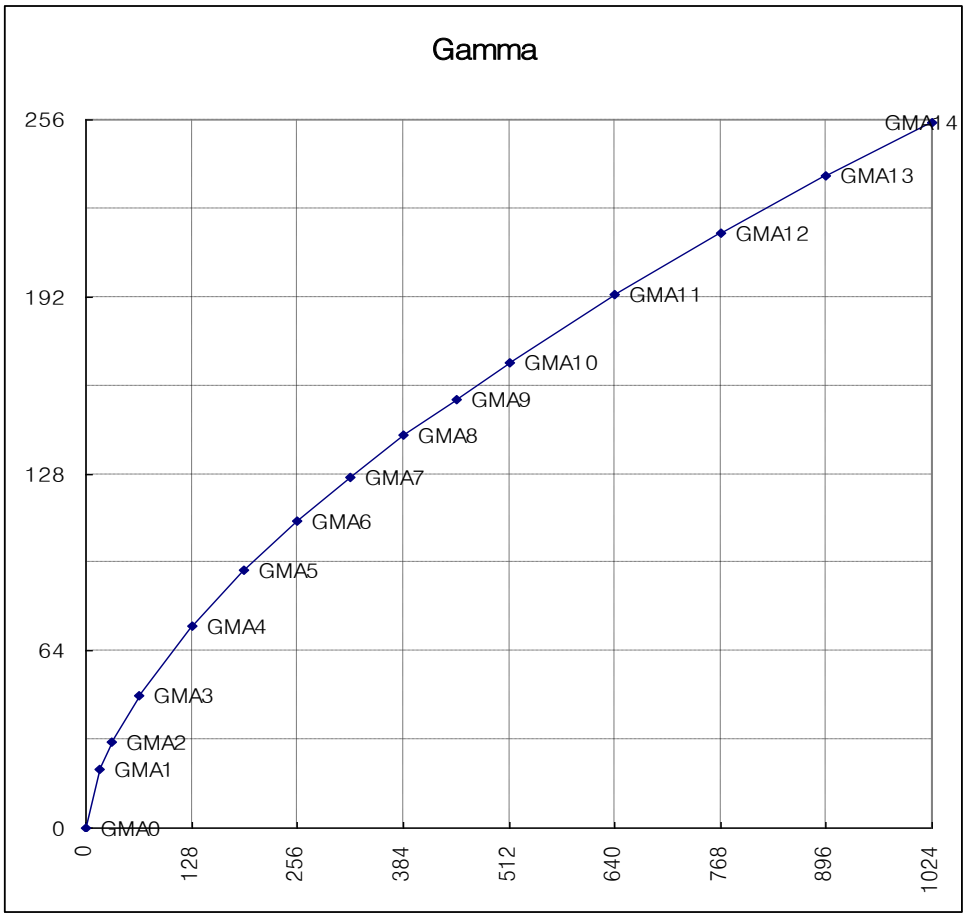
It is possible to compensate the deviation between center of lens and center of pixel array by controlling XCEN[0x20:P14], YCEN[0x21:P14].

## 4.3. Gamma Correction

Gamma correction operates on the RGB data to compensate non-linear characteristics of display device. Sensor can implement gamma correction by converting 10bit data input to 8bit data output. In following figure, piecewise linear lines are made to implement gamma curve by using 15points[GMA0 ~GMA14]. User can get various gamma curves by controlling 15points[GMA0 ~GMA14].

X-axis is 10bit-input of gamma block and Y-axis is 8bit-output of gamma block.

**<Figure 6. Gamma curve>**




## 4.4. Color Correction

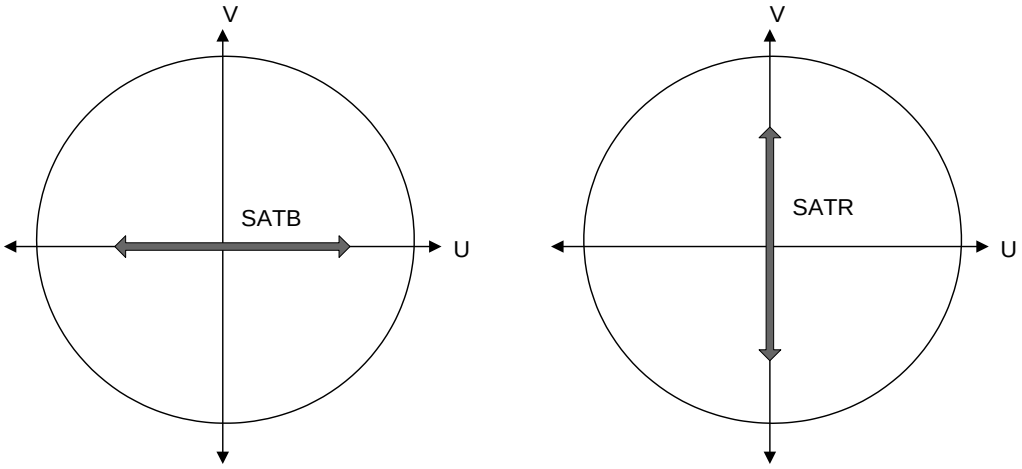
The spectral response of image sensor caused by color filter, is not the same with that of human eye. This spectral response is compensated by programming 3X3 matrix. 9-elements of matrix are controlled by CMC11[0x30:P15] ~ CMC33[0x38:P15] and CMCSIGN[0x17:P15].

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} CMC11 & CMC12 & CMC13 \\ CMC21 & CMC22 & CMC23 \\ CMC31 & CMC32 & CMC33 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

## 4.5. Color Saturation

User can get more vivid color reproduction by adjusting chrominance U/V. Color saturation is adjusted by controlling bit[3:0] of SATCTL[0x60:P10], SATB[0x62:P10] and SATR[0x63:P10]. Color saturation controls the gain of U/V chrominance. As AG[0xB0:P20] is increased, color saturation is decreased by adjusting bit[3:2] of SATCTL [0x60:P10] automatically.

<Figure 7. Color Saturation>




## 4.6. Color Space Conversion

**Equation of RGB to YUV color space conversion**

$$Y = 0.301*R + 0.586*G + 0.113*B$$
$$U = -0.168*R - 0.332*G + 0.5*B + 128$$
$$V = 0.5*R - 0.418*G - 0.082*B + 128$$

**Equation of YUV to RGB color space conversion**

$$R = Y + 1.402*(V - 128)$$
$$G = Y - 0.344*(U - 128) - 0.715*(V - 128)$$
$$B = Y + 1.773*(U - 128)$$

## 4.7. Auto Exposure Control

AE function controls AG (automatic gain) and exposure time to maintain the proper luminance level that is determined by YLVL and image statistics. When bit[7] of AECTL1 [0x10:P20] is enabled, automatic gain and exposure time will be controlled to get a good image quality automatically. Then overall luminance on image will be entered into convergence region near to proper luminance level. If overall luminance comes out of convergence region, control of exposure time, automatic gain gain will be continued until it goes inside convergence region. As overall luminance is far from convergence region, it will take longer time to enter convergence region. To overcome this problem, user can control the convergence speed by adjusting some registers. Convergence speed depends on the steps of exposure time and automatic gain.

## 4.8. Auto White Balance

AWB function controls RGAIN, GGAIN and BGAIN to compensate for color temperature of the light source. When bit[7] of AWBCTL1 [0x10:P22] is enabled, RGAIN and BGAIN will be controlled to get a color balanced image automatically. Then overall chrominance on image will be entered into convergence region near to ULVL[0x30:P22] and VLVL[0x31:P22]. If overall chrominance comes out of convergence region, control of RGAIN and BGAIN will be continued until it goes inside convergence region. However, when overall chrominance is far from locking region and is in color region, control of RGAIN and BGAIN will be stopped. And it is possible to define convergence region and color region by adjusting ULVL[0x30:P22], VLVL[0x31:P22], UVTH1[0x38:P22] and UVTH2[0x39:P22]

**Convergence Region) ULVL – UVTH1[7:4] <= Overall Chrominance U <=ULVL + UVTH1[7:4] and**
**VLVL – UVTH1[7:4] <= Overall Chrominance V <=VLVL + UVTH1[7:4]**

**Color Region) Overall Chrominance U >=ULVL + 8*UVTH2[3:0] or Overall Chrominance U <=ULVL – 8*UVTH2[3:0]**
**Overall Chrominance V >=VLVL + 8*UVTH2[3:0] or Overall Chrominance V <=VLVL – 8*UVTH2[3:0]**

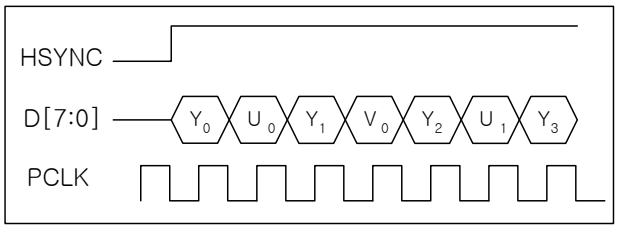
## 4.9. Video Output Data Format

Video output data format is controlled by adjusting ISPCTL1[0x10:P10].

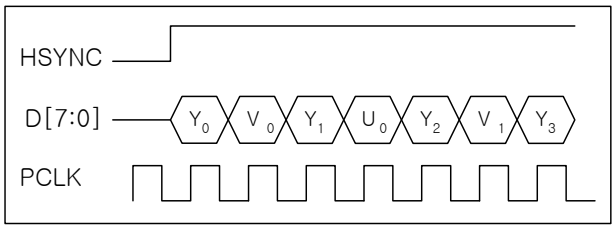
**- YUV4:2:2**

**<Figure 8. Timing of YUV4:2:2>**

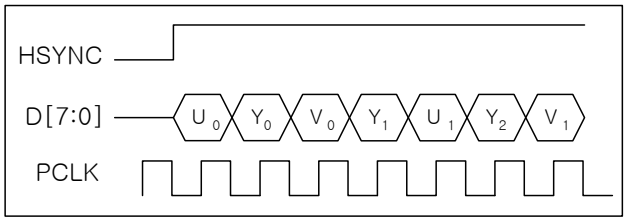
Case1) bit[1] of ISPCTL1: ON and bit[0] of ISPCTL1: ON



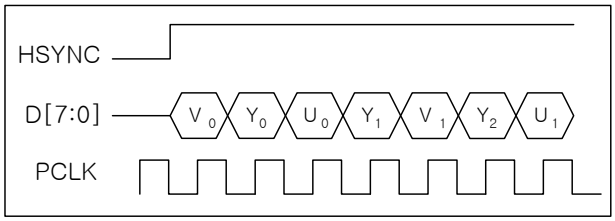

Case2) bit[1] of ISPCTL1: ON and bit[0] of ISPCTL1: OFF




Case3) bit[1] of ISPCTL1: OFF and bit[0] of ISPCTL1: ON



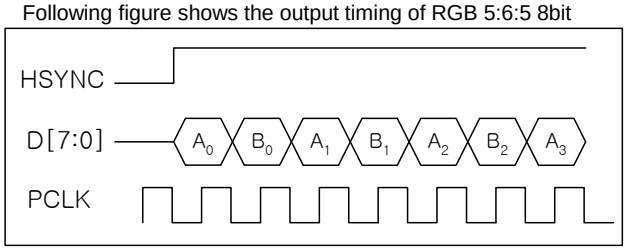

Case4) bit[1] of ISPCTL1: OFF and bit[0] of ISPCTL1: OFF




**- RGB5:6:5**

**<Figure 9. Timing of RGB5:6:5>**

Following figure shows the output timing of RGB 5:6:5 8bit




Case 1) bit[1] of ISPCTL1: ON and bit[0] of ISPCTL1: ON, Where is A = (G[7:2],B[7:6]), B = (B[5:3],R[7:3]).

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | G[7] | G[6] | G[5] | G[4] | G[3] | G[2] | B[7] | B[6] |
| B | B[5] | B[4] | B[3] | R[7] | R[6] | R[5] | R[4] | R[3] |

Case 2) bit[1] of ISPCTL1: ON and bit[0] of ISPCTL1: OFF, Where is A = (G[7:2],R[7:6]), B = (R[5:3],B[7:3]).

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | G[7] | G[6] | G[5] | G[4] | G[3] | G[2] | R[7] | R[6] |
| B | R[5] | R[4] | R[3] | B[7] | B[6] | B[5] | B[4] | B[3] |

Case 3) bit[1] of ISPCTL1: OFF and bit[0] of ISPCTL1: ON, Where is A = (B[7:3],G[7:5]), B = (G[4:2],R[7:3]).

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | B[7] | B[6] | B[5] | B[4] | B[3] | G[7] | G[6] | G[5] |
| B | G[4] | G[3] | G[2] | R[7] | R[6] | R[5] | R[4] | R[3] |

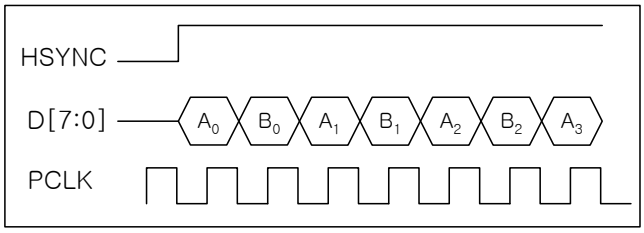
Case 4) bit[1] of ISPCTL1: OFF and bit[0] of ISPCTL1: OFF, Where is A = (R[7:3],G[7:5]), B = (G[4:2],B[7:3]).

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | R[7] | R[6] | R[5] | R[4] | R[3] | G[7] | G[6] | G[5] |
| B | G[4] | G[3] | G[2] | B[7] | B[6] | B[5] | B[4] | B[3] |

**- RGB4:4:4**

**<Figure 10. Timing of RGB4:4:4>**

Following figure shows the output timing of RGB 4:4:4 8bit.




Case 1) bit[1] of ISPCTL1: ON and bit[0] of ISPCTL1: ON

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | 0 | 0 | 0 | 0 | G[7] | G[6] | G[5] | G[4] |
| B | B[7] | B[6] | B[5] | B[4] | R[7] | R[6] | R[5] | R[4] |

Case 2) bit[1] of ISPCTL1: ON and bit[0] of ISPCTL1: OFF

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | 0 | 0 | 0 | 0 | G[7] | G[6] | G[5] | G[4] |
| B | R[7] | R[6] | R[5] | R[4] | B[7] | B[6] | B[5] | B[4] |

Case 3) bit[1] of ISPCTL1: OFF and bit[0] of ISPCTL1: ON

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | 0 | 0 | 0 | 0 | B[7] | B[6] | B[5] | B[4] |
| B | G[7] | G[6] | G[5] | G[4] | R[7] | R[6] | R[5] | R[4] |

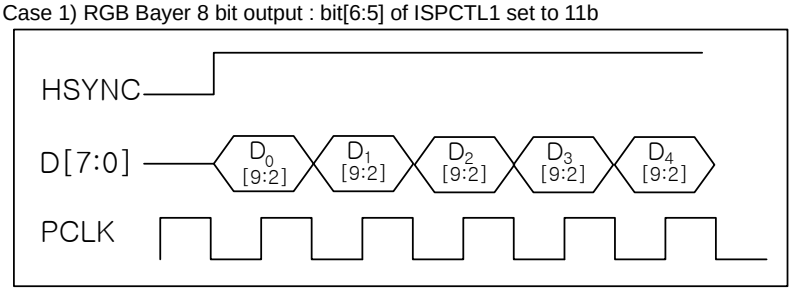
Case 4) bit[1] of ISPCTL1: OFF and bit[0] of ISPCTL1: OFF

| Pin Name | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| A | 0 | 0 | 0 | 0 | R[7] | R[6] | R[5] | R[4] |
| B | G[7] | G[6] | G[5] | G[4] | B[7] | B[6] | B[5] | B[4] |

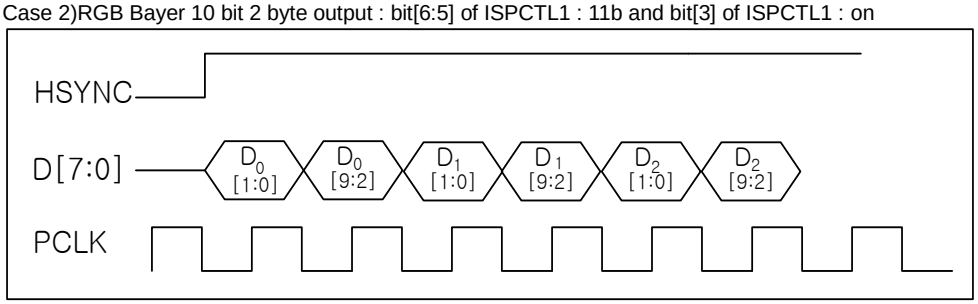
**- RGB Bayer 8/10**

**<Figure 11. Timing of RGB bayer mode>**

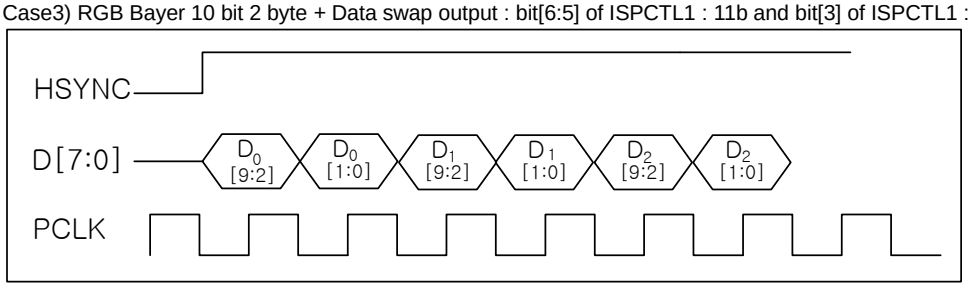
Case 1) RGB Bayer 8 bit output : bit[6:5] of ISPCTL1 set to 11b



Case 2)RGB Bayer 10 bit 2 byte output : bit[6:5] of ISPCTL1 : 11b and bit[3] of ISPCTL1 : on

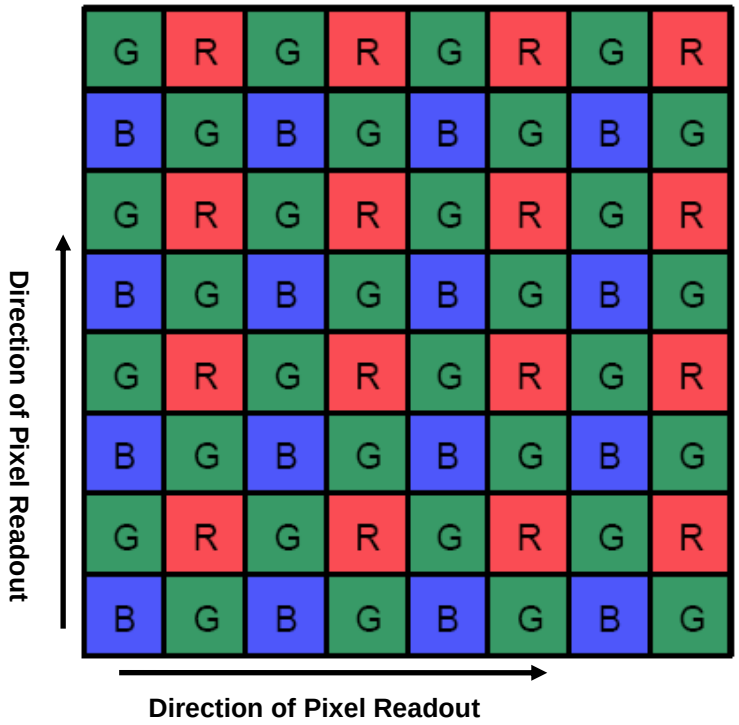



Case3) RGB Bayer 10 bit 2 byte + Data swap output : bit[6:5] of ISPCTL1 : 11b and bit[3] of ISPCTL1 : on and bit[7] of ISPCTL2 : on




**Note) BLC and LSC functions are only supported in bayer mode.**

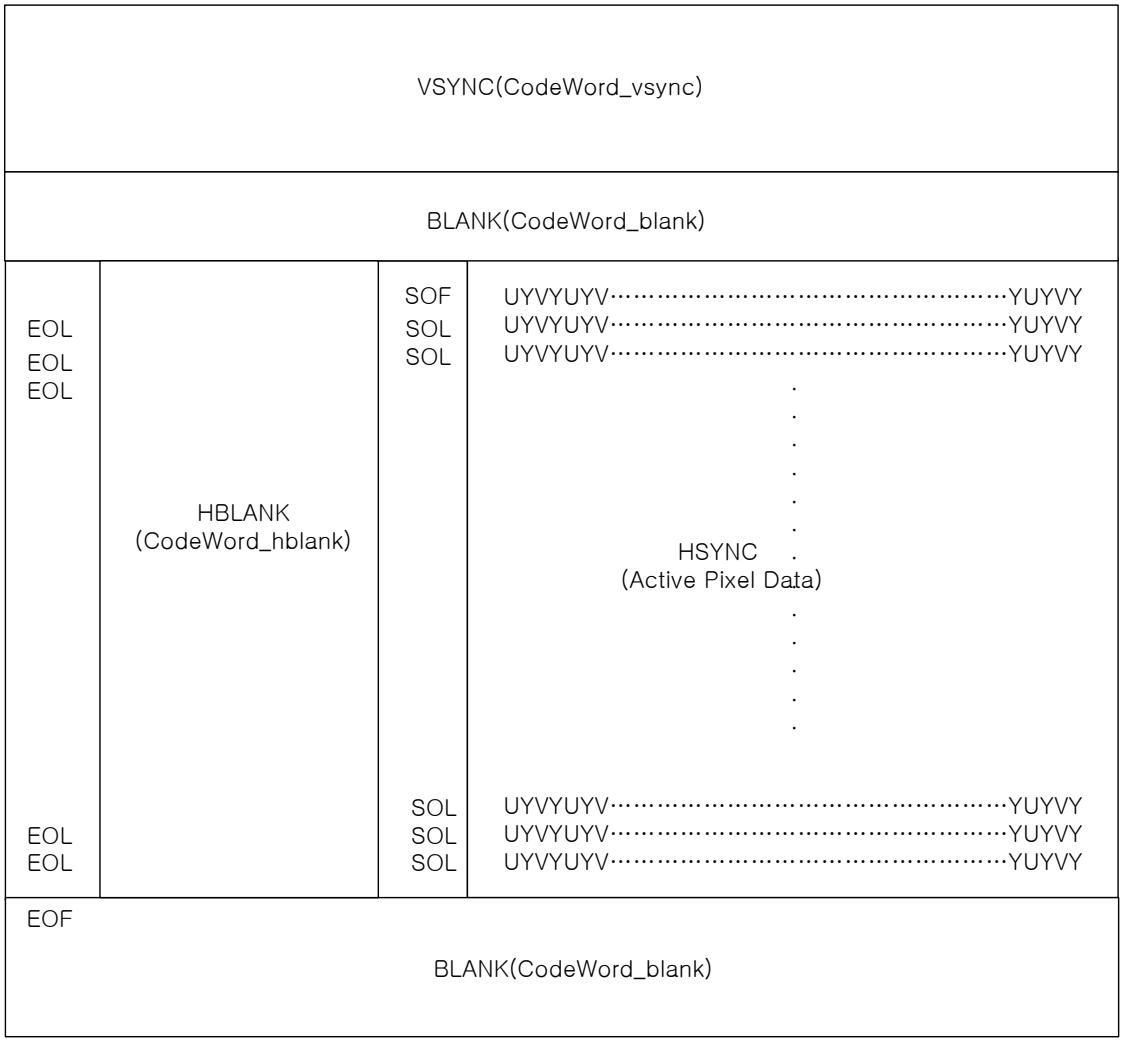
**<Figure 12. Pixel Order>**



**- ITU656-like**

To use this mode, user should set bit[2] of ISPCTL1[0x10:P10] to ON

**<Figure 13. Frame structure of ITU656-like mode>**




VSYNC(CodeWord_vsync) = 0x8010 for bit[4] of ISPCTL4[0x14:P10] = OFF
0x0000 for bit[4] of ISPCTL4[0x14:P10] = ON

