

CMOS Image Sensor
with Image Signal Processing

HV7131GP

Preliminary
V2.0

Revision History

Revision	Script Date	Comments
V1.0	2001/11/08/Thu – 2001/11/14/Thu	- HV7131GP Preliminary is released
V1.1	2001/12/21/Fri	- Gamma slope table of Knee/De-Knee is added, and some misprints are corrected
V1.2	2002/03/25/Mon	- Knee/De-Knee function is abandoned, instead 10bit ADC is implemented. - Register descriptions are revised - Frame timing is revised.
V1.3	2002/04/25/Thu	- register information is updated
V1.4	2002/05/06/Mon	- Data output timing & interface is added
V1.5	2002/05/13/Tue	- Chip layout information is revised, and miscellaneous typo errors are corrected
V1.6	2002/05/28/Tue	- chip layout information is omitted for confidentiality, and power consumption information is added.
V1.7	2002/06/14/Fri	- CLCC 40 Pin Diagram added
V1.8	2002/12/26/Thu.	- PKG Drawing Added
V1.9	2003/01/17/Fri.	- Register Description Revision
V2.0	2003/06/04/Wed.	- ENB Setting guide information is added

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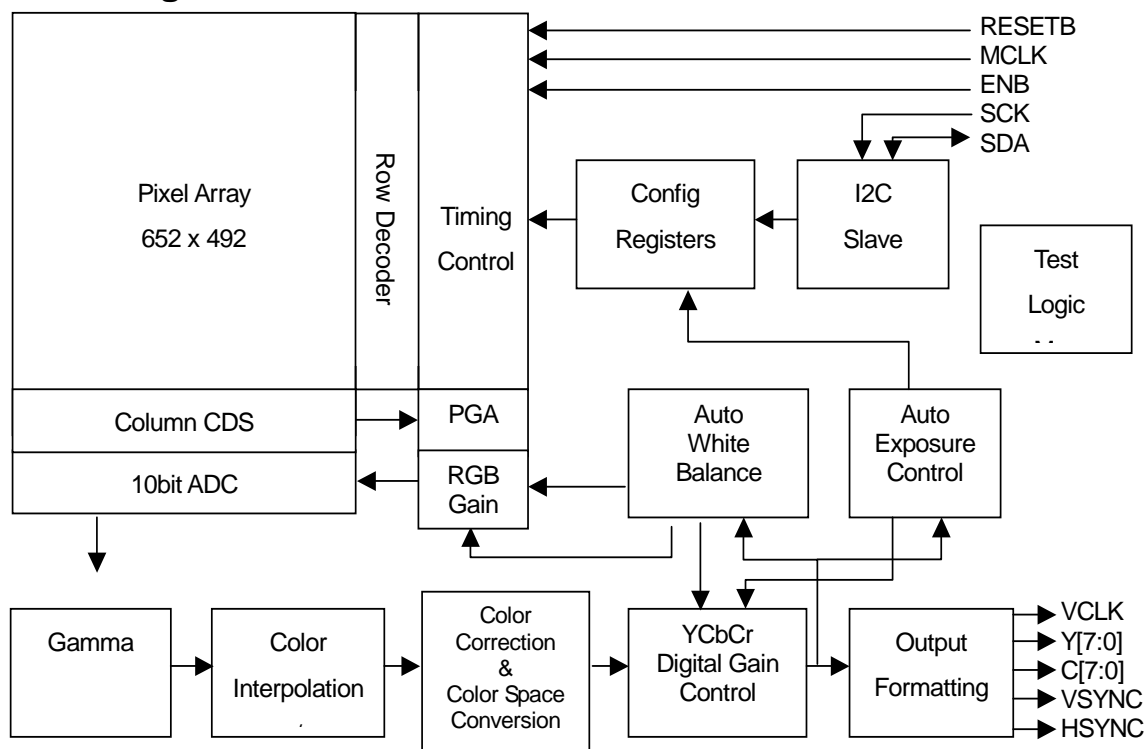
General Description

HV7131GP is a highly integrated single chip CMOS color image sensor implemented by proprietary Hynix 0.35um CMOS sensor process realizing high sensitivity and wide dynamic range. Total pixel array size is 652x492, and 652x488 pixels are active. Each active pixel composed of 4 transistors has a micro-lens to enhance sensitivity, and converts photon energy to analog pixel voltage. On-chip 10bit 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 such as gamma correction, color interpolation, color correction, color space conversion, auto exposure, and auto white balance 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 HV7131GP especially very suitable for mobile imaging systems such as IMT-2000 phone's video part that requires very low power and system compactness.

Features

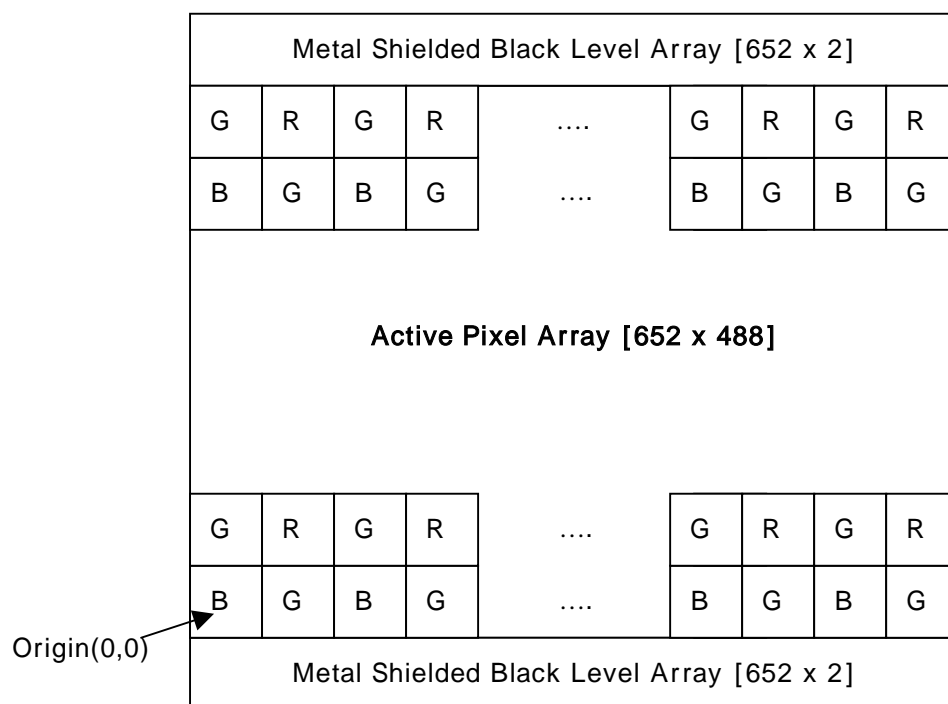
- 1/4 inch optical format
- Active pixel resolution: 652x488
- 5.6um x 5.6um active square pixel
- Micro-lens for high sensitivity
- RGB mosaic color filter array
- On-chip 10 bit ADC
- Correlated double sampling for reduction of Fixed Pattern Noise
- Black Level Compensation
- Gamma correction by programmable piecewise linear approximation
- 3x3 Color interpolation
- Color correction by programmable 3x3 matrix operation
- Color space conversion from RGB to YCbCr
- Sub-sampling Modes : 1/4, 1/16
- Various output formats : YCbCr 4:2:2, YCbCr 4:4:4, RGB 4:4:4, Bayer
- 8bit / 16bit Data Bus Mode
- Automatic Exposure Control
- Automatic White Balance Control
- Frame Rate : 30 f/s at 25Mhz, HBLANK = 208, VBLANK = 8
- Power Consumption: 86mW @ 30f/s and 2.8V, 68mW @ 15f/s and 2.8V, 336uW @ power down
- Operation Voltage Range : 2.6V ~ 3.0V, Operation Temperature : -10 ~ +50 degrees Celsius
- Package Types : CLCC 40 PIN, COB(Chip-on-Board), COF(Chip-on-Flex)

