CMOS Image Sensor with Image Signal Processing

HV7151SP

Hynix Semiconductor Inc.

Preliminary Release
Version 0.7

Revision History

Revision	Script Date	Comments
0.0	2003-June	HV7151SP Preliminary is released
0.1	2003-June	HV7151SP version 0.1 is released
0.2	2003-July	HV7151SP version 0.2 is released
0.5	2003-August	HV7151SP version 0.5 is released
0.6	2003-November	Frame rate Calculation is added
0.7	2004-January	ENB Setting Guide Information and Recommend Circuit Information is Added

Contents

General Description

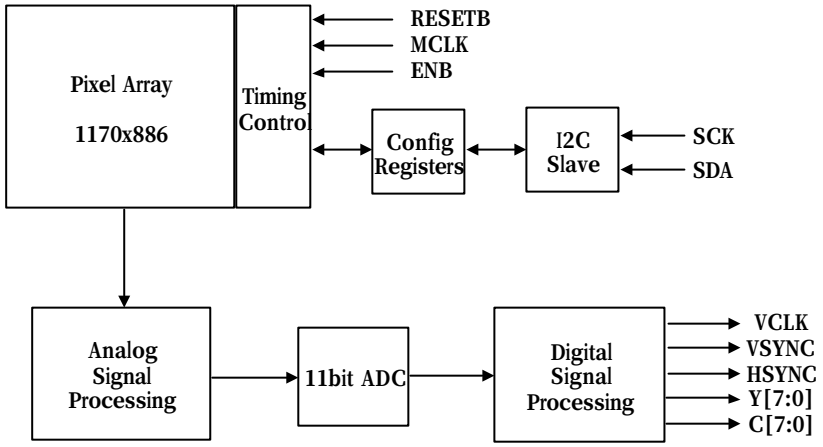
HV7151SP is a highly integrated single chip CMOS color image sensor implemented by proprietary Hynix 0.18um CMOS sensor process realizing high sensitivity and wide dynamic range. Active pixel array is 1164x886. Each active pixel composed of 4 transistors, it has a micro-lens to enhance sensitivity, and converts photon energy to analog pixel voltage. On-chip 11bit Analog to Digital Converter (ADC) digitizes analog pixel voltage, and on-chip Correlated Double Sampling (CDS) scheme reduces Fixed Pattern Noise (FPN) dramatically. General image processing functions are implemented to diversify its applications, and various output formats are supported for the sensor to easily interface with different video codec chips. The integration of sensor function and image processing functions make HV7151SP especially very suitable for mobile imaging systems such as digital still camera, PC input camera and IMT-2000 phone's video part that requires very low power and system compactness.

Features

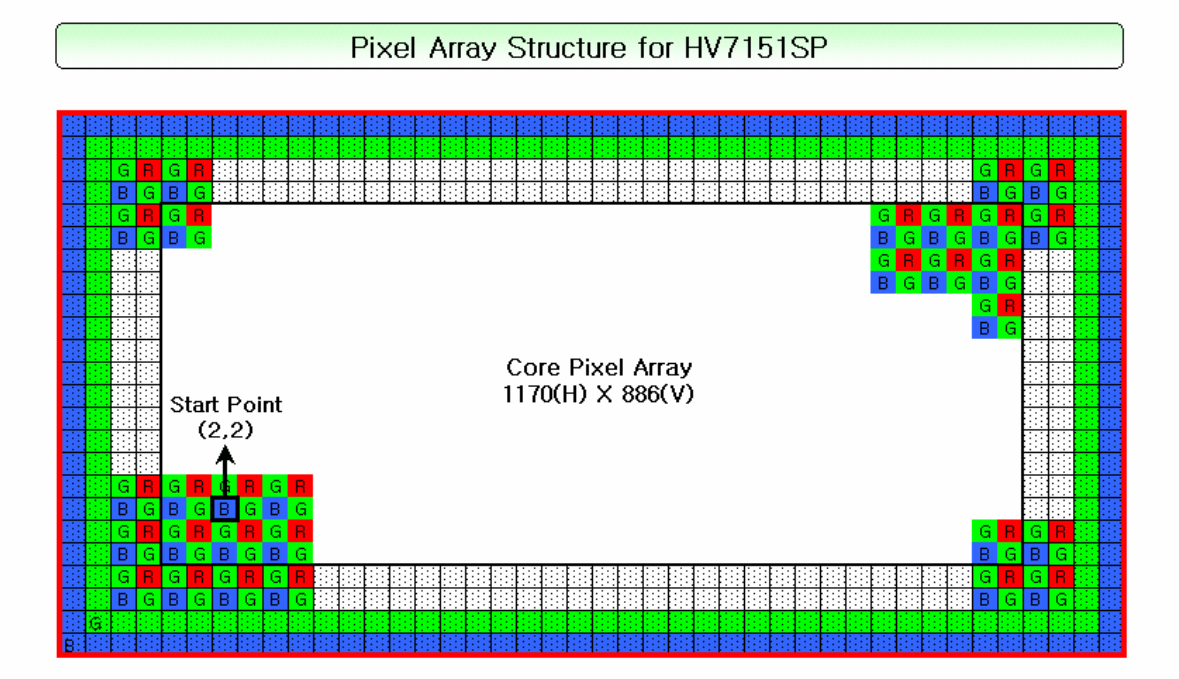
- Optical Format : 1/4 inch / Pixel Size : 3.2μm x 3.2μm
- Active Pixel Array : 1170 x 886
- Multiple Video Modes : 1152x864(MEGA), 640x480(VGA), 576x432(1/4 MEGA), 352x288(CIF), 320x240(QVGA), 288x216(1/16 MEGA), 176x144(QCIF)
- Bayer RGB Color filter array / Micro-lens for high sensitivity
- On-chip Frequency Synthesizer
- On-chip 11 bit Analog to Digital Converter
- Correlated Double Sampling (CDS) for reduction of Fixed Pattern Noise (FPN)
- Automatic Flicker Cancellation (AFC)
- Automatic Black Level Calibration (ABLC)
- Gamma Correction by programmable piecewise linear approximation
- 5x5 Color Interpolation
- Color Correction by programmable 3x3 matrix operation
- Color Space Conversion from RGB to YCbCr and Reverse Conversion from YCbCr to RGB
- Image adjustment :Contrast, Brightness, Saturation, Edge Enhancement, Chroma Suppression
- Various Output Formats: CCIR-601, CCIR-656 Compatible YCbCr 4:2:2, YCbCr 4:4:4, RGB 4:4:4, RGB 565, Bayer
- 8bit/16bit Data Bus Mode
- Automatic Exposure Control and Automatic White Balance Control
- Power Save Mode

- Typical Supply Voltage: Internal 1.8V and I/O 2.5V
- Operation Temperature : -10 ~ +50 degrees Celsius
- Package Types: CLCC 40 PIN, COB(Chip-on-Board), COF(Chip-on-Flex)

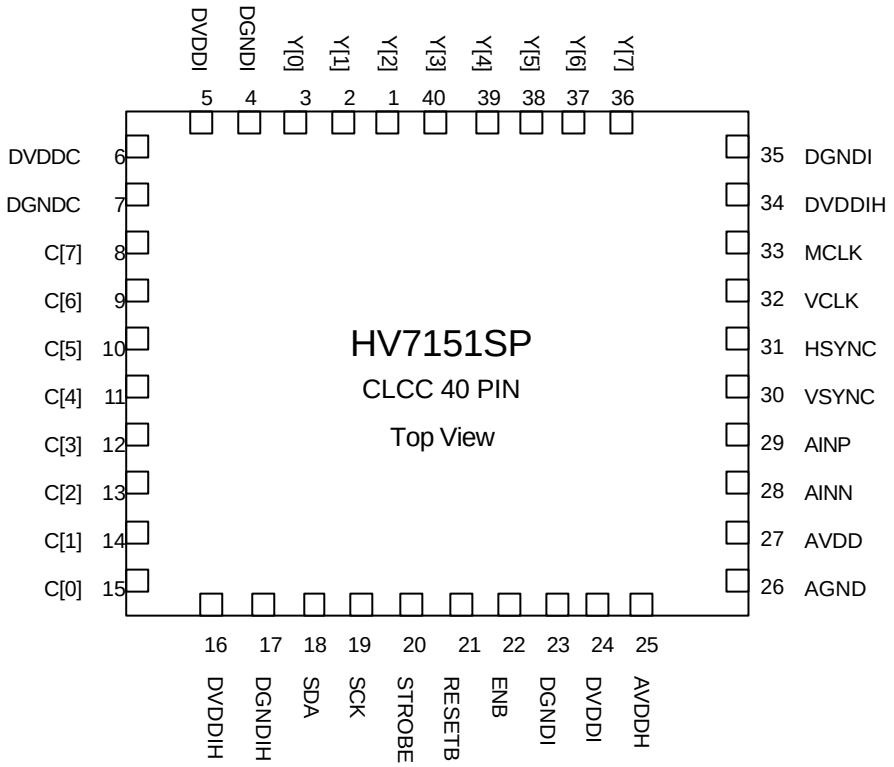
Block Diagram



Pixel Structure



Pin Diagram



Pin Diagram

C[7:0] should be set up as pull-up or pull-down when 8bit output mode is used.

Pin	Type	Symbol	Description
36-40, 1-3	B	Y[7:0]	Video Luminance Data[7:0]
4	G	DGNDI	Digital Ground for I/O Driver
5	P	DVDDI	1.8V Digital Power for I/O Driver
6	P	DVDDC	1.8V Power for Internal Digital Block
7	G	DGNDC	Ground for Internal Digital Block
8-15	B	C[7:0]	Video Chrominance Data[7:0]
16	PH	DVDDIH	2.5V Digital Power for I/O Driver
17	G	DGNDIH	Digital Ground for I/O Driver
18	B	SDA	I2C Standard data I/O port
19	I	SCK	I2C Clock Input
20	O	STROBE	Strobe Signal Output
21	I	RESETB	Sensor Reset, Low Active
22	I	ENB	Sensor sleep mode is controlled externally by this pin when sleep mode register bit is low. ENB low : sleep mode, ENB high : normal mode
23	G	DGNDI	Digital Ground for I/O Driver
24	P	DVDDI	1.8V Digital Power for I/O Driver
25	PH	AVDDPH	2.5V Analog Power for Pixel Block
26	G	AGND	Analog Ground for Analog Block
27	P	AVDD	1.8V Power for Internal Analog Block
28	AI	AINN	Analog Input Minus for Test ADC
29	AI	AINP	Analog Input Plus for Test ADC
30	B	VSYNC	Video Frame Synchronization signal. VSYNC is active at start of image data frame.
31	B	HSYNC	Video Horizontal Line Synchronization signal. Image data is valid, when HSYNC is high.
32	B	VCLK	Video Output Clock
33	I	MCLK	Master Input Clock
34	PH	DVDDIH	2.5V Digital Power for I/O Driver
35	G	DGNDI	Digital Ground for I/O Driver

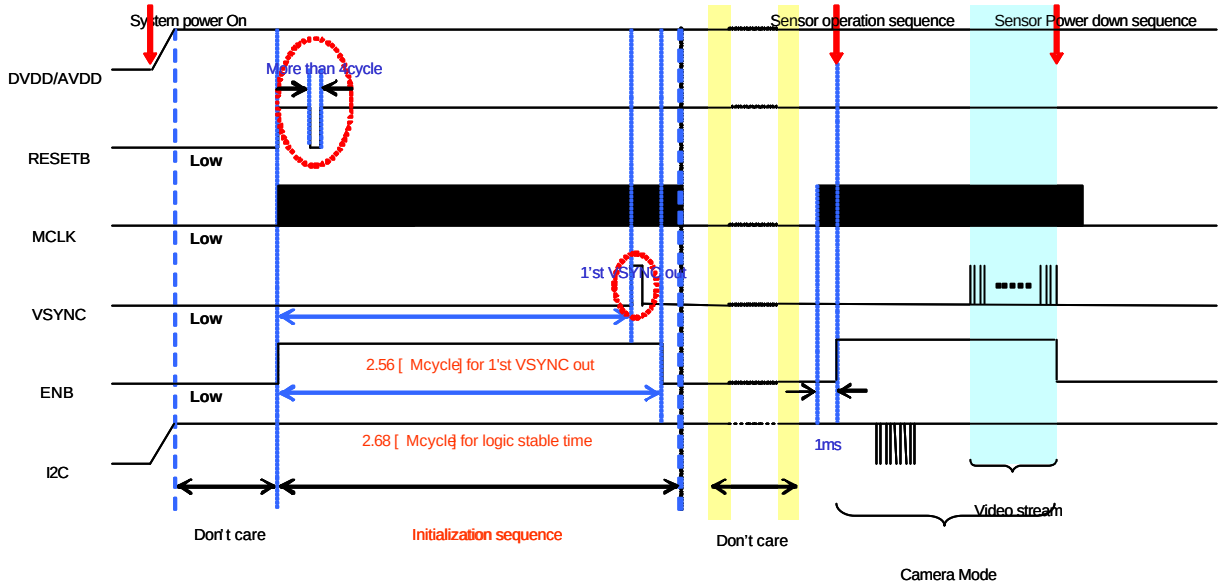
Functional Description

Pixel Architecture

Pixel architecture is a 4 transistor NMOS pixel design. The additional use of a dedicated transfer transistor in the architecture reduces most of reset level noise so that fixed pattern noise is not visible. Furthermore, micro-lens is placed upon each pixel in order to increase fill factor so that high pixel sensitivity is achieved.

ENB Setting guide information for normal stand-by mode

It is necessary that this kind of initialization sequence for the normal stand-by mode of HV7151SP after system power on



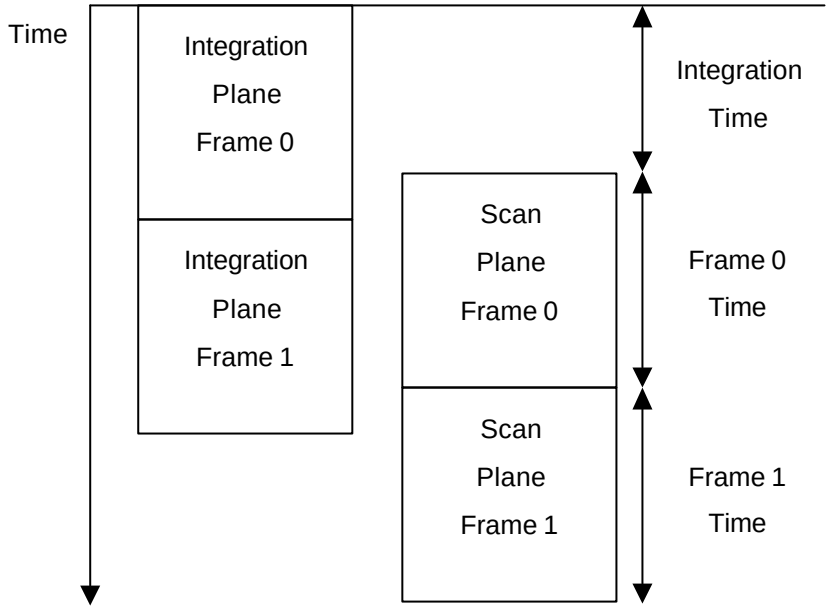
ex) If MCLK = 19.2[Mhz] and PLL 2x,

=> 2.68[Mcycle] / 38.4[MHz] = 69.79 ms

The time period of ENB high value have to keep for 69.79[ms] or more

Sensor Imaging Operation

Imaging operation is implemented by the offset mechanism of integration domain and scan domain(rolling shutter scheme). First integration plane is initiated, and after the programmed integration time is elapsed, scan plane is initiated, then image data start being produced.



On-chip Frequency Synthesizer

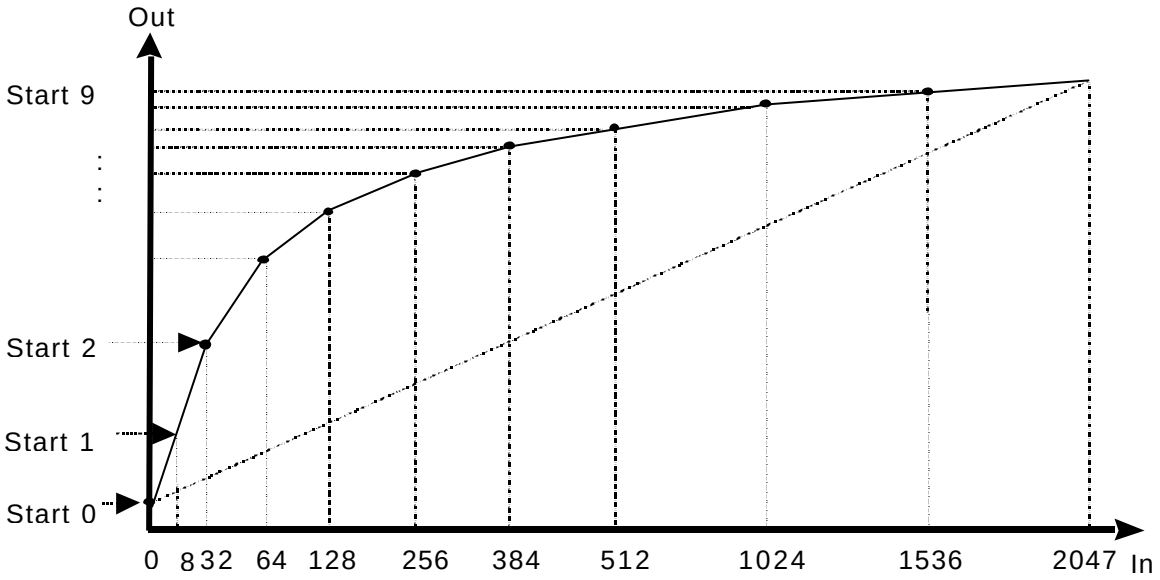
On-chip Frequency Synthesizer generates variable frequency according to the proportion of Reference(PREFDIV) to Feedback(PFDDIV) Divisor. Operating frequency is fully programmable and output range is 5MHz to 100MHz.

11bit on-chip ADC

On-chip ADC converts analog pixel voltage to 11bit digital data.

Gamma Correction

Piecewise linear approximation method is implemented. Ten piece linear segments are supported and user-programmable.



Gamma Transfer Function

Color Interpolation

5x5 linear color interpolation is used to interpolate missing R, G, or B for mosaic image data from pixel array. Interpolation is done by moving 5x5 interpolation window by one pixel horizontally and vertically.

Sub-sampling Mode

The sub-sampling modes such as 1/4 sub-sampling and 1/16 sub-sampling are supported. The sub-sampling sequence is as below. For example 1/4 sub-sampling, Row data are picked out from R,G,B bayer raw data by the rate of four to two. And after 5x5 linear color interpolation, column data also are picked out the rate of two to one. 1/16 sub-sampling is similar to 1/4 sub-sampling.

Scaling Mode

In addition to the sub-sampling mode, HV7151SP supports the scaling modes, such as 5/9 scaling VGA, 5/18 scaling QVGA, 1/3 scaling CIF and 1/6 QCIF. Because HV7151SP normal image size(1152x864) is not a multiple proportion of VGA/QVGA or CIF/QCIF image size, output data and output clock of scaling mode are asymmetry.

Color Correction

Generally, the color spread effect is mainly caused by color filter characteristics. The effect is compensated by 3x3 color correction operation. Color correction matrix may be resolved by measuring sensor's color spread characteristics for primary color source and calculating the inverse

matrix of color spread matrix. Nine registers for matrix coefficients are used in color correction operation to get the optimal pure color. The relationship between input color and color-corrected color is defined as below formula.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} CRCM11 & CRCM12 & CRCM13 \\ CRCM21 & CRCM22 & CRCM23 \\ CRCM31 & CRCM32 & CRCM33 \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

where R,G,B = Sensor color output

R',G',B' = Color-corrected output

Coefficients CRCMxx are programmable from –127/64 ~ 127/64. Programming register value for intended color correction matrix coefficients should be resolved by the following equations.