HBLANK(CodeWord_hblank) = 0x8010 for bit[4] of ISPCTL4[0x14:P10] = OFF
0x0000 for bit[4] of ISPCTL4[0x14:P10] = ON

BLANK(CodeWord_blank) = 0x8010 for bit[4] of ISPCTL4[0x14:P10] = OFF
0x0000 for bit[4] of ISPCTL4[0x14:P10] = ON

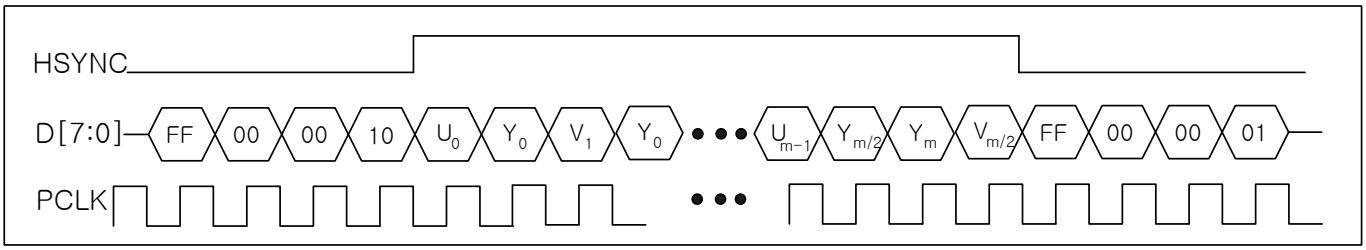
SOF = 0xFF000010 for bit[0] of ISPCTL4[0x14:P10] = OFF
0xFF000020 for bit[0] of ISPCTL4[0x14:P10] = ON

EOF = 0xFF000001 for bit[0] of ISPCTL4[0x14:P10] = OFF
0xFF000002 for bit[0] of ISPCTL4[0x14:P10] = ON

SOL = 0xFF000010

EOL = 0xFF000001

Following figure shows the SOL, EOL and image data in one line.

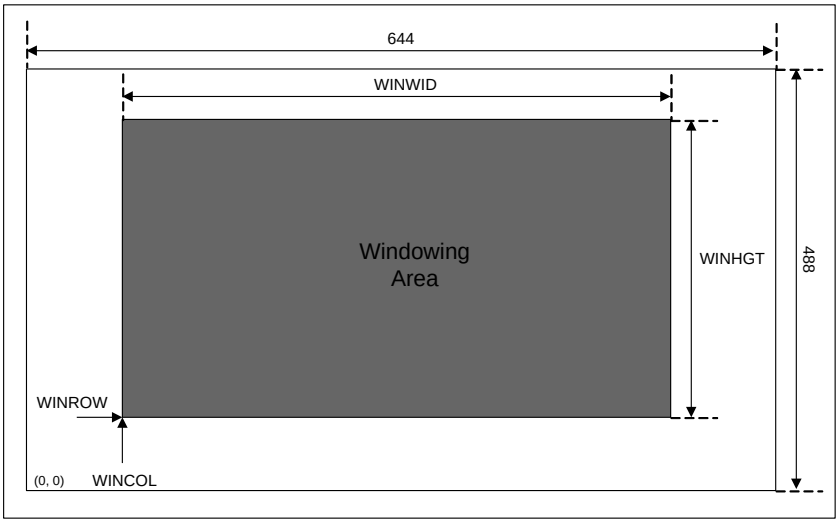


## 4.10. Windowing

Sensor has a rectangular pixel array 640 X 480. The array can be windowed by controlling WINROW[0x20, 0x21:P0], WINCOL[0x22 ,0x23:P0], WINHGT[0x24, 0x25:P0] and WINWID[0x26, 0x27:P0] when bit[7] of VDOCTL2[0x11:P0] is enabled. Following Table shows the recommended setting for each image size.

| Image Type | Output Image Size | VDOCTL1 [0x10:P0] | WINROW [0x20, 21:P0] | WINCOL [0x22, 23:P0] | WINHGT [0x24, 25:P0] | WINIWID [0x26, 27:P0] |
|---|---|---|---|---|---|---|
| VGA | 640 X 480 | 0x00 | 0x00, 0x02 | 0x00, 0x02 | 0x01, 0xE0 | 0x02, 0x80 |
| QVGA 1 | 320 X 240 | 0x10 | 0x00, 0x02 | 0x00, 0x02 | 0x01, 0xE0 | 0x02, 0x80 |
| QVGA 2 | 320 X 240 | 0x01 | 0x00, 0x02 | 0x00, 0x02 | 0x01, 0xE0 | 0x02, 0x80 |
| QQVGA 1 | 160 X 120 | 0x20 | 0x00, 0x02 | 0x00, 0x02 | 0x01, 0xE0 | 0x02, 0x80 |
| QQVGA 2 | 160 X 120 | 0x21 | 0x00, 0x02 | 0x00, 0x02 | 0x01, 0xE0 | 0x02, 0x80 |

**<Figure 14. Windowing>**



## 4.11. Frame Structure

Frame Structure is frame timing and it is controlled by HBLANK[0x40,0x41:P0] and VSYNC[0x42, 0x43:P0] and VSCLIP[0x44:P0].

When exposure time is less than the data line time, figure 14 and figure 15 is valid.

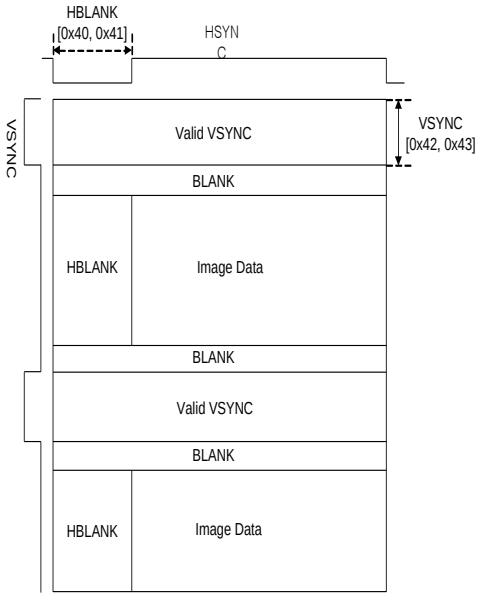
If the exposure time is over the data line time, the difference will be inserted between Image Data and Valid VSYNC.

Where data line time is (656 + HBLANK) X Height X OPCLK's period

**Height = 500 for VGA, QVGA1, QQVGA1 Height = 254 for QVGA2, QQVGA2

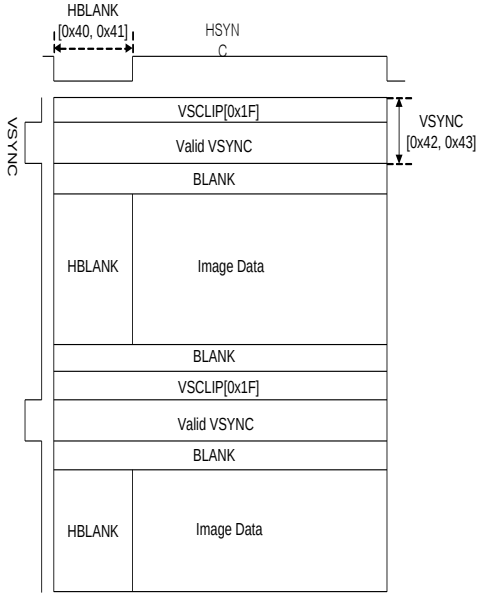
**<Figure 15. Frame Structure when VSYNC Clip is disabled>**

Case1) bit[3] of SYNCTL [0x12:P0] is OFF




**<Figure 16. Frame Structure when VSYNC Clip is enabled>**

Case2) bit[3] of SYNCTL [0x12:P0] is ON



## 4.12. Timing Description

Sensor supports VGA(640 X 480), QVGA(320 X 240).

Following table shows the register value for each image size.

| Image Type | Output Image Size | VDOCTL1[0x10:P0] | Maximum Frame Rate |
|---|---|---|---|
| VGA | 640 X 480 | 0x00 | 30fps |
| QVGA 1 | 320 X 240 | 0x10 | 30fps |
| QVGA 2 | 320 X 240 | 0x01 | 60fps |
| QQVGA 1 | 160 X 120 | 0x20 | 30fps |
| QQVGA 2 | 160 X 120 | 0x21 | 60fps |

**Timing parameters**

**To :** period of OPCLK that is internal clock to process one pixel. It is a unit of time in this device.

OPCLK = [Scale of Clock Divider * 1/2] * MCLK

**Tp :** period of PCLK that is output clock to external circuit for synchronizing D[7:0].

To catch YUV data, use the PCLK because YUV data is changed by period of PCLK

| VDOCTL1 [0X10:P0] | VGA | QVGA 1 | QVGA 2 | QQVGA 1 | QQVGA 2 |
|---|---|---|---|---|---|
| | 0x00 | 0x10 | 0x01 | 0x20 | 0x21 |
| PCLK | MCLK | MCLK/2 | MCLK/2 | MCLK/4 | MCLK/4 |

Note) Type of VSYNC is selected by bit[2] of VDOCTL1[0x10:P0] in following figures.

VSYNC of type1 is controlled by VSYNC[0x42, 43:P0] registers.

VSYNC of type2 is controlled by VSCTL1[0x45:P0], VSCTL2[0x46:P0] and VSCTL3[0x47:P0],

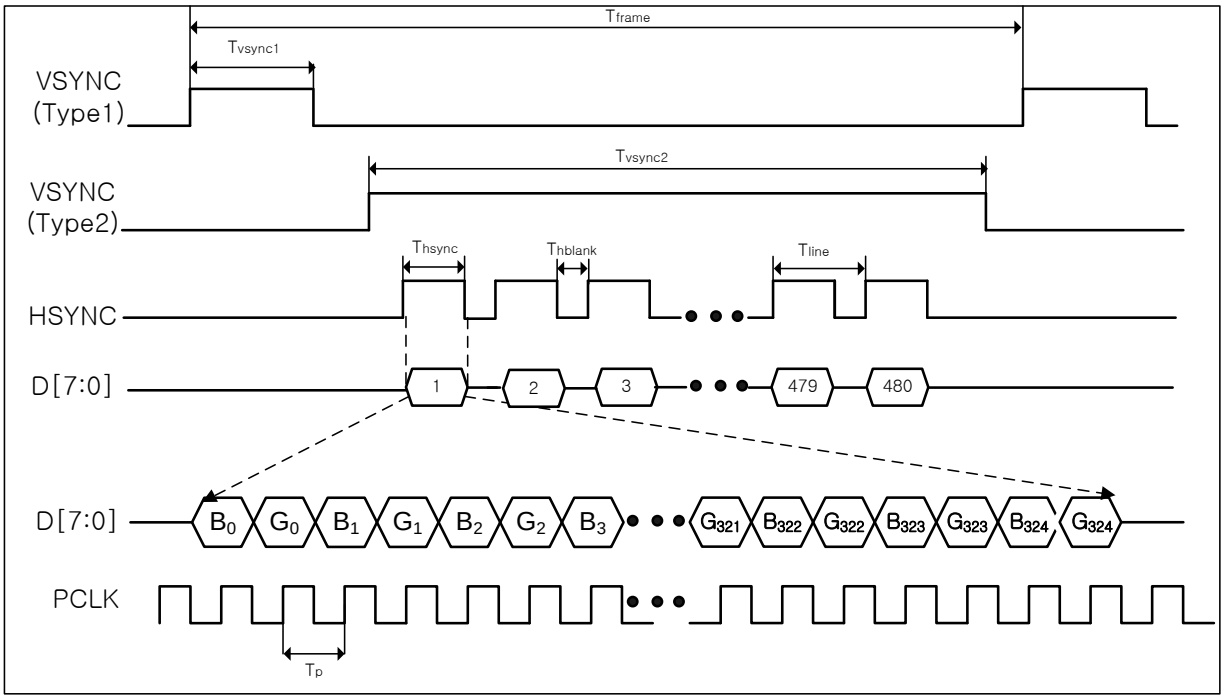
Note) OPCLK should be greater than 6 MHz

Note) Type of VSYNC is selected by bit[2] of VDOCTL1[0x10:P0] in following figures.

VSYNC of type1 is controlled by VSYNC[0x42, 43:P0] registers.

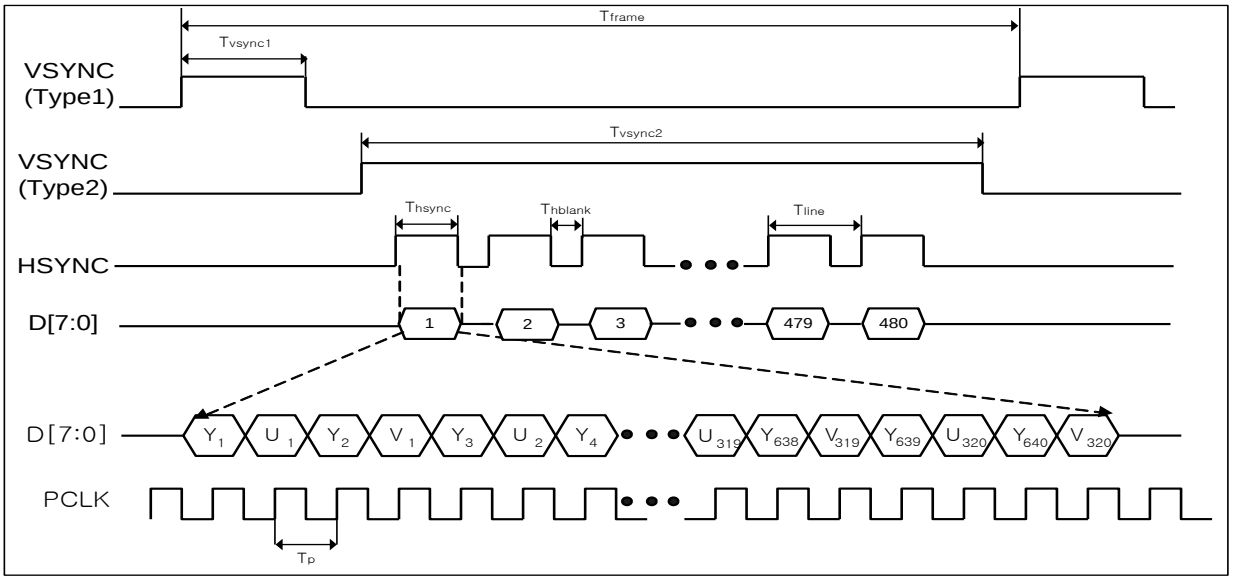
VSYNC of type2 is controlled by VSCTL1[0x45:P0], VSCTL2[0x46:P0] and VSCTL3[0x47:P0],

**<Figure 17. Frame Timing of VGA(RGB Bayer) (644 x 488)>**




Tp=To , Thsync=648*To ,
Thblank = (HBLANK+8)*To ,
Tline= (656 + HBLANK)*To, Tvsync1=VSYNC * (656 + HBLANK)*To for type1,
Tvsync2= ((VSCTL1[0]*256 + VSCTL3[7:0]) – (VSCTL1[1]*256 + VSCTL2[7:0])) * (656 + HBLANK)*To for type2,
Tframe = (500+ VSYNC) *(656 + HBLANK)*To, for EXPINT[0x80,81,82:P20] <= 500 * (656 + HBLANK)*To
= EXPINT + VSYNC * (656 + HBLANK)*To, elsewhere

**<Figure 18. Frame Timing of VGA(640 X 480)>**




Tp=1/2*To ,

Thsync=640*To ,

Thblank = (HBLANK+24)*To ,

Tline= (656 + HBLANK)*To,

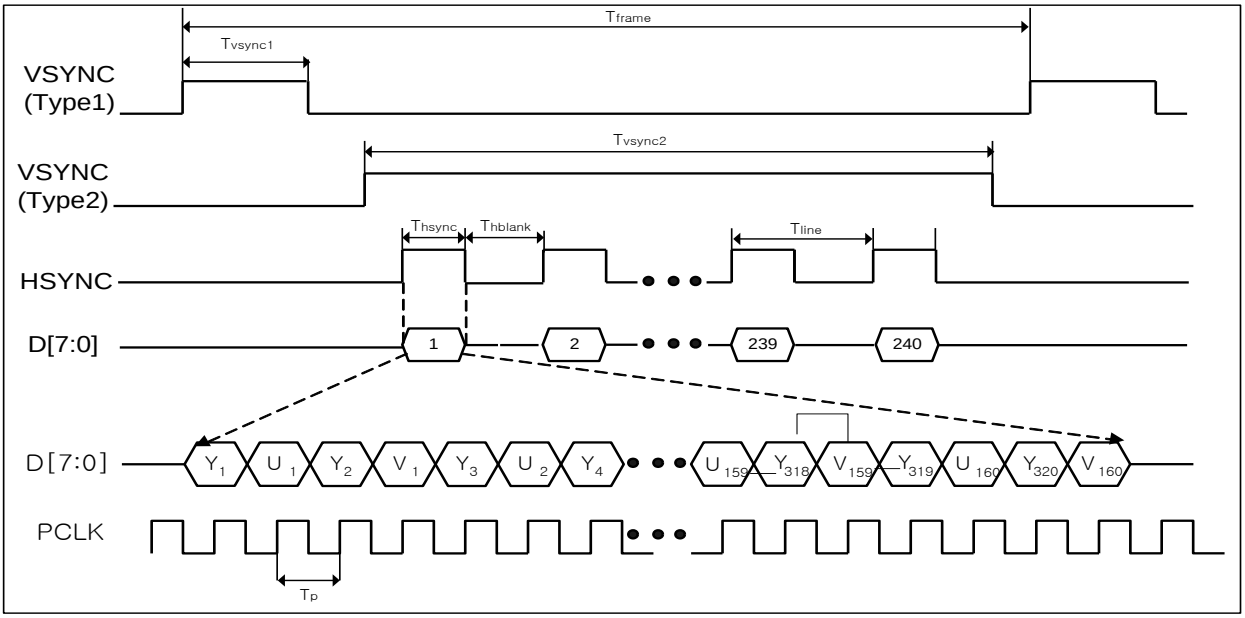
Tvsync1=VSYNC * (656 + HBLANK)*To for type1,

Tvsync2= ((VSCTL1[0]*256 + VSCTL3[7:0]) – (VSCTL1[1]*256 + VSCTL2[7:0])) * (656 + HBLANK)*To for type2,

Tframe = (500+ VSYNC) *(656 + HBLANK)*To, for EXPINT[0x80,81,82:P20] <= 500 * (656 + HBLANK)*To

= EXPINT + VSYNC * (656 + HBLANK)*To, elsewhere

**<Figure 19. Frame Timing of QVGA(320 X 240) when VDOCTL1[0x10:P0] is 0x10>**




Tp=To ,

Thsync=640*To,

Thblank = (2*HBLANK+672)*To,

Tline= 2*(656 + HBLANK)*To,

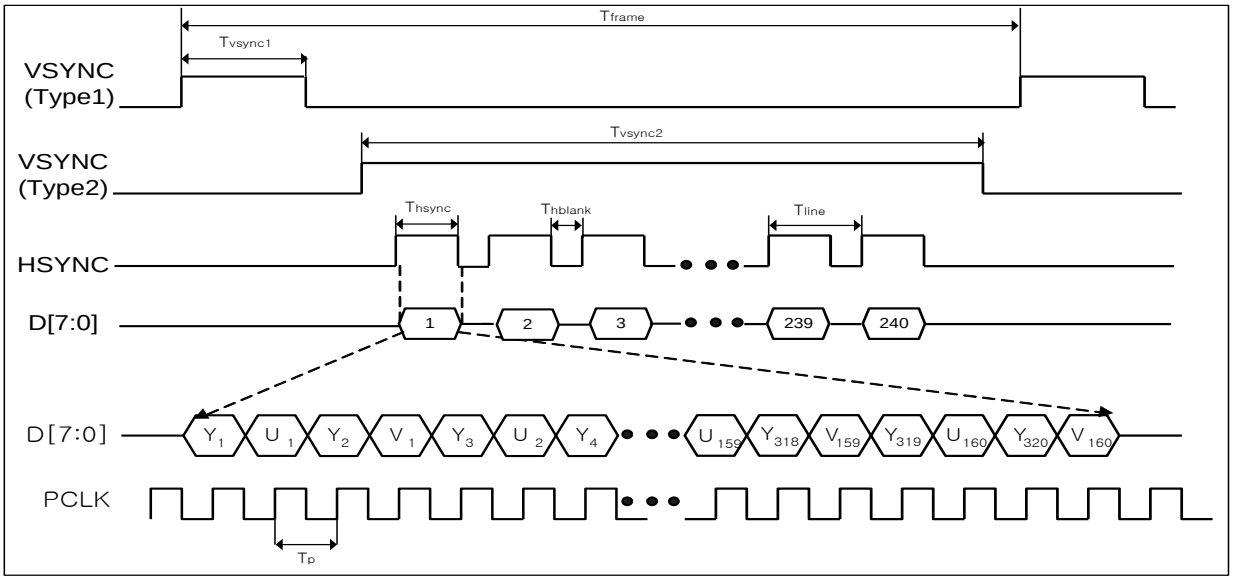
Tvsync1=VSYNC * (656 + HBLANK)*To for type1,