Block Diagram



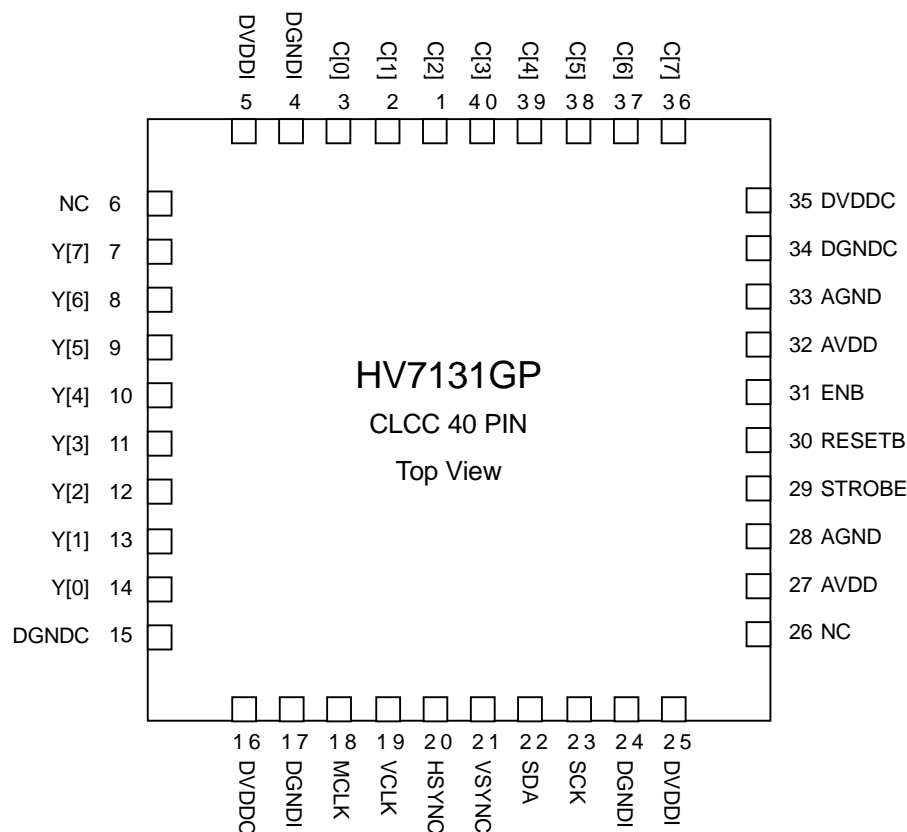
1. PGA : Programmable Gain Amplifier
2. Color Correction and Color Space Conversion are merged into one matrix operation for hardware simplification

Pixel Array Structure



Note: If black level data output is enabled(SCTRC[1] set to high) with Bayer mode set(SCTRA[1:0] == 2'b00), data output in the areas of Metal Shielded Black Level Array can be monitored during 4 line period of HSYNC right after VSYNC goes from high state to low state.

Pin Diagram



Pin Description

The input mode of HSYNC/VSYNC/Y[7:0]/C[7:0] is used to test internal image processing function in mass production so that it should be not assumed about slave mode operation. The device does not support slave mode operation. C[7:0] should be set up as pull-up or pull-down when 8bit output mode is used.

Pin	Type	Symbol	Description
1-3	B	C[2:0]	Video Chrominance Data[2:0]
4	G	DGNDI	Digital Ground for I/O Buffer
5	P	DVDDI	Digital Power for I/O Buffer
6	N	NC	No Connection
7-14	O	Y[7:0]	Video Luminance Data[7:0]
15	G	DGNDC	Ground for Internal Digital Block
16	P	DVDDC	Power for Internal Digital Block
17	G	DGNDI	Digital Ground for I/O Buffer
18	I	MCLK	Master Input Clock
19	O	VCLK	Video Output Clock
20	O	HSYNC	Video Horizontal Line Synchronization signal. Image data is valid, when HSYNC is high.
21	O	VSYNC	Video Frame Synchronization signal. VSYNC is active at start of image data frame.
22	B	SDA	I2C Standard data I/O port
23	I	SCK	I2C Clock Input
24	G	DGNDI	Digital Ground for I/O Buffer
25	P	DVDDI	Digital Power for I/O Buffer
26	N	NC	No Connection
27	P	AVDD	Power for Analog Block
28	G	AGND	Ground for Analog Block
29	O	STROBE	Strobe Signal Output
30	I	RESETB	Sensor Reset, Low Active
31	I	ENB	Sensor sleep mode is controlled externally by this pin when sleep mode register bit SCTRB[4] is low. ENB low : sleep mode, ENB high : normal mode
32	P	AVDD	Power for Analog Block
33	G	AGND	Ground for Analog Block
34	G	DGNDC	Ground for Internal Digital Block
35	P	DVDDC	Power for Internal Digital Block
36-40	B	C[7:3]	Video Chrominance Data[7:3]