For positive values, CRCMxx = Integer(Real Coefficient Value x 64);

For negative values, CRCMxx = Two's Complement(Integer(Real Coefficient Value x 64));

Real Coefficient Value values from –127/64 ~ 127/64 can be programmed.

Color Space Conversion & Reverse Color Space Conversion

Both of color space conversion and reverse color space conversion are implemented by 3x3 matrix operation. Output ranges of color space conversion and reverse conversion are existed two modes. One is 16≤ Y ≤235, 16≤ Cb,Cr ≤240 & 16≤ reverse-R,G,B ≤235 and Another is 0≤ Y,Cb,Cr ≤255 & 0≤ reverse-R,G,B ≤255. These different modes are selected by control register.

For color space conversion and reverse conversion matrix, the equation from CCIR-601 standard is normally used.

< Conversion Equation >

Mode 1 :

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} \quad \begin{matrix} Range: 0 \sim 255 \\ Range: 0 \sim 255 \\ Range: 0 \sim 255 \end{matrix}$$

Mode 2 :

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.257 & 0.504 & 0.098 \\ -0.148 & -0.291 & 0.439 \\ 0.439 & -0.368 & -0.071 \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \quad \begin{matrix} Range: 16 \sim 235 \\ Range: 16 \sim 240 \\ Range: 16 \sim 240 \end{matrix}$$

In the above equations, R, G, and B are gamma-corrected values.

< Reverse Conversion Equation >

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.402 & 1 & 0 \\ -0.714 & 1 & -0.344 \\ 0 & 1 & 1.772 \end{bmatrix} \bullet \begin{bmatrix} Cr-128 \\ Y \\ Cb-128 \end{bmatrix} \quad \begin{matrix} Range: 0 \sim 255 \quad or \quad 16 \sim 235 \\ Range: 0 \sim 255 \quad or \quad 16 \sim 235 \\ Range: 0 \sim 255 \quad or \quad 16 \sim 235 \end{matrix}$$

Same matrix equations are applied to mode1 and mode2 in the reverse color space conversion. And previously, output ranges 0 ~ 255 or 16 ~ 235 are decided by input ranges of Y,Cb,Cr.

Luminance Processing – Contrast, Brightness adjustment

For contrast adjustment, Y digital channels are scaled by the contrast factor. Contrast factor resolution is 1/128 and its range is 0 ~ 255/128.

For brightness adjustment, there is added a brightness factor to Y digital channels. Brightness factor range is –128 ~ 127 and register value for brightness adjustment is following below.

For positive values, Brightness factor = Integer;

For negative values, Brightness factor = Two's Complement(Integer);

For example, if brightness factor is 3, register value is 8h03 and if brightness factor is -3, register value is 8'hfd.

Chrominance Processing – Saturation adjustment

For saturation adjustment, Cb,Cr digital Channels are scaled by the saturation factor. Saturation factor resolution is 1/128 and its range is 0 ~ 255/128.

Edge Enhancement

Edge enhancement is performed for increasing sharpness of image. Edge weight factor is user-programmable and its range is 0.3 ~ 1.0.

Chroma Suppression

Chroma suppression is performed in the dark environment for suppressing the color and decreasing dark bad pixel effect. Suppression level is varied in accordance with amplifier gain and saturation level is user-programmable.

Automatic Flicker Cancellation

Banding noise, caused by difference between frequency of light sources and frequency of integration time of pixel, is always generated in CMOS image sensor. For Automatic Flicker Cancellation, integration time is adjusted automatically in accordance with frequency of light sources.

Output Formatting

The output formats such as YCbCr 4:2:2, YCbCr 4:4:4, RGB 4:4:4, RGB 5:6:5 and Bayer Raw Data are supported. Possible output bus widths are 8 bits and 16bits, and the sequence of Cb and Cr or R and B are programmable. The output formats are compatible with Recommendation CCIR-601, CCIR-656.

Auto Exposure Control

Y mean value is continuously calculated every frame, and the integration time or amp gain value are increased or decreased according to difference between target Y mean value and current frame Y mean value.

Auto White Balance

Cb/Cr frame mean value is calculated every frame and according to Cb/Cr frame mean values' displacement from Cb/Cr white target point, R/B scaling values for R/B data are resolved.

Register Description

Symbol	Address (Hex)	Default (Hex)	Description
DEVID	00	50	Device ID
SCTRA	01	13	Sensor Control A
SCTRB	02	00	Sensor Control B
SCTRC	03	01	Sensor Control C
RSAU	08	00	Row Start Address Upper
RSAL	09	02	Row Start Address Lower
CSAU	0A	00	Column Start Address Upper
CSAL	0B	02	Column Start Address Lower
WIHU	0C	03	Window Height Upper
WIHL	0D	60	Window Height Lower
WIWU	0E	04	Window Width Upper
WIWL	0F	80	Window Width Lower
HBLU	10	00	Horizontal Blank Time Upper
HBLL	11	D0	Horizontal Blank Time Lower
VBLU	12	00	Vertical Blank Time Upper
VBLL	13	08	Vertical Blank Time Lower
RGAIN	14	08	Red Color Gain
GGAIN	15	08	Green Color Gain
BGAIN	16	08	Blue Color Gain
AMPGAIN	17	08	Amp Gain for Pixel Output
AMPMIN	18	10	Amp Gain Minimum Value
AMPMAX	19	28	Amp Gain Maximum Value
AMPNOM	1A	18	Amp Gain Normal Value
AMPBIAS	1B	13	CDS Bias , Amplifier Bias
RSTCLMP	1C	07	Reset Level Clamp Enable, Reset Value

ADCBIAS	20	2	ADC Bias Control
OREDI	21	7F	ADC Initial Offset Value for Optical Black Red
OGRNI	22	7F	ADC Initial Offset Value for Optical Black Green
OBLUI	23	7F	ADC Initial Offset Value for Optical Black Blue
BLKTH	27	FF	Black Level Threshold Value
ISPFUN	30	FF	Image Signal Processing Functions Enable
OUTFMT	31	31	Image Data Output Format
OUTINV	32	00	Output Signal Inversion
EDGEWT	33	02	Edge Enhancement Weight
CRCM11	34	4C	Color Correction matrix coefficient 11
CRCM12	35	EC	Color Correction matrix coefficient 12
CRCM13	36	08	Color Correction matrix coefficient 13
CRCM21	37	F0	Color Correction matrix coefficient 21
CRCM22	38	76	Color Correction matrix coefficient 22
CRCM23	39	DB	Color Correction matrix coefficient 23
CRCM31	3A	FE	Color Correction matrix coefficient 31
CRCM32	3B	E8	Color Correction matrix coefficient 32
CRCM33	3C	5A	Color Correction matrix coefficient 33
GMAP0	40	00	Start point for gamma line segment 0
GMAP1	41	04	Start point for gamma line segment 1
GMAP2	42	1C	Start point for gamma line segment 2
GMAP3	43	34	Start point for gamma line segment 3
GMAP4	44	54	Start point for gamma line segment 4
GMAP5	45	78	Start point for gamma line segment 5
GMAP6	46	90	Start point for gamma line segment 6
GMAP7	47	A4	Start point for gamma line segment 7
GMAP8	48	E0	Start point for gamma line segment 8
GMAP9	49	F4	Start point for gamma line segment 9
GMAS0	50	40	Slope value for gamma line segment 0
GMAS1	51	80	Slope value for gamma line segment 1

GMAS2	52	60	Slope value for gamma line segment 2
GMAS3	53	40	Slope value for gamma line segment 3
GMAS4	54	24	Slope value for gamma line segment 4
GMAS5	55	18	Slope value for gamma line segment 5
GMAS6	56	14	Slope value for gamma line segment 6
GMAS7	57	0F	Slope value for gamma line segment 7
GMAS8	58	05	Slope value for gamma line segment 8
GMAS9	59	02	Slope value for gamma line segment 9
BRIGHTY	5A	00	Brightness factor for brightness adjustment
SATCR	5B	80	Saturation factor for Saturation adjustment
SATCB	5C	80	Saturation factor for Saturation adjustment
EDTHLO	5D	05	Edge Enhancement Vth Low
EDTHHI	5E	80	Edge Enhancement Vth High
CHSUPFNC	5F	64	Chroma Suppression Function
AEMODE1	60	BD	Auto Exposure Control Mode 1
AEMODE2	61	5D	Auto Exposure Control Mode 2
CSCMODE	62	00	Color Space Conversion Mode Select
INTH	63	13	Integration Time High
INTM	64	88	Integration Time Middle
INTL	65	00	Integration Time Low
AETRGT	66	70	Luminance Target Value
AELFBND	67	A2	Y frame mean value displacement boundary
AEULBND	68	2A	Y frame mean value displacement from AE target where AE update speed transits from 2x integration unit speed to 1x integration unit speed
ASFCON	69	00	AE Speed and Frame Control
AESTEPH	6A	02	AE Anti-Banding Step High
AESTEPM	6B	EE	AE Anti-Banding Step Middle
AESTEPL	6C	00	AE Anti-Banding Step Low
AEINTH	6D	3A	AE Integration Time Limit High
AEINTM	6E	98	AE Integration Time Limit Middle

AEINTL	6F	00	AE Integration Time Limit Low
AWBMODE1	70	41	Auto White Balance Control Mode 1
AWBMODE2	71	02	Auto White Balance Control Mode 2
CBTRGT	73	80	Cb Frame Mean Value for AWB.
CRTRGT	74	80	Cr Frame Mean Value for AWB.
AWBLBND	75	02	Cb, Cr Frame Mean Displacement from Cb Target and Cr Target where AWB goes into LOCK state
AWBULBND	76	06	Displacement from ideal white pixel where AWB release from LOCK state
AWBWBND	77	30	Displacement from ideal white pixel where AWB recognizes a pixel as a white pixel affected by light source
AESTAT	7B	RO	Current AE Operation Status
AWBSTAT	7C	RO	Current AWB Operation Status
LUMEAN	7D	RO	Active Y Frame Mean Value
CBMEAN	7E	RO	Active Cb Frame Mean Value
CRMEAN	7F	RO	Active Cr Frame Mean Value
BNDGMIN	80	08	Minimum gain value with Anti-Banding enabled
BNDGMAX	81	18	Maximum gain value with Anti-Banding enabled
AWBWHT	8A	C8	During Cb, Cr frame mean value calculation, AWB discards pixel of which luminance is larger than this register value.
AWBBLK	8B	0A	During Cb, Cr frame mean value calculation, AWB discards pixel of which luminance is smaller than this register value.
AWBVALID	8C	02	AWB update when the number of valid color pixel is larger than (this minimum value x 64)
DPCMODE	90	01	Dark Bad Pixel Concealment Mode selection
DPCINTVALH	91	29	Integration Time Value High Byte where filtering operation gets active when dark bad pixel Concealment mode is enabled.
DPCINTVALM	92	DA	Integration Time Value Middle Byte where filtering operation gets active when dark bad pixel Concealment mode is enabled.
DPCINTVALL	93	49	Integration Time Value Lower Byte where filtering operation gets active when dark bad pixel Concealment mode is enabled.
DPCGTH	94	20	Neighbor-differential threshold value that specify G dark bad pixel
DPCCTH	95	20	Neighbor-differential threshold value that specify R/B dark bad pixel
DPCGAINVAL	96	38	Reference of Amp Gain which Dark Bad Pixel Concealment mode is enabled or disabled
CONTY	97	80	Contrast factor for Contrast Adjustment
PCTRA	A0	01	PLL Control Mode A
PCTRB	A1	1D	PLL Control Mode B
PFDDIVH	A4	00	PLL Feedback Divisor High

PFDDIVL	A5	02	PLL Feedback Divisor Low
PXNUMH	B9	04	Pixel Number High
PXNUML	BA	00	Pixel Number Low
STTHVAL	BB	30	Stable Range Variation
CHTHVAL	BC	20	Frequency Change Variation
AFCMODE	BD	00	AFC Mode Control
INTEGT50H	C0	02	50Hz Integration Time High
INTEGT50M	C1	EE	50Hz Integration Time Middle
INTEGT50L	C2	00	50Hz Integration Time Low
INTEGT60H	C3	02	60Hz Integration Time High
INTEGT60M	C4	71	60Hz Integration Time Middle
INTEGT60L	C5	00	60Hz Integration Time Low

Device ID [DEVID : 00h : 50h]

7	6	5	4	3	2	1	0
Product ID				Revision Number			
0	1	0	1	0	0	0	0

High Nibble represents Sensor Resolution, Low Nibble represents Revision Number.

Sensor Control A [SCTRA : 01h : 13h]

7	6	5	4	3	2	1	0
Reserved			X-Flip	Y-Flip	Video Mode		
0	0	0	1	0	0	1	1

X-Flip	Image is horizontally flipped
Y-Flip	Image is vertically flipped
Video Mode	111 1/6 scaling QCIF mode 110 1/3 scaling CIF mode 101 5/18 scaling QVGA mode 100 5/9 scaling VGA mode 011 5x5 linear color interpolation mode 010 1/4 sub-sampling mode 001 1/16 sub-sampling mode 000 Bayer output mode

Sensor Control B [SCTRB : 02h : 00h]

7	6	5	4	3	2	1	0
AE/AWB Block Sleep	Datapath Block Sleep	Analog Block Sleep	Sleep Mode	Strobe Enable	Clock Division		
0	0	0	0	0	0	0	0

AE/AWB Block Sleep	AE/AWB block goes into sleep mode with this bit set to high.
Datapath Block Sleep	Image processing datapath block goes into sleep mode with this bit set to high.
Analog Block Sleep	all internal analog block goes into sleep mode with this bit set to high. With All Digital Block Sleep active, sensor goes into power down mode.
Sleep Mode	all internal digital and analog block goes into sleep with this bit set to high.
Strobe Enable	When strobe signal is enabled by this bit, STROBE pin will indicates when strobe light should be splashed in the dark environment to get adequate lighted image.
Clock Division	divides input master clock(IMC) for internal use. Internal divided clock frequency(DCF) is defined as master clock frequency(MCF) divided by specified clock divisor. Internal divided clock frequency(DCF) is as follows. 000 : MCF, 001 : MCF/2, 010 : MCF/4, 011 : MCF/8 100 : MCF/16, 101 : MCF/32, 110 : MCF/64, 111 : MCF/128

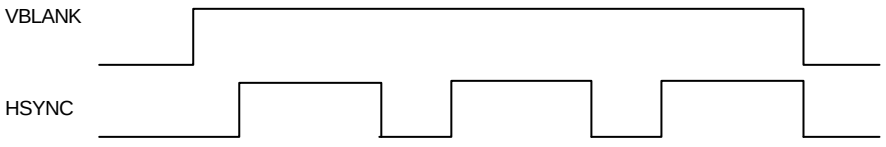
Sensor Control C [SCTRC : 03h : 01h]

7	6	5	4	3	2	1	0
reserved			HSYNC in VBLANK	VBLANK Unit	Unified Gain	Black Level Data Enable	Black Level Compens-ation
0	0	0	0	0	0	0	1

HSYNC in VBLANK

0 : There are no valid HSYNC during valid VBLANK.

1 : There are valid HSYNC during valid VBLANK. At time, VBLANK unit must be Line unit.



VBLANK unit

0 : Line unit. VBLANK unit is based on multiple line period time of sensor.

1 : Pixel unit. VBLANK unit is based on multiple pixel clock period time of sensor.

Unified Gain

1 : G analog gain is used for R,G and B analog gain.

0 : R,G and B analog gain is used individually.

Black Level Data Enable

HSYNC is generated for light-shielded pixels in 4 lines.

Black Level Compensation

Black level average values of light-shielded pixels are compensated when active image data is produced.

Row Start Address Upper [RSAU : 08h : 00h]

7	6	5	4	3	2	1	0
Reserved						Row Start Address Upper	
0	0	0	0	0	0	0	0

Row Start Address Lower [RSAL : 09h : 02h]

7	6	5	4	3	2	1	0
Row Start Address Lower							
0	0	0	0	0	0	1	0

Row Start Address register defines the row start address of image read out operation.

Column Start Address Upper [CSAU : 0ah : 00h]

7	6	5	4	3	2	1	0
Reserved					Column Start Address Upper		
0	0	0	0	0	0	0	0

Column Start Address Lower [CSAL : 0bh : 02h]

7	6	5	4	3	2	1	0

Column Start Address Lower							
0	0	0	0	0	0	1	0

Column Start Address register defines the column start address of image read out operation.

Window Height Upper [WIHU : 0ch : 03h]

7	6	5	4	3	2	1	0
Reserved						Window Height Upper	
0	0	0	0	0	0	1	1

Window Height Lower [WIHL : 0dh : 60h]

7	6	5	4	3	2	1	0
Window Height Lower							
0	1	1	0	0	0	0	0

Window Height register defines the height of image to be read out.

Window Width Upper [WIWU : 0eh : 04h]

7	6	5	4	3	2	1	0
Reserved					Window Width Upper		
0	0	0	0	0	1	0	0

Window Width Lower [WIWL : 0fh : 80h]

7	6	5	4	3	2	1	0
Window Width Lower							
1	0	0	0	0	0	0	0

Window Width Address register defines the width of image to be read out.

Horizontal Blank Time Upper [HBLU : 10h : 00h]

7	6	5	4	3	2	1	0
Horizontal Blank Time Upper							
0	0	0	0	0	0	0	0

Horizontal Blank Time Lower [HBLL : 11h : d0h]

7	6	5	4	3	2	1	0
Horizontal Blank Time Lower							
1	1	0	1	0	0	0	0

HBLANK Time register defines data blank time between current line and next line by using Sensor Clock Period unit, and should be larger than 208(d0h).

Vertical Blank Time Upper [VBLU : 12h : 00h]

7	6	5	4	3	2	1	0
Vertical Blank Time Upper							
0	0	0	0	0	0	0	0

Vertical Blank Time Lower [VBLL : 13h : 08h]

7	6	5	4	3	2	1	0
Vertical Blank Time Lower							
0	0	0	0	1	0	0	0

VBLANK Time register defines active high duration of VSYNC output. Active high VSYNC indicates frame boundary between continuous frames.

Each sensor has a little different photo-diode characteristics so that the sensor provides internal adjustment registers that calibrates internal sensing circuit in order to get optimal performance. Sensor characteristics adjustment registers are as below.

Red Color Gain [RGAIN : 14h : 08h]

7	6	5	4	3	2	1	0
Reserved			Red Amplifier Gain				

0	0	0	0	1	0	0	0

Green Color Gain [GGAIN : 15h : 08h]

7	6	5	4	3	2	1	0
Reserved			Green Amplifier Gain				
0	0	0	0	1	0	0	0

Blue Color Gain [BGAIN : 16h : 08h]

7	6	5	4	3	2	1	0
Reserved			Blue Amplifier Gain				
0	0	0	0	1	0	0	0

There are three color gain registers for R, G, B pixels, respectively. Programmable range is from 0.5X ~ 2.5X. Effective Gain = 0.5 + B<4:0>/16. These registers may be used for white balance and color effect with independent R,G,B color control. Default gain is 1X.

Amp Gain [AMPGAIN : 17h : 08h]

7	6	5	4	3	2	1	0
Reserved	Amp Gain						
0	0	0	0	1	0	0	0

Amp Gain is common gain for R, G, B channel and used for auto exposure control. Programmable range is from 0.5X ~ 8.5X. Default gain is 1X.
Gain = 0.5 + B<6:0>/16

Amp Gain Minimum Value [AMPMIN : 18h : 10h]

7	6	5	4	3	2	1	0
Reserved	Amp Gain Minimum						
0	0	0	1	0	0	0	0

Amp Gain Minimum Value is minimum value of amplifier gain when sensor adjusts amplifier gain for auto exposure control. Programmable range is same as Amp Gain. Recommended value is 1.5X.

Amp Gain Maximum Value [AMPMAX : 19h : 28h]

7	6	5	4	3	2	1	0
Reserved	Amp Gain Maximum						

0	0	1	0	1	0	0	0

Amp Gain Maximum Value is maximum value of amplifier gain when sensor adjusts amplifier gain for auto exposure control. Programmable range is same as Amp Gain. Recommended value is 3X.