Tvsync2= ((VSCTL1[0]*256 + VSCTL3[7:0]) – (VSCTL1[1]*256 + VSCTL2[7:0])) * (656 + HBLANK)*To for type2,

Tframe = (500+ VSYNC) *(656 + HBLANK)*To, for EXPINT[0x80,81,82:P20] <= 500 * (656 + HBLANK)*To

= EXPINT + VSYNC * (656 + HBLANK)*To, elsewhere

**<Figure 20. Frame Timing of QVGA(320 X 240) when VDOCTL1[0x10:P0] is 0x01>**




Tp=To ,

Thsync=640*To,

Thblank = (HBLANK+16)*To,

Tline= (656 + HBLANK)*To,

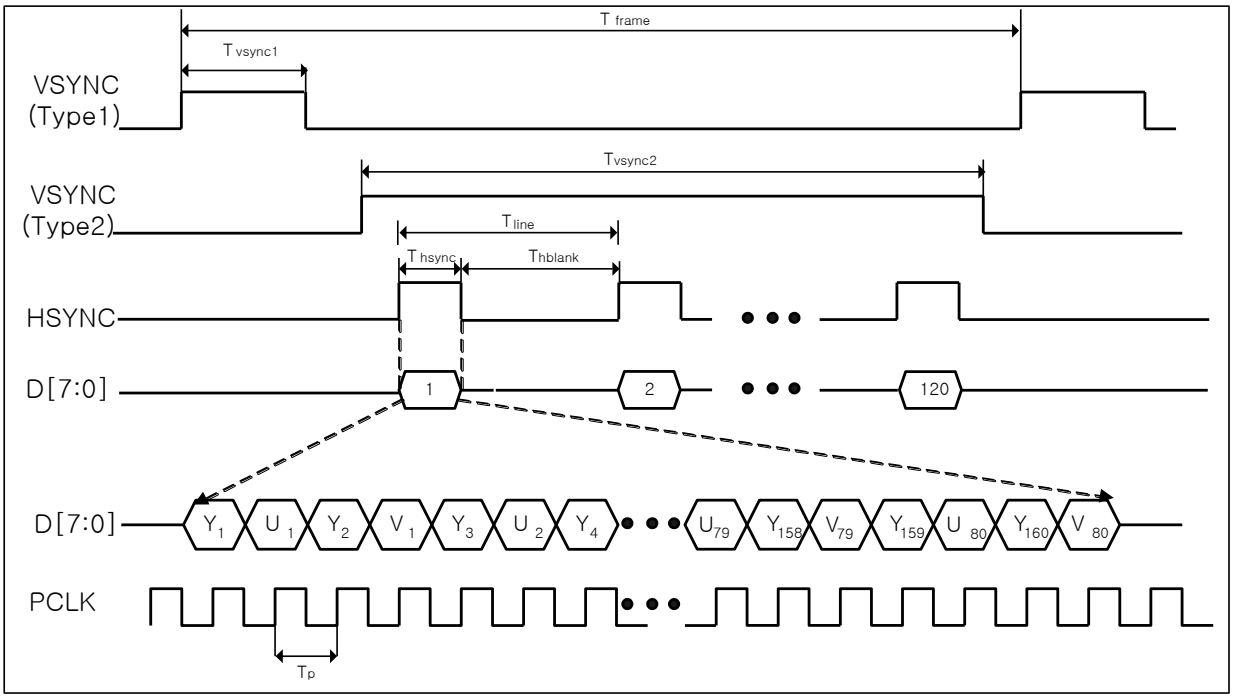
Tvsync1=VSYNC * (656 + HBLANK)*To for type1,

Tvsync2= ((VSCTL1[0]*256 + VSCTL3[7:0]) – (VSCTL1[1]*256 + VSCTL2[7:0])) * (656 + HBLANK)*To for type2,

Tframe = (254+ VSYNC) *(656 + HBLANK)*To, for EXPINT[0x80,81,82:P20] <= 254 * (656 + HBLANK)*To

= EXPINT + VSYNC * (656 + HBLANK)*To, elsewhere

**<Figure 21. Frame Timing of QQVGA(160 X 120) when VDOCTL1[0x10:P0] is 0x20>**




Tp=2*To ,

Thsync=640*To,

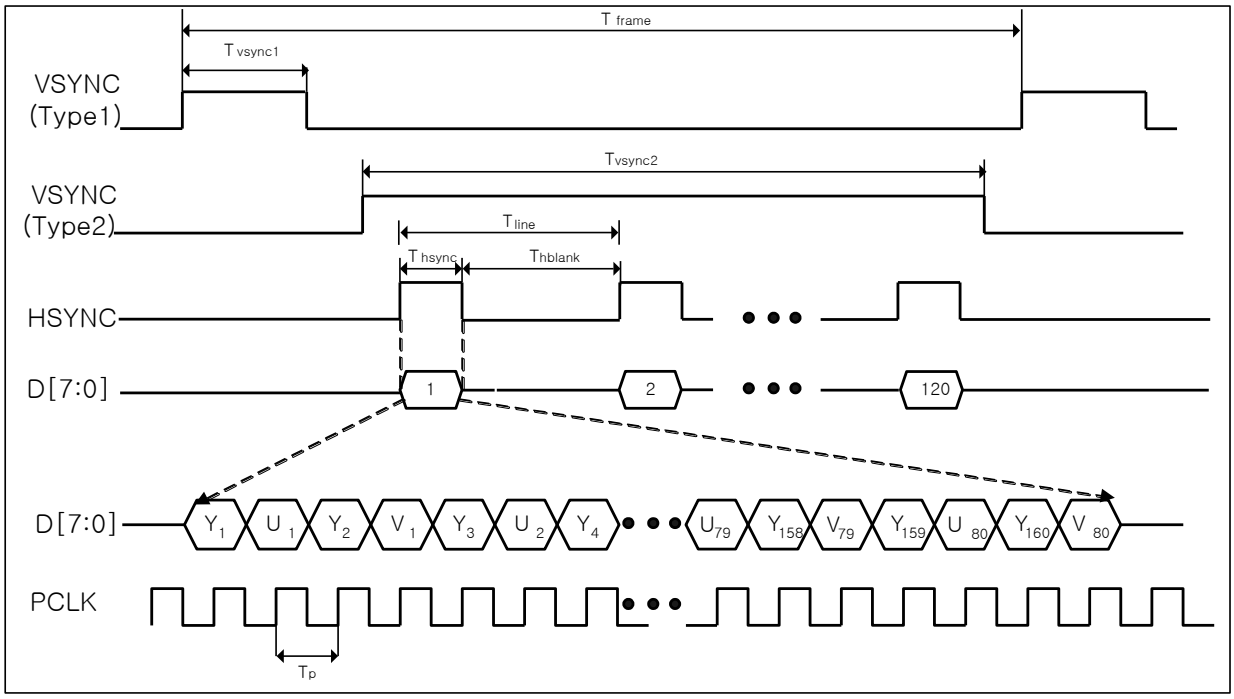
Thblank = (4*HBLANK+1984)*To,

Tline= 4*(656+ HBLANK)*To, Tvsync1=VSYNC * (656+ HBLANK)*To for type1,

Tvsync2= {VSCTL1[0], VSCTL3[7:0]} – {VSCTL1[1], VSCTL2[7:0]} * (656+ HBLANK)*To for type2,

Tframe = (500 + VSYNC) *(656+ HBLANK)*To, where VSYNC [0x42,0x43:P0], HBLANK[0x40,0x41:P0], VSCTL1,2,3[0x45,46,47:P0].

**<Figure 22. Frame Timing of QQVGA(160 X 120) when VDOCTL1[0x10:P0] is 0x21>**




Tp=2*To ,

Thsync=640*To,

Thblank = (2*HBLANK+672)*To,

Tline= 2*(656+ HBLANK)*To, Tvsync1=VSYNC * (656+ HBLANK)*To for type1,

Tvsync2= {VSCTL1[0], VSCTL3[7:0]} – {VSCTL1[1], VSCTL2[7:0]} * (656+ HBLANK)*To for type2,

Tframe = (254 + VSYNC) *(656+ HBLANK)*To, where VSYNC [0x42,0x43:P0], HBLANK[0x40,0x41:P0], VSCTL1,2,3[0x45,46,47:P0].

## 4.13. Fixed Frame Rate Timing

There are two kind of frame rate. One is fixed frame rate and other is variable frame rate.

Fixed frame rate depends on the EXPMAX and EXPFIX. It has constant frame rate regardless of changing exposure time, but maximum frame rate is slower than that of variable frame rate . Variable frame rate is faster than fixed frame rate, but the interval of frames is variable when exposure time is changed. For fixed frame rate user should be set EXPMAX and EXPFIX as following table.

Note) User should consider EXPMAX, HBLANK and Frame time for auto flicker cancellation (50Hz/60Hz)

1) EXPMAX should be multiple of 1/100sec and 1/120sec for auto flicker cancellation.
   Therefore 50msec, 100msec, 150msec and 200msec are possible for EXPMAX.
2) Frame time should be not the multiple of 1/100sec and 1/120sec for auto flicker cancellation.
3) HBLANK should be set to meet following equations for auto flicker cancellation

Equation1) (EXP100[0x8B,8C:P20] * 8 * TOPCLK) / Line Time should be integer .

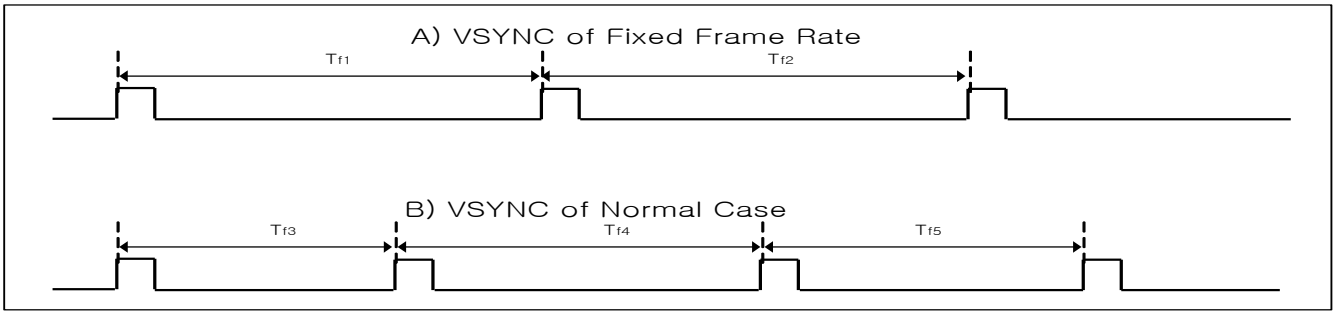
Equation2) (EXP120[0x8D,8E:P20] * 8 * TOPCLK) / Line Time should be integer.

Where Line Time = (664 + HBLANK) * TOPCLK

| Fixed Frame Time | |
|---|---|
| Case 1 | Following register should be set at fixed frame mode<br>B[3:2] of VDOCTL2[0x11:P0] = 01b,<br>AECTL2[0x11:P20] = 0x00, AEFINECTL3[0x2A:P20] = 0x00, AEFINECTL4[0x2B:P20] = 0x35 |
| | EXPFIX[0x91, 0x92, 0x93:P20] >= (656 + HBLANK) * Height * TOPCLK + 10(8.3333)msec + 24* TOPCLK.<br>EXPMAX[0x88, 0x89, 0x8A:P20] <= (656 + HBLANK) * Height * TOPCLK<br>**Height = 500 for VGA, QVGA1, QQVGA1 Height = 254 for QVGA2, QQVGA2<br>where 8.333msec for 120Hz flicker cancellation and 10msec for 100Hz flicker cancellation.<br>Frame time =( EXPFIX[0x94, 0x95, 0x96:P20] + (656 + HBLANK) * VSYNC[0x42, 0x43:P0] )* TOPCLK |
| Case 2 | Following register should be set at fixed frame mode<br>B[3:2] of VDOCTL2[0x11:P0] = 11b,<br>AECTL2[0x11:P20] = 0x00, AEFINECTL3[0x2A:P20] = 0x00, AEFINECTL4[0x2B:P20] = 0x35 |
| | EXPFIX[0x91, 0x92, 0x93:P20] >= (656 + HBLANK) * Height * TOPCLK + 10(8.3333)msec + 24* TOPCLK.<br>EXPMAX[0x88, 0x89, 0x8A:P20] <= (656 + HBLANK) * Height * TOPCLK<br>**Height = 500 for VGA, QVGA1, QQVGA1 Height = 254 for QVGA2, QQVGA2<br>where 8.333msec for 120Hz flicker cancellation and 10msec for 100Hz flicker cancellation.<br>Frame time = EXPFIX[0x94, 0x95, 0x96:P20] * TOPCLK |
| **Variable Frame Time** | |
| Case 1 | Condition : EXPINT[0x80,81,82:P20] <= (656 + HBLANK) * 500 * $T_{OPCLK}$. |
| | Frame time = (656 + HBLANK) *(500 + VSYNC) * $T_{OPCLK}$ |
| Case 2 | Condition : EXPINT > (656 + HBLANK [0x40,0x41:P0]) * 500 * $T_{OPCLK}$ |
| | Frame time = EXPINT + (656 + HBLANK) * VSYNC * $T_{OPCLK}$ |

In below figure, Tf1 is always same asTf2. However, Tf3 and Tf4 and Tf5 are related to the change of exposure time.

**<Figure 23. Timing of Fixed Frame Rate >**



## 4.14. Power Timing

**Power On Sequence**

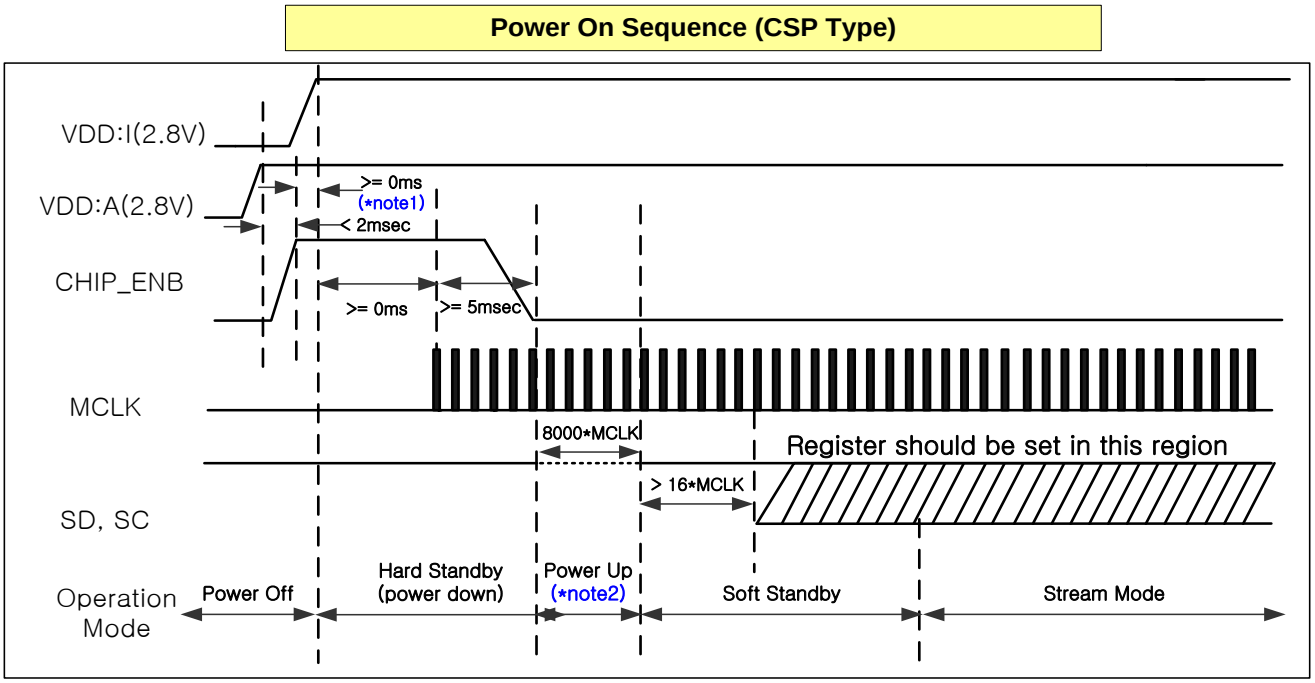
**Case 1) Single power supply (VDD:A = VDD:I = 2.8V)**

**VDD:A 2.8V(ON) → CHIP_ENB(L→H) → VDD:I 2.8V(ON) → MCLK(ON) → CHIP_ENB(H->L) →**

**Set Software reset register(Toggle bit[1] of PWRCTL[0x01:P0] : Low → Hi → Low)) ->**

**Set registers for normal operation → Normal Operation**

**<Figure 24. Timing of Power On Sequence >**

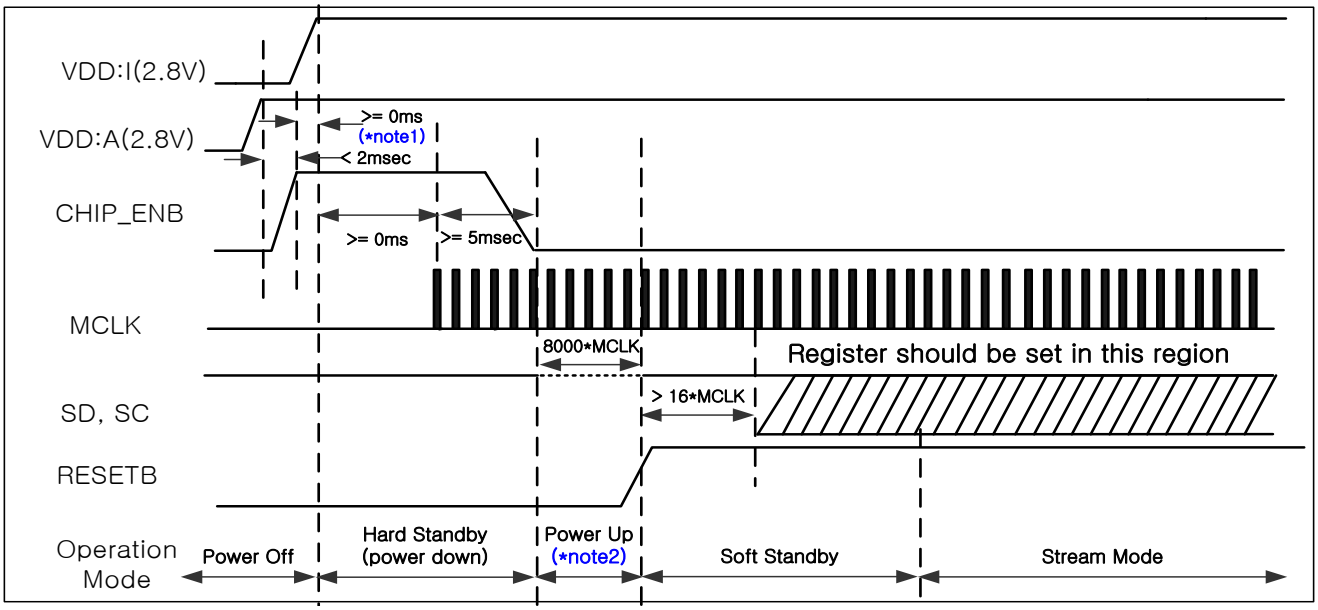


**VDD:A 2.8V(ON) → CHIP_ENB(L→H) → VDD:I 2.8V(ON) → MCLK(ON) → CHIP_ENB(H→L) → RESETB(L→H) →**

**Set Software reset register(Toggle bit[1] of PWRCTL[0x01:P0] : Low → Hi → Low)) ->**

**Set registers for normal operation → Normal Operation**

**Power On Sequence (CoB Type)**




*note 1 :

In order to maintain High level of SD signal on Hard Standby state, CHIP_ENB should be transition (Low to High) before the power (VDD:I) is supplied, as shown in figure. And this period should be minimized for reducing power consumption. If CHIP_ENB goes Low to High after the power supply, SD signal is unknown state during this period. I2C communication of other device sharing I2C line can cause a malfunction during this period.
If possible, VDDIO and CHIP_ENB are supplied at same time.

*note 2 :

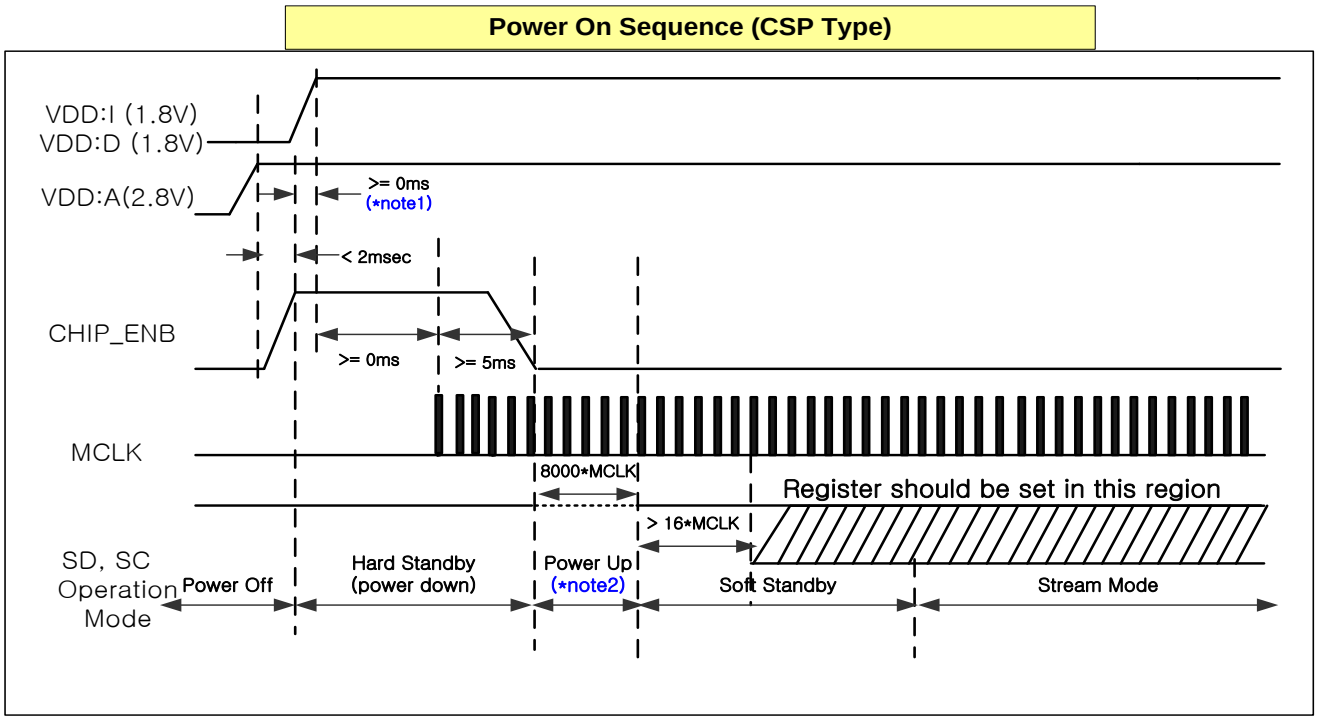
Power Up state condition : (A) or (B)
(A) Until MCLK*8000 after CHIP_ENB signal transition (High to Low)
(B) Until RESET_B goes Low to High
SD signal is unknown state during Power Up state, as shown in Figure.
And I2C communication of other device sharing I2C line can cause a malfunction during this period.
To solve this problem, the following conditions should be followed.
(1) Host (Ex. Baseband) have to set to operate as a I2C Master mode, and I2C Master should be in Idle state (No Read/Write) during this period.