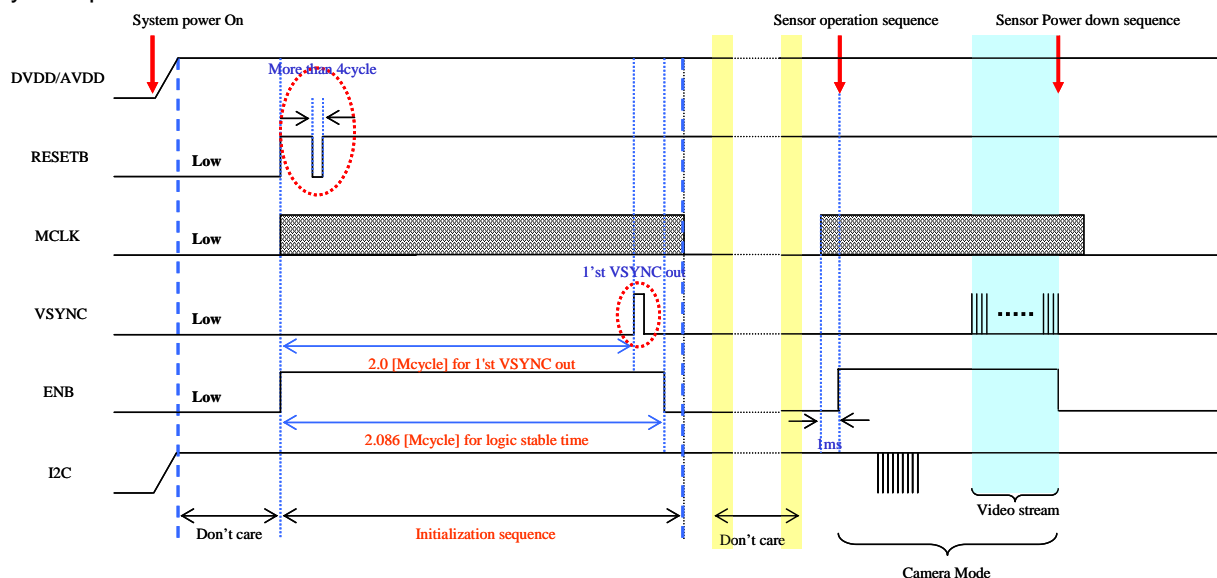
Functional Description

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 HV7131GP after system power on



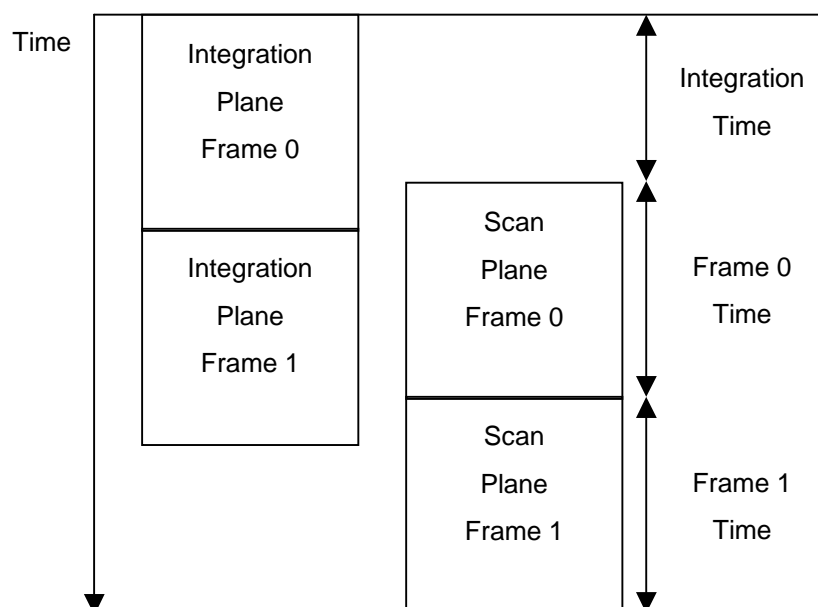
ex) If MCLK = 25[Mhz]

$$\Rightarrow 2.086[\text{Mcycle}] / 25[\text{MHz}] = 83.44 \text{ ms}$$

The time period of ENB high value have to keep for 83.44[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.



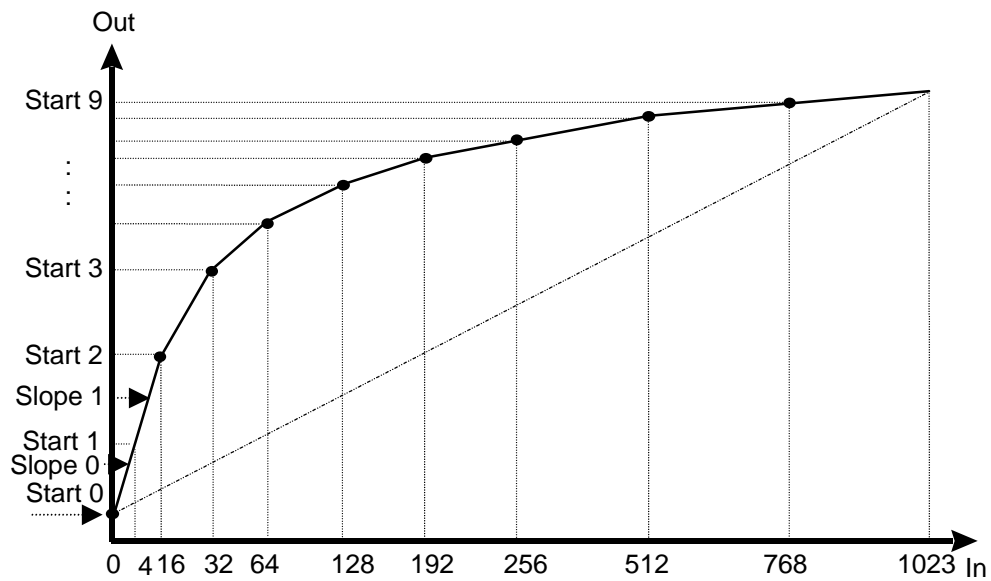
10bit on-chip ADC

On-chip ADC converts analog pixel voltage to 10bit digital data.

Gamma Correction

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

Gamma Slope Registers are programmed as the integer value of real slope value that is multiplied by 64.



Gamma Transfer Function

Color Interpolation

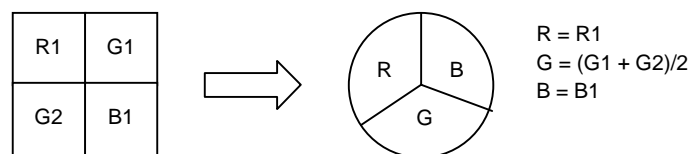
Three methods are supported to interpolate missing R, G, or B for mosaic image data from pixel array as follows.