Amp Gain Normal Value [AMPNOM : 1ah : 18h]

7	6	5	4	3	2	1	0
Reserved	Amp Gain Normal						
0	0	0	1	1	0	0	0

Amp Gain Normal Value is reference value of amp gain when sensor adjusts amp gain for auto exposure control. First, sensor controls integration time before adjusting amp gain for auto exposure control. After integration time is changed to the minimum or maximum value, sensor adjusts amp gain from this register value. Refer to figure of AE mode1 register(60H).
Programmable range is same as amp gain. Recommended value is 2X.

ASP Bias [ASPBIAS : 1bh : 13h]

7	6	5	4	3	2	1	0
Reserved	Pixel Bias			Amplifier Bias			
0	0	0	1	0	0	1	1

Pixel Bias	controls the amount of current in internal pixel bias circuit to amplify pixel output effectively. The larger register value increases the amount of current.
Amplifier Bias	controls the amount of current in internal amplifier bias circuit to amplify pixel output effectively. The larger register value increases the amount of current.

Reset Level Clamp [RSTCLMP : 1ch : 07h]

7	6	5	4	3	2	1	0
Reserved			Clamp On	Reset Level Clamp			
0	0	0	0	0	1	1	1

Because extremely bright image like sun affects reset data voltage of pixel to lower, bright image is captured as black image in image sensor regardless of correlated double sampling. To solve this extraordinary phenomenon, we adopt the method to clamp reset data voltage. Reset Level Clamp

controls the reset data voltage to prevent inversion of extremely bright image. The larger register value clamps the reset data level at highest voltage level. Default value is 7 to clamp the reset data level at appropriate voltage level.

ADC Bias [ADCBIAS : 20h : 02h]

7	6	5	4	3	2	1	0
Reserved					ADC Bias		
0	0	0	0	0	0	1	0

ADC Bias controls the amount of current in ADC bias circuit to operate ADC effectively.

ADC Initial Offset Value for Optical Black Red [OREDI : 21h : 7fh]

7	6	5	4	3	2	1	0
Red Pixel Black Offset							
0	1	1	1	1	1	1	1

ADC Initial Offset Value for Optical Black Green [OGRNI : 22h : 7fh]

7	6	5	4	3	2	1	0
Green Pixel Black Offset							
0	1	1	1	1	1	1	1

ADC Initial Offset Value for Optical Black Blue [OBLUI : 23h : 7fh]

7	6	5	4	3	2	1	0
Blue Pixel Black Offset							
0	1	1	1	1	1	1	1

These registers control the offset voltage of ADC that changes the black level value for light-shielded pixels, R,G,B respectively. Register bit functions are composed as follows.

Pixel Black Offset[7]	The bit specifies whether to subtract or add offset voltage in ADC input for light-shielded pixels.
Pixel Black Offset[6:0]	This value specifies the amount of offset voltage for light-shielded pixels.

Black Level Threshold Value [BLKTH : 27h : ffh]

7	6	5	4	3	2	1	0
Black Level Threshold							
1	1	1	1	1	1	1	1

The register specifies the maximum value that determines whether light-shielded pixel output is valid. When light-shielded pixel output exceeds this limit, the pixel is not accounted for black level calculation.

ISP Function Enable [ISPFUN : 30h : ffh]

7	6	5	4	3	2	1	0
Reserved	Contrast Adjustment	Chroma Suppression	Edge Enhancement	Color Space Conversion	Color Correction	Color Interpolation	Gamma Correction
0	1	1	1	1	1	1	1

Contrast Adjustment

0 : Disable.

1 : Enable. Y Output multiplied by Contrast factor

Chroma Suppression

0 : Disable.

1 : Enable. Chroma Suppressed Cb,Cr Output

Edge Enhancement

0 : Disable.

1 : Enable.

Color Space Conversion

0 : Disable. R,G,B Output

1 : Enable. Y,Cb,Cr Output

Color Correction

0 : Disable.

1 : Enable.

Color Interpolation

0 : Disable.

1 : Enable.

Gamma Correction

0 : Disable. Normal Bayer Output

1 : Enable. Gamma Corrected Bayer Output

Output Format [OUTFMT : 31h : 31h]

7	6	5	4	3	2	1	0
Gamma-Corrected Bayer	Bayer 8bit Output	Cb/B First	Y First	YCbCr 4:4:4 / 4:2:2	RGB 4:4:4	RGB 565	8 bit Output
0	0	1	1	0	0	0	1

Gamma-Corrected Bayer	Gamma-corrected Bayer data are output when Bayer mode is set in SCTRA register.
Bayer 8bit Output	Bayer data is output with 8bit mode, two LSB of 11 bit Bayer data is stripped out.
Cb/B First	Cb(B) pixel in front of Cr(R) pixel in 16bit or 8bit video data output modes.
Y First	Y pixel in front of Cb and Cr pixels in 8bit video output mode. This option is meaningful only with YCbCr 4:2:2 8bit output mode.
YCbCr 4:4:4 / 4:2:2	This bit is high, output format is YCbCr 4:4:4 16bit mode, otherwise output format is YCbCr 4:2:2 8bit/16bit mode.
RGB 4:4:4	R,G,B 24bit data for a pixel is produced with 16bit output mode.
RGB 565	Data format of RGB 565 mode is composed with {R[7:3]/G[7:5]} , {G[4:2]/B[7:3]} or {B[7:3]/G[7:5]}, {G[4:2]/R[7:3]}. OUTFMT[5](Cb/B First) register affects above data form.
8 Bit Output	Image Data is produced only in Y[7:0]. C[7:0] should be discarded.

Default mode of Output Format is YCbCr 4:2:2 8bit mode.

Output Signal Inversion [OUTINV : 32h : 00h]

7	6	5	4	3	2	1	0
Reserved				Clocked HSYNC	VSYNC inversion	HSYNC inversion	VCLK inversion
0	0	0	0	0	0	0	0

Clocked HSYNC	In HSYNC, VCLK is embedded, that is, HSYNC is toggling at VCLK rate during normal HSYNC time
VSYNC inversion	VSYNC output polarity is inverted
HSYNC inversion	HSYNC output polarity is inverted

VCLK inversion	VCLK output polarity is inverted

Edge Enhancement Weight [EDGEWT : 33h : 02h]

7	6	5	4	3	2	1	0
Reserved					Edge Enhancement Weight		
0	0	0	0	0	0	1	0

Edge Enhancement Weight range is 0.3(3'h000) ~ 1(3'h111), and default value is 0.5(3'h010). As Edge Enhancement Weight is large, the effect of Edge Enhancement grows stronger.

Color Correction Matrix Coefficient 11 [CRCM11 : 34h : 4ch]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 11							
0	1	0	0	1	1	0	0

Color Correction Matrix Coefficient 12 [CRCM 12 : 35h : ech]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 12							
1	1	1	0	1	1	0	0

Color Correction Matrix Coefficient 13 [CRCM 13 : 36h : 08h]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 13							
0	0	0	0	1	0	0	0

Color Correction Matrix Coefficient 21 [CRCM 21 : 37h : f0h]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 21							
1	1	1	1	0	0	0	0

Color Correction Matrix Coefficient 22 [CRCM 22 : 38h : 76h]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 22							
0	1	1	1	0	1	1	0

Color Correction Matrix Coefficient 23 [CRCM 23 : 39h : dbh]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 23							
1	1	0	1	1	0	1	1

Color Correction Matrix Coefficient 31 [CRCM 31 : 3ah : feh]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 31							
1	1	1	1	1	1	1	0

Color Correction Matrix Coefficient 32 [CRCM 32 : 3bh : e8h]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 32							
1	1	1	0	1	0	0	0

Color Correction Matrix Coefficient 33 [CRCM 33 : 3ch : 5ah]

7	6	5	4	3	2	1	0
Color Correction Matrix Coefficient 33							
0	1	0	1	1	0	1	0

Gamma Segment Start Points

Gamma Segment Start Points specify the start points of nine line segments for piecewise gamma approximation. Current default gamma curve is very selected for optimum gray gradation.

Gamma Point 0 [GAMP0 : 40h : 00h]

7	6	5	4	3	2	1	0
Gamma Point 0							
0	0	0	0	0	0	0	0

Gamma Point 1 [GMAP1 : 41h : 04h]

7	6	5	4	3	2	1	0
Gamma Point 1							
0	0	0	0	0	1	0	0

Gamma Point 2 [GMAP2 : 42h : 1ch]

7	6	5	4	3	2	1	0
Gamma Point 2							
0	0	0	1	1	1	0	0

Gamma Point 3 [GMAP3 : 43h : 34h]

7	6	5	4	3	2	1	0
Gamma Point 3							
0	0	1	1	0	1	0	0

Gamma Point 4 [GMAP4 : 44h : 54h]

7	6	5	4	3	2	1	0
Gamma Point 4							
0	1	0	1	0	1	0	0

Gamma Point 5 [GMAP5 : 45h : 78h]

7	6	5	4	3	2	1	0
Gamma Point 5							
0	1	1	1	1	0	0	0

Gamma Point 6 [GMAP6 : 46h : 90h]

7	6	5	4	3	2	1	0
Gamma Point 6							
1	0	0	1	0	0	0	0

Gamma Point 7 [GMAP7 : 47h : a4h]

7	6	5	4	3	2	1	0
Gamma Point 7							
1	0	1	0	0	1	0	0

Gamma Point 8 [GMAP8 : 48h : e0h]

7	6	5	4	3	2	1	0
Gamma Point 8							
1	1	1	0	0	0	0	0

Gamma Point 9 [GMAP9 : 49h : f4h]

7	6	5	4	3	2	1	0
Gamma Point 9							
1	1	1	1	0	1	0	0

Gamma Slope 0 [GMAS0 : 50h : 40h]

7	6	5	4	3	2	1	0
Gamma Slope 0							
0	1	0	0	0	0	0	0

Gamma Slope 1 [GMAS1 : 51h : 80h]

7	6	5	4	3	2	1	0
Gamma Slope 1							
1	0	0	0	0	0	0	0

Gamma Slope 2 [GMAS2 : 52h : 60h]

7	6	5	4	3	2	1	0
Gamma Slope 2							
0	1	1	0	0	0	0	0

Gamma Slope 3 [GMAS3 : 53h : 40h]

7	6	5	4	3	2	1	0
Gamma Slope 3							
0	1	0	0	0	0	0	0

Gamma Slope 4 [GMAS4 : 54h : 24h]

7	6	5	4	3	2	1	0
Gamma Slope 4							
0	0	1	0	0	1	0	0

Gamma Slope 5 [GMAS5 : 55h : 18h]

7	6	5	4	3	2	1	0
Gamma Slope 5							
0	0	0	1	1	0	0	0

Gamma Slope 6 [GMAS6 : 56h : 14h]

7	6	5	4	3	2	1	0
Gamma Slope 6							
0	0	0	1	0	1	0	0

Gamma Slope 7 [GMAS7 : 57h : 0fh]

7	6	5	4	3	2	1	0
Gamma Slope 7							
0	0	0	0	1	1	1	1

Gamma Slope 8 [GMAS8 : 58h : 05h]

7	6	5	4	3	2	1	0
Gamma Slope 8							
0	0	0	0	0	1	0	1

Gamma Slope 9 [GMAS9 : 59h : 02h]

7	6	5	4	3	2	1	0
Gamma Slope 9							
0	0	0	0	0	0	1	0

Brightness Factor Y [BRIGHTY : 5ah : 00h]

7	6	5	4	3	2	1	0
Brightness Factor Y							
0	0	0	0	0	0	0	0

Brightness Adjustment is performed for summing Y data and Brightness Factor Y. Brightness Factor Y is two's complement and its range is –128 ~ 127.

Bright Y = Y data + Brightness Factor Y.

for positive values, B<7:0> = Integer;

for negative values, B<7:0> = Two's Complement(Integer);

Saturation Factor Cr [SATCR : 5bh : 80h]

7	6	5	4	3	2	1	0
Saturation Factor Cr							
1	0	0	0	0	0	0	0

Saturation Factor Cb [SATCB : 5ch : 80h]

7	6	5	4	3	2	1	0
Saturation Factor Cb							
1	0	0	0	0	0	0	0

Saturation Adjustment is performed for multiplying Cr,Cb data by Saturation Factor Cr,Cb, respectively. Programmable range of Saturation Factor Cb,Cr is 0 ~ 2.

For instant, Sat Cb = Cb data * B<7:0>/128.

Edge Enhancement Threshold Low [EDTHLO : 5dh : 05h]

7	6	5	4	3	2	1	0
Edge Enhancement Threshold Low							
0	0	0	0	0	1	0	1

Edge Enhancement Threshold High [EDTHHI : 5eh : 80h]

7	6	5	4	3	2	1	0
Edge Enhancement Threshold High							
1	0	0	0	0	0	0	0

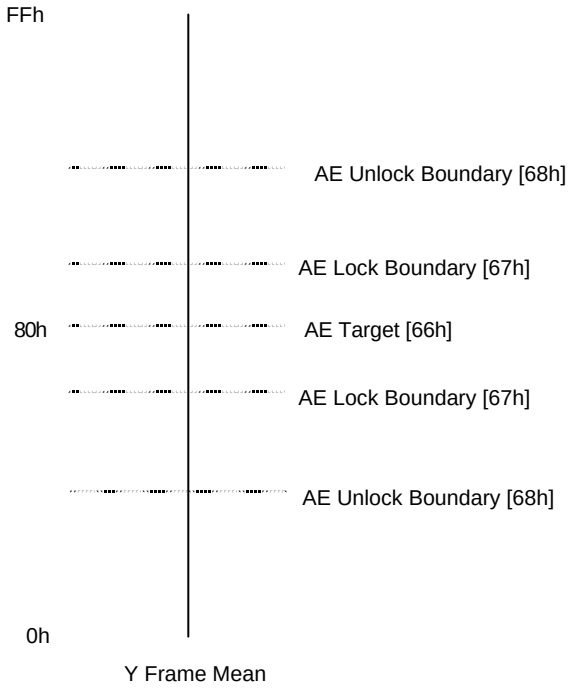
Chroma Suppression Function [CHSUPFNC : 5fh : 64h]

7	6	5	4	3	2	1	0
Saturation Level		Suppression Gain Minimum					
0	1	1	0	0	1	0	0

Saturation Level	11	0% of difference between Current Cb,Cr data and reference Cb,Cr level. So, Chroma Suppressed Cb,Cr data are equal to Current Cb,Cr data.
	10	25% of difference between Current Cb,Cr data and reference Cb,Cr level.
	01	50% of difference between Current Cb,Cr data and reference Cb,Cr level.
	00	75% of difference between Current Cb,Cr data and reference Cb,Cr level.
Suppression Gain Minimum	When Amp Gain is greater than Suppression Gain Minimum, Chroma Suppression Function is started.	

Auto Exposure

Y mean value is continuously calculated every frame, and the integration time value is increased or decreased according to the displacement between current frame Y mean value and target Y mean value.



AE Mode Control 1 [AEMODE1 : 60h : bdh]

7	6	5	4	3	2	1	0
Anti – Banding Enable	Full Window	Window Mode		AE speed		AE Mode	
1	0	1	1	1	1	0	1

Anti-Banding Enable	When Anti-Banding is enabled, AE initializes Integration Time registers[63h-65h] to 4 x Anti-Banding Step value[6ah-6ch], and integration increment/decrement amount is set to Anti-Banding Step value in order to remove banding noise caused by intrinsic energy waveform of light sources. Banding noise is inherent in CMOS image sensor that adopts rolling shutter scheme for image acquisition. In this mode, AE operates with very large unit, typically a reciprocal of (2 x power line frequency), so that minute integration time tuning is not liable. Therefore, this mode is recommended for only indoor use.	
Full Window	With this bit set to high, window mode is discarded and full image data is accounted for AE Y frame mean evaluation	
Window Mode	11	1/8 center weighted window mode. Weighting ratio is 8:1 for inside area vs. outside area
	10	1/8 center only window mode.
	01	1/4 center weighted window mode. Weighting ratio is 4:1 for inside area vs. outside area
	00	1/4 center only window mode.
AE Speed	(fast)11 – 10 – 01 – 00(slow)	
AE Mode	11	Gain-Only control mode. Only preamp gain is controlled to get optimum exposure state.
	10	Time-Only control mode. Only integration time is controlled to get optimum exposure state.
	01	Time-Gain control mode. Integration time and preamp gain are controlled to get optimum exposure state.
	00	AE function is disabled

AE Mode Control 2 [AEMODE2 : 61h : 5dh]

7	6	5	4	3	2	1	0
Reserved	Gain Speed		Integration Time Fine Tune	Amp Gain Fine Tune	Anti-Banding Minimum Break	AE Sub-sampling mode	AE Analog Gain Control
0	1	0	1	1	1	0	1

Gain Speed	Gain update speed is specified as follows. (fast)11 – 10 – 01 – 00(slow)
Integration Time Fine Tune	Integration time fine tuning is performed when AE arrive around AE Fine Tune Boundary to settle into AE lock state smoothly.
Amp Gain Fine Tune	Amp gain fine tuning is performed when AE arrive around AE Fine Tune Boundary to settle into AE lock state smoothly.
Anti-Banding Minimum Break	When AE is still of out lock state despite that AE preamp analog gain update value exceeds preamp minimum gain value(18h) and integration time(63h-65h) is reached to AE Anti-Banding Step(6ah-6ch), integration time(63h-65h) is broken to less than AE Anti-Banding Step(6ah-6ch).
AE Sub-sampling Mode	AE statistics is executed on 1/4 of original image data to save power consumption
AE Analog Gain Control	AE updates Amp gain register(17h) in order to reach optimum exposure state

Color Space Conversion Mode [CSCMODE : 62h : 00h]

7	6	5	4	3	2	1	0
Reserved					CSC Mode	Reserved	
0	0	0	1	0	0	0	0

CSC Mode

0 : Mode 1

1 : Mode 2

Integration Time High [INTH: 63h : 13h]

7	6	5	4	3	2	1	0
Integration Time Higher							
0	0	0	1	0	0	1	1

Integration Time Middle [INTM: 64h: 88h]

7	6	5	4	3	2	1	0
Integration Time Middle							
1	0	0	0	1	0	0	0

Integration Time Low [INTL: 65h: 00h]

7	6	5	4	3	2	1	0
Integration Time Lower							
0	0	0	0	0	0	0	0

Integration time value register defines the time which active pixel element evaluates photon energy that is converted to digital data output by internal ADC processing. Integration time is equivalent to exposure time of general camera so that integration time needs to be increased in dark environment and decreased according to lighting condition. Maximum integration time is register maximum value(2^{24}-1) x sensor clock period (52ns, SCF 19.2Mhz) = 0.87sec.

SCF = Sensor Clock Frequency

Luminance Target Value [AETRGT : 66h : 70h]

7	6	5	4	3	2	1	0
Luminance Target							
0	1	1	1	0	0	0	0

This register defines the target luminance value for AE operation.

AE Lock & Fine Tune Boundary [AELFBND : 67h : a2h]

7	6	5	4	3	2	1	0
AE Fine Boundary				AE Lock Boundary			
1	0	1	0	0	0	1	0

AE Lock Boundary specifies the displacement of Y Frame Mean value(7dh) from AE Target in which AE goes into LOCK state. With Anti-Banding is enabled, this displacement condition is discarded, and instead AE Speed Unlock Boundary is used as Lock boundary.

AE Fine Boundary specifies the displacement of Y Frame Mean value(7dh) from AE Target in which

AE start to tune fine integration time or amp gain in order to goes into lock state smoothly.

AE Unlock Boundary [AEULBND : 68h : 2ah]

7	6	5	4	3	2	1	0
AE Unlock Boundary							
0	0	1	0	1	0	1	0

AE Speed Boundary 0 specifies Y Frame Mean displacement from AE Target where integration time increment/decrement speed changes from 2x (integration unit step) to 1x (integration unit step). In anti-banding mode, this boundary is used as lock boundary for exposure control.