**Case 2) Dual power supply (VDD:A = 2.8V, VDD:I = 1.8V, VREF = 1.8V)**

**VDD:A 2.8V(ON) → CHIP_ENB(L→H) → VDD :I & VREF 1.8V(ON) → VDD:D 1.8V(ON) →> MCLK(ON) →**

**CHIP_ENB(H→L) → wait 10msec → Set Software reset register(Toggle bit[1] of PWRCTL[0x01:P0] : Low → Hi → Low))**

**→ Set registers for normal operation → Normal Operation**




*. When building a module using COB Type(Bare Die), In order to use Dual power LDO should be off OFF ( LDO_EN = Low )

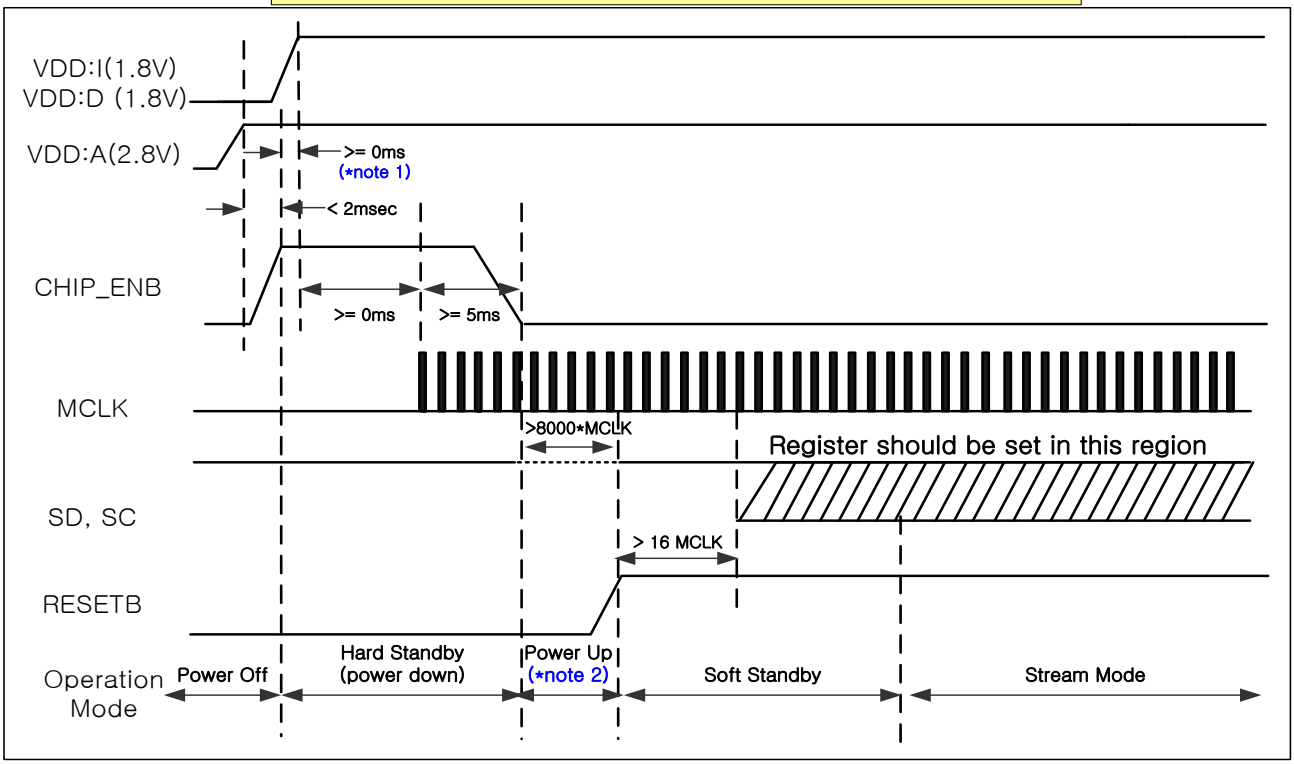
**VDD:A 2.8V(ON) → CHIP_ENB(L→H) → VDD :I & VREF 1.8V(ON) → VDD:D 1.8V(ON) →> MCLK(ON) →**

**CHIP_ENB(H→L) → wait 10msec → RESETB(L→H) →**

**Set Software reset register(Toggle bit[1] of PWRCTL[0x01:P0] : Low → Hi → Low)) →**

**Set registers for normal operation → Normal Operation**

**Power On Sequence (CoB Type)**




*note 1 :

In order to maintain High level of SD signal on Hard Standby state, CHIP_ENB should be transition (Low to High) before the power (VDD:I) is supplied, as shown in figure. And this period should be minimized for reducing power consumption. If CHIP_ENB goes Low to High after the power supply, SD signal is unknown state during this period. I2C communication of other device sharing I2C line can cause a malfunction during this period.
If possible, VDDIO and CHIP_ENB are supplied at same time.

*note 2 :

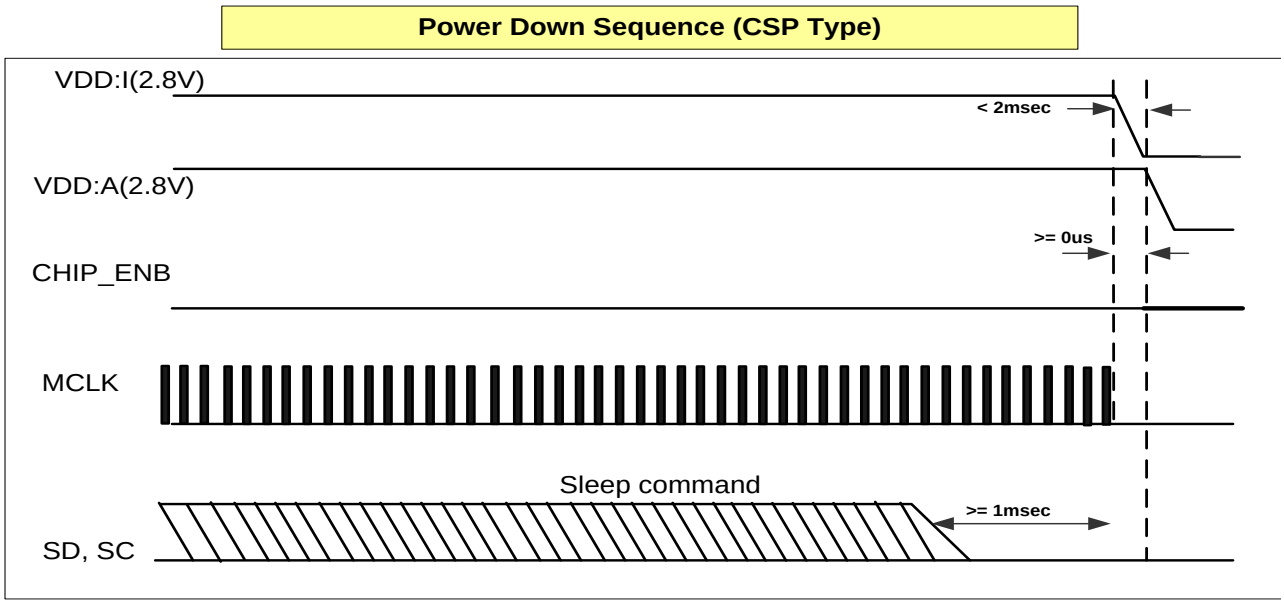
Power Up state condition : (A) or (B)
(C) Until MCLK*8000 after CHIP_ENB signal transition (High to Low)
(D) Until RESET_B goes Low to High
SD signal is unknown state during Power Up state, as shown in Figure.
And I2C communication of other device sharing I2C line can cause a malfunction during this period.
To solve this problem, the following conditions should be followed.
(2) Host (Ex. Baseband) have to set to operate as a I2C Master mode, and I2C Master should be in Idle state (No Read/Write) during this period.

**Power Off Sequence**

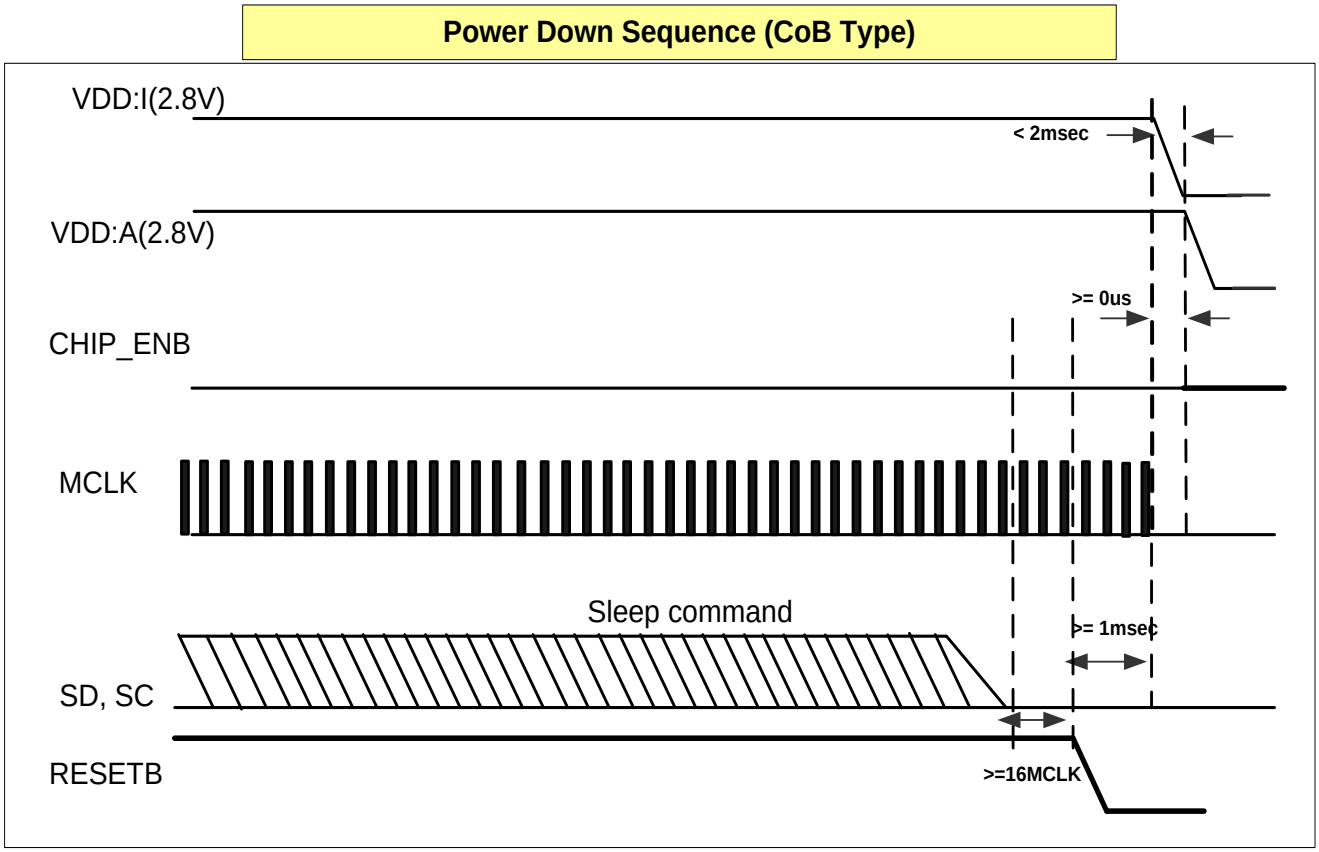
**<Figure 25. Timing of Power Off Sequence >**

**Case 1) Single power supply (LDO On) (VDD:A = VDD:I = 2.8V)**

**Normal Operation → Power Sleep command → SC, SD (OFF) → CHIP_ENB(L) → MCLK (OFF) → VDD:I(OFF) → VDD:A(OFF)**



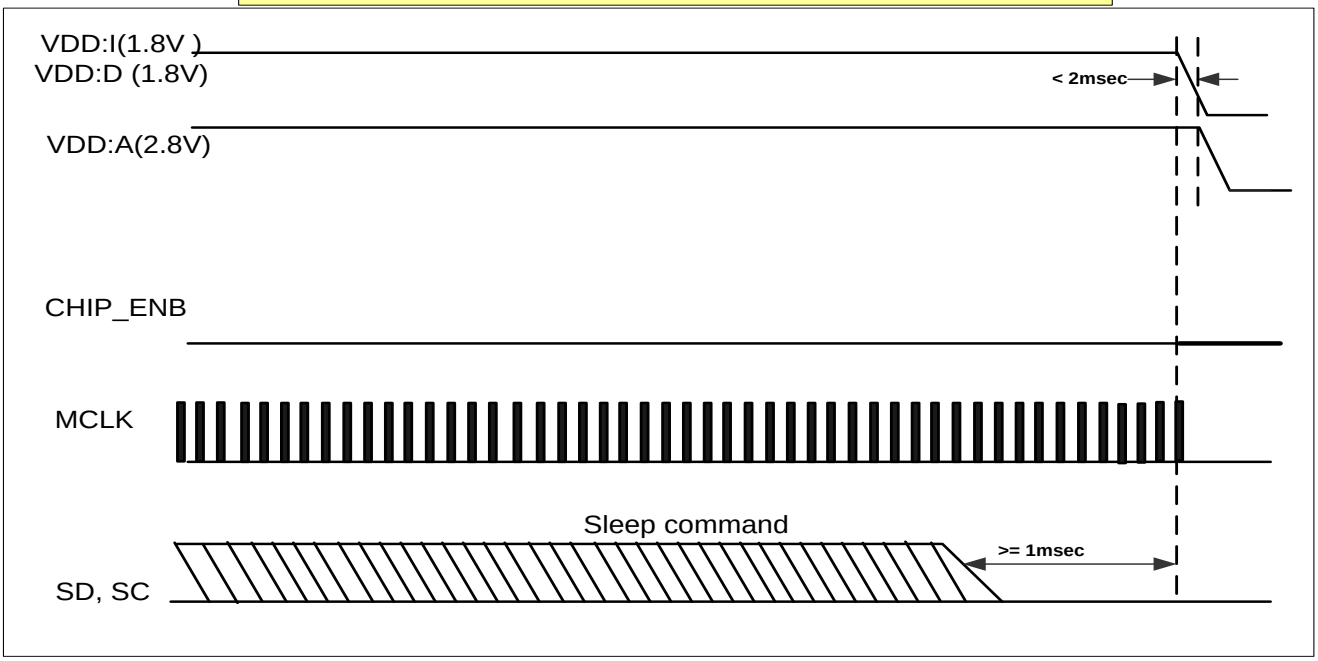

**Normal Operation → Power Sleep command → SC, SD (OFF) → CHIP_ENB(L) → RESETB(H→L) → MCLK (OFF) → VDD:I(OFF) → VDD:A(OFF)**



**Case 2) Dual power supply (VDD:A = 2.8V, VDD:I = 1.8V, VREF = 1.8V)**

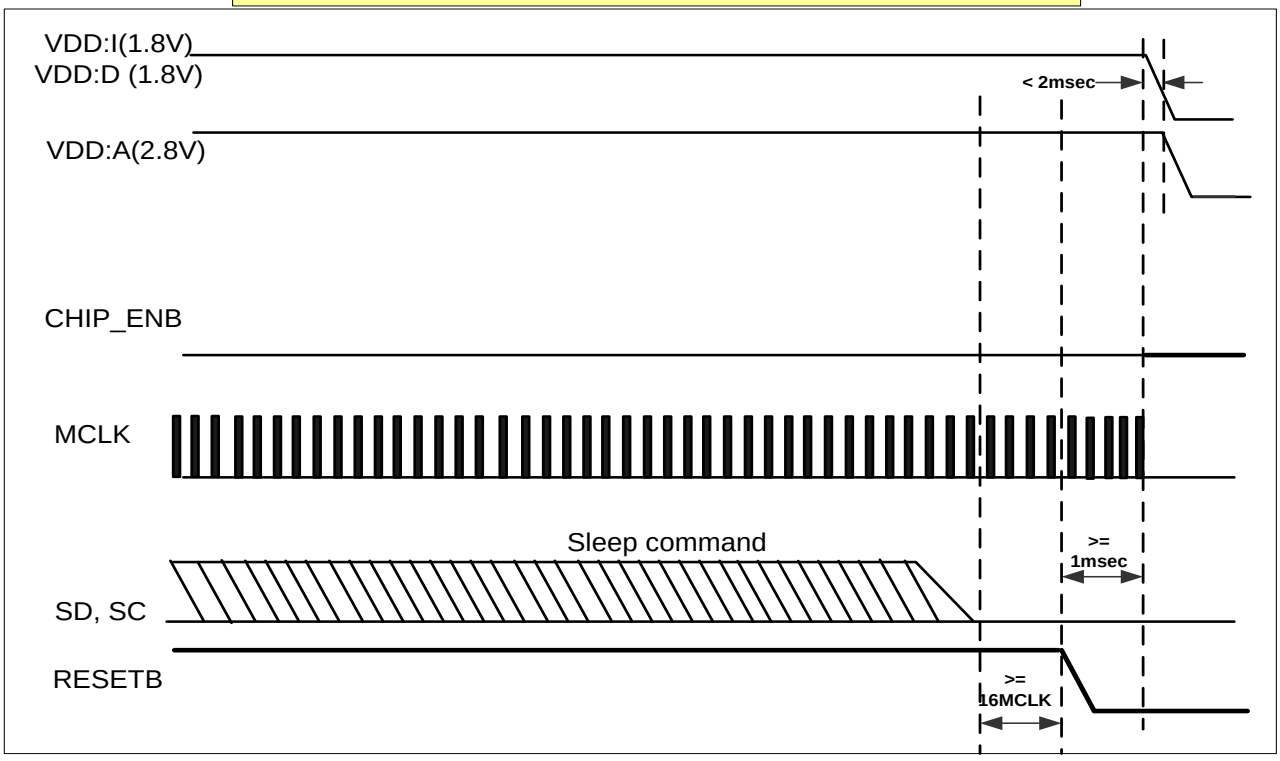
**Normal Operation → Power Sleep command → SC,SD (OFF) → CHIP_ENB(L) → MCLK (OFF) → VDD:A(OFF) → VDD:I & VREF(OFF)**

**Power Down Sequence (CSP Type)**




**Normal Operation → Power Sleep command → SC,SD (OFF) → RESETB(H→L) → CHIP_ENB(L) → MCLK (OFF) → VDD:A(OFF) → VDD:I & VREF(OFF)**

**Power Down Sequence (CoB Type)**

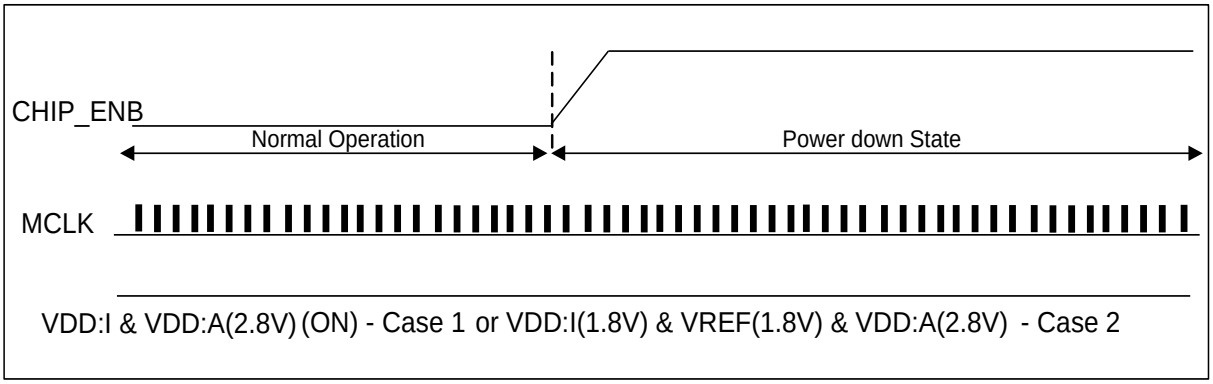


### From Normal Operation State to Stand-by(Power down) State

When CHIP_ENB is high, output pins go to Hi-Z.

Before CHIP_ENB is high, user should set power sleep through the two wire serial bus.

**<Figure 26. Timing of Normal Operation to Stand-by >**




### From Stand-by(Power down) State to Normal Operation State

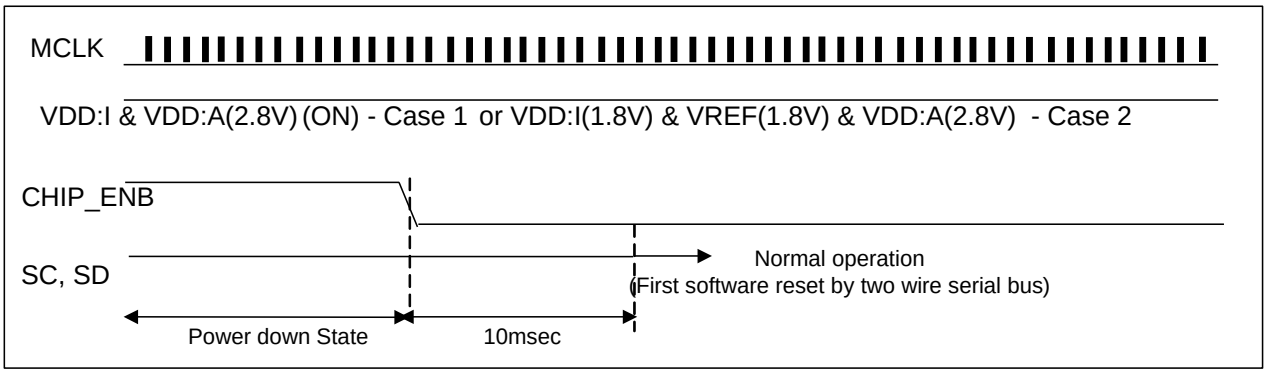
1) Set CHIP_ENB to Low.