a) 3x3 linear color interpolation

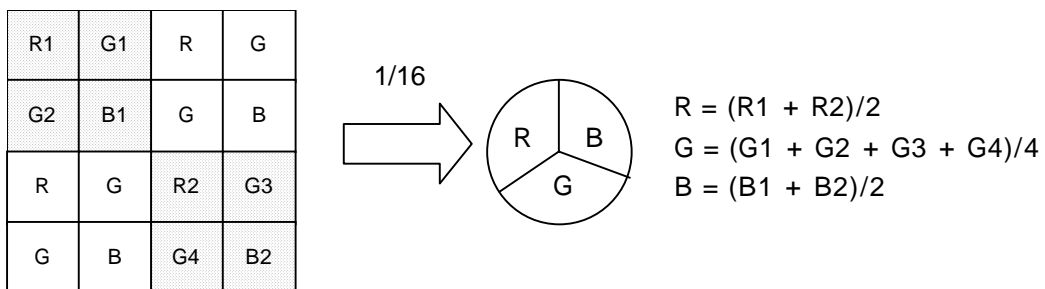
Interpolation is done by moving 3x3 interpolation window by one pixel horizontally and vertically

b) 1/4 subsampling color interpolation

Interpolation is done by moving 2x2 interpolation window by two pixels each time horizontally and vertically. The equation for color interpolation in each 2x2 window is simple as follows.



c) 1/16 subsampling color interpolation



Color Correction & Color Space Conversion

Both of Color Correction and Color Space conversion are implemented by 3x3 matrix operation, so that two stages may be merged into one matrix stage.

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. For color space conversion matrix, the equation from CCIR-601 standard is normally used. Therefore, the intended single matrix for color correction and color space conversion may be resolved as below.

$$\text{Intended single matrix} = \text{Color Space Conversion Matrix} * \text{Color Correction Matrix}$$

Intended single matrix coefficients are programmable from $-127/64$ to $127/64$. Programming register value for intended single matrix coefficients should be resolved by the following equations.

For positive values, $\text{CMAxx} = \text{Integer}(\text{Real Coefficient Value} \times 64)$;

For negative values, $\text{CMAxx} = \text{Two Complement}(\text{Integer}(\text{Real Coefficient Value} \times 64))$;

Real Coefficient Value values from $-127/64$ to $127/64$ can be programmed.

CCIR-601 YCbCr color space conversion equation

< Conversion Equation >

$$Y = (77R + 150G + 29B)/256 \quad \text{Range: } 16 \sim 235$$

$$Cb = (-44R - 87G + 131B)/256 + 128 \quad \text{Range: } 16 \sim 240$$

$$Cr = (131R - 110G - 21B)/256 + 128 \quad \text{Range: } 16 \sim 240$$

< Reverse Conversion >

$$R = Y + 1.371(Cr - 128)$$

$$G = Y - 0.698(Cr - 128) - 0.336(Cb - 128)$$

$$B = Y + 1.732(Cb - 128)$$

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

Digital Gain Control

Y, Cb, and Cr digital channels are scaled by this block that receives scaling values from Auto Exposure and Auto White Balance blocks. Scaling resolution is $1/128$ and value range is $1.9 \sim 0.1$.

Output Formatting

The output formats such as Bayer Raw Data, RGB 4:4:4, YCbCr 4:4:4, and YCbCr 4:2:2 are supported. Possible output bus widths are 8 bits and 16bits, and the sequence of Cb and Cr are programmable.

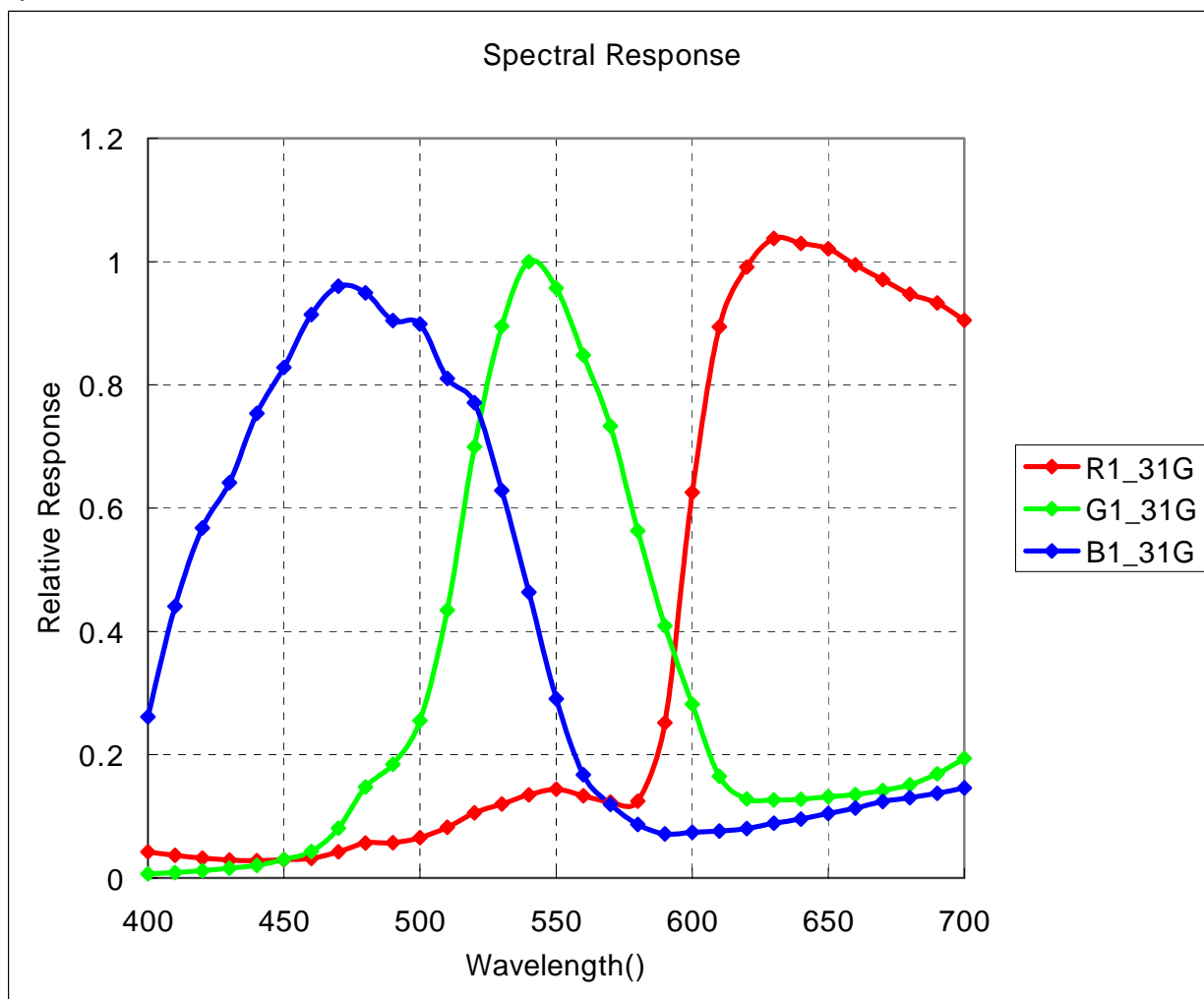
Auto Exposure Control

Y mean value is continuously calculated every frame, and the integration time value is 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.