AE Speed and Frame Control [ASFCON : 69h : 00h]

7	6	5	4	3	2	1	0
Reserved		AE Speed 2		Y Frame Control		Cb,Cr Frame Control	
0	0	0	0	0	0	0	0

AE Speed 2	(fast)11 – 10 – 01 – 00(slow)	
Y Frame Control	11	4 Frame mean Value. (For AE)
	10	2 Frame mean Value.
	01, 00	1 Frame mean Value.
Cb,Cr Frame Control	11	4 Frame mean Value. (For AWB)
	10	2 Frame mean Value.
	01, 00	1 Frame mean Value.

AE Speed 2 is different in use to AE Speed 1. When Y Frame Mean is out of Unlock boundary, AE updates quickly Amp Gain register(17h) in order to reach Lock boundary state.

Gain update speed is specified as follows.

(fast)11 – 10 – 01 – 00(slow)

Frame Control register can be use 1, 2, 4 Frame mean Value. 4 Frame mean value has a history component of previous 3 Frame mean Value. To use 1 Frame mean Value is that AE changed every Frame instantly.

AE Anti-Banding Step High [AESTEPH : 6ah : 02h]

7	6	5	4	3	2	1	0
Reserved						Integration Step Higher	
0	0	0	0	0	0	1	0

AE Anti-Banding Step Middle [AESTEPM : 6bh : eeh]

7	6	5	4	3	2	1	0
Integration Step Middle							
1	1	1	0	1	1	1	0

AE Anti-Banding Step Low [AESTEPL : 6ch : 00h]

7	6	5	4	3	2	1	0
Integration Step Lower							
0	0	0	0	0	0	0	0

AE Anti-Banding Step specifies integration time unit value that AE uses when Anti-Banding is enabled.

Anti-Banding Step value is resolved by the following equation.

Anti-Banding Step Value = Sensor Operation Frequency (SCF) / (2x power line frequency)

The default value is set with SCF 19.2Mhz, 50Hz power line, that is,

Anti-Banding Step Value = 19.2Mhz / (2 x 50) = 192000d = 02ee00h

AE Integration Time Limit High [AEINTH : 6dh : 3ah]

7	6	5	4	3	2	1	0
AE Integration Time Limit Higher							
0	0	1	1	1	0	1	0

AE Integration Time Limit Middle [AEINTM : 6eh : 98h]

7	6	5	4	3	2	1	0

AE Integration Time Limit Middle							
1	0	0	1	1	0	0	0

AE Integration Time Limit Low [AEINTL : 6fh : 00h]

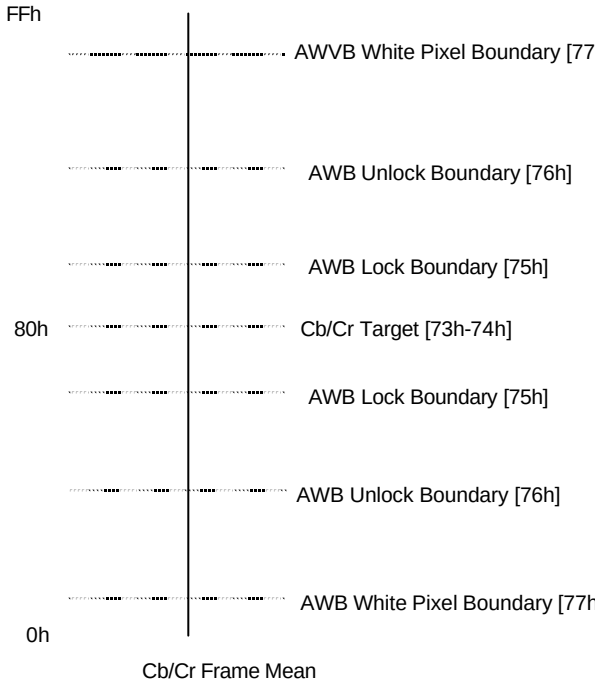
7	6	5	4	3	2	1	0
AE Integration Time Limit Lower							
0	0	0	0	0	0	0	0

These three registers define the maximum integration time value that is allowed to sensor operation. It is desirable to set the value to multiples of AE Anti-Banding Step to easily operate with Anti-banding mode enabled. The default value is set to 1/5sec with SCF set to 19.2Mhz

19.2Mhz / 5 = 3840500d = 3a9800h

Auto White Balance

Cb/Cr frame mean value is calculated every frame and according to Cb/Cr frame mean values' displacement from Cb/Cr white target point, R/B scaling values for R/B data are resolved.



AWB Mode Control 1 [AWBMODE1 : 70h : 41h]

7	6	5	4	3	2	1	0
Reserved	Full Window	Reserved	Window Mode	AWB speed		Reserved	AWB On
0	1	0	0	0	0	0	1

Full Window	With this bit set to high, window mode is discarded and full image data is accounted for AE Y frame mean evaluation	
Window Mode	1	1/4 center weighted window mode. Weighting ratio is 4:1 for inside area vs. outside area
	0	1/4 center only window mode.
AWB Speed	(Fast)11 - 10 - 01 - 00(slow)	
AWB On	Auto White Balance Control Enabled	

AWB Mode Control 2 [AEMODE2 : 71h : 02h]

7	6	5	4	3	2	1	0
Reserved				AWB Low Speed	AWB Sub-sampling mode	AWB Analog Gain Control	Reserved
0	0	0	0	0	0	1	0

AWB Low Speed	With this bit set to high, analog gain speed is decreased to 1/4 of the normal speed.
AWB Sub-sampling Mode	AWB statistics is executed on 1/4 of original image data to save power consumption
AWB Analog Gain Control	AWB updates R/B gain registers(14h,16h) in order to reach optimum white balance state

Cb Frame Mean Value [CBTRGT : 73h : 80h]

7	6	5	4	3	2	1	0
Cb Frame Mean							
1	0	0	0	0	0	0	0

This register defines Cb target frame mean value for AWB operation.

Cr Frame Mean Value [CRTRGT : 74h : 80h]

7	6	5	4	3	2	1	0
Cr Frame Mean							
1	0	0	0	0	0	0	0

This register defines Cr target frame mean value for AWB operation.

AWB Lock Boundary [AWBLBND : 75h : 02h]

7	6	5	4	3	2	1	0
Reserved				AWB Lock Boundary			
0	0	0	0	0	0	1	0

It specifies Cb/Cr frame mean values' displacement from Cb/Cr Target (73h-74h) value where AWB

goes into LOCK state.

AWB Unlock Boundary [AWBULBND : 76h : 06h]

7	6	5	4	3	2	1	0
AWB Unlock Boundary							
0	0	0	0	0	1	1	0

It specifies Cb/Cr frame mean values' displacement from Cb/Cr Target (73h-74h) where AWB is released from LOCK state. AWB operation retains LOCK state unless Cb/Cr frame mean values' displacement value exceeds this boundary. The value should be larger AWB Lock Boundary.

AWB White Pixel Boundary [AWBWBND : 77h : 30h]

7	6	5	4	3	2	1	0
AWB White Pixel Boundary							
0	0	1	1	0	0	0	0

When Cb/Cr frame mean values' displacement from Cb/Cr Target exceeds AWB White Pixel Boundary value, AWB accept frame color as it is and does not try to correct white balance deviation.

Current AE Operation Status [AESTAT : 7bh : RO]

7	6	5	4	3	2	1	0
AE Mode State				AE Lock state			
RO	RO	RO	RO	RO	RO	RO	RO

AE Mode State	This nibble represents the mode where internal Y plane FSM is currently placed among time-gain control, time-only control, or gain-only control modes.
AE Lock State	Y channel FSM status, "0000" means that AE Y plane is in lock state

Current AWB Operation Status [AWBSTAT : 7ch : RO]

7	6	5	4	3	2	1	0
reserved			AE/AWB Lock	Cb Lock State		Cr Lock State	
RO	RO	RO	RO	RO	RO	RO	RO

AE/AWB Lock	This single status bit indicates that AE and AWB are in lock state for optimum still image capture.
Cb Lock State	Cb channel FSM status. “00” means that AWB Cb plane is in lock state
Cr Lock State	Cr channel FSM status. “00” means that AWB Cr plane is in lock state

Active Y Frame Mean Value [LUMEAN : 7dh : RO]

7	6	5	4	3	2	1	0
Y Frame Mean							
RO	RO	RO	RO	RO	RO	RO	RO

The register reports current Y plane frame mean value.

Active Cb Frame Mean Value [CBMEAN : 7eh : RO]

7	6	5	4	3	2	1	0
Cb Frame Mean							
RO	RO	RO	RO	RO	RO	RO	RO

The register reports current Cb plane frame mean value.

Active Cr Frame Mean Value [CRMEAN : 7fh : RO]

7	6	5	4	3	2	1	0
Cr Frame Mean							
RO	RO	RO	RO	RO	RO	RO	RO

The register reports current Cr plane frame mean value.

Minimum Anti-Banding Gain [BNDGMIN : 80h : 08h]

7	6	5	4	3	2	1	0
Minimum Anti-Banding Gain							
0	0	0	0	1	0	0	0

The register specifies the minimum limit to which AE may decrease preamp gain or Y digital gain in order to get optimum exposure value while Anti-Banding Mode is enabled and the following condition is met.

AE Lock Boundary < (Y Frame Mean - AE Target) < AE Unlock Boundary.

Maximum Anti-Banding Gain [BNDGMAX : 81h : 18h]

7	6	5	4	3	2	1	0
Maximum Anti-Banding Gain							
0	0	0	1	1	0	0	0

The register specifies the maximum limit to which AE may increase preamp gain or Y digital gain in order to get optimum exposure value while Anti-Banding Mode is enabled and the following condition is met.

AE Lock Boundary < (AE Target - Y Frame Mean) < AE Unlock Boundary.

AWB Luminance Higher Limit [AWBWHT : 8ah : c8h]

7	6	5	4	3	2	1	0
AWB Luminance Higher Limit							
1	1	0	0	1	0	0	0

During Cb/Cr frame mean value calculation, AWB discards pixel of which luminance value is larger than this register value.

AWB Luminance Lower Limit [AWBBLK : 8bh : 0ah]

7	6	5	4	3	2	1	0
AWB Luminance Lower Limit							
0	0	0	0	1	0	1	0

During Cb/Cr frame mean value calculation, AWB discards pixel of which luminance value is smaller than this register value.

AWB Valid Number of Pixel [AWBVALID : 8ch : 02h]

7	6	5	4	3	2	1	0
AWB Valid Number of Pixel							
0	0	0	0	0	0	1	0

AWB update when the number of valid color pixel is larger than (this valid value x 64).

Dark Bad Pixel Concealment Mode [DPCMODE : 90h : 01h]

7	6	5	4	3	2	1	0
Reserved						Dark Bad Pixel Concealment Mode	
0	0	0	0	0	0	0	1

Dark Bad Pixel Concealment Mode	10	Dark Bad Pixel Concealment is always performed.
	01	Dark Bad Pixel Concealment is performed when Integration Time (63h-65h) exceeds Dark Bad Integration Time(91h-93h)
	11, 00	Dark Bad Pixel Concealment is turned off

Dark Bad Integration Time High [DPCINTH : 91h : 29h]

7	6	5	4	3	2	1	0
Dark Integration Time Higher							
0	0	1	0	1	0	0	1

Dark Bad Integration Time Middle [DPCINTM : 92h : dah]

7	6	5	4	3	2	1	0
Dark Integration Time Middle							
1	1	0	1	1	0	1	0

Dark Bad Integration Time Low [DPCINTL : 93h : 49h]

7	6	5	4	3	2	1	0
Dark Integration Time Lower							
1	1	0	0	1	0	0	1

Dark Bad Integration Time registers(91h-93h) specify minimum integration time value(63h-65h) where dark bad concealment operation is performed when dark bad pixel concealment mode is “01 (binary)”.

Dark G Threshold [DPCGTH : 94h : 20h]

7	6	5	4	3	2	1	0
Dark G Threshold							
0	0	1	0	0	0	0	0

The register value specify the current G pixel's differential value with neighboring G pixels, and is used to check whether current G pixel is dark bad pixel or not.

Dark R/B Threshold [DPCGTH : 95h : 20h]

7	6	5	4	3	2	1	0
Dark R/B Threshold							
0	0	1	0	0	0	0	0

The register value specify the current R or B pixel's differential value with neighboring G pixels, and is used to check whether current R or B pixel is dark bad pixel or not.

Reference of Amp Gain for Dark Bad Pixel Concealment [DPCGAIN : 96h : 38h]

7	6	5	4	3	2	1	0
Reference of Amp Gain for Dark Bad Pixel Concealment							
0	0	1	1	1	0	0	0

Amp Gain exceeds Reference of Amp Gain for Dark Bad Pixel Concealment, dark bad concealment operation is performed when dark bad pixel concealment mode is "01

Contrast factor Y [CONTY : 97h : 80h]

7	6	5	4	3	2	1	0
Contrast factor Y							
1	0	0	0	0	0	0	0

Contrast Adjustment is performed for multiplying Y data by Contrast Factor Y, respectively. Programmable range of Contrast Factor Y is 0 ~ 2.

Cont Y = Y data * B<7:0>/128.

PLL Control Mode A [PCTRA : a0h : 01h]

7	6	5	4	3	2	1	0
Reserved					VCO Power Down	PLL Power Down	Bypass Mode
0	0	0	0	0	0	0	1

VCO Power Down (Active High)	When VCO Power Down is active, VCO does not oscillate. For getting out of VCO Power Down, VCO initialization is required.
PLL Power Down (Active High)	When PLL Power Down is active, digital circuits of PLL do not operate and the charge pump circuits is disabled. Also Bypass Mode or Sleep Mode(SCTRB[4]) register is set to high, PLL goes into sleep.
Bypass Mode	0 PLL output clock is 1/F(ck). 1 PLL output clock is the same of PLL input clock.

*** VCO initialization**

To ensure the proper operation of the PLL, the activation of VCO initialization signal is required just after the deactivation of the VCO Power Down. During power-up sequence VCO initialization signal is recommended for more than 100ns.

PLL Control Mode B [PCTRB : a1h : 1dh]

7	6	5	4	3	2	1	0
Reserved		Post Divisor		Charge Pump Bias			
0	0	0	1	1	1	0	1

The value of Post Divisor according to the output frequency

Post Divisor	F(ck)	
	Min	Max
11	5MHz	12.5MHz
10	10MHz	25MHz
01	20MHz	50MHz
00	40MHz	100MHz

PLL Feedback Divisor High [PFDDIVH : a4h : 00h]

7	6	5	4	3	2	1	0
PLL Feedback Divisor High							
0	0	0	0	0	0	0	0

PLL Feedback Divisor Low [PFDDIVL : a5h : 02h]

7	6	5	4	3	2	1	0
PLL Feedback Divisor Low							
0	0	0	0	0	0	1	0

The operation frequency of PLL is related to the proportion of Reference(PREFDIV) to Feedback(PFDDIV) Divisor. F(ck) is actually determined by the following equation.

$$F(ck) = \frac{F(ref) * (Feedback \quad Divisor)}{(Reference \quad Divisor)}$$

F(ck) : frequency of output

F(ref) : frequency of PLL input

Feedback Divisor : PFDDIV[13:0] + 2

Reference Divisor : 2

Pixel Number High [PXNUMH : b9h : 04h]

7	6	5	4	3	2	1	0
Pixel Number High							
0	0	0	0	0	1	0	0

Pixel Number Low [PXNUML : bah : 00]

7	6	5	4	3	2	1	0
Pixel Number Low							
0	0	0	0	0	0	0	0

Stable Range variation [STTHVAL : bbh : 30h]

7	6	5	4	3	2	1	0
Stable Range variation							
0	0	1	1	0	0	0	0

Frequency Change Variation [CHTHVAL : bch : 20h]

7	6	5	4	3	2	1	0
Frequency Change Variation							
0	0	1	0	0	0	0	0

AFC Mode Control [AFCMODE : bdh : 00h]

7	6	5	4	3	2	1	0
Reserved			AFC Mode	Reserved			AFC Enable
0	0	0	0	0	0	0	0

AFC Mode	0	selected first AFC algorithm
	1	selected second AFC algorithm
AFC Enable	0	AFC off
	1	AFC on

50Hz Integration Time High [INTEG50H : c0h : 02h]

7	6	5	4	3	2	1	0
50Hz Integration Time High							
0	0	0	0	0	0	1	0

50Hz Integration Time Middle [INTEG50M : c1h : eeh]

7	6	5	4	3	2	1	0
50Hz Integration Time Middle							

1	1	1	0	1	1	1	0

50Hz Integration Time Low [INTEG50L : c2h : 00h]

7	6	5	4	3	2	1	0
50Hz Integration Time Low							
0	0	0	0	0	0	0	0

60Hz Integration Time High [INTEGT60H : c3h : 02h]

7	6	5	4	3	2	1	0
60Hz Integration Time High							
0	0	0	0	0	0	1	0

60Hz Integration Time Middle [INTEGT60M : c4h : 71h]

7	6	5	4	3	2	1	0
60Hz Integration Time Middle							
0	0	0	0	0	0	0	0

60Hz Integration Time Low [INTEGT60L :c5h : 00h]

7	6	5	4	3	2	1	0
60Hz Integration Time Low							
0	0	0	0	0	0	0	0

Anti-Banding Configuration

For Anti-Banding mode to work correctly, the following registers should be configured to the appropriate values.

AE Mode	60h	Anti-Banding Enable[7]
AE Anti-Banding Step	6a-6ch	(Sensor Clock Frequency) / (2 x power line frequency)
AE Integration Time Limit	6d-6fh	The value should be multiples of AE Anti-Banding Step

When Anti-Banding is enabled, AE initializes Integration Time registers[63-65h] to 4 x Anti-Banding Step value[6a-6ch], and integration increment/decrement amount is set to Anti-Banding Step value in order to remove anti-banding noise caused by intrinsic energy waveform of light sources. Banding noise is inherent in CMOS image sensor that adopts rolling shutter scheme for image acquisition.

Frame Timing

For clear description of frame timing, clocks' acronyms are reminded in here again.

< Clock Acronym Definition >

MCF : Master Clock Frequency	PCF : PLL Out Clock Frequency
DCF : Divided Clock Frequency	SCF : Sensor Clock Frequency
ICF : Image Processing Clock Frequency	LCF : Line Clock Frequency
VCF : Video Clock Frequency	

< Frame Time Calculation >

Core Frame Time is

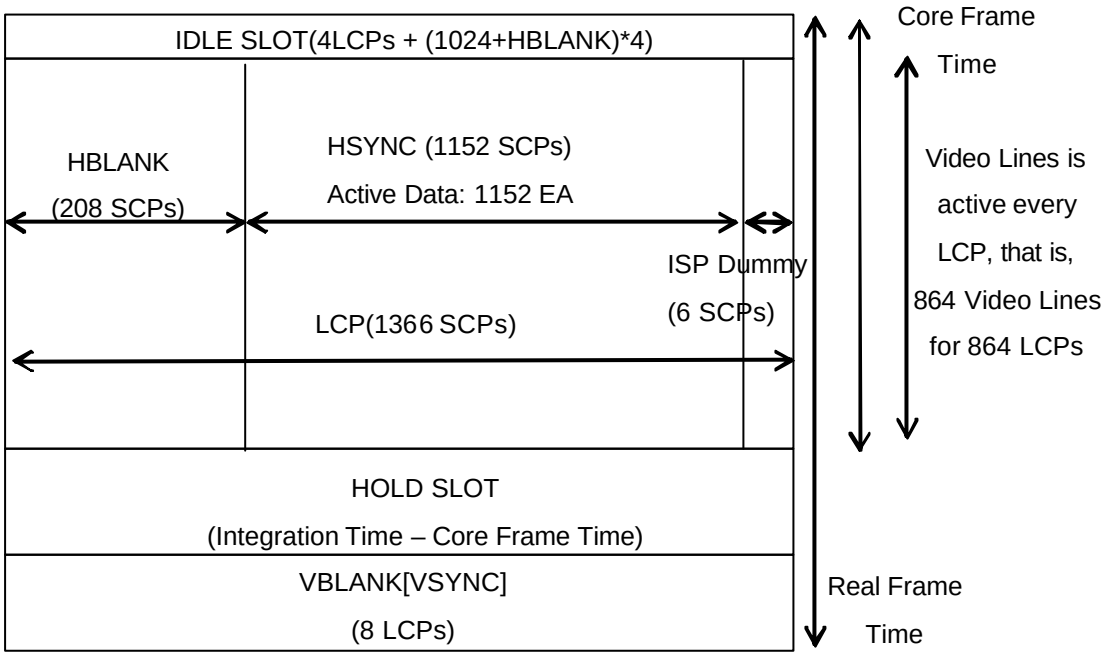
(IDLE SLOT + Video Height * LCP)

and Real Frame Time is resolved as follows.