2) Wait 10msec.

3) Set the software reset register(Toggle bit[1] of PWRCTL[0x01:P0] : Low → Hi → Low))

4) Set the registers for normal operation

**<Figure 27. Timing of Stand-by to Normal Operation>**



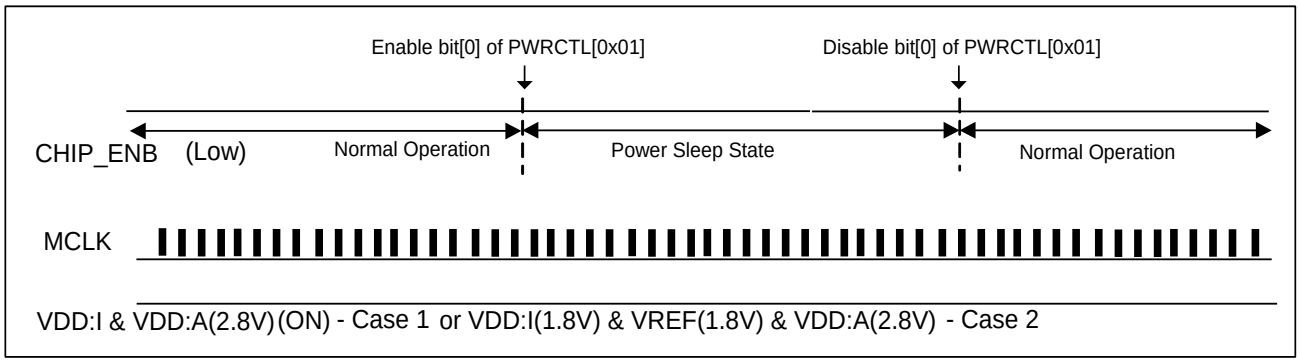

### From Normal Operation State to Power Sleep State

Set the PWLCTL[0x01:P0]'s bit[0] to high.

### From Power Sleep State to Normal Operation State

Set PWLCTL[0x01:P0]'s bit[0] to low

**<Figure 28. Timing of Power Sleep to Normal Operation>**



# 5. REGISTER DESCRIPTION

**[Table 8. Register Description]**

| sensor address in two-wire serial bus : 60H(write) , 61H(read) RO[read only] | | | | |
|---|---|---|---|---|
| **Address (Hex)** | **Register** | **Description** | **Default (Hex)`** | **Renewal Frame** |
| **Common Group** | | | | |
| 0x03(P0) | PAGEMODE | 0x00 = control image size, windowing, sync, black level calibration<br>0x10 = control image format, image effect<br>0x11 = control ZLPF<br>0x12 = control YCLPF and BLPF.<br>0x13 = control edge enhancement<br>0x14 = control lens shading correction.<br>0x15 = control color correction.<br>0x16 = control gamma correction.<br>0x17 = control auto flicker cancellation<br>0x20 = control auto exposure<br>0x22 = control auto white balance. | 0x00 | Current |
| **Device ID and Image Size and Windowing and Sync (Page Mode = 0)** | | | | |
| 0x01(P0) | PWRCTL | Power sleep mode | 0x51 | Current |
| 0x04(P0) | DEVID | Device ID1 | 0x96 | RO |
| 0x10(P0) | VDOCTL1 | Control sub-sampling and vsync type | 0x00 | Next |
| 0x11(P0) | VDOCTL2 | Control strobe, windowing, fixed frame rate, X/Y flip and skip frame | 0x90 | Next |
| 0x12(P0) | SYNCCTL | Control polarity of H/VSYNC and PCLK, and Internal clock divider | 0x04 | Next |
| 0x20(P0) | WINROWH | High byte of row start address for windowing | 0x00 | Current |
| 0x21(P0) | WINROWL | Low byte of row start address for windowing | 0x05 | Current |
| 0x22(P0) | WINCOLH | High byte of column start address for windowing | 0x00 | Current |
| 0x23(P0) | WINCOLL | Low byte of column start address for windowing | 0x07 | Current |
| 0x24(P0) | WINHGTH | High byte of height for windowing | 0x01 | Current |
| 0x25(P0) | WINHGTL | Low byte of height for windowing | 0xE0 | Current |
| 0x26(P0) | WINWIDH | High byte of width for windowing | 0x02 | Current |
| 0x27(P0) | WINWIDL | Low byte of width for windowing | 0x80 | Current |
| 0x40(P0) | HBLANKH | High byte of duration for horizontal blanking | 0x01 | Current |
| 0x41(P0) | HBLANKL | Low byte of duration for horizontal blanking | 0x58 | Current |
| 0x42(P0) | VSYNCH | High byte of duration for vertical synchronization(Type1) | 0x00 | Current |
| 0x43(P0) | VSYNCL | Low byte of duration for vertical synchronization(Type1) | 0x14 | Current |
| 0x44(P0) | VSCLIP | Clipping duration in vertical synchronization | 0x09 | Current |
| 0x45(P0) | VSCTL1 | High 4bits of start/stop row position for vertical synchronization(Type2) | 0x01 | Current |
| 0x46(P0) | VSCTL2 | Low byte of start row position for vertical synchronization(Type2) | 0x02 | Current |
| 0x47(P0) | VSCTL3 | Low byte of stop row position for vertical synchronization(Type2) | 0xE2 | Current |
| **Black level calibration (Page Mode = 0)** | | | | |
| 0x80(P0) | BLCCTL | Control optical black level calibration | 0x08 | Current |
| 0x90(P0) | BLCTIMETHON | Exposure time threshold to enable additional BLC | 0x0C | Current |
| 0x91(P0) | BLCTIMETHOFF | Exposure time threshold to disable additional BLC | 0x0C | Current |
| 0x92(P0) | BLCAGTHH | AG threshold to enable additional BLC | 0x60 | Current |
| 0x93(P0) | BLCAGTHL | AG threshold to disable additional BLC | 0x60 | Current |
| 0xA0(P0) | DOFSB | Blue color1 offset for additional BLC | 0x00 | Current |
| **Image Output Format and Image Effect (Page Mode = 10)** | | | | |
| 0x10(P10) | ISPCTL1 | Control the format of image data | 0x03 | Next |
| 0x11(P10) | ISPCTL2 | Control image effect and color interpolation and color space conversion | 0x03 | Next |
| 0x12(P10) | ISPCTL3 | Control color offset and brightness | 0x00 | Next |
| 0x14(P10) | ISPCTL4 | Control the format of image data | 0x00 | Next |
| 0x15(P10) | PADCTL | Output Pad Control | 0x00 | Current |

| | | | | |
|---|---|---|---|---|
| 0x40(P10) | YOFS | Offset of luminance | 0x00 | Current |
| 0x41(P10) | DYOFS | Offset of luminance at dark condition | 0x00 | Current |
| 0x42(P10) | UOFS | Offset of U chrominance | 0x00 | Next |
| 0x43(P10) | VOFS | Offset of V chrominance | 0x00 | Next |
| 0x44(P10) | UCON | Constant of U chrominance | 0x80 | Next |
| 0x45(P10) | VCON | Constant of V chrominance | 0x80 | Next |
| 0x47(P10) | BINARY | Threshold of binary effect. | 0x7F | Current |
| 0x48(P10) | CONTRAST | Contrast coefficient | 0x80 | Current |
| 0x50(P10) | AGBRT | Threshold of AG in auto bright | 0x60 | Current |
| 0x60(P10) | SATCTL | Control color saturation | 0x00 | Current |
| 0x62(P10) | SATB | Blue color saturation coefficient | 0x80 | Current |
| 0x63(P10) | SATR | Red color saturation coefficient | 0x80 | Current |
| 0x64(P10) | AGSAT | Threshold of AG in auto saturation | 0x60 | Current |
| **Z-LPF(Page Mode = 11)** | | | | |
| 0x10(P11) | ZLPFCTL1 | Control Z-LPF | 0x00 | Current |
| 0x11(P11) | ZLPFCTL2 | Control Z-LPF | 0x1A | Current |
| 0x20(P11) | ZLPFCTL3 | Control Z-LPF | 0x00 | Current |
| 0x21(P11) | ZLPFAGTH | Threshold of AG for automatic LPF | 0x20 | Current |
| 0x23(P11) | ZLPFEXPTH | Threshold of Exposure time for automatic LPF | 0x10 | Current |
| 0x60(P11) | ZLPFTH1 | Threshold for Z-LPF | 0x40 | Current |
| 0x61(P11) | ZLPFTH2 | Threshold for Z-LPF | 0x40 | Current |
| 0x62(P11) | ZLPFHLVL | Threshold of Z-LPF high level. | 0x83 | Current |
| 0x63(P11) | ZLPFLLVL | Threshold of Z-LPF low level. | 0x43 | Current |
| 0x64(P11) | ZLPFDYTH | Threshold of dynamic range for Z-LPF | 0x23 | Current |
| **YC-LPF (Page Mode = 12)** | | | | |
| 0x40(P12) | YCLPFCTL1 | Control YC-LPF | 0x00 | Current |
| 0x41(P12) | YCLPFCTL2 | Control YC-LPF | 0x30 | Current |
| 0x50(P12) | YCLPFTH | Threshold of YUV for YC-LPF | 0x10 | Current |
| **B-LPF(Page Mode = 12)** | | | | |
| 0x70(P12) | BLPFCTL | Control B-LPF | 0x1C | Current |
| 0x74(P12) | BLPFTH1 | Threshold for B-LPF | 0x10 | Current |
| 0x75(P12) | BLPFTH2 | Threshold for B-LPF | 0x10 | Current |
| **DPC(Page Mode = 12)** | | | | |
| 0x90(P12) | DPCCTL | Control DPC | 0x3D | Current |
| **Edge Enhancement (Page Mode = 13)** | | | | |
| 0x10(P13) | EDGECTL1 | Control edge enhancement | 0x18 | Current |
| 0x14(P13) | EDGECTL2 | Control edge enhancement. | 0x00 | Current |
| 0x20(P13) | EDGENGAIN | Edge gain to emphasize negative edge data | 0x07 | Current |
| 0x21(P13) | EDGEPGAIN | Edge gain to emphasize positive edge data | 0x07 | Current |
| 0x23(P13) | EDGEHCLIPTH | High clip threshold. | 0x30 | Current |
| 0x24(P13) | EDGELCLIPTH | Low clip threshold. | 0x00 | Current |
| 0x28(P13) | EDGETIMETH | Threshold of Exposure time for automatic edge enhancement. | 0x10 | Current |
| 0x29(P13) | EDGEAGTH | Threshold of AG for automatic edge enhancement. | 0x30 | Current |
| 0x80(P13) | EDGE2DCTL1 | Control $2^{nd}$ edge enhancement | 0x06 | Current |
| 0x81(P13) | EDGE2DCTL2 | Control $2^{nd}$ edge enhancement | 0x10 | Current |
| 0x90(P13) | EDGE2DNGAIN | Edge gain to emphasize negative edge data for $2^{nd}$ edge enhancement | 0x07 | Current |
| 0x91(P13) | EDGE2DPGAIN | Edge gain to emphasize positive edge data for $2^{nd}$ edge enhancement | 0x07 | Current |
| 0x93(P13) | EDGE2DHCLIPTH | High clip threshold for $2^{nd}$ edge enhancement | 0x30 | Current |

| | | | | |
|---|---|---|---|---|
| 0x94(P13) | EDGE2DLCLIPTH | Low clip threshold for 2nd edge enhancement | 0x00 | Current |
| | | | | |
| **Lens Shading (Page Mode = 14)** | | | | |
| 0x10(P14) | LENSCTL | Control lens shading correction | 0x00 | Current |
| 0x20(P14) | XCEN | Optical center on X-axis in pixel array for lens shading correction | 0x80 | Current |
| 0x21(P14) | YCEN | Optical center on Y-axis in pixel array for lens shading correction | 0x80 | Current |
| 0x22(P14) | LENSR | Lens shading correction coefficient in R color | 0x60 | Current |
| 0x23(P14) | LENSG | Lens shading correction coefficient in G color | 0x60 | Current |
| 0x24(P14) | LENSB | Lens shading correction coefficient in B color | 0x60 | Current |
| 0x25(P14) | LAGOFF | AG threshold to disable Lens Shading Correction Gain | 0x60 | Current |
| 0x26(P14) | LAGON | AG threshold to enable Lens Shading Correction Gain | 0x60 | Current |
| **Color Correction (Page Mode = 15)** | | | | |
| 0x10(P15) | CMCCTL | Control color correction | 0x0E | Current |
| 0x14(P15) | CMCOFSGH | High threshold of color offset gain | 0x38 | Current |
| 0x16(P15) | CMCOFSGL | Low threshold of color offset gain | 0x20 | Current |
| 0x17(P15) | CMCSIGN | Sign bit of color correction coefficient | 0x2F | Current |
| 0x30(P15) | CMC11 | Color correction coefficient 11 | 0x4C | Current |
| 0x31(P15) | CMC12 | Color correction coefficient 12 | 0x0C | Current |
| 0x32(P15) | CMC13 | Color correction coefficient 13 | 0x00 | Current |
| 0x33(P15) | CMC21 | Color correction coefficient 21 | 0x26 | Current |
| 0x34(P15) | CMC22 | Color correction coefficient 22 | 0x80 | Current |
| 0x35(P15) | CMC23 | Color correction coefficient 23 | 0x1A | Current |
| 0x36(P15) | CMC31 | Color correction coefficient 31 | 0x20 | Current |
| 0x37(P15) | CMC32 | Color correction coefficient 32 | 0x80 | Current |
| 0x38(P15) | CMC33 | Color correction coefficient 33 | 0xE0 | Current |
| 0x40(P15) | CMCOFS11 | Color correction offset coefficient 11 | 0x12 | Current |
| 0x41(P15) | CMCOFS12 | Color correction offset coefficient 12 | 0xA0 | Current |
| 0x42(P15) | CMCOFS13 | Color correction offset coefficient 13 | 0x0E | Current |
| 0x43(P15) | CMCOFS21 | Color correction offset coefficient 21 | 0x84 | Current |
| 0x44(P15) | CMCOFS22 | Color correction offset coefficient 22 | 0x08 | Current |
| 0x45(P15) | CMCOFS23 | Color correction offset coefficient 23 | 0x84 | Current |
| 0x46(P15) | CMCOFS31 | Color correction offset coefficient 31 | 0x8A | Current |
| 0x47(P15) | CMCOFS32 | Color correction offset coefficient 32 | 0x02 | Current |
| 0x48(P15) | CMCOFS33 | Color correction offset coefficient 33 | 0x08 | Current |
| **Gamma Correction (Page Mode = 16)** | | | | |
| 0x10(P16) | GMACTL | Control gamma correction | 0x01 | Current |
| 0x30(P16) | GMA0 | Gamma corrected output at 0(0)code in 10(8)bit linear input | 0x00 | Current |
| 0x31(P16) | GMA1 | Gamma corrected output at 16(4)code in 10(8)bit linear input | 0x15 | Current |
| 0x32(P16) | GMA2 | Gamma corrected output at 32(8)code in 10(8)bit linear input | 0x1F | Current |
| 0x33(P16) | GMA3 | Gamma corrected output at 64(16)code in 10(8)bit linear input | 0x30 | Current |
| 0x34(P16) | GMA4 | Gamma corrected output at 128(32)code in 10(8)bit linear input | 0x49 | Current |
| 0x35(P16) | GMA5 | Gamma corrected output at 192(48)code in 10(8)bit t linear input | 0x5D | Current |
| 0x36(P16) | GMA6 | Gamma corrected output at 256(64)code in 10(8)bit linear input | 0x6F | Current |
| 0x37(P16) | GMA7 | Gamma corrected output at 320(80)code in 10(8)bit linear input | 0x7F | Current |
| 0x38(P16) | GMA8 | Gamma corrected output at 384(96)code in 10(8)bit linear input | 0x8E | Current |
| 0x39(P16) | GMA9 | Gamma corrected output at 448(112)code in 10(8)bit linear input | 0x9B | Current |
| 0x3A(P16) | GMA10 | Gamma corrected output at 512(128)code in 10(8)bit linear input | 0xA8 | Current |
| 0x3B(P16) | GMA11 | Gamma corrected output at 640(160)code in 10(8)bit linear input | 0xC1 | Current |

| | | | | |
|---|---|---|---|---|
| 0x3C(P16) | GMA12 | Gamma corrected output at 768(192)code in 10(8)bit linear input | 0xD7 | Current |
| 0x3D(P16) | GMA13 | Gamma corrected output at 896(224)code in 10(8)bit linear input | 0xF6 | Current |
| 0x3E(P16) | GMA14 | Gamma corrected output at 1023(255)code in 10(8)bit linear input | 0xFF | Current |
| | | | | |
| **Auto Flicker Cancellation (Page Mode = 17)** | | | | |
| 0xC0(P17) | FLKMODE | Number of skipped frames in AFC operation | 0x00 | Current |
| 0xC4(P17) | FLK200 | Number of horizontal line for 1/200sec | 0x3C | Current |
| 0xC5(P17) | FLK240 | Number of horizontal line for 1/240sec | 0x32 | Current |
| 0xC6(P17) | FLKTH1 | Low threshold to detect flicker noise | 0x02 | Current |
| 0xC7(P17) | FLKTH2 | High threshold to detect flicker noise | 0x20 | Current |
| **Auto Exposure (Page Mode = 20)** | | | | |
| 0x10(P20) | AECTL1 | Control automatic exposure | 0x0C | Next |
| 0x11(P20) | AECTL2 | Control automatic exposure | 0x04 | Next |
| 0x20(P20) | AEFRAMECTL | Frame control for automatic exposure | 0x01 | Current |
| 0x28(P20) | AEFINECTL1 | Speed option for automatic exposure | 0x03 | Current |
| 0x29(P20) | AEFINECTL2 | Speed option for automatic exposure | 0xA5 | Current |
| 0x2A(P20) | AEFINECTL3 | Speed option for automatic exposure | 0xF0 | Current |
| 0x2B(P20) | AEFINECTL4 | Speed option for automatic exposure | 0x35 | Current |
| 0x60(P20) | AEWGT | Weight coefficient of each AE region | 0x95 | Current |
| 0x68(P20) | AECENHST | Horizontal start address for AE center area. | 0x28 | Current |
| 0x69(P20) | AECENHEN | Horizontal stop address for AE center area. | 0x78 | Current |
| 0x6A(P20) | AECENVST | Vertical start address for AE center area. | 0x50 | Current |
| 0x6B(P20) | AECENVED | Vertical stop address for AE center area. | 0xA0 | Current |
| 0x70(P20) | YLVL | Luminance level to converge in AE | 0x50 | Current |
| 0x78(P20) | YTH1 | Threshold1 of hysteresis in AE | 0x45 | Current |
| 0x79(P20) | YTH2 | Threshold2 of hysteresis in AE | 0x50 | Current |
| 0x7C(P20) | YTH3 | Threshold2 of hysteresis in AE | 0x28 | Current |
| 0x80(P20) | EXPINTH | High byte of internal exposure time | RO | Current |
| 0x81(P20) | EXPINTM | Middle byte of internal exposure time | RO | Current |
| 0x82(P20) | EXPINTL | Low byte of internal exposure time | RO | Current |
| 0x83(P20) | EXPTIMEH | High byte of manual exposure time | 0x00 | Next |
| 0x84(P20) | EXPTIMEM | Middle byte of manual exposure time | 0xC3 | Next |
| 0x85(P20) | EXPTIMEL | Low byte of manual exposure time | 0x50 | Next |
| 0x86(P20) | EXPMINH | High byte of minimum exposure time | 0x01 | Current |
| 0x87(P20) | EXPMINL | Low byte of minimum exposure time | 0xF4 | Current |
| 0x88(P20) | EXPMAXH | High byte of maximum exposure time | 0x02 | Current |
| 0x89(P20) | EXPMAXM | Middle byte of maximum exposure time | 0x49 | Current |
| 0x8A(P20) | EXPMAXL | Low byte of maximum exposure time | 0xF0 | Current |
| 0x8B(P20) | EXP100H | High byte of exposure time for 1/100sec | 0x3A | Current |
| 0x8C(P20) | EXP100L | Low byte of exposure time for 1/100sec | 0x98 | Current |
| 0x8D(P20) | EXP120H | High byte of exposure time for 1/120sec | 0x30 | Current |
| 0x8E(P20) | EXP120L | Low byte of exposure time for 1/120sec | 0xD4 | Current |
| 0x91(P20) | EXPFIXH | High byte of exposure time for fixed frame rate | 0x02 | Current |
| 0x92(P20) | EXPFIXM | Middle byte of exposure time for fixed frame rate | 0xF9 | Current |
| 0x93(P20) | EXPFIXL | Low byte of exposure time for fixed frame rate | 0xB8 | Current |
| 0x98(P20) | EXPOUT1 | Threshold of exposure time to define bright condition. | 0x9A | Current |
| 0x99(P20) | EXPOUT2 | Threshold of exposure time to define very bright condition. | 0x45 | Current |
| 0x9C(P20) | EXPLMTH | High byte of exposure time for low limit. | 0x01 | Current |