Spectral Characteristics



Register Description

Register	Symbol	Address (Hex)	Default (Hex)	Description
Device ID	DEVID	00	40	Product ID, Revision No.
Sensor Control A	SCTRA	01	0b	Operation mode, X/Y flip, Image size
Sensor Control B	SCTRB	02	00	Power down, Clock division
Sensor Control C	SCTRC	03	01	Sensor Internal control Register
Row Start Address High	RSAH	08	00	Row Start Address[8]
Row Start Address Low	RSAL	09	02	Row Start Address[7:0]
Column Start Address High	CSAH	0a	00	Column Start Address[9:8]
Column Start Address Low	CSAL	0b	02	Column Start Address[7:0]
Window Height High	WIHH	0c	01	Window Height Address[8]
Window Height Low	WIHL	0d	e0	Window Height Address[7:0]
Window Width High	WIWH	0e	02	Window Width Address[9:8]
Window Width Low	WIWL	0f	80	Window Width Address[7:0]
HBLANK Time High	HBLANKH	10	00	HBLANK Time [15:8]
HBLANK Time Low	HBLANKL	11	d0	HBLANK Time [7:0]
VBLANK Time High	VBLANKH	12	00	VBLANK Time [15:8]
VBLANK Time Low	VBLANKL	13	08	VBLANK Time [7:0]
Red Color Gain	RCG	14	10	Gain for Red Pixel Output
Green Color Gain	GCG	15	10	Gain for Green Pixel Output
Blue Color Gain	BCG	16	10	Gain for Blue Pixel Output
Preamplifier Gain	PREAMP	17	10	Preamplifier Gain for Pixel Output
Preamplifier Gain Min	PREMIN	18	00	Preamplifier Gain Min Value for AE
Preamplifier Gain Max	PREMAX	19	3f	Preamplifier Gain Max Value for AE
Preamplifier Gain Nominal	PRENOM	1a	10	Preamplifier Gain Normal Value for AE
ASP Bias	ASPBias	1b	13	Amp Bias, Pixel Bias
Reset Clamp	RSTCLMP	1c	07	Reset Level Clamping Value
ADC Bias	ADCBias	20	0f	ADC Bias
Red Pixel Black Offset	OREDI	21	7f	ADC Offset Value for Light-shielded Red Pixel
Green Pixel Black Offset	OGRNI	22	7f	ADC Offset Value for Light-shielded Green Pixel
Blue Pixel Black Offset	OBLUI	23	7f	ADC Offset Value for Light-shielded Blue Pixel

Red Pixel Active Offset	OREDU	24	RO	ADC Offset Value for Active Red Pixel
Green Pixel Active Offset	OGRNU	25	RO	ADC Offset Value for Active Green Pixel
Blue Pixel Active Offset	OBLUU	26	RO	ADC Offset Value for Active Blue Pixel
Black Level Threshold	BLCTH	27	ff	Black Level Threshold Value
ISP Function Enable	ISPFEN	30	0f	Image processing functions enable
ISP Output Format	OUTFMT	31	39	Image data output format control
ISP Output Polarity	OUTINV	32	00	Output signal polarity control
Green Edge Threshold	EDGETH	33	00	Green pixel edge threshold for 3x3 color interpolation
Color Matrix Coefficient 11	CMA11	34	2e	Color matrix coefficient 11
Color Matrix Coefficient 12	CMA12	35	c5	Color matrix coefficient 12
Color Matrix Coefficient 13	CMA13	36	0c	Color matrix coefficient 13
Color Matrix Coefficient 21	CMA21	37	0d	Color matrix coefficient 21
Color Matrix Coefficient 22	CMA22	38	3c	Color matrix coefficient 22
Color Matrix Coefficient 23	CMA23	39	f7	Color matrix coefficient 23
Color Matrix Coefficient 31	CMA31	3a	f8	Color matrix coefficient 31
Color Matrix Coefficient 32	CMA32	3b	cf	Color matrix coefficient 32
Color Matrix Coefficient 33	CMA33	3c	39	Color matrix coefficient 33
Gamma Segment Point 0	GMAP0	40	00	Start point for gamma line segment 0
Gamma Segment Point 1	GMAP1	41	04	Start point for gamma line segment 1
Gamma Segment Point 2	GMAP2	42	1c	Start point for gamma line segment 2
Gamma Segment Point 3	GMAP3	43	34	Start point for gamma line segment 3
Gamma Segment Point 4	GMAP4	44	54	Start point for gamma line segment 4
Gamma Segment Point 5	GMAP5	45	78	Start point for gamma line segment 5
Gamma Segment Point 6	GMAP6	46	90	Start point for gamma line segment 6
Gamma Segment Point 7	GMAP7	47	a4	Start point for gamma line segment 7
Gamma Segment Point 8	GMAP8	48	e0	Start point for gamma line segment 8
Gamma Segment Point 9	GMAP9	49	f4	Start point for gamma line segment 9
Gamma Segment Slope 0	GMAS0	50	40	Slope value for gamma line segment 0
Gamma Segment Slope 1	GMAS1	51	80	Slope value for gamma line segment 1
Gamma Segment Slope 2	GMAS2	52	60	Slope value for gamma line segment 2
Gamma Segment Slope 3	GMAS3	53	40	Slope value for gamma line segment 3
Gamma Segment Slope 4	GMAS4	54	24	Slope value for gamma line segment 4
Gamma Segment Slope 5	GMAS5	55	18	Slope value for gamma line segment 5
Gamma Segment Slope 6	GMAS6	56	14	Slope value for gamma line segment 6