When Integration Time > Core Frame Time, Real Frame Time is (Integration Time + VBLANK * LCP), otherwise is (Core Frame Time + VBLANK * LCP).

1. 5x5 Color Interpolation Timing (Full Size Mode)

5x5 Color Interpolation Frame Timing Related Parameters			
Master Clock Frequency(MCF)	19.2Mhz	PLL Out Clock Frequency(PCF)	MCF*2 = 38.4Mhz
Divided Clock Frequency(DCF)	PCF/1 = 38.4Mhz	Sensor Clock Frequency(SCF)	DCF/2 = 19.2Mhz
Sensor Clock Period(SCP)	1/19.2Mhz = 52ns	Window Width	1152
Window Height	864	HBLANK Value	208
VBLANK Value	8	VSYNC Mode	Line Mode
Line Clock Period(LCP)	1366 SCPs	Output Bus Width	8bit
VGA Video Output Frequency	SCF * 2 = 38.4Mhz	Final Video Output Size	1152x864



If Integration Time < Core Frame Time, Real Frame Time is

4 * (208 + 1152+6) SCPs + 864 * (208 + 1152+6) SCPs + 8 * (208 + 1152+6) SCPs + 4 * (208+1024)= 1201544 SCPs = 0.062580sec -> 15.979 frame per sec.

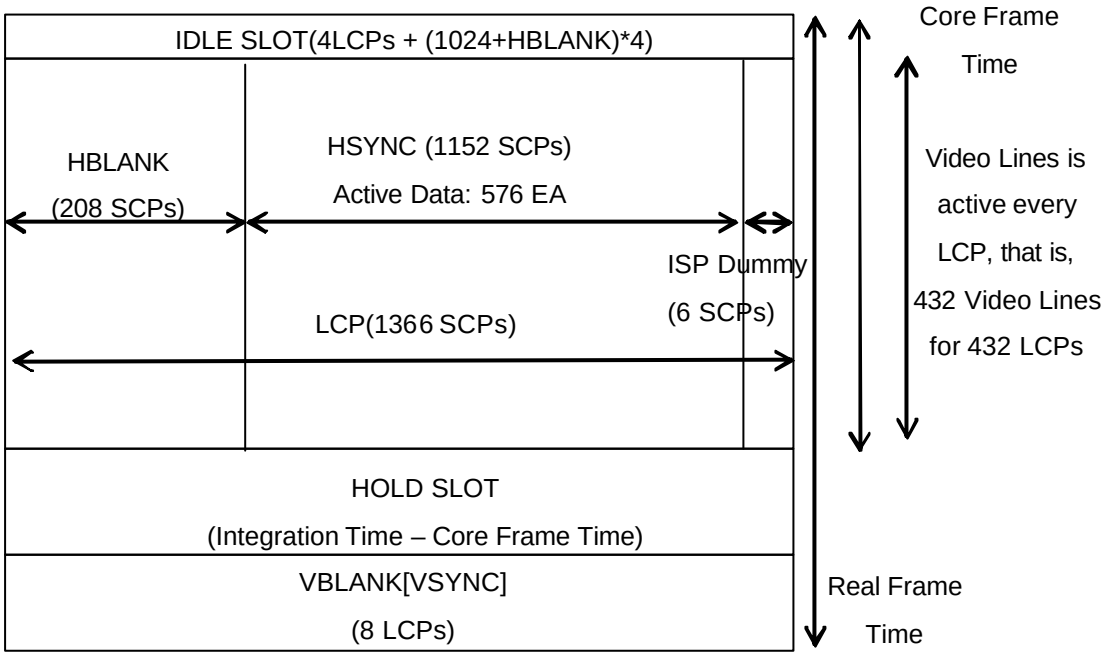
else Real Frame Time is

Integration Time * SCPs + 8 * (208 + 1152 + 6) SCPs.

HOLD SLOT in frame timing appears only if integration time is larger than core frame time.

2. 5x5 Color Interpolation Timing (1/4 Sub-Sampling Mode)

5x5 Color Interpolation Frame Timing Related Parameters			
Master Clock Frequency(MCF)	19.2Mhz	PLL Out Clock Frequency(PCF)	MCF*2 = 38.4Mhz
Divided Clock Frequency(DCF)	PCF/1 = 38.4Mhz	Sensor Clock Frequency(SCF)	DCF/2 = 19.2Mhz
Sensor Clock Period(SCP)	1/19.2Mhz = 52ns	Window Width	576
Window Height	432	HBLANK Value	208
VBLANK Value	8	VSYNC Mode	Line Mode
Line Clock Period(LCP)	1366 SCPs	Output Bus Width	8bit
VGA Video Output Frequency	SCF = 19.2Mhz	Final Video Output Size	576x432



If Integration Time < Core Frame Time, Real Frame Time is

4 * (208 + 1152+6) SCPs + 432 * (208 + 1152+6) SCPs + 8 * (208 + 1152+6) SCPs + 4 * (208+1024)= 611432 SCPs = 0.031845sec -> 31.402 frame per sec.

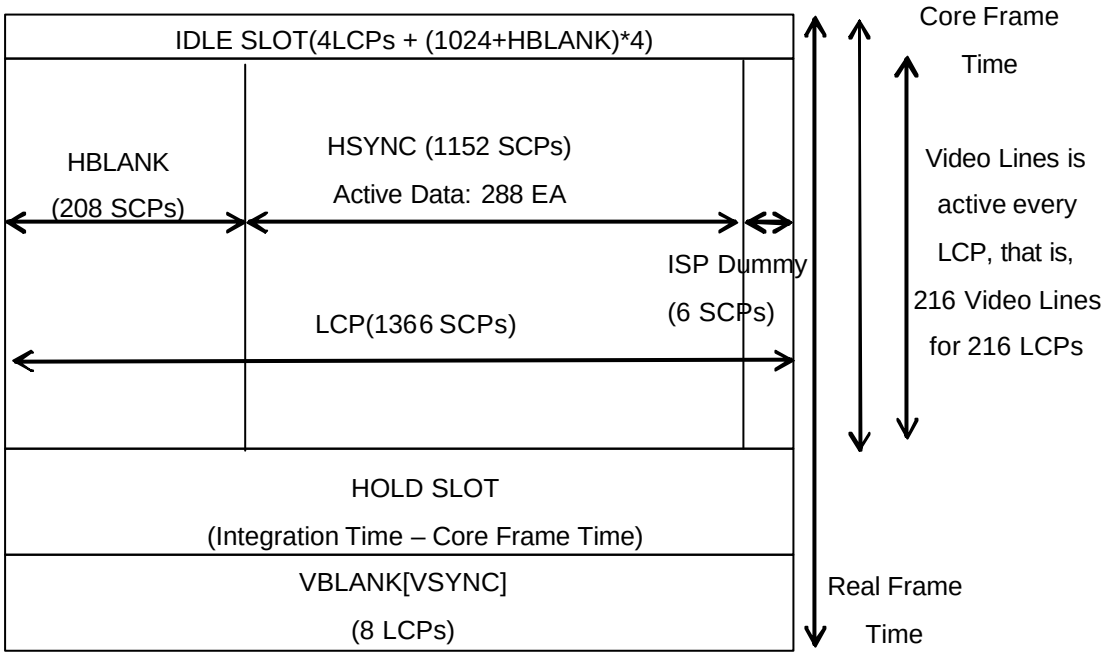
else Real Frame Time is

Integration Time * SCPs + 8 * (208 + 1152 + 6) SCPs.

HOLD SLOT in frame timing appears only if integration time is larger than core frame time.

3. 5x5 Color Interpolation Timing (1/16 Mode)

5x5 Color Interpolation Frame Timing Related Parameters			
Master Clock Frequency(MCF)	19.2Mhz	PLL Out Clock Frequency(PCF)	MCF*2 = 38.4Mhz
Divided Clock Frequency(DCF)	PCF/1 = 38.4Mhz	Sensor Clock Frequency(SCF)	DCF/2 = 19.2Mhz
Sensor Clock Period(SCP)	1/19.2Mhz = 52ns	Window Width	288
Window Height	216	HBLANK Value	208
VBLANK Value	8	VSYNC Mode	Line Mode
Line Clock Period(LCP)	1366 SCPs	Output Bus Width	8bit
VGA Video Output Frequency	SCF/2 = 9.6Mhz	Final Video Output Size	288x216



If Integration Time < Core Frame Time, Real Frame Time is

4 * (208 + 1152+6) SCPs + 216 * (208 + 1152+6) SCPs + 8 * (208 + 1152+6) SCPs + 4 * (208+1024)= 316376 SCPs = 0.016478sec -> 60.687frame per sec.

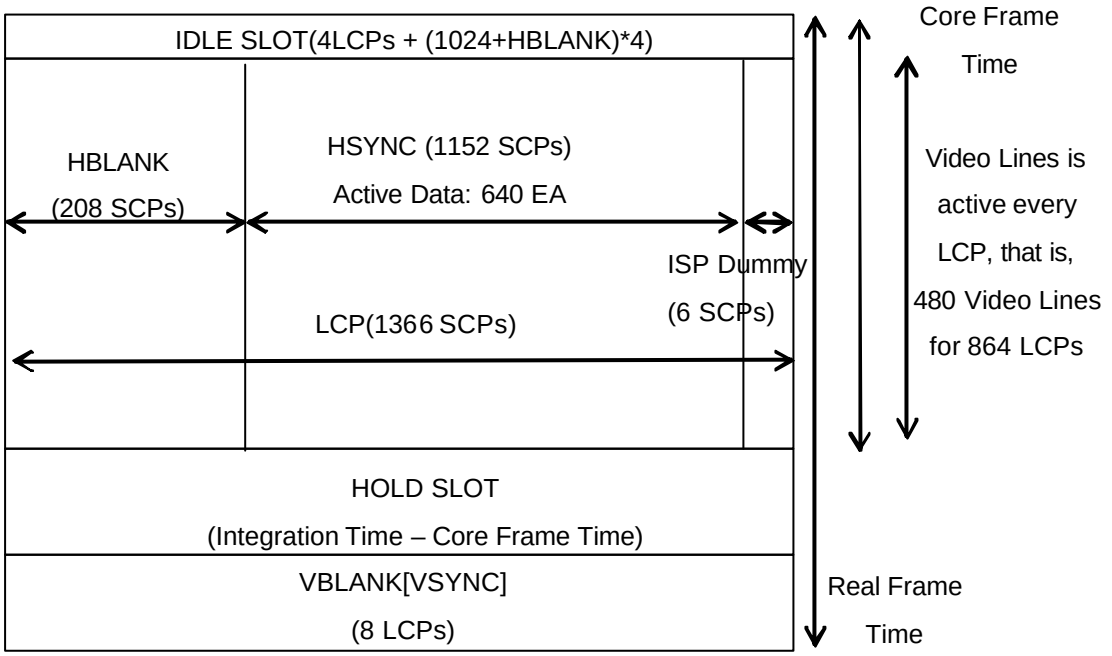
else Real Frame Time is

Integration Time * SCPs + 8 * (208 + 1152 + 6) SCPs.

HOLD SLOT in frame timing appears only if integration time is larger than core frame time.

4. 5x5 Color Interpolation Timing (VgaMode)

5x5 Color Interpolation Frame Timing Related Parameters			
Master Clock Frequency(MCF)	19.2Mhz	PLL Out Clock Frequency(PCF)	MCF*2 = 38.4Mhz
Divided Clock Frequency(DCF)	PCF/1 = 38.4Mhz	Sensor Clock Frequency(SCF)	DCF/2 = 19.2Mhz
Sensor Clock Period(SCP)	1/19.2Mhz = 52ns	Window Width	640
Window Height	480	HBLANK Value	208
VBLANK Value	8	VSYNC Mode	Line Mode
Line Clock Period(LCP)	1366 SCPs	Output Bus Width	8bit
VGA Video Output Frequency	Irregular clock	Final Video Output Size	640x480



If Integration Time < Core Frame Time, Real Frame Time is

4 * (208 + 1152+6) SCPs + 864 * (208 + 1152+6) SCPs + 8 * (208 + 1152+6) SCPs + 4 * (208+1024)= 1201544 SCPs = 0.062580sec -> 15.979 frame per sec.

else Real Frame Time is

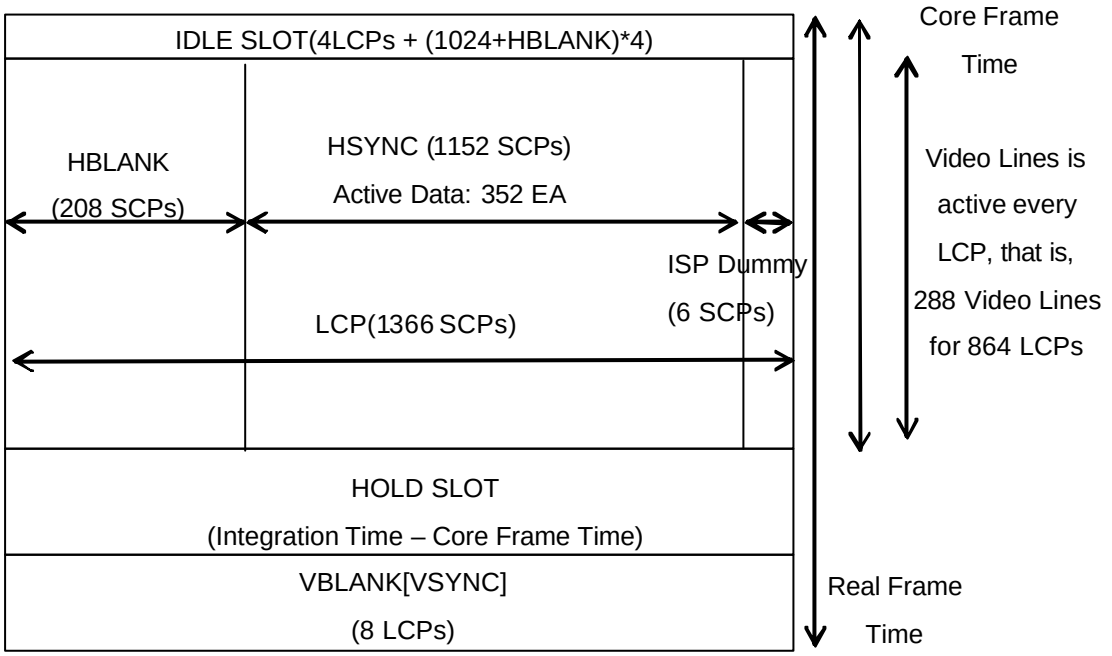
Integration Time * SCPs + 8 * (208 + 1152 + 6) SCPs.

HOLD SLOT in frame timing appears only if integration time is larger than core frame time.

VgaMode Frame rate is same as Full Size Mode. And QVgaMode has same frame rate.

5. 5x5 Color Interpolation Timing (CifMode)

5x5 Color Interpolation Frame Timing Related Parameters			
Master Clock Frequency(MCF)	19.2Mhz	PLL Out Clock Frequency(PCF)	MCF*2 = 38.4Mhz
Divided Clock Frequency(DCF)	PCF/1 = 38.4Mhz	Sensor Clock Frequency(SCF)	DCF/2 = 19.2Mhz
Sensor Clock Period(SCP)	1/19.2Mhz = 52ns	Window Width	352
Window Height	288	HBLANK Value	208
VBLANK Value	8	VSYNC Mode	Line Mode
Line Clock Period(LCP)	1366 SCPs	Output Bus Width	8bit
VGA Video Output Frequency	Irregular clock	Final Video Output Size	352x288



If Integration Time < Core Frame Time, Real Frame Time is

4 * (208 + 1152+6) SCPs + 864 * (208 + 1152+6) SCPs + 8 * (208 + 1152+6) SCPs + 4 * (208+1024)= 1201544 SCPs = 0.062580sec -> 15.979 frame per sec.

else Real Frame Time is

Integration Time * SCPs + 8 * (208 + 1152 + 6) SCPs.

HOLD SLOT in frame timing appears only if integration time is larger than core frame time.

QCifMode Frame rate is same as CifMode Frame rate.

Output Data according to Video Mode

Output Data according to Video Mode is controlled by configuring Sensor Control A[01h] and Output Format register[31h]. Configurable options are specified again for your reference.

Sensor Control A [SCTRA : 01h : 13h]

7	6	5	4	3	2	1	0
Reserved			X-Flip	Y-Flip	Video Mode		
0	0	0	1	0	0	1	1

Output Format [OUTFMT : 31h : 31h]

7	6	5	4	3	2	1	0
Gamma-Corrected Bayer	Bayer 8bit Output	Cb/B First	Y First	YCbCr 4:4:4 / 4:2:2	RGB 4:4:4	RGB 565	8 bit Output
0	0	1	1	0	0	0	1

Output timings for general configurations are described below. Slot named as “X” means that it is has no meaningful value and should be discarded. 8bit Output is active, C[7:0] are always Hi-Z state. In Case of Cb or Cr data, the digit stands for its sequence, respectively. For example, Cb01 is equal to average of Cb0 and Cb1.