| | | | | |
|---|---|---|---|---|
| 0x9D(P20) | EXPLMTL | Low byte of exposure time for low limit. | 0xF4 | Current |
| 0x9E(P20) | EXPUNITH | High byte of unit step of EXPLMT | 0x00 | Current |
| 0x9F(P20) | EXPUNITL | Low byte of unit step of EXPLMT | 0xC8 | Current |
| 0xB0(P20) | AG | Automatic gain (AG) | 0x10 | Next |
| 0xB1(P20) | AGMIN | Minimum AG in AE | 0x10 | Current |
| 0xB2(P20) | AGMAX | Maximum AG in AE | 0x80 | Current |
| 0xB3(P20) | AGLVL | Target level of AG in AE | 0x10 | Current |
| 0xB4(P20) | AGTH1 | Minimum threshold of Band AG in AE | 0x10 | Current |
| 0xB5(P20) | AGTH2 | Maximum threshold of Band AG in AE | 0x33 | Current |
| 0xB6(P20) | AGBTH1 | Threshold1 of Adaptive AG in AE. | 0x22 | Current |
| 0xB7(P20) | AGBTH2 | Threshold2 of Adaptive AG in AE. | 0x1C | Current |
| 0xB8(P20) | AGBTH3 | Threshold3 of Adaptive AG in AE. | 0x19 | Current |
| 0xB9(P20) | AGBTH4 | Threshold4 of Adaptive AG in AE. | 0x17 | Current |
| 0xBA(P20) | AGBTH5 | Threshold5 of Adaptive AG in AE. | 0x15 | Current |
| 0xBB(P20) | AGBTH6 | Threshold6 of Adaptive AG in AE. | 0x14 | Current |
| 0xBC(P20) | AGBTH7 | Threshold7 of Adaptive AG in AE. | 0x13 | Current |
| 0xBD(P20) | AGBTH8 | Threshold8 of Adaptive AG in AE. | 0x12 | Current |
| 0xC0(P20) | AGSKY | Threshold of AG in very bright condition | 0x14 | Current |
| 0xC3(P20) | AGDPCON | Threshold of AG to enter into dark condition at DPC operation | 0x60 | Current |
| 0xC4(P20) | AGDPCOFF | Threshold of AG to escape from dark condition at DPC operation | 0x58 | Current |
| 0xD3(P20) | YAVG | Average of luminance. | RO | |
| **Auto White Balance (Page Mode = 20)** | | | | |
| 0x10(P22) | AWBCTL1 | Control automatic white balance | 0x6B | Next |
| 0x11(P22) | AWBCTL2 | Control automatic white balance | 0x28 | Next |
| 0x30(P22) | ULVL | U chrominance level to converge in AWB | 0x80 | Current |
| 0x31(P22) | VLVL | V chrominance level to converge in AWB | 0x80 | Current |
| 0x38(P22) | UVTH1 | U/V chrominance threshold1 in AWB | 0x13 | Current |
| 0x39(P22) | UVTH2 | U/V chrominance threshold2 in AWB | 0x66 | Current |
| 0x40(P22) | YRANGE | Valid luminance range to detect white pixel | 0x88 | Current |
| 0x41(P22) | CDIFF | Threshold of chrominance difference to detect white pixel | 0x88 | Current |
| 0x42(P22) | CSUM | Threshold of chrominance summation to detect white pixel | 0x66 | Current |
| 0x46(P22) | WHTPXLTH | Threshold of number of white pixel for AWB | 0x0A | Current |
| 0x80(P22) | RGAIN | Red color gain | 0x30 | Next |
| 0x81(P22) | GGAIN | Green color gain | 0x20 | Next |
| 0x82(P22) | BGAIN | Blue color gain | 0x38 | Next |
| 0x83(P22) | RMAX | Maximum RGAIN in AWB | 0x50 | Current |
| 0x84(P22) | RMIN | Minimum RGAIN in AWB | 0x20 | Current |
| 0x85(P22) | BMAX | Maximum BGAIN in AWB | 0x50 | Current |
| 0x86(P22) | BMIN | Minimum BGAIN in AWB | 0x20 | Current |
| 0x87(P22) | RMAXB | Upper limit of RGAIN in bright condition | 0x50 | Current |
| 0x88(P22) | RMINB | Lower limit of RGAIN in bright condition | 0x3E | Current |
| 0x89(P22) | BMAXB | Upper limit of BGAIN in bright condition | 0x2E | Current |
| 0x8A(P22) | BMINB | Lower limit of BGAIN in bright condition | 0x20 | Current |
| 0x8B(P22) | RBEXPLMT | Threshold of exposure time to change the boundary of RGAIN / BGAIN | 0x08 | Current |
| 0x8D(P22) | RDELTA | Increasing (Decreasing) step of RGAIN | 0x04 | Current |
| 0x8E(P22) | BDELTA | Increasing (Decreasing) step of BGAIN | 0x60 | Current |
| 0x91(P22) | BGAINPARA3 | Parameter3 of BGAIN | 0x48 | Current |
| 0x92(P22) | BGAINPARA4 | Parameter4 of BGAIN | 0x46 | Current |

| | | | | |
|---|---|---|---|---|
| 0x93(P22) | BGAINPARA5 | Parameter5 of BGAIN | 0x44 | Current |
| 0x94(P22) | BGAINPARA6 | Parameter6 of BGAIN | 0x42 | Current |
| 0x95(P22) | BGAINPARA7 | Parameter7 of BGAIN | 0x40 | Current |
| 0x96(P22) | BGAINPARA8 | Parameter8 of BGAIN | 0x3E | Current |
| 0x97(P22) | BGAINPARA9 | Parameter9 of BGAIN | 0x3C | Current |
| 0x98(P22) | BGAINPARA10 | Parameter10 of BGAIN | 0x28 | Current |
| 0x99(P22) | BGAINPARA11 | Parameter11 of BGAIN | 0x26 | Current |
| 0x9A(P22) | BGAINPARA12 | Parameter12 of BGAIN | 0x24 | Current |
| 0x9B(P22) | BGAINBND | Boundary of BGAIN | 0x04 | Current |
| 0xB2(P22) | MRGAIN | RGAIN for manual white balance | 0x48 | Current |
| 0xB3(P22) | MBGAIN | BGAIN for manual white balance | 0x40 | Current |
| 0xD2(P22) | UAVG | Average of U chrominance of white pixels in frame | RO | |
| 0xD3(P22) | VAVG | Average of V chrominance of white pixels in frame | RO | |

## 5.1. Common Group

**0x03 [common mode]: PAGEMODE [default=0x00, r/ w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Page Mode | ***User should set this register before controlling registers to adjust functions.***<br>***This register classified the group of function to control registers***.<br>0x00 = control image size, windowing, sync, black level calibration<br>0x02 = control analog circuit.<br>0x10 = control image format, image effect<br>0x11 = control Z-LPF<br>0x12 = control YC-LPF, B-LPF, dead pixel concealment.<br>0x13 = control edge enhancement<br>0x14 = control lens shading correction.<br>0x15 = control color correction<br>0x16 = control gamma correction.<br>0x17 = control auto flicker cancellation<br>0x20 = control auto exposure<br>0x22 = control auto white balance. | 0000_0000b |

**0x01 [page mode 0]: PWRCTL [default=0x51, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | PCLK Drive | It increases drivability of PCLK pin as high value | 01b |
| B[5:4] | Output Drive | It increases drivability of output pin as high value<br>(VSYNC, HSYNC, D[7:0] D_LSB0, D_LSB1) | 01b |
| B[3:2] | | Reserved | 00b |
| B[1] | Soft Reset | Enable Software reset. When this bit is high, registers' values are initialized. | 0b |
| B[0] | Power Sleep | Set power sleep by preserving the value of all registers. (0: OFF, 1: ON) | 1b |

## 5.2. Device Identification

**0x04 [page mode 0]: DEVID [default=0x96, r]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Device ID | Device ID to define YACBAE1SDDAC | 1001_0110b |

## 5.3. Image Size / Windowing / HSYNC / VSYNC [Type1]

**0x10 [page mode 0]: VDOCTL1 [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | | Reserved | 00b |
| B[5:4] | Sub-sampling | This function reduces image output resolution by skipping the number of rows and columns, while maintaining the same view and frame rate.<br>00: No sub-sampling(VGA), 01: 1/2 sub-sampling(skipping 2pixel, QVGA),<br>10: 1/4 sub-sampling(QQVGA), 11: Reserved | 00b |
| B[3] | VSYNC Type | 0 : HSYNC doesn't overlap with VSYNC [Type1]<br>1 : HSYNCs are in the VSYNC [Type2]. Refer to the timing description. | 0b |
| B[2] | PCLK option1 | PCLK Hi-z mode at VBLANK. | 0b |
| B[1] | PCLK option2 | PCLK Hi-z mode at HBLANK. | 0b |
| B[0] | Preview mode | Enable Preview mode | 0b |

Note) Refer to 4.12 [Timing Description]

**0x11 [page mode 0]: VDOCTL2 [default=0x90, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Windowing | User changes image size by setting WINROW[0x20,0x21:P0], WINCOL [0x22,0x23:P0], WINHGT [0x24,0x25:P0] and WINWID[0x26,0x27:P0]. (0:OFF, 1:ON) | 1b |
| B[6:4] | Bad Frame Skip | It is used to skip bad frames when image size is changed.<br>001: Skip 1frame. 010: Skip 2frames, 011: Skip 3frames<br>Note) Do not set 0. | 001b |
| B[3] | Fixed Frame Rate2 | It is used to exclude VBLANK at frame rate when frame time to be constant.<br>Refer to 5.13[Fixed Frame Rate Timing] | 0b |
| B[2] | Fixed Frame Rate1 | Set frame time to be constant, regardless of the change of exposure time. (0:OFF, 1:ON)<br>Refer to 5.13[Fixed Frame Rate Timing] | 0b |
| B[1] | Y Flip | Vertical Flip Function (0:OFF, 1:ON) | 0b |
| B[0] | X Flip | Horizontal Flip Function (0:OFF, 1:ON) | 0b |

**0x12 [page mode 0]: SYNCCTL [default=0x04, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | | Reserved | 00b |
| B[5] | VSYNC Polarity | Select polarity of VSYNC[Type1].<br>0 : When VSYNC[Type1] is high, there are no valid HSYNCs<br>When VSYNC[Type2] is high, there are valid HSYNCs<br>1 : When VSYNC[Type1] is low, there are no valid HSYNCs<br>When VSYNC[Type2] is low, there are valid HSYNCs | 0b |
| B[4] | HSYNC Polarity | Select polarity of HSYNC.<br>0: Active High : When HSYNC is high, image data is valid.<br>1: Active Low : When HSYNC is low, image data is valid. | 0b |
| B[3] | VSYNC Clipping | Clip VSYNC[Type1]. Refer to VSCLIP[0x44:P0] (0:OFF, 1:ON) | 0b |
| B[2] | Clock Inversion | Select phase of PCLK<br>0: D[7:0] are synchronized at rising edge of PCLK<br>1: D[7:0] are synchronized at falling edge of PCLK | 1b |
| B[1:0] | Clock Divider | Divides the frequency of internal CLOCK<br>00:1x, 01:1/2x, 10: 1/4x. 11: 1/8x | 00b |

**0x20[page mode 0]: WINROWH [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | Windowing | Reserved | 0000_0b |
| B[2:0] | | High byte of row start point for windowing<br>WINROW[8:0]= WINROWH[0] X 256 + WINROWL[7:0]<br>Both WINROWH and WINROWL should be updated when WINROW is changed.<br>Refer to 5.10[Windowing] for recommended setting value | 000b |

**0x21[page mode 0]: WINROWL [default=0x05, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Windowing | Low byte of row start point for windowing | 0000_0101b |

**0x22[page mode 0]: WINCOLH [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | Windowing | Reserved | 0000_0b |
| B[2:0] | | High byte of column start point for windowing<br>WINCOL[8:0]= WINCOLH[0] X 256 + WINCOLL[7:0]<br>Both WINCOLH and WINCOLL should be updated when WINCOL is changed.<br>Refer to 5.10[Windowing] | 000b |

**0x23[page mode 0]: WINCOLL [default=0x07, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Windowing | Low byte of column start point for windowing | 0000_0111b |

**0x24[page mode 0]: WINHGTH [default=0x01, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | Windowing | Reserved | 0000_0b |
| B[2:0] | | High byte of height for windowing<br>WINHGT[9:0]= WINHGTH[1:0] X 256 + WINHGTL[7:0].<br>Both WINHGTH and WINHGTL should be updated when WINHGT is changed.<br>Refer to 5.10[Windowing] | 001b |

**0x25[page mode 0]: WINHGTL [default=0xE0, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Windowing | Low byte of height for windowing | 1110_0000b |

**0x26[page mode 0]: WINWIDH [default=0x02, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | | Reserved | 0000_0b |
| B[2:0] | Windowing | High byte of width for windowing<br>WINWID[9:0]= WINWIDH[1:0] X 256 + WINWIDL[7:0].<br>Both WINWIDH and WINWIDL should be updated when WINWID is changed.<br>Refer to 5.10[Windowing] | 010b |

**0x27[page mode 0]: WINWIDL [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Windowing | Low byte of width for windowing | 1000_0000b |

**0x40[page mode 0]: HBLANKH [default=0x01, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | HBLANK | Reserved | 0000b |
| B[3:0] | | High byte of horizontal blanking time. Unit of HBLANK is OPCLK's period<br>HBLANK[11:0] = HBLANKH[3:0] X 256 + HBLANKL[7:0] .<br>HBLANK is interval between continuous image data lines(HSYNC).<br>HBLANK should be greater than 196 and should be multiple of 4.<br>Both HBLANKH and HBLANKL should be updated when HBLANK is changed.<br>Refer to 5.11[Frame Structure] and 5.12[Timing Description]<br>We recommend that HBLANK is set to meet following equation.<br>1) (EXP100[0x8B,8C:P20] * 8 * $T_{OPCLK}$) / (656 + HBLANK) should be integer for 100Hz flicker cancellation<br>2) (EXP120[0x8D,8E:P20] * 8 * $T_{OPCLK}$) / (656 + HBLANK) should be integer for 120Hz flicker cancellation<br>Note) When auto-flicker cancellation(100Hz/120Hz) is enabled, HBLANK should be set to meet 1) and 2). | 0001b |

**0x41[page mode 0]: HBLANKL [default=0x58, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | HBLANK | Low byte of horizontal blanking time | 0101_1000b |

**0x42[page mode 0]: VSYNCH [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | VSYNC | High byte of duration for vertical synchronization[Type1]<br>VSYNC is interval between continuous image frames.<br>VSYNC[15:0] = VSYNCH[7:0] X 256 + VSYNCL[7:0]<br>Unit of VSYNC is one line processing time (656 + HBLANK).<br>Both VSYNCH and VSYNCL should be updated when VSYNC is changed.<br>Refer to 5.11[Frame Structure] and 5.12[Timing Description]<br>Note) VSYNC should be over 4. | 0000_0000b |

**0x43[page mode 0]: VSYNCL [default=0x14, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | VSYNC | Low byte of duration for vertical synchronization[Type1] | 0001_0100b |

**0x44[page mode 0]: VSCLIP [default=0x09, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | VSYNC | VSCLIP is clipping line in VSYNC[Type1] when enabling bit[3] of SYNCTL[0x12:P0].<br>When the interval between last HSYNC and VSYNC[Type1] should be controlled, VSCLIP is used to adjust the interval.<br>Unit of VSYNC is one line processing time (656 + HBLANK)<br>Refer to 5.11[Frame Structure] and 5.12[Timing Description]<br>Note) VSCLIP should be under VSYNC | 0000_1001b |

**0x45[page mode 0]: VSCTL1 [default=0x01, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:2] | VSYNC | Reserved. | 0000_00b |
| B[1] | | High 1bits of start row position for vertical synchronization(Type2) | 0b |
| B[0] | | High 1bits of stop row position for vertical synchronization(Type2) | 1b |

**0x46[page mode 0]: VSCTL2 [default=0x02, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | VSYNC [Type2] | Low byte of start row position for vertical synchronization(Type2)<br>Vertical start row position = VSCTL1[1]*256 + VSCTL2[7:0]<br>Unit of Vertical start(stop) row position is one line processing time (664 + HBLANK).<br>VSYNC[Type2] duration = Vertical stop row position - Vertical start row position<br>Refer to 5.11[Frame Structure] and 5.12[Timing Description]<br>Note) Vertical start row position should not be under 4. | 0000_0010b |

**0x47[page mode 0]: VSCTL3 [default=0xE2, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | VSYNC [Type2] | Low byte of stop row position for vertical synchronization(Type2)<br>Vertical stop row position = VSCTL1[0]*256 + VSCTL3[7:0]. | 1110_0010b |

## 5.4. Black Level Calibration

**0x80[page mode 0]: BLCCTL [default=0x08, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | BLC | Reserved. | 0000b |
| B[3] | | Enable Black Level Calibration. (0: OFF, 1: ON) | 1b |
| B[2:1] | | Reserved | 00b |
| B[0] | | Enable additional black level. | 0b |

**0x90[page mode 0]: BLCTIMETHON [default=0x0C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[5:0] | BLC | Exposure time threshold to enable additional BLC | 0000_1100b |

**0x91[page mode 0]: BLCTIMETHOFF [default=0x0C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | BLC | Exposure time threshold to disable additional BLC | 0000_1100b |

**0x92[page mode 0]: BLCAGTHH [default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | BLC | AG threshold to enable additional BLC | 0110_0000b |

**0x93[page mode 0]: BLCAGTHL [default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | BLC | AG threshold to disable additional BLC | 0110_0000b |

**0xA0[page mode 0]: DOFSB [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | BLC | Reserved. | 0b |
| B[6] | | 0 = Plus offset, 1 = Minus offset | 0b |
| B[5:0] | | Blue color offset for additional black level | 00_0000b |

## 5.5. Image Output Format and Image Effect

**0x10[page mode 10]: ISPCTL1[default=0x03, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | Data Format | 0000: YUV4:2:2 8bit, 0100: RGB5:6:5 8bit, 0111: RGB4:4:4 | 0000b |
| B[3] | | Reserved. | 0b |
| B[2] | ITU656 | ITU656-like(0:OFF, 1:ON) | 0b |
| B[1] | Y Phase | Select U/V(R/B) and Y(G) phase for output data.<br>0: UYVY …. for U Phase is ON, VYUY…. for U Phase is OFF<br>1: YUYV …. for U Phase is ON, YVYU…. for U Phase is OFF | 1b |
| B[0] | U Phase | Select U(B) and V(R) phase for output data.<br>0: VYUY… for Y Phase is OFF, YVYU…. for Y Phase is ON<br>1: UYVY… for Y Phase is OFF, YUYV…. for Y Phase is ON | 1b |

**0x11[page mode 10]: ISPCTL2[default=0x03, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Byte | Enable Byte swap. | 0b |
| B[6] | Contrast | Enable Contrast Effect. (0:OFF, 1:ON)<br>User can control contrast effect by adjusting CONTRAST[0x48:P10]. | 0b |
| B[5] | Embossing | Embossing Effect (0:OFF, 1:ON) | 0b |
| B[4] | Sketch | Sketch Effect (0:OFF, 1:ON) | 0b |
| B[3] | Binary | Enable Binary Effect.(0:OFF, 1:ON)<br>User can control binary effect by adjusting BINARY[0x49:P10] | 00b |
| B[2] | Negative | When Negative Effect is enabled, user can select effect 1 of effect 2.<br>0: Negative Effect1, 1: Negative Effect2 | |
| B[1] | Color Space Conversion | Color space conversion is done by enabling this bit. (0:OFF, 1:ON)<br>RGB => YUV (Refer to 5.6[Color Space Conversion]) | 1b |
| B[0] | Color Interpolation | Because the raw data of the pixel array has only one of R, G or B for each pixel, sensor should perform color interpolation to recover the missing color component for each pixel. Color interpolation is done, by enabling this bit. (0:OFF, 1:ON) | 1b |

**0x12[page mode 10]: ISPCTL3[default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | V OFFSET | Control V by adding or subtracting VOFS[0x42:P10]. (0:OFF, 1:ON) | 0b |
| B[6] | U OFFSET | Control U by adding or subtracting UOFS[0x43:P10]. (0:OFF, 1:ON) | 0b |
| B[5] | Auto Bright | Control Y by adding DYOFS[0x41:P10] at dark environment. (0:OFF, 1:ON) | 0b |
| B[4] | Y OFFSET | Control Y by adding or subtracting YOFS[0x40:P10]. (0:OFF, 1:ON) | 0b |
| B[3] | Negative | Enable Negative effect | 0b |
| B[2] | Color Inversion | U' = V, V' = U (0:OFF, 1:ON) | 0b |
| B[1] | V Constant | This bit makes the output of V constant. User can get mono, sepia and other special image by setting UCON[0x44:P10] and VCON[0x45:P10]. (0:OFF, 1:ON) | 0b |
| B[0] | U Constant | This bit makes the output of U constant. User can get mono, sepia and other special image by setting UCON[0x44:P10] and VCON[0x45:P10]. (0:OFF, 1:ON) | 0b |

**0x14[page mode 10]: ISPCTL4[default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:5] | | Reserved | 000b |
| B[4] | ITU656 | BLANK code word (0: 0x8010, 1: 0x0000) | 0b |
| B[3] | | Reserved | 0b |
| B[2] | Range | Select range of YUV output data.<br>0= Y: 0 ~255, U: 0~255, V: 0~255, 1= Y: 16 ~235, U: 16~240, V: 16~240 | 0b |
| B[1] | | Reserved | 0b |
| B[0] | ITU656 | ITU656-like(0:OFF, 1:ON) | 0b |

**0x15[page mode 10]: PADCTL[default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | | Reserved | 0000b |
| B[3:2] | Pad control | Output pad control for Power Down Mode and Sleep Mode ( Data[7:0], Vsync, Hsync, Pclk).<br>0 : Hi-Z, 1 : VDD, 2 : GND | 00b |
| B[1:0] | | Reserved | 00b |

**0x40[page mode 10]: YOFS [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Brightness | Luminance offset(Brightness function) is controlled by the following equation and bit[4] of ISPCTL2[0x12:P10].<br>Y' = Y + YOFS[6:0], for YOFS[7] = 0<br>= Y - YOFS[6:0], for YOFS[7] = 1 | 0000_0000b |

**0x41[page mode 10]: DYOFS [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | | Reserved | 00b |
| B[5:0] | Auto Brightness | Luminance offset coefficient at dark condition.<br>When AG[0xB0:P20] is greater than AGBRT[0x50:P10] at dark environment by auto exposure control, sensor controls luminance by following equation<br>Y' = Y + DYOFS[5:0] for AG > AGBRT<br>= Y elsewhere | 00_0000b |

**0x42[page mode 10]: UOFS [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | U Offset | U chrominance offset coefficient.<br>U chrominance offset is controlled by the following equation and bit[6] of ISPCTL3[0x12:P10].<br>U' = U + UOFS[6:0], for UOFS[7] = 0<br>= U - UOFS[6:0], for UOFS[7] = 1 | 0000_0000b |

**0x43[page mode 10]: VOFS [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | V Offset | V chrominance offset coefficient.<br>V chrominance offset is controlled by the following equation and bit[7] of ISPCTL2[0x12:P10].<br>V' = V + VOFS[6:0], for VOFS[7] = 0<br>= V - VOFS[6:0], for VOFS[7] = 1 | 0000_0000b |

**0x44[page mode 10]: UCON [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Chrominance Constant | UCON makes the output of U constant and VCON makes the output of V constant.<br>User can get mono, sepia and other special image by controlling these values and bit[1:0] of ISPCTL2[0x12:P10].<br>Example) Mono: UCON=0x80 and VCON=0x80 | 1000_0000b |