Gamma Segment Slope 7	GMAS7	57	0f	Slope value for gamma line segment 7
Gamma Segment Slope 8	GMAS8	58	05	Slope value for gamma line segment 8
Gamma Segment Slope 9	GMAS9	59	02	Slope value for gamma line segment 9
AE Mode 1	AEM1	60	39	Auto exposure mode selection 1
AE Mode 2	AEM2	61	ba	Auto exposure mode selection 2
Integration Time High	INTH	63	07	Integration Time [23:16]
Integration Time Middle	INTM	64	a1	Integration Time [15:8]
Integration Time Low	INTL	65	20	Integration Time [7:0]
AE Target	AETGT	66	70	Frame Luminance Target Value
AE Lock & Fine Tune Boundary	AELBND	67	a2	Y frame mean value displacement boundary from AE target where AE goes into Lock state. Fine tuning boundary is also specified.
AE Unlock Boundary	AEUNLCK	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
AE Integration Step High	AEINCH	6a	1	Integration Increment Step Unit [17:16]
AE Integration Step Middle	AEINCM	6b	e8	Integration Increment Step Unit [15:8]
AE Integration Step Low	AEINCL	6c	48	Integration Increment Step Unit [7:0]
AE Integration Limit High	AELMH	6d	17	Integration Time Limit [23:16]
AE Integration Limit Middle	AELMM	6e	d7	Integration Time Limit [15:8]
AE Integration Limit Low	AELML	6f	84	Integration Time Limit [7:0]
AWB Mode 1	AWBM1	70	41	AWB mode selection 1
AWB Mode 2	AWBM2	71	2	AWB mode selection 2
Cb Target	CBTGT	73	80	Cb Plane Target Frame Mean Value. Normal white point is 80h.
Cr Target	CRTGT	74	80	Cr Plane Target Frame Mean Value. Normal white point is 80h.
AWB Lock Boundary	AWBLB	75	2	Cb/Cr Frame Mean Displacement from Cb Target and Cr Target where AWB goes into LOCK state
AWB Unlock Boundary	AWBULB	76	06	Displacement from ideal white pixel where AWB release from LOCK state

AWB White Pixel Boundary	AWBWPB	77	30	Displacement from ideal white pixel where AWB recognizes a pixel as a white pixel affected by light source
Y Digital Gain	YGAIN	78	40	Y digital gain for Auto Exposure Control
Cb Digital Gain	CBGAIN	79	40	Cb digital gain for Auto White Balance control
Cr Digital Gain	CRGAIN	7a	40	Cr digital gain for Auto White Balance control
AE Status	AEST	7b	RO	AE operation status
AWB Status	AWBST	7c	RO	AWB operation status
Y Frame Mean	YFMEAN	7d	RO	Y Frame Mean Value
Cb Frame Mean	CBFMEAN	7e	RO	Cb Frame Mean Value
Cr Frame Mean	CRFMEAN	7f	RO	Cr Frame Mean Value
Minimum Anti-Banding Gain	BNDGMIN	80	08	Minimum gain value with Anti-Banding enabled
Maximum Anti-Banding Gain	BNDGMAX	81	18	Maximum gain value with Anti-Banding enabled
Integration-Scan Plane Offset High	ISOFSH	82	RO	Integration-Scan Plane Offset[23:16]
Integration-Scan Plane Offset Middle	ISOFSM	83	RO	Integration-Scan Plane Offset[16:8]
Integration-Scan Plane Offset Low	ISOFSL	84	RO	Integration-Scan Plane Offset[7:0]
AWB Luminance High Boundary	AWBLUHI	8a	C8	During CbCr frame mean value calculation, AWB discards pixel of which luminance is larger than this register value.
AWB Luminance Low Boundary	AWBLULO	8b	0a	During CbCr frame mean value calculation, AWB discards pixel of which luminance is smaller than this register value.
AWB Valid Number	AWBNO	8c	02	AWB update when the number of valid color pixel is larger than (this minimum value x 64)
Dark Bad Pixel Concealment Mode	DPCMODE	90	0	Dark Bad Pixel Concealment Mode selection

Dark Bad Integration Time High	DPCINTH	91	13	Integration Time Value High Byte where filtering operation gets active when dark bad pixel filtering mode is enabled.
Dark Bad Integration Time Middle	DPCINTM	92	12	Integration Time Value Middle Byte where filtering operation gets active when dark bad pixel filtering mode is enabled.
Dark Bad Integration Time Low	DPCINTL	93	D0	Integration Time Value Low Byte where filtering operation gets active when dark bad pixel filtering mode is enabled.
Dark Bad G Threshold	DPCGTH	94	0c	Neighbor-differential threshold value that specify G dark bad pixel
Dark Bad R/B Threshold	DPCCTH	95	0c	Neighbor-differential threshold value that specify R/B dark bad pixel

Device ID [DEVID : 00h : 40h]

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

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

Sensor Control A [SCTRA : 01h : 0bh]

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

Category	Operation Mode	Note
TestC	1111	At CDS operation, reset and image bit-lines are all written to high. This mode is just for monitoring purpose.
	1110	At CDS operation, image bit-line is written to high. In this mode, all Bayer data output are 8'h00.
	1101	At CDS operation, reset bit-line is written to high. In this mode, all Bayer data output are 8'hff.
	1100	Reserved
TestA	10x1	ADC overflow test with CDS output disconnected. In this mode, all Bayer data output are 8'hff.

	10x0	ADC underflow test with CDS output disconnected. In this mode, all Bayer data output are 8'h00.
TestI	011x	Image processing function test
TestB	0101	I2C state machine test
	0100	Sensor operation state machine test
Normal	0000	Normal imaging operation

X-Flip	Image is horizontally flipped		
Y-Flip	Image is vertically flipped		
Video Mode	11	3x3 color interpolation	
	10	1/4 subsampling mode	
	01	1/16 subsampling mode	
	00	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

< Clock Acronym Definition >

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

< Clock Frequency Relation >

MCF : MCF	DCF : MCF/Clock Division	
SCF : DCF/2	ICF	SCF for 3x3 interpolation, SCF/2 for 1/4 subsampling mode SCF/4 for 1/16 subsampling mode
VCF : ICF for 16bit output, ICF*2 for 8bit output	LCF : 1/(HBLANK Period + HSYNC Period)	

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
Black Level Average Output	Y[7:0] Pad Output with HSYNC high	C[7:0] Pad Output with 8bit mode	HSYNC in VBLANK	reserved	Unified Gain	Black Level Data Enable	Black Level Compensation
0	0	0	0	0	0	0	1

Black Level Average Output	This bit enable R/G/B Active Offset registers[24h-26h] to represent black level average value, instead of updated active offset values
Y[7:0] Pad Output with HSYNC high	With this bit set to high, Y[7:0] pads go into tri-state when HSYNC is inactive.
C[7:0] Pad Output with 8bit mode	With this bit set to high, C[7:0] pads go into zero driving state with 8bit output mode enabled. Otherwise, these pads go into tri-state.
HSYNC in VBLANK	VBLANK is equivalent to VSYNC, and HSYNC is the inversion of HBLANK, and this bit control whether HSYNC is active or not when VBLANK unit is LCF.