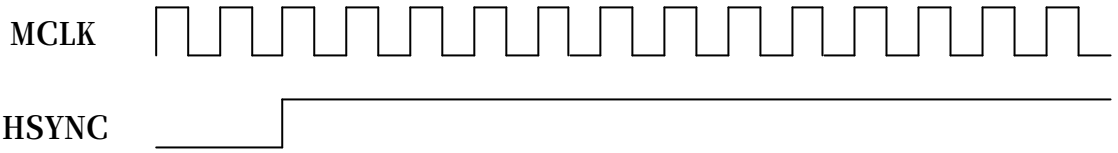
5X5 Mode or Sub-sampling(1/4, 1/16) Mode

1. YCbCr 4:2:2 with 8bit output

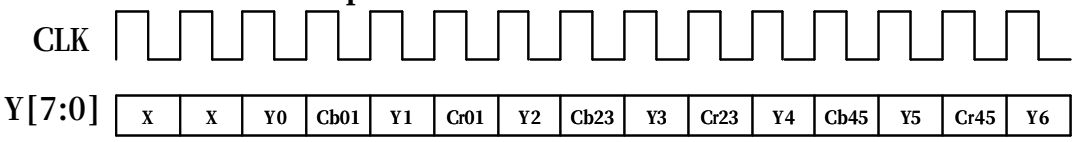
Register bit configurations

Sensor Control A : 5x5 Mode or Sub-sampling Mode

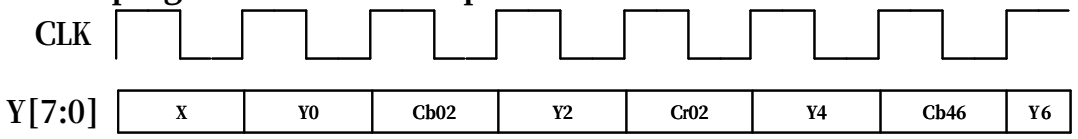
Output Format : 8bit Output, Y First, Cb/B First



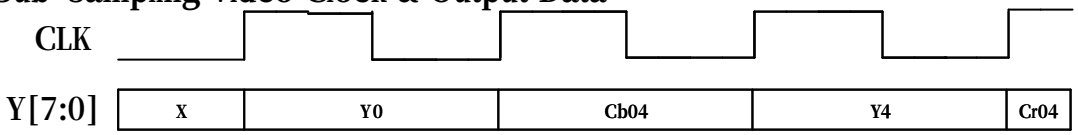
5X5 Mode Video Clock & Output Data



1/4 Sub-sampling Video Clock & Output Data



1/16 Sub-sampling Video Clock & Output Data

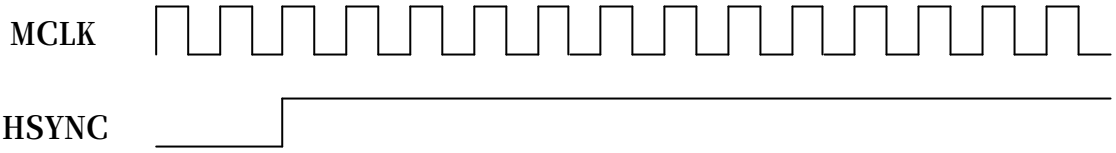


2. YCbCr 4:2:2 with 16bit output

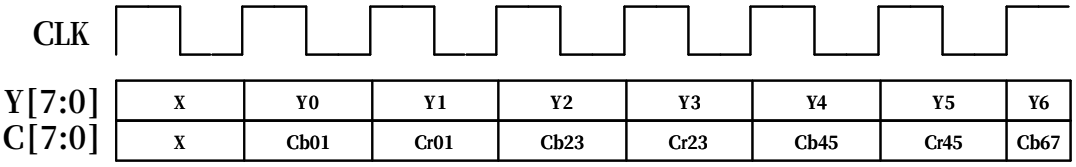
Register bit configurations

Sensor Control A : 5x5 Mode or Sub-sampling Mode

Output Format : 16bit Output, Cb/B First

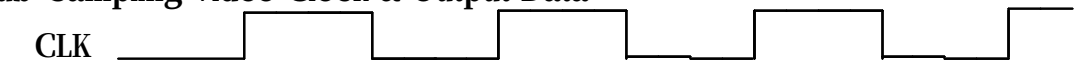


5X5 Mode Video Clock & Output Data



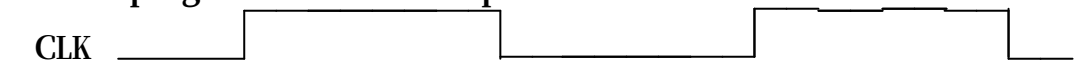
Y[7:0]	X	Y0	Y1	Y2	Y3	Y4	Y5	Y6
C[7:0]	X	Cb01	Cr01	Cb23	Cr23	Cb45	Cr45	Cb67

1/4 Sub-sampling Video Clock & Output Data



Y[7:0]	X	Y0	Y2	Y4	Y6
C[7:0]	X	Cb02	Cr02	Cb46	Cr46

1/16 Sub-sampling Video Clock & Output Data



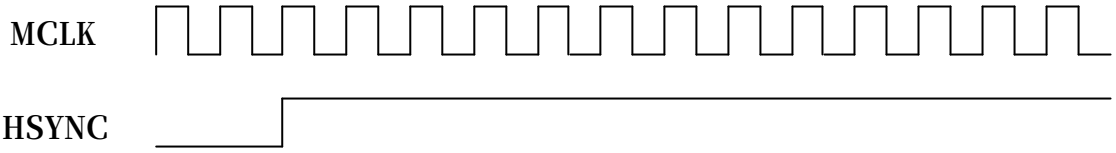
Y[7:0]	X	Y0	Y4
C[7:0]	X	Cb04	Cr04

3. YCbCr 4:4:4 with 16bit output

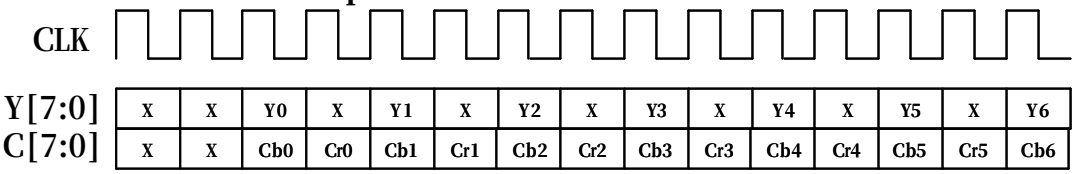
Register bit configurations

Sensor Control A : 5x5 Mode or Sub-sampling Mode

Output Format : 16bit Output, Y First, Cb/B First

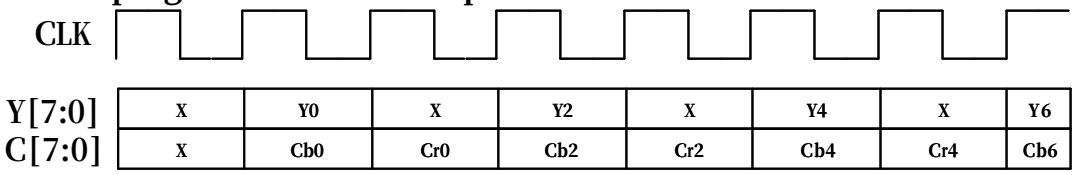


5X5 Mode Video Clock & Output Data



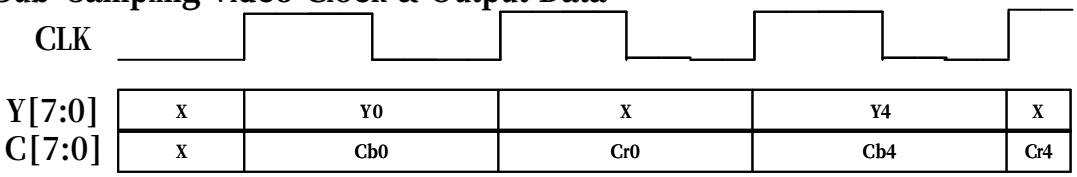
Y[7:0]	X	X	Y0	X	Y1	X	Y2	X	Y3	X	Y4	X	Y5	X	Y6
C[7:0]	X	X	Cb0	Cr0	Cb1	Cr1	Cb2	Cr2	Cb3	Cr3	Cb4	Cr4	Cb5	Cr5	Cb6

1/4 Sub-sampling Video Clock & Output Data



Y[7:0]	X	Y0	X	Y2	X	Y4	X	Y6
C[7:0]	X	Cb0	Cr0	Cb2	Cr2	Cb4	Cr4	Cb6

1/16 Sub-sampling Video Clock & Output Data



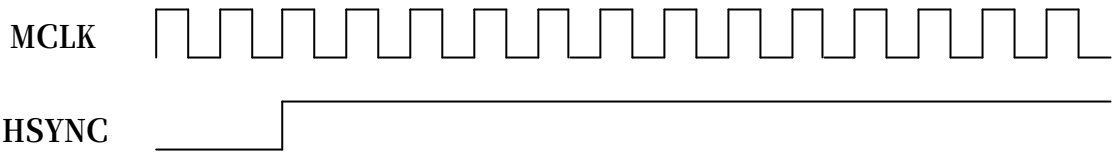
Y[7:0]	X	Y0	X	Y4	X
C[7:0]	X	Cb0	Cr0	Cb4	Cr4

4. RGB 565 with 8bit output

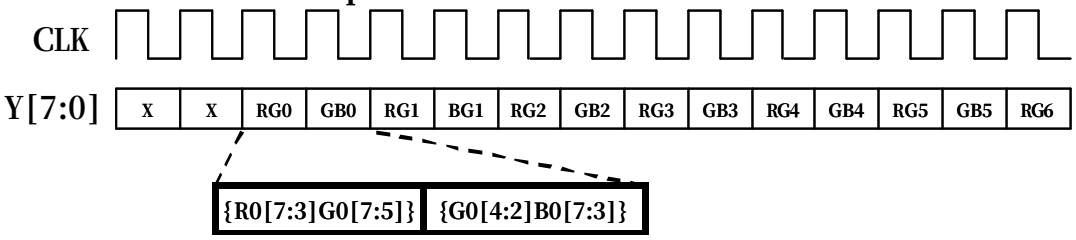
Register bit configurations

Sensor Control A : 5x5 Mode or Sub-sampling Mode

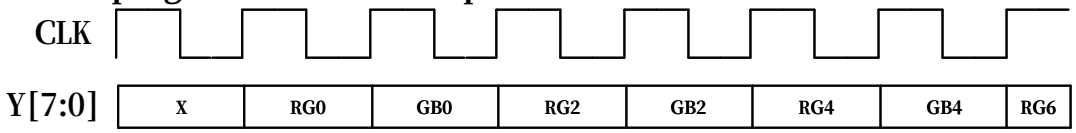
Output Format : 8bit Output, Cb/B First, RGB565



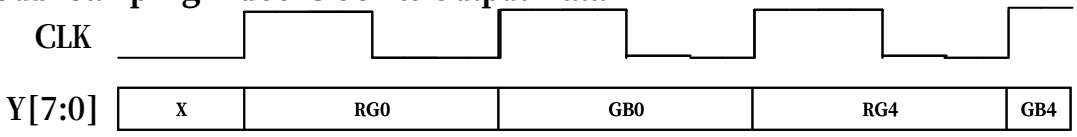
5X5 Mode Video Clock & Output Data



1/4 Sub-sampling Video Clock & Output Data



1/16 Sub-sampling Video Clock & Output Data

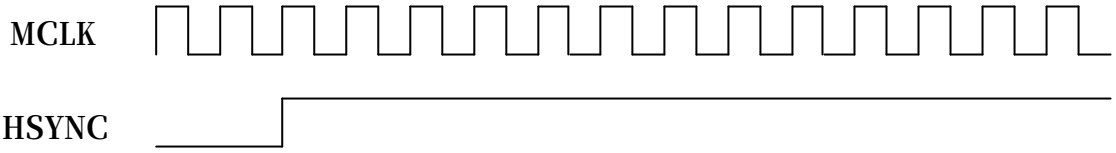


5. RGB 565 with 16bit output

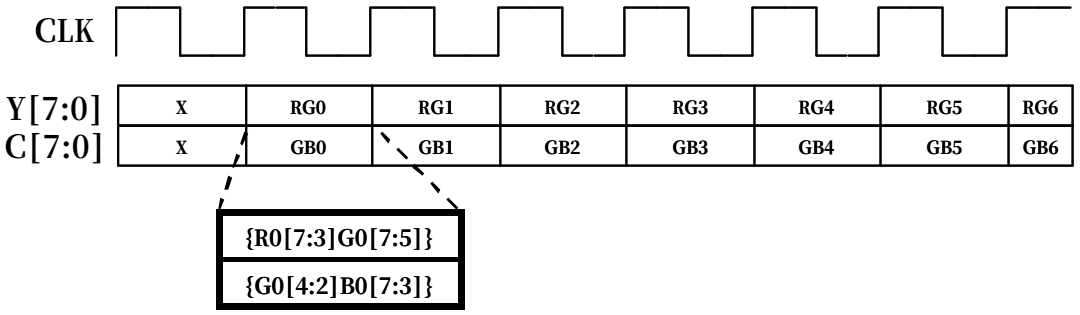
Register bit configurations

Sensor Control A : 5x5 Mode or Sub-sampling Mode

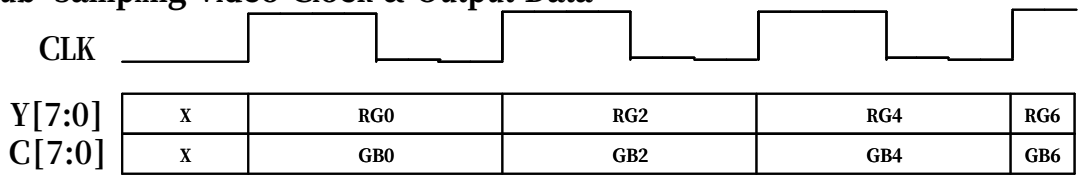
Output Format : 16bit Output, Cb/B First, RGB565



5X5 Mode Video Clock & Output Data



1/4 Sub-sampling Video Clock & Output Data



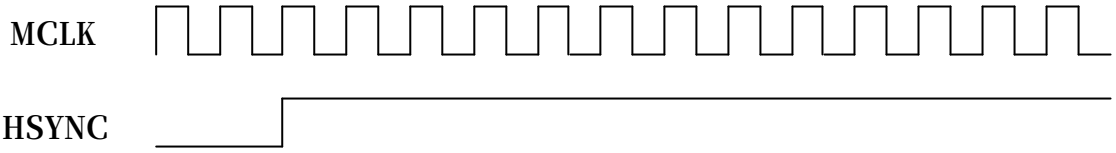
1/16 Sub-sampling Video Clock & Output Data

6. RGB 4:4:4 with 16bit output

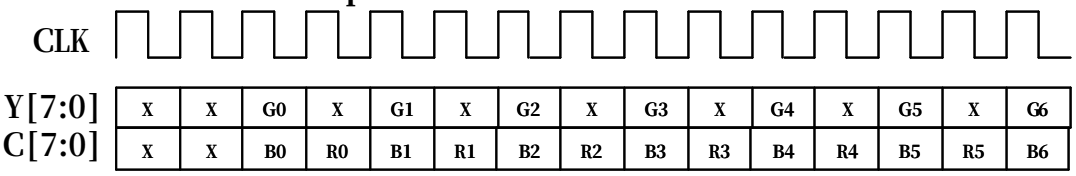
Register bit configurations

Sensor Control A : 5x5 Mode or Sub-sampling Mode

Output Format : 16bit Output, Cb/B First, RGB4:4:4

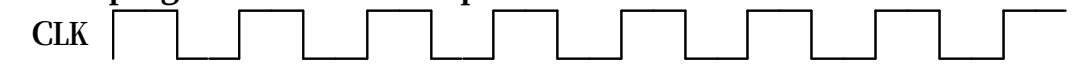


5X5 Mode Video Clock & Output Data



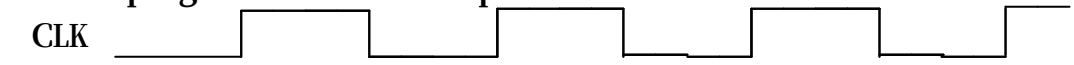
Y[7:0]	X	X	G0	X	G1	X	G2	X	G3	X	G4	X	G5	X	G6
C[7:0]	X	X	B0	R0	B1	R1	B2	R2	B3	R3	B4	R4	B5	R5	B6