**0x45[page mode 10]: VCON [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Chrominance Constant | UCON makes the output of U constant and VCON makes the output of V constant.<br>User can get mono, sepia and other special image by controlling these values and bit[1:0] of ISPCTL2[0x12:P10].<br>Example) Mono: UCON=0x80 and VCON=0x80 | 1000_0000b |

**0x47[page mode 10]: BINARY [default=0x7F, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Binary Effect | Threshold of Binary Effect. | 0111_1111b |

**0x48[page mode 10]:CONTRAST [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Contrast | Parameter for Contrast Effect.<br>Programmable range is from 0x80 (1x) to from 0xFF(1.99x) | 1000_0000b |

**0x50[page mode 10]:AGBRT [default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Auto Bright | When AG is greater than AGBRT at dark environment by auto exposure control, sensor controls luminance by enabling bit[5] of ISPCTL2[0x12:P10] and setting DYOFS[0x41:P10]. | 0110_0000b |

**0x60[page mode 10]: SATCTL[default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | | Reserved | 0000b |
| B[3:2] | Suppression Ratio | Suppression ratio in auto color saturation. 00 ~ 11(more suppression) | 00b |
| B[1] | Auto Color Saturation | Enable auto color saturation. As AG[0xB0:P20] is increased, the more color noise is occurred in image. To suppress the color noise, color saturation is decreased as AG (0:OFF, 1:ON) | 0b |
| B[0] | Manual Color Saturation | When this bit is enabled, SATB[0x61:P10] and SATR[0x62:P10] are multiplied to U and V. (0:OFF, 1:ON) | 0b |

**0x62[page mode 10]: SATB [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Saturation B Gain | Blue color saturation coefficient. SATB is gain of color difference signal U.<br>It is enabled by bit[0] of SATCTL[0x60:P10]. 0x00 ~ 0xFF(more U color saturation) | 1000_0000b |

**0x63[page mode 10]: SATR [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Saturation R Gain | Red color saturation coefficient. SATR is gain of color difference signal V.<br>It is enabled by bit[0] of SATCTL [0x60:P10]. 0x00 ~ 0xFF(more V color saturation) | 1000_0000b |

**0x64[page mode 10]:AGSAT [default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Saturation | When AG is greater than AGSAT, auto color de-saturation is performed by setting bit[3:1] of SATCTL[0x60:P10].<br>AGSAT = 0.5 + B[7:0]/32. | 0110_0000b |

## 5.6. Z-LPF (Noise Reduction)

**0x10[page mode 11]: ZLPFCTL1 [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Z-LPF | Disable Z-LPF at bright condition. (0:OFF, 1:ON) | 0b |
| B[6] | | Reserve | 0b |
| B[5:3] | | Ratio of automatic LPF threshold for Z-LPF ( 00(more blur) ~ 11) | 000b |
| B[2] | | When AG is over the AGDPCON is enabled | 0b |
| B[1] | | Enable I-LPF at all condition(0:OFF, 1:ON). | 0b |
| B[0] | | Enable Z-LPF (0:OFF, 1:ON). | 0b |

**0x11[page mode 11]: ZLPFCTL2 [default=0x1A, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Z-LPF | Option for Z-LPF | 0001_1010b |

**0x20[page mode 11]: ZLPFCTL3 [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | Z-LPF | Reserved. | 00b |
| B[5:4] | | Reserved. | 00b |
| B[3:2] | | Ratio for increase volume of automatic Z-LPF threshold to AG<br>00(more blur) ~ 11 | 00b |
| B[1:0] | | Ratio for increase volume of automatic Z-LPF threshold to exposure time.<br>00(more blur) ~ 11 | 00b |

**0x21[page mode 11]: ZLPFAGTH [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Z-LPF | Threshold of AG to reinforce LPF.<br>When AG is increased and over the LPFAGTH, automatic LPF threshold is increased. | 0010_0000b |

**0x23[page mode 11]: ZLPFEXPTH [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Z-LPF | Threshold of exposure time to reinforce LPF.<br>When exposure time is increased and over the LPFEXPTH, automatic LPF threshold is increased. | 0001_0000b |

**0x60[page mode 11]: ZLPFTH1 [default=0x40, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Z-LPF | Threshold for Z-LPF<br>0x00 ~ 0xFF(more blur) | 0100_0000b |

**0x61[page mode 11]: ZLPFTH2 [default=0x40, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Z-LPF | Threshold for Z-LPF<br>0x00 ~ 0xFF(more blur) | 0100_0000b |

**0x62[page mode 11]: ZLPFHLVL [default=0x83, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:2] | Z-LPF | Threshold to reinforce Z-LPF at high level | 1000_00b |
| B[1:0] | | Z-LPF ratio at high level 0 ~ 3(more blur) | 11b |

**0x63[page mode 11]: ZLPFLLVL[default=0x43, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:2] | Z-LPF | Threshold to reinforce Z-LPF at low level | 0100_00b |
| B[1:0] | | Z-LPF ratio at low level , 0 ~3(more blur) | 11b |

**0x64[page mode 11]: ZLPFDYTH [default=0x23, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:2] | Z-LPF | Threshold of dynamic range for Z-LPF. | 0010_00b |
| B[1:0] | | Reserved. | 11b |

## 5.7. YC-LPF (Noise Reduction)

**0x40[page mode 12]: YCLPFCTL1 [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:2] | YC-LPF | Option for YC-LPF | 0000_00b |
| B[1] | | Enable C-LPF (0: OFF, 1:ON) | 0b |
| B[0] | | Enable Y-LPF (0: OFF, 1:ON) | 0b |

**0x41[page mode 12]: YCLPFCTL2 [default=0x30, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | YC-LPF | Option for YC-LPF | 0011_0000b |

**0x50[page mode 12]: YCLPFTH [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[6:0] | YC-LPF | Threshold for YC-LPF | 0001_0000b |

## 5.8. B-LPF (Noise Reduction)

**0x70[page mode 12]: BLPFCTL [default=0x1C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:1] | B-LPF | Option for B-LPF | 0001_110b |
| B[0] | | Enable B-LPF (0: OFF, 1:ON) | 0b |

**0x74[page mode 12]:BLPFTH1 [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[6:0] | B-LPF | Threshold of B-LPF for G color | 0001_0000b |

**0x75[page mode 12]: BLPFTH2 [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | B-LPF | Threshold of B-LPF for R/B color. | 0001_0000b |

## 5.9. Dead Pixel Concealment

**0x90[page mode 12]: DPC_CTL1 [default=0x3D, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | | Reserved | 00b |
| B[5] | | Reserved | 1b |
| B[4] | DPC Dark Option | If enabled, activate median algorithm(dark option) in dark condition | 1b |
| B[3:2] | | Reserved | 11b |
| B[1] | Dpc_thld_sel | '1' = fixed threshold<br>'0' = adaptive threshold | 0b |
| B[0] | Dpc_Enable | DPC ENABLE | 1b |

## 5.10. Edge Enhancement

**0x10[page mode 13]: EDGECTL1 [default=0x18, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | Edge Enhancement | Reserved | 0001_1b |
| B[2:1] | | Reserved | 00b |
| B[0] | | Enable edge enhancement (0:OFF, 1:ON) | 0b |

**0x14[page mode 13]: EDGECTL2 [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | Edge Enhancement | Reserved. | 00b |
| B[5:3] | | Ratio for edge gain as AG | 00_0b |
| B[2:0] | | Ratio for edge gain as exposure time | 000b |

**0x20[page mode 13]: EDGENGAIN[default=0x07, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[5:0] | Edge Enhancement | Edge gain to emphasize negative edge data. 0x00~ 0x3F(more sharp) | 00_0111b |

**0x21[page mode 13]: EDGEPGAIN[default=0x07, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[5:0] | Edge Enhancement | Edge gain to emphasize positive edge data. 0x00~ 0x3F(more sharp) | 00_0111b |

**0x23[page mode 13]: EDGEHCLIPTH [default=0x30]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Edge Enhancement | High clip threshold | 0011_0000b |

**0x24[page mode 13]: EDGELCLIPTH [default=0x00]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Edge Enhancement | Low clip threshold | 0000_0000b |

**0x28[page mode 13]: EDGETIMETH [default=0x10]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Edge Enhancement | Threshold of Exposure time for automatic edge enhancement. | 0001_0000b |

**0x29[page mode 13]: EDGEAGTH [default=0x30]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Edge Enhancement | Threshold of AG for automatic edge enhancement. | 0011_0000b |

**0x80[page mode 13]: EDGE2DCTL1[default=0x06, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | Edge Enhancement | Reserved | 0000b |
| B[3:1] | | Low clip option for 2nd edge enhancement | 011b |
| B[0] | | Enable 2nd edge enhancement (0:OFF, 1:ON) | 0b |

**0x81[page mode 13]: EDGE2DCTL2[default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | Edge Enhancement | Reserved. | 00b |
| B[5:4] | | Option for 2nd edge enhancement | 01b |
| B[3:1] | | Ratio of low clip for 2nd edge enhancement | 000b |
| B[0] | | Enable high clip for 2nd edge enhancement | 0b |

**0x90[page mode 13]: EDGE2DNGAIN[default=0x07, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[5:0] | Edge Enhancement | Edge gain to emphasize negative edge data for 2nd edge enhancement.<br>0x00~ 0x3F(more sharp) | 00_0111b |

**0x91[page mode 13]: EDGE2DPGAIN[default=0x07, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[5:0] | Edge Enhancement | Edge gain to emphasize positive edge data for 2nd edge enhancement.<br>0x00~ 0x3F(more sharp) | 00_0111b |

**0x93[page mode 13]: EDGE2DHCLIPTH [default=0x30]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Edge Enhancement | High clip threshold for 2nd edge enhancement. | 0011_0000b |

**0x94[page mode 13]: EDGE2DLCLIPTH [default=0x00]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Edge Enhancement | Low clip threshold for 2nd edge enhancement. | 0000_0000b |

## 5.11. Lens Shading Correction

**0x10[page mode 14]: LENSCTL[default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | Lens Shading Correction | Reserved | 0000_0b |
| B[2:1] | | When B[2:1] is 2'b11, lens shading is controlled by AG. | 00b |
| B[0] | | Enable lens shading correction (0:OFF, 1:ON) | 0b |

**0x20[page mode 14]: XCEN[default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Lens Shading Correction | It indicates optical center point on x-axis of pixel array to compensate lens shading.<br>Optical center on x-axis = 196 + b[7:0] | 1000_0000b |

**0x21[page mode 14]: YCEN[default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Lens Shading Correction | It indicates optical center point on y-axis of pixel array to compensate lens shading.<br>Optical center on y-axis = 118 + b[7:0] | 1000_0000b |

**0x22[page mode 14]: LENSR[default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Lens Shading Correction | Lens shading compensation coefficient in R color. | 0110_0000b |

**0x23[page mode 14]: LENSG[default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Lens Shading Correction | Lens shading compensation coefficient in G color. | 0110_0000b |

**0x24[page mode 14]: LENSB[default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Lens Shading Correction | Lens shading compensation coefficient in B color. | 0110_0000b |

**0x25[page mode 14]: LAGOFF[default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Lens Shading Correction | When AG is over LAGOFF and bit[2:1] of LENSCTL are enabled, lens shading correction is disabled automatically. | 0110_0000b |

**0x26[page mode 14]: LAGON[default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Lens Shading Correction | When AG is under LAGON and bit[2:1] of LENSCTL are enabled, lens shading correction is enabled automatically. | 0110_0000b |

## 5.12. Color Correction

**0x10[page mode 15]: CMCCTL[default=0x0E, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | | Reserved | 0000b |
| B[3] | CMC1x double | 0 : The range of CMC11, CMC12, CMC13 = -1.99 ~ 1.99<br>1 : The range of CMC11, CMC12, CMC13 = -3.99 ~ 3.99 | 1b |
| B[2] | CMC2x double | 0 : The range of CMC21, CMC22, CMC23 = -1.99 ~ 1.99<br>1 : The range of CMC21, CMC22, CMC23 = -3.99 ~ 3.99 | 1b |
| B[1] | CMC3x double | 0 : The range of CMC31, CMC32, CMC33 = -1.99 ~ 1.99<br>1 : The range of CMC31, CMC32, CMC33 = -3.99 ~ 3.99 | 1b |
| B[0] | CMC ON | Enable color correction (0:OFF, 1:ON) | 0b |

**0x14[page mode 15]: CMCOFSGH [default=0x38, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | High threshold of color offset gain | 0011_1000b |

**0x16[page mode 15]: CMCOFSGL [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Low threshold of color offset gain | 0010_0000b |

**0x17[page mode 15]: CMCSIGN [default=0x2F, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | Color Correction | Reserved | 00b |
| B[5] | | Sign of CMC12, 0: + , 1: - | 1b |
| B[4] | | Sign of CMC13, 0: + , 1: - | 0b |
| B[3] | | Sign of CMC21, 0: + , 1: - | 1b |
| B[2] | | Sign of CMC23, 0: + , 1: - | 1b |
| B[1] | | Sign of CMC31, 0: + , 1: - | 1b |
| B[0] | | Sign of CMC32, 0: + , 1: - | 1b |

Note) Sign of CMC11 and CMC22 and CMC33 is always +(positive)

**0x30[page mode 15]: CMC11 [default=0x4C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient11.<br>0x00(0) ~ 0xFF(1.99) for bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(3.99) for bit[3] of CMCCTL[0x10:P15] = 1 | 0100_1100b |

**0x31[page mode 15]: CMC12 [default=0x0C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient12.<br>Bit[5] of CMCSIGN[0x17:P15] = 0 and bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(1.99),<br>Bit[5] of CMCSIGN[0x17:P15] = 1 and bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(-1.99),<br>Bit[5] of CMCSIGN[0x17:P15] = 0 and bit[3] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(3.99),<br>Bit[5] of CMCSIGN[0x17:P15] = 1 and bit[3] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(-3.99) | 0000_1100b |

**0x32[page mode 15]: CMC13 [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient13.<br>Bit[4] of CMCSIGN[0x17:P15] = 0 and bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(1.99),<br>Bit[4] of CMCSIGN[0x17:P15] = 1 and bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(-1.99),<br>Bit[4] of CMCSIGN[0x17:P15] = 0 and bit[3] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(3.99),<br>Bit[4] of CMCSIGN[0x17:P15] = 1 and bit[3] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(-3.99) | 0000_0000b |

**0x33[page mode 15]: CMC21 [default=0x26, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient21<br>Bit[3] of CMCSIGN[0x17:P15] = 0 and bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(1.99),<br>Bit[3] of CMCSIGN[0x17:P15] = 1 and bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(-1.99),<br>Bit[3] of CMCSIGN[0x17:P15] = 0 and bit[2] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(3.99),<br>Bit[3] of CMCSIGN[0x17:P15] = 1 and bit[2] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(-3.99) | 0010_0110b |

**0x34[page mode 15]: CMC22 [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient22.<br>0x00(0) ~ 0xFF(1.99) for bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(3.99) for bit[2] of CMCCTL[0x10:P15] = 1 | 1000_0000b |

**0x35[page mode 15]: CMC23 [default=0x1A, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient23.<br>Bit[2] of CMCSIGN[0x17:P15] = 0 and bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(1.99),<br>Bit[2] of CMCSIGN[0x17:P15] = 1 and bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(-1.99),<br>Bit[2] of CMCSIGN[0x17:P15] = 0 and bit[2] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(3.99),<br>Bit[2] of CMCSIGN[0x17:P15] = 1 and bit[2] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(-3.99) | 0001_1010b |

**0x36[page mode 15]: CMC31 [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient31.<br>Bit[1] of CMCSIGN[0x17:P15] = 0 and bit[1] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(1.99),<br>Bit[1] of CMCSIGN[0x17:P15] = 1 and bit[1] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(-1.99),<br>Bit[1] of CMCSIGN[0x17:P15] = 0 and bit[1] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(3.99),<br>Bit[1] of CMCSIGN[0x17:P15] = 1 and bit[1] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(-3.99) | 0010_0000b |

**0x37[page mode 15]: CMC32 [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient32.<br>Bit[0] of CMCSIGN[0x17:P15] = 0 and bit[1] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(1.99),<br>Bit[0] of CMCSIGN[0x17:P15] = 1 and bit[1] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(-1.99),<br>Bit[0] of CMCSIGN[0x17:P15] = 0 and bit[1] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(3.99),<br>Bit[0] of CMCSIGN[0x17:P15] = 1 and bit[1] of CMCCTL[0x10:P15] = 1<br>0x00(0) ~ 0xFF(-3.99) | 1000_0000b |

**0x38[page mode 15]: CMC33 [default=0xE0, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Color Correction | Color correction coefficient33.<br>0x00(0) ~ 0xFF(1.99) for bit[0] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0xFF(3.99) for bit[0] of CMCCTL[0x10:P15] = 1 | 1110_0000b |

**0x40[page mode 15]: CMCOFS11 [default=0x12, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS11, 0: + , 1: - | 0b |
| B[6:0] | | It is color offset coefficient of CMC11. Absolute value of CMCOFS11.<br>0x00(0) ~ 0x7F(0.1245) for bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[3] of CMCCTL[0x10:P15] = 1 | 001_0010b |

**0x41[page mode 15]: CMCOFS12 [default=0xA0, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS12, 0: + , 1: - | 1b |
| B[6:0] | | It is color offset coefficient of CMC12. Absolute value of CMCOFS12.<br>0x00(0) ~ 0x7F(0.1245) for bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[3] of CMCCTL[0x10:P15] = 1 | 010_0000b |

**0x42[page mode 15]: CMCOFS13 [default=0x0E, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS13, 0: + , 1: - | 0b |
| B[6:0] | | It is color offset coefficient of CMC13. Absolute value of CMCOFS13.<br>0x00(0) ~ 0x7F(0.1245) for bit[3] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[3] of CMCCTL[0x10:P15] = 1 | 000_1110b |

**0x43[page mode 15]: CMCOFS21 [default=0x84, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS21, 0: + , 1: - | 1b |
| B[6:0] | | It is color offset coefficient of CMC21. Absolute value of CMCOFS21.<br>0x00(0) ~ 0x7F(0.1245) for bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[2] of CMCCTL[0x10:P15] = 1 | 000_0100b |

**0x44[page mode 15]: CMCOFS22 [default=0x08, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS22, 0: + , 1: - | 0b |
| B[6:0] | | It is color offset coefficient of CMC22. Absolute value of CMCOFS22.<br>0x00(0) ~ 0x7F(0.1245) for bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[2] of CMCCTL[0x10:P15] = 1 | 000_1000b |

**0x45[page mode 15]: CMCOFS23 [default=0x84, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS23, 0: + , 1: - | 1b |
| B[6:0] | | It is color offset coefficient of CMC23. Absolute value of CMCOFS23.<br>0x00(0) ~ 0x7F(0.1245) for bit[2] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[2] of CMCCTL[0x10:P15] = 1 | 000_0100b |

**0x46[page mode 15]: CMCOFS31 [default=0x8A, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS31, 0: + , 1: - | 1b |
| B[6:0] | | It is color offset coefficient of CMC31. Absolute value of CMCOFS31.<br>0x00(0) ~ 0x7F(0.1245) for bit[1] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[1] of CMCCTL[0x10:P15] = 1 | 000_1010b |

**0x47[page mode 15]: CMCOFS32 [default=0x02, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS32, 0: + , 1: - | 0b |
| B[6:0] | | It is color offset coefficient of CMC32. Absolute value of CMCOFS32.<br>0x00(0) ~ 0x7F(0.1245) for bit[1] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[1] of CMCCTL[0x10:P15] = 1 | 000_0010b |

**0x48[page mode 15]: CMCOFS33 [default=0x08, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | Color Correction | Sign of CMCOFS33, 0: + , 1: - | 0b |
| B[6:0] | | It is color offset coefficient of CMC33. Absolute value of CMCOFS33.<br>0x00(0) ~ 0x7F(0.1245) for bit[1] of CMCCTL[0x10:P15] = 0<br>0x00(0) ~ 0x7F(0.2490) for bit[1] of CMCCTL[0x10:P15] = 1 | 000_1000b |

## 5.13. Gamma Correction

**0x10[page mode 16]: GMACTL [default=0x01, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:1] | Gamma Correction | Reserved | 0000_000b |
| B[0] | | Enable Gamma Correction | 1b |

**0x30[page mode 16]: GMA0 [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 0(0)code in 10(8)bit linear input | 0000_0000b |

**0x31[page mode 16]: GMA1 [default=0x15, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 16(4)code in 10(8)bit linear input | 0001_0101b |

**0x32[page mode 16]: GMA2 [default=0x1F, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 32(8)code in 10(8)bit linear input | 0001_1111b |

**0x33[page mode 16]: GMA3 [default=0x30, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 64(16)code in 10(8)bit linear input | 0011_0000b |

**0x34[page mode 16]: GMA4 [default=0x49, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 128(32)code in 10(8)bit linear input | 0100_1001b |

**0x35[page mode 16]: GMA5 [default=0x5D, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 192(48)code in 10(8)bit linear input | 0101_1101b |

**0x36[page mode 16]: GMA6 [default=0x6F, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 256(64) 10(8)bit linear input | 0110_1111b |

**0x37[page mode 16]: GMA7 [default=0x7F, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 320(80)code in 10(8)bit linear input | 0111_1111b |

**0x38[page mode 16]: GMA8 [default=0x8E, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 384(96)code in 10(8)bit linear input | 1000_1110b |

**0x39[page mode 16]: GMA9 [default=0x9B, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 448(112)code in 10(8)bit linear input | 1001_1011b |

**0x3A[page mode 16]: GMA10 [default=0xA8, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 512(128)code in 10(8)bit linear input | 1010_1000b |

**0x3B[page mode 16]: GMA11 [default=0xC1, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 640(160)code in 10(8)bit linear input | 1100_0001b |

**0x3C[page mode 16]: GMA12 [default=0xD7, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 768(192)code in 10(8)bit linear input | 1101_0111b |

**0x3D[page mode 16]: GMA13 [default=0xF6, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 896(224)code in 10(8)bit linear input | 1111_0110b |

**0x3E[page mode 16]: GMA14 [default=0xFF, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Gamma Correction | Gamma corrected output at 1023(255)code in 10(8)bit linear input | 1111_1111b |

## 5.14. Auto Flicker Cancellation

**0xC0[page mode 17]: FLKMODE [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | Auto Flicker Cancellation | Reserved | 0000_00b |
| B[1:0] | | Number of skipped frames in Auto flicker cancellation.<br>00: Reserved, 01: 1 frame, 10: 2frame, 11: 3frame<br>Note) Do not select 0 for auto flicker cancellation | 00b |