Unified Gain	G gain is used for R, G, and B analog gain
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 High [RSAH : 08h : 0h]

7	6	5	4	3	2	1	0
reserved							Row Start Address High
0	0	0	0	0	0	0	0

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

7	6	5	4	3	2	1	0
Row Start Address Low							
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 High [CSAH : 0ah : 0h]

7	6	5	4	3	2	1	0
reserved						Column Start Address High	
0	0	0	0	0	0	0	0

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

7	6	5	4	3	2	1	0
Column Start Address Low							
0	0	0	0	0	0	1	0

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

Window Height High [WIHH : 0ch : 1h]

7	6	5	4	3	2	1	0
reserved							Window Height High
0	0	0	0	0	0	0	1

Window Height Low [WIHL : 0dh : e0h]

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

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

Window Width High [WIWH : 0eh : 2h]

7	6	5	4	3	2	1	0
reserved						Window Width High	
0	0	0	0	0	0	1	0

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

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

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

HBLANK Time High [HBLANKH : 10h : 00h]

7	6	5	4	3	2	1	0
HBLANK Time High							
0	0	0	0	0	0	0	0

HBLANK Time Low [HBLANKL : 11h : d0h]

7	6	5	4	3	2	1	0
HBLANK Time Low							
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 (1/SCF), and should be larger than 208(d0h).

VLANK Time High[VBLANK : 12h : 00h]

7	6	5	4	3	2	1	0
VBLANK Time High							
0	0	0	0	0	0	0	0

VBLANK Time Low[VBLANK : 13h : 08h]

7	6	5	4	3	2	1	0
VBLANK Time Low							
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. For VSYNC-HSYNC timing relation in the frame transition, please refer to Frame Timing section.

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

R Color Gain [RCG : 14h : 10h]

7	6	5	4	3	2	1	0
reserved		R Color Gain					
0	0	0	1	0	0	0	0

G Color Gain [RCG : 15h : 10h]

7	6	5	4	3	2	1	0
reserved		G Color Gain					
0	0	0	1	0	0	0	0

B Color Gain [RCG : 16h : 10h]

7	6	5	4	3	2	1	0
reserved		B Color Gain					
0	0	0	1	0	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 = $0.5 + B<5:0>/32$. These registers may be used for white balance and color effect with independent R,G,B color control. Default gain is 1X.

Preamp Gain [PREAMP : 17h : 10h]

7	6	5	4	3	2	1	0
Preamp Gain							
0	0	0	1	0	0	0	0

Preamp Gain is common gain for R, G, B channel and used for auto exposure control. Programmable range is from 0.5X ~ 16.5X. Default gain is 1.5X.

Gain = $0.5 + B_{<7:0>}/16$

Preamp Gain Min [PREMIN : 18h : 00h]

7	6	5	4	3	2	1	0
Preamp Gain Min							
0	0	0	0	0	0	0	0

Preamp Gain Min is minimum value of preamp gain when sensor adjusts pre-amplifier gain for auto exposure control. Programmable range is same as preamp gain. Recommended value is 0.5X.

Preamp Gain Max [PREMAX : 19h : 3fh]

7	6	5	4	3	2	1	0
Preamp Gain Max							
0	0	1	1	1	1	1	1

Preamp Gain Max is maximum value of preamp gain when sensor adjusts preamp gain for auto exposure control. Programmable range is same as preamp gain. Recommended value is 16.5X.

Preamp Gain Normal [PRENOR : 1ah : 10h]

7	6	5	4	3	2	1	0
Preamp Gain Normal							
0	0	0	1	0	0	0	0

Preamp Gain Normal is reference value of preamp gain when sensor adjusts preamp gain for auto exposure control. First, sensor controls integration time before adjusting preamp gain for auto exposure control. After integration time is changed to the minimum or maximum value, sensor adjusts preamp gain from this register value. Refer to figure of AE mode1 register(60H).

Programmable range is same as preamp gain. Recommended value is 1.5X.

ASP Bias [ASPBIAS : 1bh : 13h]

7	6	5	4	3	2	1	0
reserved	Pixel Bias			Amp 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				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 : 0fh]

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

ADC Bias controls the amount of current in ADC bias circuit to operate ADC effectively. The larger register value increases the amount of current.

Red Pixel Black Offset [OREDI : 21h : 7fh]

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

Green Pixel Black Offset [OGRNI : 22h : 7fh]

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

Blue Pixel Black Offset [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, red, green and blue pixel 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.

Red Pixel Active Offset [OREDU : 24h : RO]

7	6	5	4	3	2	1	0
Red Pixel Active Offset							
RO	RO	RO	RO	RO	RO	RO	RO

Green Pixel Active Offset [OGRNU : 25h : RO]

7	6	5	4	3	2	1	0
Green Pixel Active Offset							
RO	RO	RO	RO	RO	RO	RO	RO

Blue Pixel Active Offset [OBLUU : 26h : RO]

7	6	5	4	3	2	1	0
Blue Pixel Active Offset							
RO	RO	RO	RO	RO	RO	RO	RO

These registers control the offset voltage of ADC that changes the black level value for active pixels, red, green and blue pixel respectively. The registers are internally updated by black level compensation logic, and are read-only registers. Register bit functions are composed as follows.

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

Black Level Threshold [BLCTH : 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 which 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 [ISPFEN : 30h : 0fh]

7	6	5	4	3	2	1	0
Reserved				Matrix Operation	Color Interpolation	Gamma Correction	reserved
0	0	0	0	1	1	1	1

Matrix Conversion	In HV7131GP, two matrix operations of color correction & color space conversion are merged into one matrix operation. With this bit set to high, the matrix operation is enabled, and otherwise R/G/B data is output through output formatter.
Color Interpolation	With SCTRA[1:0] set to 3x3 color interpolation, this bit control the final channel between color interpolated R/G/B and Bayer data. With this bit set to low, R/G/B channels for one pixel are fed with the same one Bayer value so that image similar to black & white is produced.
Gamma Correction	With this bit set to high, 10 segments piecewise approximate gamma is enabled.

Output Format [OUTFMT : 31h : 39h]

7	6	5	4	3	2	1	0
Gamma- corrected Bayer	Bayer 8bit output	Cb First	Y First	8 Bit Output	reserved	YCbCr 4:4:4	YCbCr 4:2:2
0	0	1	1	1	0	0	1

Gamma-corrected Bayer	Bayer data that are gamma corrected is output when Bayer mode is set in SCTRA register.
Bayer 8bit output	Bayer data is output with 8bit mode. two LSB of 10 bit Bayer data is stripped out.
Cb First	Cb pixel in front of Cr 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 8bit output mode.
8 Bit Output	Image Data is produced only in Y[7:0]. C[7:0] should be discarded
YCbCr 4:4:4	YCbCr 24bit data for a pixel is produced with 16bit output mode. With color space conversion disabled, RGB 24bit data for a pixel is produced in this mode. This mode is meaningful only with 16bit output mode.
YCbCr 4:2:2	YCbCr data for a pixel is produced with 8/16 output mode

Output Inversion[OUTINV : 32h : 0h]

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

Green Edge Threshold[EDGETH : 33h : 00h]

7	6	5	4	3	2	1	0
Green Edge Threshold							
0	0	0	0	0	0	0	0

In 3x3 color interpolation mode, missing G pixel is interpolated with edge detection considering neighbor G pixels, and this register controls edge threshold to select edge direction. The smaller value means that the more patterns are recognized as edge, and image may get sharper, but not always.