1/4 Sub-sampling Video Clock & Output Data



Y[7:0]	X	G0	X	G2	X	G4	X	G6
C[7:0]	X	B0	R0	B2	R2	B4	R4	B6

1/16 Sub-sampling Video Clock & Output Data



Y[7:0]	X	G0	X	G4	X
C[7:0]	X	B0	R0	B4	R4

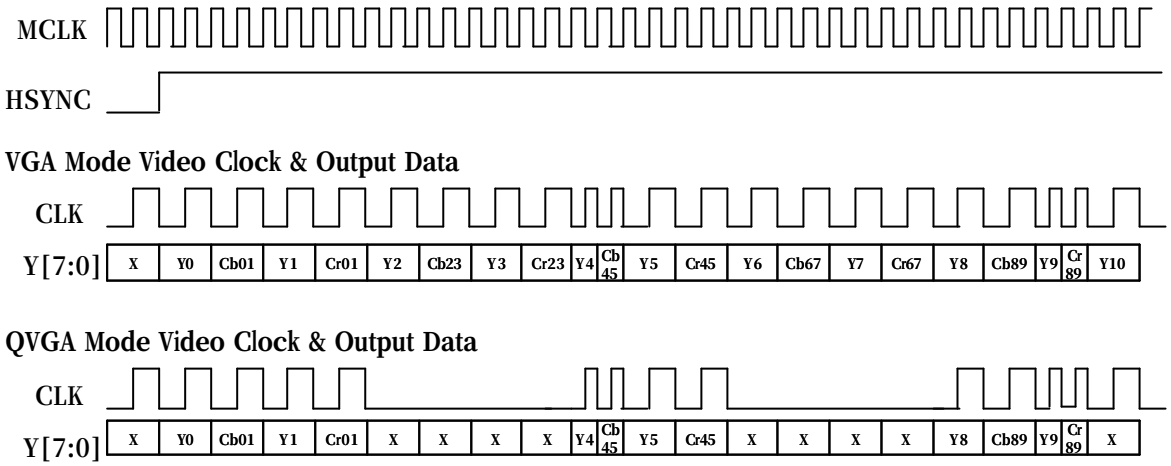
VGA Mode or QVGA Mode

1. YCbCr 4:2:2 with 8bit output

Register bit configurations

Sensor Control A : VGA Mode or QVGA Mode

Output Format : 8bit Output, Y First, Cb/B First

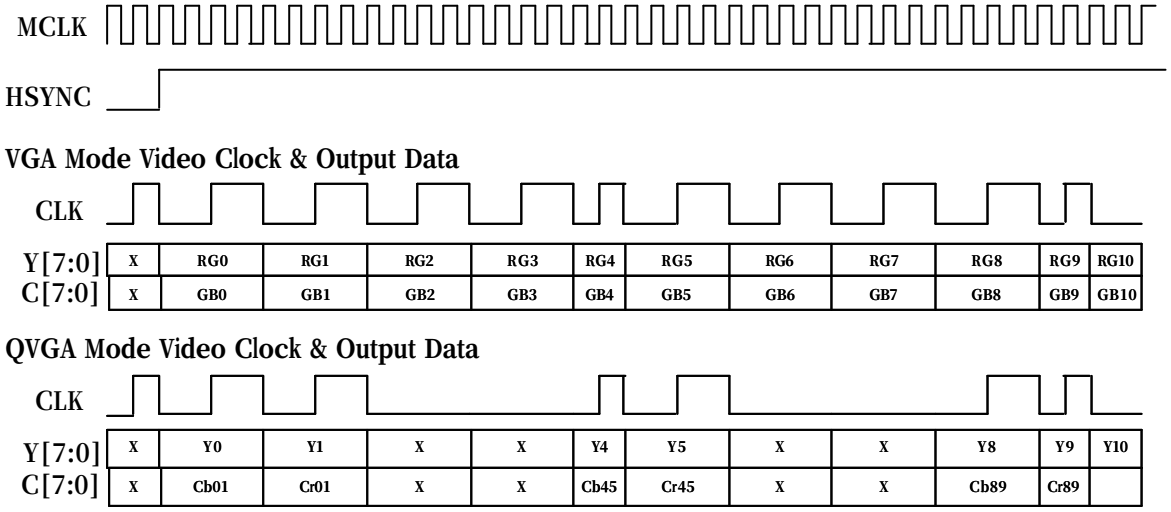


2. YCbCr 4:2:2 with 16bit output

Register bit configurations

Sensor Control A : VGA Mode or QVGA Mode

Output Format : 16bit Output, Cb/B First

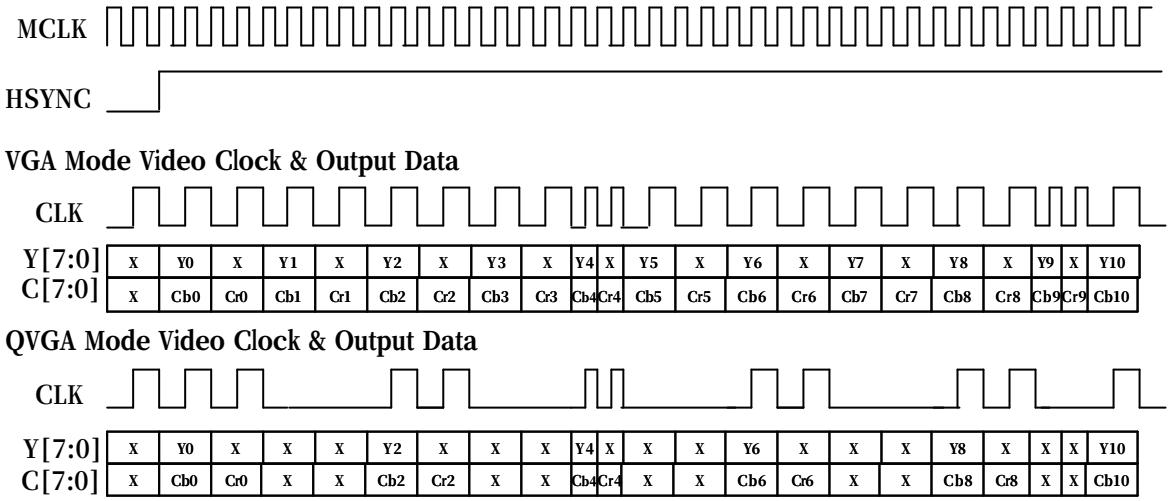


3. YCbCr 4:4:4 with 16bit output

Register bit configurations

Sensor Control A : VGA Mode or QVGA Mode

Output Format : 16bit Output, Y First, Cb/B First

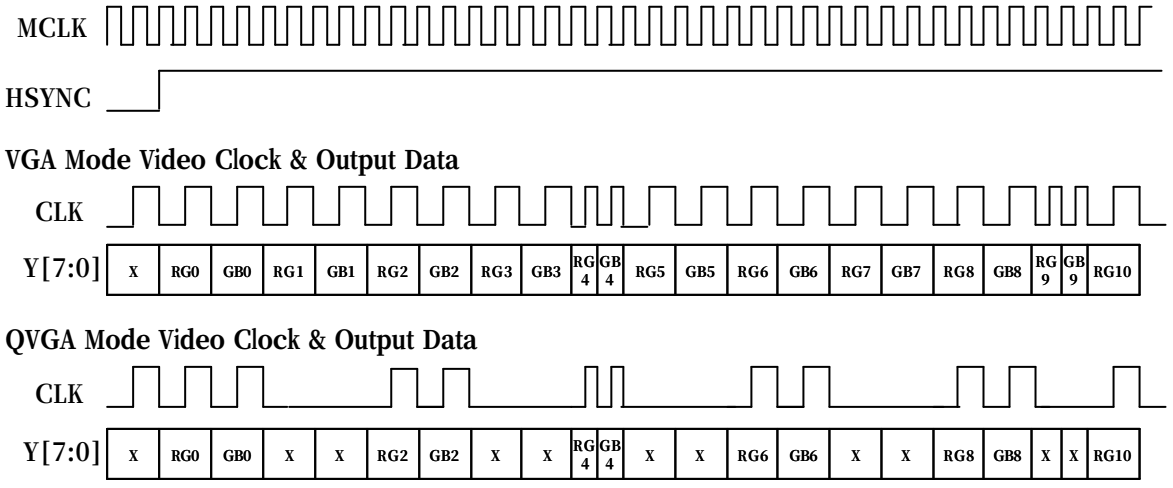


4. RGB 565 with 8bit output

Register bit configurations

Sensor Control A : VGA Mode or QVGA Mode

Output Format : 8bit Output, Cb/B First, RGB565

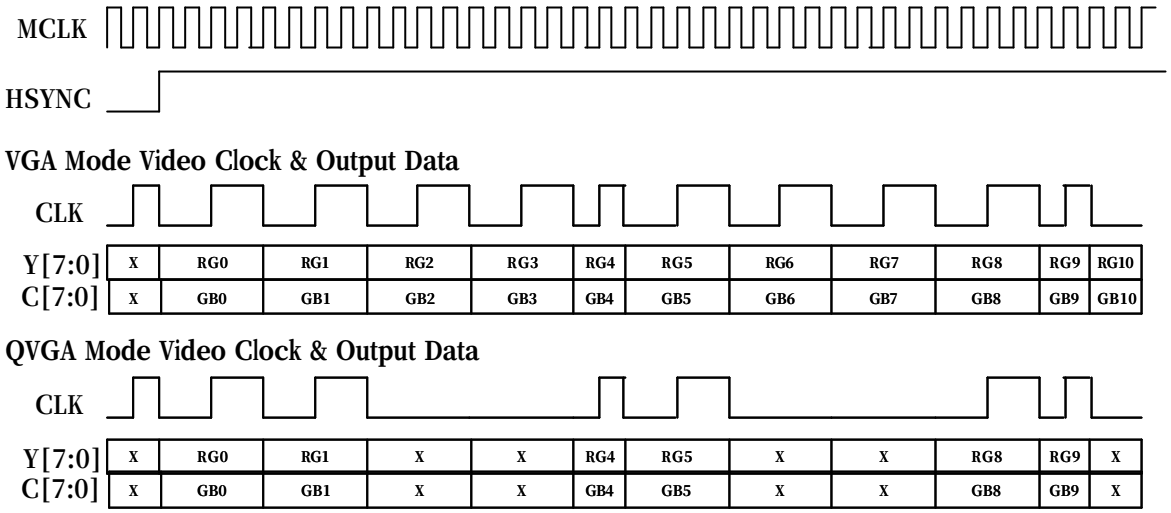


5. RGB 565 with 16bit output

Register bit configurations

Sensor Control A : VGA Mode or QVGA Mode

Output Format : 16bit Output, Cb/B First, RGB565

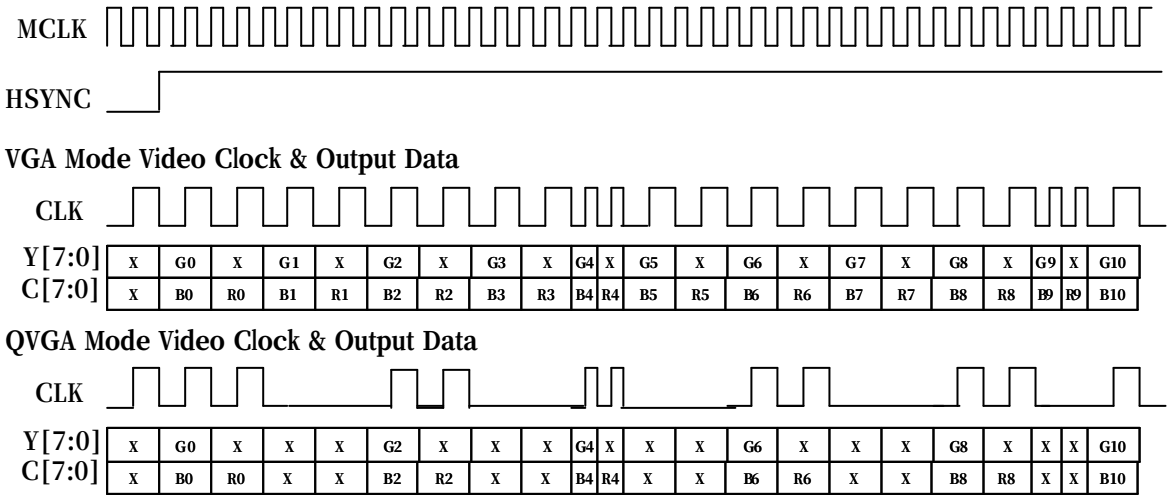


6. RGB 4:4:4 with 16bit output

Register bit configurations

Sensor Control A : VGA Mode or QVGA Mode

Output Format : 16bit Output, Cb/B First, RGB4:4:4



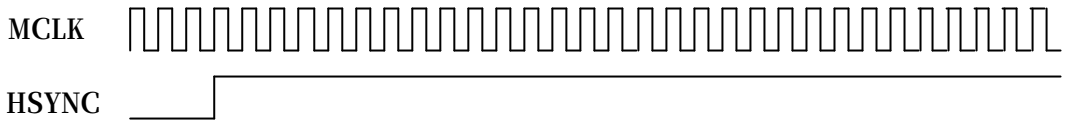
CIF Mode or QCIF Mode

1. YCbCr 4:2:2 with 8bit output

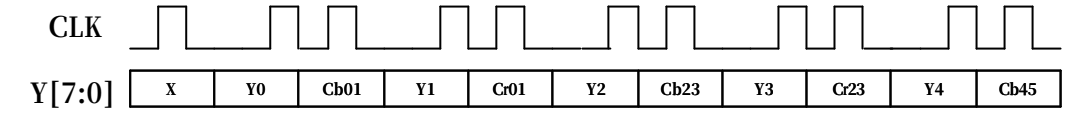
Register bit configurations

Sensor Control A : CIF Mode or QCIF Mode

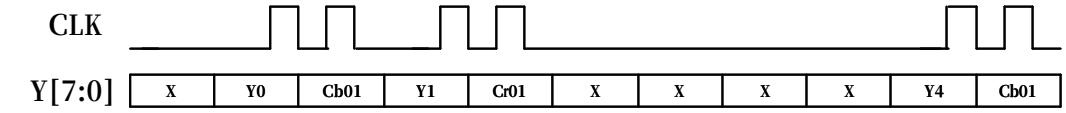
Output Format : 8bit Output, Y First, Cb/B First



CIF Mode Video Clock & Output Data



QCIF Mode Video Clock & Output Data

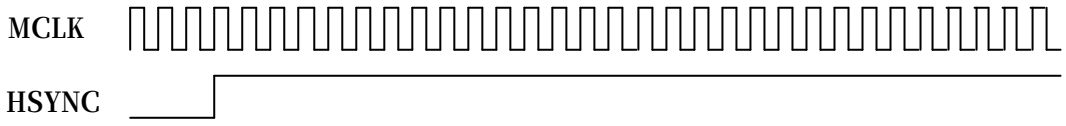


2. YCbCr 4:2:2 with 16bit output

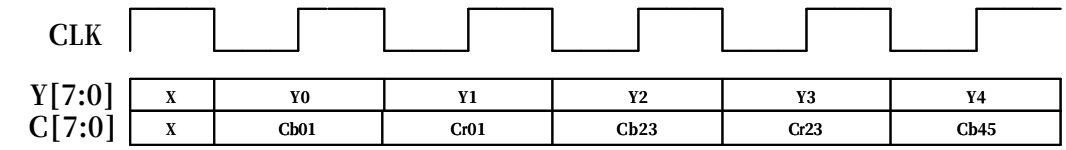
Register bit configurations

Sensor Control A : CIF Mode or QCIF Mode

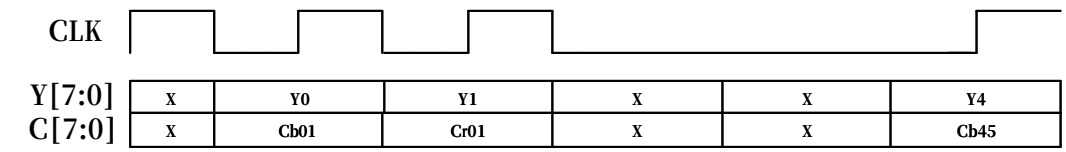
Output Format : 16bit Output, Cb/B First



CIF Mode Video Clock & Output Data



QCIF Mode Video Clock & Output Data

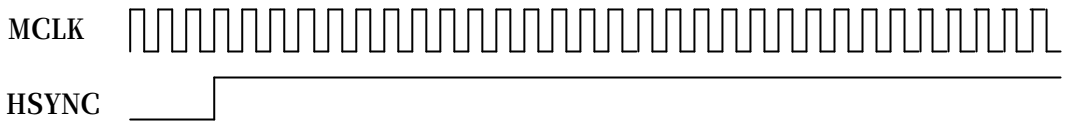


3. YCbCr 4:4:4 with 16bit output

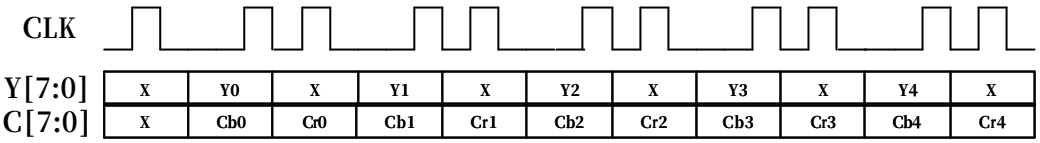
Register bit configurations

Sensor Control A : CIF Mode or QCIF Mode

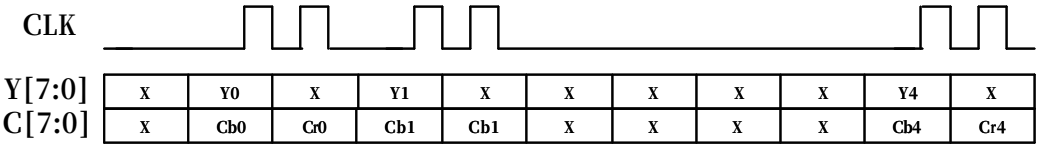
Output Format : 16bit Output, Y First, Cb/B First



CIF Mode Video Clock & Output Data



QCIF Mode Video Clock & Output Data

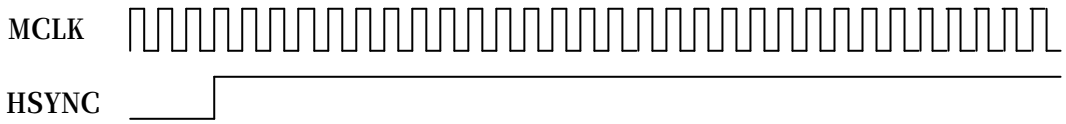


4. RGB 565 with 8bit output

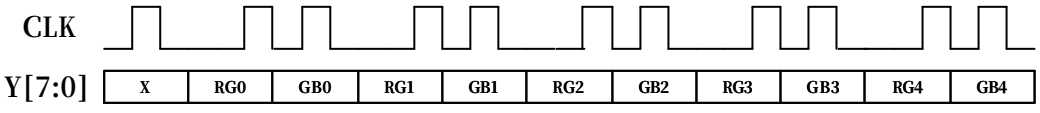
Register bit configurations

Sensor Control A : CIF Mode or QCIF Mode

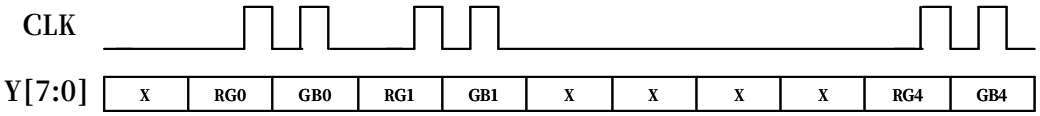
Output Format : 8bit Output, Cb/B First, RGB565



CIF Mode Video Clock & Output Data



QCIF Mode Video Clock & Output Data

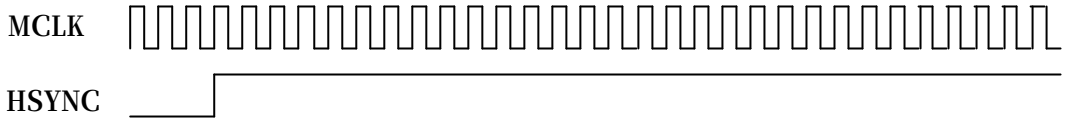


5. RGB 565 with 16bit output

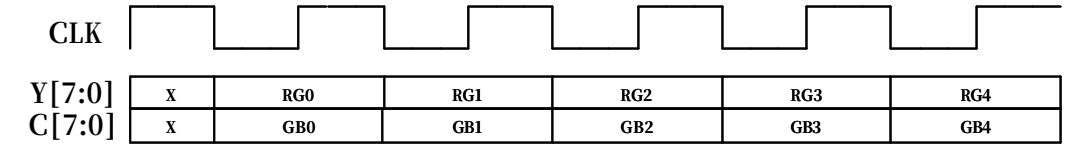
Register bit configurations

Sensor Control A : CIF Mode or QCIF Mode

Output Format : 16bit Output, Cb/B First, RGB565



CIF Mode Video Clock & Output Data



Y[7:0]	X	RG0	RG1	RG2	RG3	RG4
C[7:0]	X	GB0	GB1	GB2	GB3	GB4

QCIF Mode Video Clock & Output Data

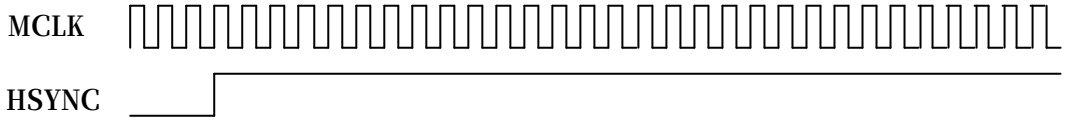
Y[7:0]	X	RG0	RG1	X	X	RG4
C[7:0]	X	GB0	GB1	X	X	GB4

6. RGB 4:4:4 with 16bit output

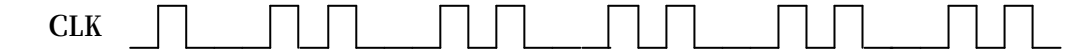
Register bit configurations

Sensor Control A : CIF Mode or QCIF Mode

Output Format : 16bit Output, Cb/B First, RGB4:4:4



CIF Mode Video Clock & Output Data



Y[7:0]	X	G0	X	G1	X	G2	X	G3	X	G4	X
C[7:0]	X	B0	R0	B1	R1	B2	R2	B3	R3	B4	R4

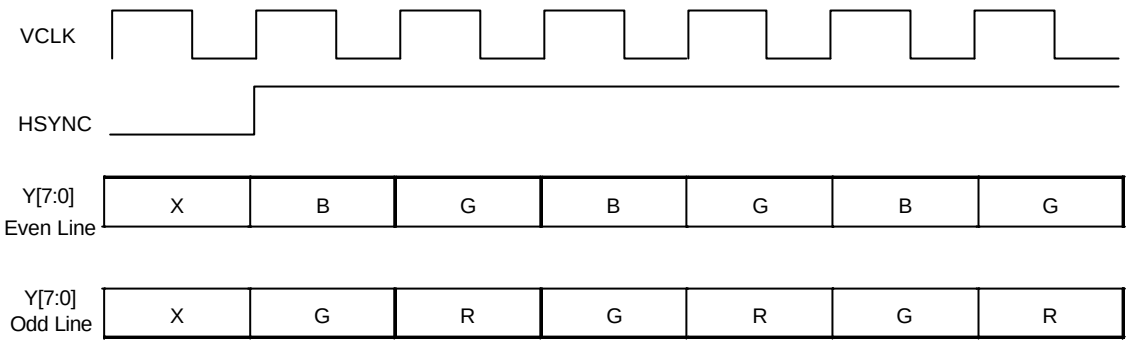
QCIF Mode Video Clock & Output Data

Y[7:0]	X	G0	X	G1	X	X	X	X	X	G4	X
C[7:0]	X	B0	R0	B1	R1	X	X	X	X	B4	R4

Bayer Data Format

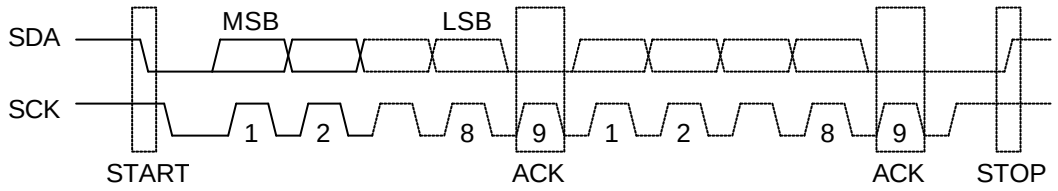
SCTRA[2:0] is set to Bayer mode

- When Bayer output mode is selected, Window Width x Window Height raw image data are produced with the following sequence. After VSYNC goes low state, the first HSYNC line of a frame is activated with B pixel data appearing first when both of Column Start Address and Row Start Address are even.



I2C Chip Interface

The serial bus interface consists of the SDA(serial data) and SCK(serial clock) pins. HV7151SP sensor can operate only as a slave. The SCK only controls the serial interface. However, MCLK should be supplied and RESET should be high signal during controlling the serial interface. The Start condition is that logic transition (High to Low) on the SDA pin while the SCK pin is at high state. The Stop condition is that logic transition (Low to High) on the SDA pin while the SCK pin is at high state. To generate Acknowledge signal, the Sensor drives the SDA low when the SCK pin is at high state. Every byte consists of 8 bits. Each byte transferred on the bus must be followed by an Acknowledge. The most significant bit of the byte should always be transmitted first.