**0xC4[page mode 17]: FLK200 [default=0x3C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Auto Flicker Cancellation | Number of horizontal line for 1/200sec.<br>FLK200 = (1/200sec) / horizontal line time ,<br>where horizontal line time= (656 + HBALNK)* OPCLK's period<br>When auto-flicker cancellation is enabled, HBLANK should be selected to meet that FLK200 and FLK240 are integer. | 0011_1100b |

**0xC5[page mode 17]:FLK240 [default=0x32, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Auto Flicker Cancellation | Number of horizontal line for 1/240sec<br>FLK240 = integer [ (1/240sec) / horizontal line ],<br>where horizontal line = (656 + HBALNK) * OPCLK's period<br>When auto-flicker cancellation is enabled, HBLANK should be selected to meet that FLK200 and FLK240 are integer. | 0011_0010b |

**0xC6[page mode 17]: FLKTH1 [default=0x02, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Auto Flicker Cancellation | Low Threshold to find flicker condition.<br>When internal calculated value is over FLKTH1 and under FLKTH2, sensor can detect flicker noise(banding noise) on image. | 0000_0010b |

**0xC7[page mode 17]: FLKTH2 [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | Auto Flicker Cancellation | High threshold to find flicker condition.<br>When internal calculated value is over FLKTH1 and under FLKTH2, sensor can detect flicker noise(banding noise) on image. | 0010_0000b |

## 5.15. Auto Exposure

**0x10[page mode 20]: AECTL1[default=0x0C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | AE Enable | Enable auto exposure. (0:OFF, 1:ON)<br>When this bit is disabled, AFC(Auto Flicker Cancellation) operation is also disabled. | 0b |
| B[6] | Auto Anti-Flicker | Sensor detects the frequency of fluorescent lamp(100Hz/120Hz) and adjusts exposure time to multiple of period of the frequency automatically. (0:OFF, 1:ON) | 0b |
| B[5] | | Reserved | 0b |
| B[4] | 120Hz/100Hz | On canceling flicker manually, user should select the frequency of a fluorescent lamp.<br>0: 120Hz, 1: 100Hz | 0b |
| B[3:0] | | Reserved. | 1100b |

**0x11[page mode 20]: AECTL2[default=0x04, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Option for AE. | 0000_0100b |

**0x20[page mode 20]: AEFRAMECTL [default=0x01, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:1] | | Reserved | 0000_000b |
| B[0] | AE WEIGHT | Enable AE weight (0:OFF, 1:ON), Refer to AEWGT[0x60:P20 ] | 1b |

**0x28[page mode 20]: AEFINECTL1 [default=0x27, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | AE | Reserved. | 0010_0b |
| B[2] | | Exposure Step option. | 1b |
| B[1:0] | | Reserved. | 11b |

**0x29[page mode 20]: AEFINECTL2 [default=0xA5, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Option for speed of AE | 1010_0101b |

**0x2A[page mode 20]: AEFINECTL3 [default=0xF0, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Option for speed of AE<br>Recommended value = 0xF0 for variable frame rate.<br>= 0x00 for fixed frame rate. | 1111_0000b |

**0x2B[page mode 20]: AEFINECTL4 [default=0x35, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Option for speed of AE<br>Recommended value = 0x34 for variable frame rate.<br>= 0x35 for fixed frame rate. | 0011_0101b |

**0x60[page mode 20]: AEWGT [default=0x95, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:6] | AE | Center area weighting, 00 ~ 11 (more weight) | 10b |
| B[5:4] | | Top area weighting, 00 ~ 11 (more weight) | 01b |
| B[3:2] | | Bottom area weighting, 00 ~ 11 (more weight) | 01b |
| B[1:0] | | Side area weighting, 00 ~ 11 (more weight) | 01b |

Image Area is divided by center, top, bottom and side area for AE operation. User can set each area to separate weighting value.

**0x68[page mode 20]:AECENHST [default=0x40, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Horizontal start address for AE center area = B[7:0] * 4 | 0100_0000b |

**0x69[page mode 20]: AECENHEN [default=0x78, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Horizontal stop address for AE center area = B[7:0] * 4 | 0111_1000b |

**0x6A[page mode 20]: AECENVST [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Vertical start address for AE center area = B[7:0] * 2 | 0101_0000b |

**0x6B[page mode 20]: AECENVEN [default=0xA0, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Vertical stop address for AE center area = B[7:0] * 2 | 1010_0000b |

**0x70[page mode 20]:YLVL [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | YLVL is luminance level to converge in AE operation. | 0101_0000b |

**0x78[page mode 20]:YTH1 [default=0x22, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AE | Marginal range of Y convergence level in AE operation. | 0010b |
| B[3:0] | | Hysteresis range1 in AE operation. | 0010b |

**0x79[page mode 20]:YTH2 [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Hysteresis plus range2 in AE operation. | 0101_0000b |

**0x7C[page mode 20]:YTH3[default=0x28, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Hysteresis minus range2 in AE operation. | 0010_1000b |

**0x80[page mode 20]: EXPINTH [r]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | High byte of internal exposure time<br>EXPINT[23:0] = {EXPINTH[7:0], EXPINTM[7:0], EXPINTL[7:0]}<br>EXPINT is internal exposure time in current frame.<br>Example) EXPINTH=0x01, EXPINTM=0x86, EXPINTL=0xA0, period of OPCLK=83.333ns (MCLK=24MHz, OPCLK=12MHz)<br>EXPTIME = 0x01_86_A0 = 100000 decimal.<br>Exposure time = 100,000 X 8 X 83.333ns = 66.666ms | RO |

**0x81[page mode 20]: EXPINTM [r]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Middle byte of internal exposure time | RO |

**0x82[page mode 20]: EXPINTL [r]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Low byte of internal exposure time | RO |

**0x83[page mode 20]: EXPTIMEH [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | High byte of manual exposure time<br>EXPTIME[23:0] = {EXPTIMEH[7:0], EXPTIMEM[7:0], EXPTIMEL[7:0]}<br>EXPTIME is exposure time that makes pixel element to accumulate photons and convert electrons. Since the brightness of image may change by amount of exposure time, user should control the exposure time adequately. However, user does not need to control exposure time on auto exposure. The unit of exposure time is 8 times of OPCLK's period.<br>Example) EXPINTH=0x00, EXPINTM=0xC3, EXPINTL=0x50, period of OPCLK=83.333ns (MCLK=24MHz, OPCLK=12MHz)<br>EXPTIME = 0x00_C3_50 = 50,000 decimal.<br>Exposure time = 50,000 X 8 X 83.333ns = 33.333ms | 0000_0000b |

**0x84[page mode 20]: EXPTIMEM [default=0xC3, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Middle byte of manual exposure time | 1100_0011b |

**0x85[page mode 20]: EXPTIMEL [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Low byte of manual exposure time | 0101_0000b |

**0x86[page mode 20]: EXPMINH [default=0x01, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | High byte of minimum exposure time<br>EXPMIN = {EXPMINH, EXPMINL}<br>EXPMIN is minimum time of EXPTIME in AE operation. User should set EXPTIME[0x83, 0x84, 0x85:P20] over EXPMIN and EXPMIN should be greater than (664+HBLANK) /4.<br>Unit is 8 OPCLK's period. | 0000_0001b |

**0x87[page mode 20]: EXPMINL [default=0xF4, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Low byte of minimum exposure time | 1111_0100b |

**0x88[page mode 20]: EXPMAXH [default=0x02, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | High byte of maximum exposure time<br>EXPMAX[23:0] = {EXPMAXH[7:0], EXPMAXM[7:0], EXPMAXL[7:0]}<br>EXPMAX is maximum time of EXPTIME in AE operation.<br>Example) EXPMAXH=0x01, EXPMAXM=0x86, EXPMAXL=0xA0, period of OPCLK=83.333ns (MCLK=24MHz, OPCLK=12MHz)<br>EXPMAX = 0x01_86_A0 = 100,000 decimal.<br>Maximum exposure time = 100,000 X 8 X 83.333ns = 66.666msms | 0000_0010b |

**0x89[page mode 20]: EXPMAXM [default=0x49, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Middle byte of maximum exposure time | 0100_1001b |

**0x8A[page mode 20]: EXPMAXL [default=0xF0, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Low byte of maximum exposure time | 1111_0000b |

**0x8B[page mode 20]: EXP100H [default=0x3A, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE<br>AFC<br>(Auto Flicker Cancellation) | High byte of exposure time for 1/100sec<br>EXP100[15:0] = {EXP100H[7:0], EXP100L[7:0]}<br>EXP100 is anti-flickering exposure time step for 100Hz.<br>The unit of exposure time is 8 times of OPCLK's period (1 pixel clock period).<br>Example) EXP100 = anti-flickering exposure time step for 100Hz / (8 X period of OPCLK),<br>= 10ms / (8 X 83.333ns) = 15000(decimal)= 0x3A98<br>where MCLK = 24MHz and OPCLK =12MHz | 0011_1010b |

**0x8C[page mode 20]: EXP100L [default=0x98, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE/AFC | Low byte of exposure time for 1/100sec | 1001_1000b |

**0x8D[page mode 20]: EXP120H [default=0x30, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE/AFC | High byte of exposure time for 1/120sec<br>EXP120[15:0] = {EXP120H[7:0], EXP120L[7:0]}<br>EXP120 is anti-flickering exposure time step for 120Hz.<br>The unit of exposure time is 8 times of OPCLK's period (1 pixel clock period).<br>Example) EXP120 = anti-flickering exposure time step for 120Hz / (8 X period of OPCLK),<br>= 8.3333ms / (8 X 83.333ns) = 12500(decimal)= 0x30D4<br>where MCLK = 24MHz and OPCLK =12MHz | 0011_0000b |

**0x8E[page mode 20]: EXP120L [default=0xD4, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE/AFC | Low byte of exposure time for 1/120sec | 1101_0100b |

**0x91[page mode 20]: EXPFIXH [default=0x02, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | FFR (Fixed Frame Rate) | High byte of exposure time for fixed frame rate<br>EXPFIX[23:0]= {EXPFIXH[7:0], EXPFIXM[7:0], EXPFIXL[7:0]}<br>EXPFIX makes Frame Time constant by enabling bit[2] of VDOCTL2[0x11:P0] regardless of the change of exposure time . EXPFIX should be over 1.25 times of EXPMAX.<br>EXPFIX should be set multiple of one line. (One line = 656 + HBLANK)<br>Frame Time = EXPFIX Duration + VSYNC Duration<br>Example) EXPFIXH=0x1, EXPFIXM=0xFB, EXPFIXL=0xD0, period of OPCLK=41.666ns (MCLK=24MHz, OPCLK=12MHz)<br>EXPFIX = 0x01_FB_D0 = 130,000 decimal.<br>Exposure time for fixed frame rate= 130,000 X 8 X 83.333ns = 86.666ms | 0000_0010b |

**0x92[page mode 20]: EXPFIXM [default=0xF9, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | FFR | Middle byte of exposure time for fixed frame rate | 1111_1001b |

**0x93[page mode 20]: EXPFIXL [default=0xB8, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | FFR | Low byte of exposure time for fixed frame rate | 1011_1000b |

**0x98[page mode 20]: EXPOUT1 [default=0x9A, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AE | Threshold of exposure time to enter into bright condition | 1001b |
| B[3:0] | | Threshold of exposure time to escape from bright condition | 1010b |

**0x99[page mode 20]: EXPOUT2 [default=0x45, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AE | Threshold of exposure time to enter into very bright condition | 0100b |
| B[3:0] | | Threshold of exposure time to escape from very bright condition | 0101b |

**0x9C[page mode 20]: EXPLMTH [default=0x01, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | High byte of exposure time for low limit.<br>EXPLMT[15:0] = {EXPLMTH[7:0], EXPLMTL[7:0]}<br>It should be multiple of (664+HBLANK)/2. | 0000_0001b |

**0x9D[page mode 20]: EXPLMTL [default=0xF4, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Low byte of exposure time for low limit. | 1111_0100b |

**0x9E[page mode 20]: EXPUNITH [default=0x00, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | High byte of unit step of EXPLMT.<br>EXPUNIT = {EXPUNITH[7:0], EXPUNITL[7:0]}<br>It should be multiple of (664+HBLANK)/4. | 0000_0000b |

**0x9F[page mode 20]: EXPUNITL [default=0xC8, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Low byte of unit step of EXPLMT | 1100_1000b |

**0xB0[page mode 20]:AG [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | AG is common gain for R, G and B channel and is used for AE operation.<br>AG = 0.5 + B[7:0]/32. | 0001_0000b |

**0xB1[page mode 20]:AGMIN [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | AGMIN is minimum AG in AE operation.<br>AGMIN should be under the AGTH1[0xB4:P20]. | 0001_0000b |

**0xB2[page mode 20]:AGMAX [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | AGMAX is maximum AG in AE operation.<br>AGMAX should be over the AGTH2[0xB5:P20]. | 1000_0000b |

**0xB3[page mode 20]:AGLVL [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | AGLVL is target of AG to converge on abrupt transition | 0001_0000b |

**0xB4[page mode 20]:AGTH1 [default=0x10, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | AGTH1 is lower limit of AG, when exposure time is from 1/100sec(1/120sec) to EXPMAX. | 0001_0000b |

**0xB5[page mode 20]:AGTH2 [default=0x33, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | AGTH2 is upper limit of AG, when exposure time is from 1/100sec(1/120sec) to EXPMAX | 0011_0011b |

**0xB6[page mode 20]: AGBTH1 [default=0x22, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold1 of Adaptive AG in AE. | 0010_0010b |

**0xB7[page mode 20]: AGBTH2 [default=0x1C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold2 of Adaptive AG in AE. | 0001_1100b |

**0xB8[page mode 20]: AGBTH3 [default=0x19, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold3 of Adaptive AG in AE. | 0001_1001b |

**0xB9 [page mode 20]: AGBTH4 [default=0x17, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold4 of Adaptive AG in AE. | 0001_0111b |

**0xBA[page mode 20]: AGBTH5 [default=0x15, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold5 of Adaptive AG in AE. | 0001_0101b |

**0xBB[page mode 20]: AGBTH6 [default=0x14, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold6 of Adaptive AG in AE. | 0001_0100b |

**0xBC[page mode 20]: AGBTH7 [default=0x13, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold7 of Adaptive AG in AE. | 0001_0011b |

**0xBD[page mode 20]: AGBTH8 [default=0x12, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold8 of Adaptive AG in AE. | 0001_0010b |

**0xC0[page mode 20]: AGSKY[default=0x14, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold of AG at very bright condition | 0001_0100b |

**0xC3[page mode 20]:AGDPCON [default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold of AG to enter into dark condition at DPC operation | 0110_0000b |

**0xC4[page mode 20]:AGDPCOFF[default=0x58, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Threshold of AG to escape from dark condition at DPC operation | 0101_1000b |

**0xD3[page mode 20]: YAVG[r]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AE | Average of luminance in frame. | RO |

## 5.16. Auto White Balance

**0x10[page mode 22]: AWBCTL1[default=0x6B, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | AWB | Enable Automatic White Balance (0: OFF, 1: ON) | 0b |
| B[6:4] | | The update speed of AWB (slow) 000 ~ 111 (fast) | 110b |
| B[3:0] | | Option for speed of AWB | 1011b |

**0x11[page mode 22]: AWBCTL2[default=0x28, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:3] | AWB | Reserved | 0010_1b |
| B[2] | | Use the relation of RGAIN and BGAIN (0:OFF, 1:ON) | 0b |
| B[1] | | Change the boundary of RGAIN and BGAIN at bright condition (0:OFF, 1:ON) | 0b |
| B[0] | | Enable manual white balance (0:OFF, 1:ON) | 0b |

**0x30[page mode 22]: ULVL [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | U chrominance level to converge in AWB. | 1000_0000b |

**0x31[page mode 22]: VLVL [default=0x80, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | V chrominance level to converge in AWB. | 1000_0000b |

**0x38[page mode 22]: UVTH1 [default=0x13, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | Marginal range of white U/V convergence level in AWB operation | 0001b |
| B[3:0] | | Hysteresis range1 of white U/V in AWB operation | 0011b |

**0x39[page mode 22]: UVTH2 [default=0x66, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | B[7:4]*2 is Hysteresis range2 of white U/V in AWB operation | 0110b |
| B[3:0] | | B[3:0]*8 is Hysteresis range3 of white U/V in AWB operation | 0110b |

**0x40[page mode 22]: YRANGE [default=0xF3, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | YMAX is maximum luminance to find white pixel. YMAX = 128 + B[7:4]*8. | 1111b |
| B[3:0] | | YMIN is minimum luminance to find white pixel. YMIN = B[3:0]*8. | 0011b |

**0x41[page mode 22]: CDIFF [default=0x66, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | It is high threshold of the difference between U and V and is used to find the white pixel | 0110b |
| B[3:0] | | It is low threshold of the difference between U and V and is used to find the white pixel | 0110b |

**0x42[page mode 22]: CSUM [default=0x44, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | It is high threshold of the summation of U and V and is used to find the white pixel. | 0100b |
| B[3:0] | | It is low threshold of the summation of U and V and is used to find the white pixel. | 0100b |

**0x46[page mode 22]: WHTPXLTH [default=0x0A, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Threshold of white pixels in frame. | 0000_1010b |

**0x80[page mode 22]: RGAIN [default=0x30, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | | Reserved | 0b |
| B[6:0] | AWB | RGAIN (Red Color Gain) = 0.5 + B[6:0]/64 (0.5 ~ 2.5x)<br>Sensor has red, green, and blue color gain respectively. User can control white balance manually by setting these value and bit[7] of AWBCTL1[0x10:P22]=OFF. | 011_0000b |

**0x81[page mode 22]: GGAIN [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | | Reserved | 0b |
| B[6:0] | AWB | GGAIN (Green Color Gain) = 0.5 + B[6:0]/64(0.5 ~ 2.5x)<br>Sensor has red, green, and blue color gain respectively. User can control white balance manually by setting these value and bit[7] of AWBCTL1[0x10:P22]=OFF. | 010_0000b |

**0x82[page mode 22]: BGAIN [default=0x38, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7] | | Reserved | 0b |
| B[6:0] | AWB | BGAIN (Blue Color Gain) = 0.5 + B[6:0]/64(0.5 ~ 2.5x)<br>Sensor has red, green, and blue color gain respectively. User can control white balance manually by setting these value and bit[7] of AWBCTL1[0x10:P22]=OFF. | 011_1000b |

**0x83[page mode 22]: RMAX [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is maximum of RGAIN. | 0101_0000b |

**0x84[page mode 22]: RMIN [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is minimum of RGAIN. | 0010_0000b |

**0x85[page mode 22]: BMAX [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is maximum of BGAIN. | 0101_0000b |

**0x86[page mode 22]: BMIN [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is minimum of BGAIN. | 0010_0000b |

**0x87[page mode 22]: RMAXB [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is maximum of RGAIN at bright condition. | 0101_0000b |

**0x88[page mode 22]: RMINB [default=0x3E, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is minimum of RGAIN at bright condition. | 0011_1110b |

**0x89[page mode 22]: BMAXB [default=0x2E, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is maximum of BGAIN at bright condition. | 0010_1110b |

**0x8A[page mode 22]: BMINB [default=0x20, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | It is minimum of BGAIN at bright condition. | 0010_0000b |

**0x8B[page mode 22]: RBEXPLMT [default=0x08, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Threshold of exposure time to change the boundary of RGAIN/ BGAIN | 0000_1000b |

**0x8D[page mode 22]: RDELTA [default=0x04, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | The amount of increasing step to change the boundary of RGAIN | 0000b |
| B[3:0] | | The amount of decreasing step to change the boundary of RGAIN | 0100b |

**0x8E[page mode 22]: BDELTA [default=0x60, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | The amount of increasing step to change the boundary of BGAIN | 0110b |
| B[3:0] | | The amount of decreasing step to change the boundary of BGAIN | 0000b |

**0x8F[page mode 22]: BGAINPARA1 [default=0x50, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter1 of BGAIN. | 0101_0000b |

**0x90[page mode 22]: BGAINPARA2 [default=0x4C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter2 of BGAIN. | 0100_1100b |

**0x91[page mode 22]: BGAINPARA3 [default=0x48, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter3 of BGAIN.. | 0100_1000b |

**0x92[page mode 22]: BGAINPARA4 [default=0x46, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter4 of BGAIN. | 0100_0110b |

**0x93[page mode 22]: BGAINPARA5 [default=0x44, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter5 of BGAIN. | 0100_0100b |

**0x94[page mode 22]: BGAINPARA6 [default=0x42, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter6 of BGAIN. | 0100_0010b |

**0x95[page mode 22]: BGAINPARA7 [default=0x40, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter7 of BGAIN. | 0100_0000b |

**0x96[page mode 22]: BGAINPARA8 [default=0x3E, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter8 of BGAIN. | 0011_1110b |

**0x97[page mode 22]: BGAINPARA9 [default=0x3C, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter9 of BGAIN. | 0011_1100b |

**0x98[page mode 22]: BGAINPARA10 [default=0x28, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter10 of BGAIN. | 0010_1000b |

**0x99[page mode 22]: BGAINPARA11 [default=0x26, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter11 of BGAIN. | 0010_0110b |

**0x9A[page mode 22]: BGAINPARA12 [default=0x24, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | Parameter12 of BGAIN. | 0010_0100b |

**0x9B[page mode 22]: BGAINBND [default=0x04, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:4] | AWB | Reserved | 0000b |
| B[3:0] | | It is marginal range of BGAIN | 0100b |

**0xB2[page mode 22]: MRGAIN [default=0x48, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | When bit[0] AWBCTL2 is enabled, it is used for manual RGAIN in white balance.<br>MRGAIN = 0.5 + B[6:0]/64. Default is 1.625x | 0100_1000b |

**0xB3[page mode 22]: MBGAIN [default=0x40, r/w]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | When bit[0] AWBCTL2 is enabled, it is used for manual BGAIN in white balance.<br>MBGAIN = 0.5 + B[6:0]/64. Default is 1.5x | 0100_0000b |

**0xD2[page mode 22]: UAVG [r]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | U chrominance of white pixels in frame. | RO |

**0xD3[page mode 22]: VAVG [r]**

| Bit | Function | Description | Default |
|---|---|---|---|
| B[7:0] | AWB | V chrominance of white pixels in frame. | RO |

# 6. Color Filter Characteristics

<Figure 29. Spectral Response>