Register Write Sequences

One Byte Write

S	22H	A	01H	A	04H	A	P
*1	*2	*3	*4	*5	*6	*7	*8

Set "Sensor Control A" register into Window mode

*1. Drive: I2C start condition

*2. Drive: 22H(001_0001 + 0) [device address + R/W bit]

*3. Read: acknowledge from sensor

*4. Drive: 01H [sub-address]

*5. Read: acknowledge from sensor

*6. Drive: 04H [Video Mode : VGA]

*7. Read: acknowledge from sensor

*8. Drive: I2C stop condition

Multiple Byte Write using Auto Address Increment

S	22H	A	0cH	A	03H	A	60H	A	P
*1	*2	*3	*4	*5	*6	*7	*8	*9	*10

Set "AE Integration Step High/Low" register as 5161H with auto address increment

*1. Drive: I2C start condition

*2. Drive: 22H(001_0001 + 0) [device address + R/W bit]

*3. Read: acknowledge from sensor

*4. Drive: 0cH [sub-address]

*5. Read: acknowledge from sensor

*6. Drive: 03H [Window Height Upper]

*7. Read: acknowledge from sensor

*8. Drive: 60H [Window Height Lower]

*9. Read: acknowledge from sensor

*10. Drive: I2C stop condition

Register Read Sequence

S	22H	A	1cH	A	S	23H	A	Data of 07H	A	P
*1	*2	*3	*4	*5	*6	*7	*8	*9	*10	*11

Read "Reset Level Clamp" register from HV7151SP

*1. Drive: I2C start condition

*2. Drive: 22H(001_0001 + 0) [device address + R/W bit(be careful. R/W=0)]

*3. Read: acknowledge from sensor

*4. Drive: 1cH [sub-address]

*5. Read: acknowledge from sensor

*6. Drive: I^2C start condition

*7. Drive: 23H(001_0001 + 1) [device address + R/W bit(be careful. R/W=1)]

*8. Read: acknowledge from sensor

*9. Read: Read “Reset Level Clamp” from sensor

*10. Drive: acknowledge to sensor. If there is more data bytes to read, SDA should be driven to low and data read states(*9, *10) is repeated. Otherwise SDA should be driven to high to prepare for the read transaction end.

*11. Drive: I2C stop condition

AC/DC Characteristics

Absolute Maximum Ratings

Symbol	Parameter	Units	Min.	Max.
Viopp	I/O block supply voltage	Volts	-0.3	3.3
Vdpp	Internal digital supply voltage	Volts	-0.3	2.5
Vapp	Analog supply voltage	Volts	-0.3	2.5
Vipp	Input signal voltage	Volts	-0.3	3.3
Top	Operating Temperature	°C	-10	50
Tst	Storage Temperature	°C	-30	80

Caution: Stresses exceeding the absolute maximum ratings may induce failure.

DC Operating Conditions

Symbol	Parameter	Units	Min.	Max.	Load[pF]	Notes
Vio	I/O block supply voltage	Volt	2.3	2.8		
V_{dd}	Internal operation supply voltage	Volt	1.6	2.0		
V_{ih}	Input voltage logic "1"	Volt	2.3	2.5	6.5	
V_{il}	Input voltage logic "0"	Volt	0	0.8	6.5	
V_{oh}	Output voltage logic "1"	Volt	2.15	Vio	60	
V_{ol}	Output voltage logic "0"	Volt		0.4	60	
I_{oh}	Output High Current	mA		-4	60	
I_{ol}	Output Low Current	mA		4	60	
T_a	Ambient operating temperature	Celsius	-10	50		

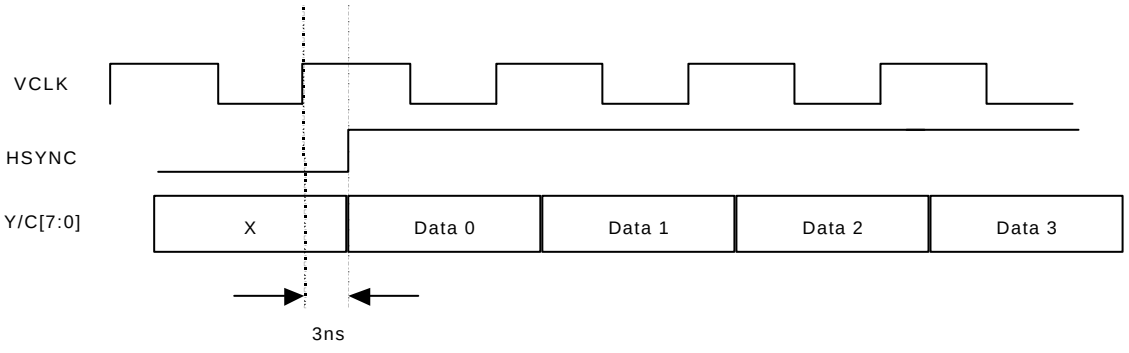
AC Operating Conditions

Symbol	Parameter	Max Operation Frequency	Units	Notes
MCLK	Main clock frequency	1) PLL off : 38.4 2) PLL on : $\frac{38.4*(Reference\ Divisor)}{(Feedback\ Divisor)}$	MHz	1,2,3
SCK	I^2C clock frequency	400	KHz	4

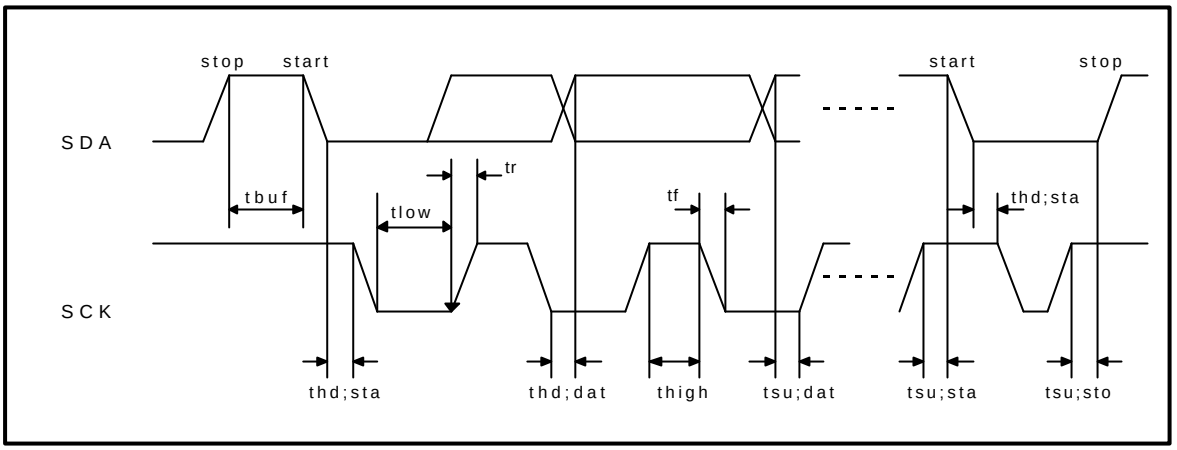
1. MCLK may be divided by internal clock division logic for easy integration with high speed video codec system.
2. Reference Divider and Feedback Divider is registers a3h and a4h, a5h, respectively.
3. Frame Rate : 15 frames/sec at 38.4Mhz and PLL off , HBLANK = 208, VBLANK = 8
4. SCK is driven by host processor. For the detail serial bus timing, refer to I2C chip interface section

Output AC Characteristics

All output timing delays are measured with output load 60[pF]. Output delay includes the internal clock path delay and output driving delay that changes in respect to the output load, the operating environment, and a board design. Due to the variable valid time delay of the output, video output signals Y[7:0], C[7:0], HSYNC, and VSYNC may be latched in the negative edge of VCLK for the stable data transfer between the image sensor and video codec.



I2C Bus Timing

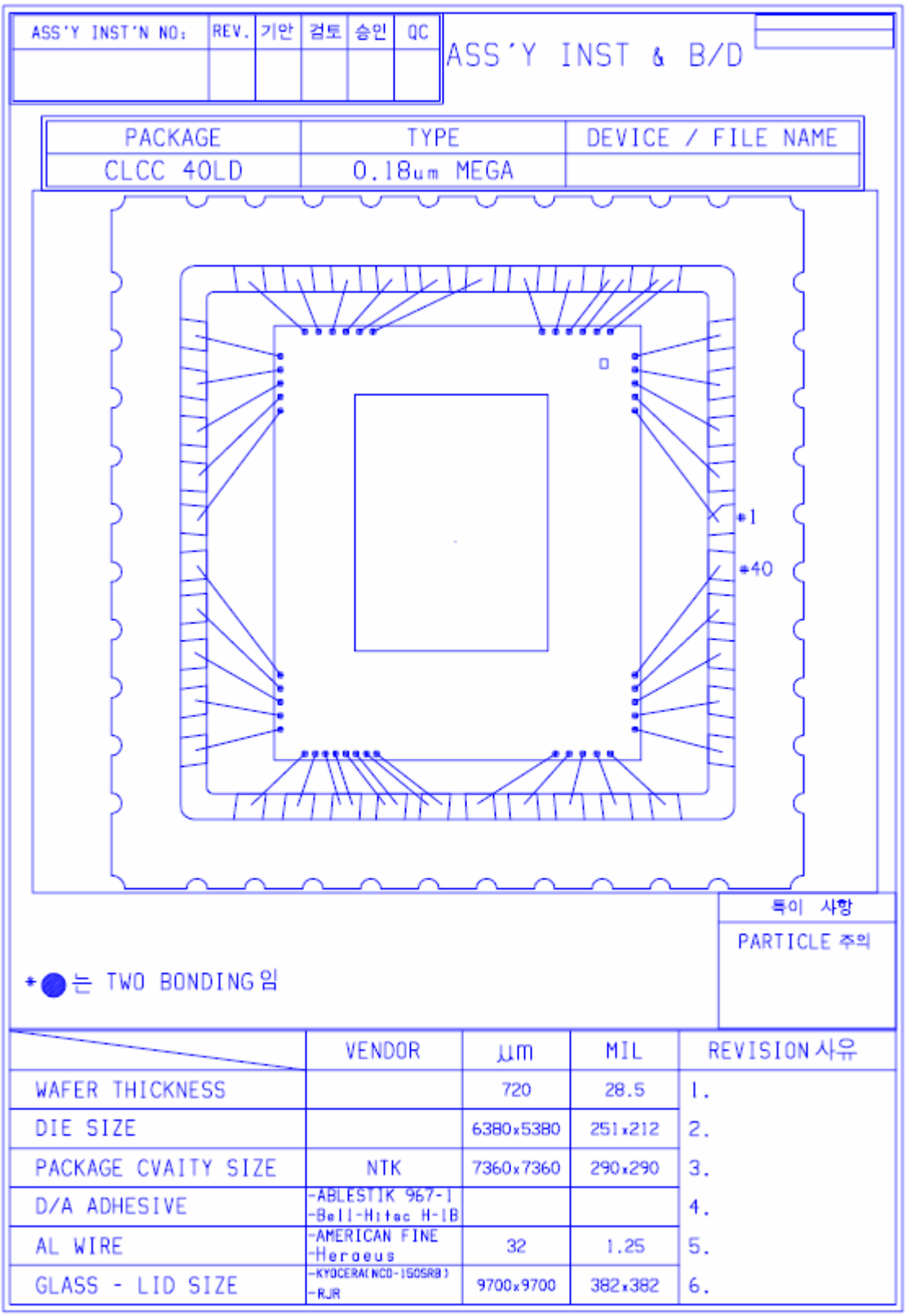


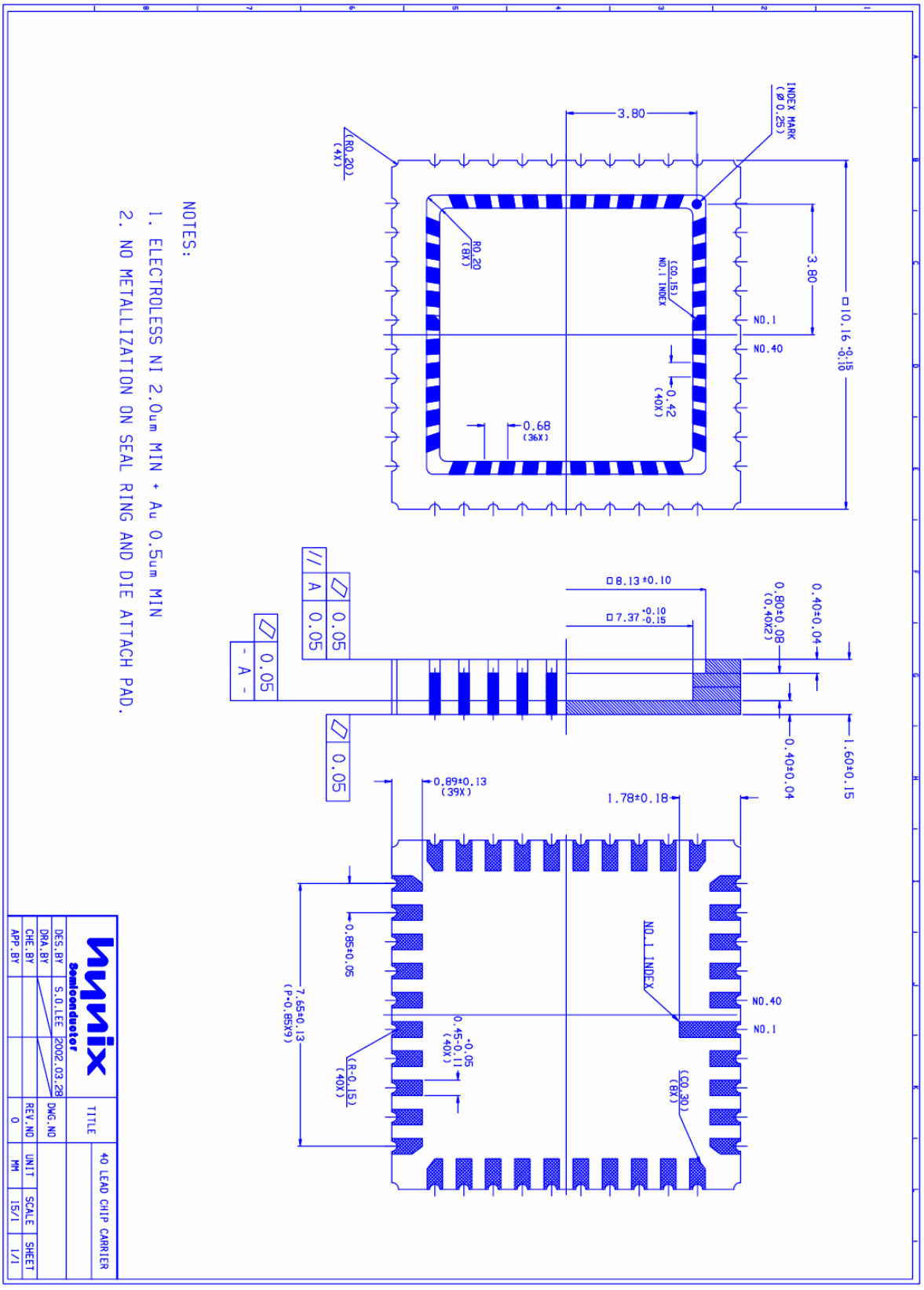
Parameter	Symbol	Min.	Max.	Unit
SCK clock frequency	f_{sck}	0	400	KHz
Time that I^2C bus must be free before a new transmission can start	t_{buf}	1.2	-	us
Hold time for a START	$t_{hd};s_{ta}$	1.0	-	us
LOW period of SCK	t_{low}	1.2	-	us
HIGH period of SCK	t_{high}	1.0	-	us
Setup time for START	$t_{su};s_{ta}$	1.2	-	us
Data hold time	$t_{hd};d_{at}$	0.1	-	us
Data setup time	$t_{su};d_{at}$	250	-	ns
Rise time of both SDA and SCK	t_r	-	250	ns
Fall time of both SDA and SCK	t_f	-	300	ns
Setup time for STOP	$t_{su};s_{to}$	1.2	-	us
Capacitive load of SCK/SDA	C_b	-	-	pf

Electro-Optical Characteristics

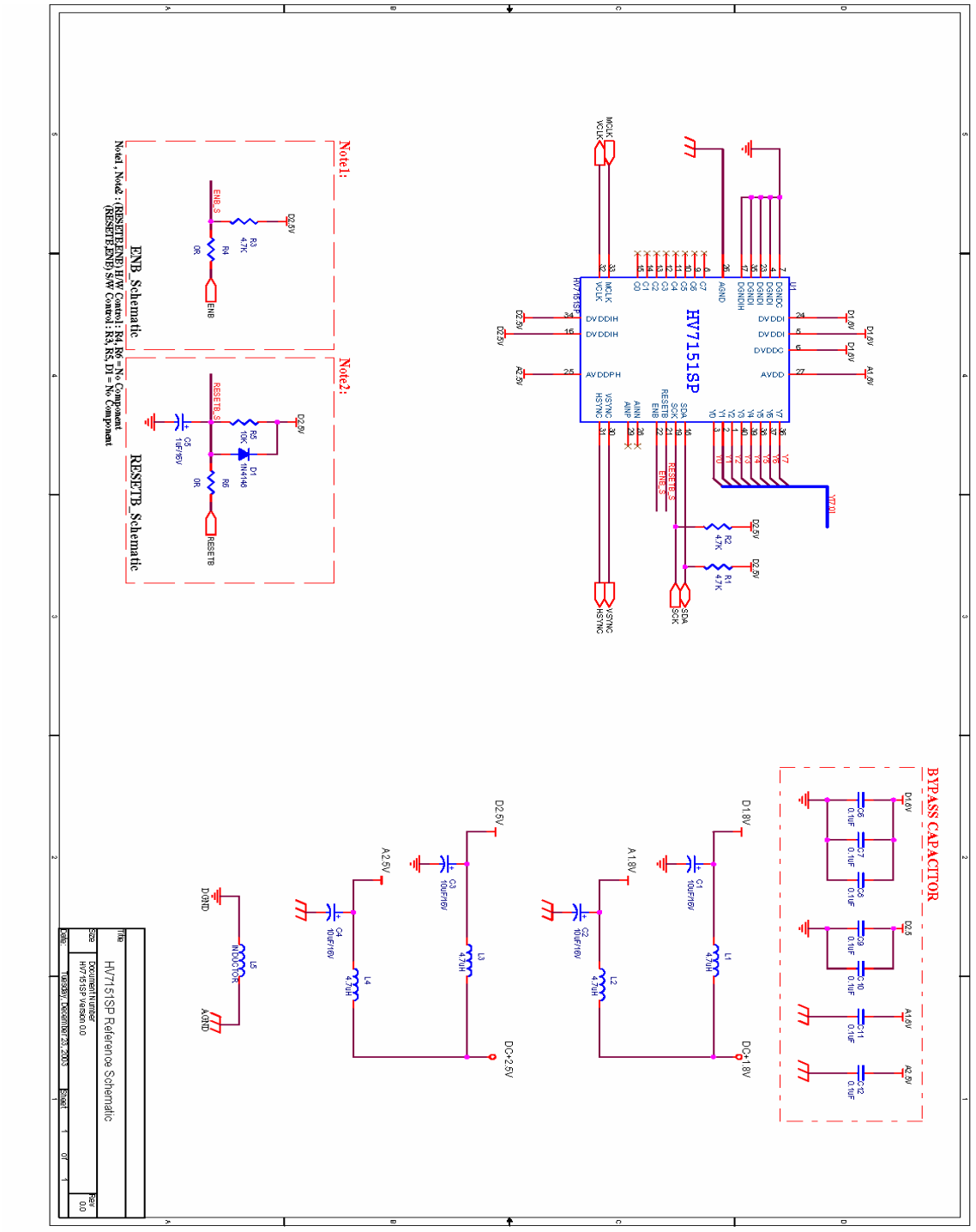
Parameter	Units	Min.	Typical	Max.	Target
Sensitivity	mV / lux·sec		1175		2200
Dark Signal	mV/ sec		TBD		Under 1
Dark Shading	mV/sec		TBD		
Output Signal Shading	%		TBD		
Output Saturation Signal	mV		610		600
Power Consumption (Normal Mode)	mW		60		

Package information





Reference Circuit Information



MEMO

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