Color Matrix Coefficients

Both of Color Correction and Color Space conversion are implemented by 3x3 matrix operation, so that two stages may be merged into one matrix stage.

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. For color space conversion matrix, the equation from CCIR-601 standard is normally used. Therefore, the intended single matrix for color correction and color space conversion may be resolved as below.

$$\text{Intended single matrix} = \text{Color Space Conversion Matrix} * \text{Color Correction Matrix}$$

Intended single matrix coefficients are programmable from $-127/64$ to $127/64$. Programming register value for intended single matrix coefficients should be resolved by the following equations.

For positive values, $CMA_{xx} = \text{Integer}(\text{RealCoefficientValue} \times 64)$;

For negative values, $CMA_{xx} = \text{TwoComplement}(\text{Integer}(\text{RealCoefficientValue} \times 64))$;

RealCoefficientValue values from $-127/64$ to $127/64$ can be programmed.

CCIR-601 YCbCr color space conversion equation

< Conversion Equation >

$Y = (77R + 150G + 29B)/256$ Range: 16 ~ 235

$Cb = (-44R - 87G + 131B)/256 + 128$ Range: 16 ~ 240

$Cr = (131R - 110G - 21B)/256 + 128$ Range: 16 ~ 240

< Reverse Conversion >

$R = Y + 1.371(Cr - 128)$

$G = Y - 0.698(Cr - 128) - 0.336(Cb - 128)$

$B = Y + 1.732(Cb - 128)$

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

Color Matrix Coefficient 11 [CMA11 : 34h : 2eh]

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

Color Matrix Coefficient 12 [CMA12 : 35h : c5h]

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

Color Matrix Coefficient 13 [CMA13 : 36h : 0ch]

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

Color Matrix Coefficient 21 [CMA21 : 37h : 0dh]

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

Color Matrix Coefficient 22 [CMA22 : 38h : 3ch]

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

Color Matrix Coefficient 23 [CMA23 : 39h : f7h]

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

Color Matrix Coefficient 31 [CMA31 : 3ah : f8h]

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

Color Matrix Coefficient 32 [CMA32 : 3bh : cfh]

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

Color Matrix Coefficient 33 [CMA33 : 3ch : 39h]

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

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 Values

Gamma Slope Registers are programmed as the integer value of real slope value that is multiplied by 64.

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 1							
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]

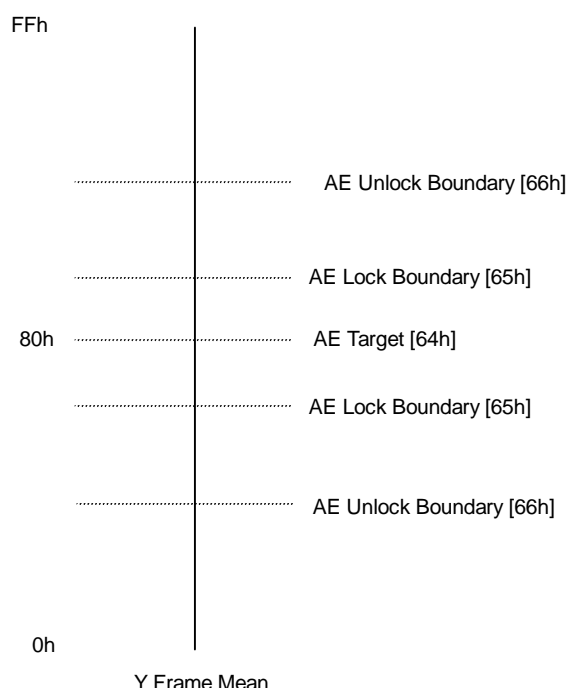
7	6	5	4	3	2	1	0
Gamma Slope 8							
0	0	0	0	0	1	0	1

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

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 [AEM1 : 60h : 39h]

7	6	5	4	3	2	1	0
Anti – Banding Enable	Full Window	Window Mode		AE speed		AE Mode	
0	0	1	1	1	0	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 [AEM2 : 61h : bah]

7	6	5	4	3	2	1	0
Gain Speed		Integration Time Fine Tune	Preamp Gain Fine Tune	Anti-Banding Minimum Break	AE Subsampling mode	AE Analog Gain Control	AE Digital Gain control
1	0	1	1	1	0	1	0

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.
Preamp Gain Fine Tune	Preamp 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 Subsampling Mode	AE statistics is executed on 1/4 of original image data to save power consumption
AE Analog Gain Control	AE updates preamp gain register(17h) in order to reach optimum exposure state

AE Digital Gain Control	AE updates Y digital gain register(78h) in order to reach optimum exposure state
-------------------------	--

Integration Time High [INTH: 63h : 07h]

7	6	5	4	3	2	1	0
Integration Time High [23:16]							
0	0	0	0	0	1	1	1

Integration Time Middle [INTM: 64h: a1h]

7	6	5	4	3	2	1	0
Integration Time Middle[15:8]							
1	0	1	0	0	0	0	1

Integration Time Low [INTL: 65h: 20h]

7	6	5	4	3	2	1	0
Integration Time Low[7:0]							
0	0	1	0	0	0	0	0

Integration time value register defines the time during 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 need 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(80ns, SCF 12.5Mhz @ DCF 25Mhz) = 1.34sec.

AE Target [AETGT : 66h : 70h]

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

This register defines the target luminance value for AE operation.

AE Lock Boundary [AELBND : 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 preamp gain in order to goes into lock state smoothly.

AE Unlock Boundary [AEUNLCK : 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 Anti-Banding Step High [AEANTH : 6ah : 1h]

7	6	5	4	3	2	1	0
reserved						AE Anti-Banding Step High	
0	0	0	0	0	0	0	1

AE Anti-Banding Step Middle [AEANTM : 6bh : e8h]

7	6	5	4	3	2	1	0
AE Anti-Banding Step High							
1	1	1	0	1	0	0	0

AE Anti-Banding Step Low [AEANTL : 6ch : 48h]

7	6	5	4	3	2	1	0
AE Anti-Banding Step Low							
0	1	0	0	1	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.

$$\text{Anti-Banding Step Value} = \text{Sensor Operation Frequency (SCF)} / (2x \text{ power line frequency})$$

The default value is set with SCF 12.5Mhz, 50Hz power line, that is,

$$\text{Anti-Banding Step Value} = 12.5\text{Mhz} / (2 \times 50) = 125000d = 1e848h$$

AE Integration Time Limit High [AELMH : 6dh : 17h]

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

AE Integration Time Limit Middle [AELMM : 6eh : d7h]

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

AE Integration Time Limit Low [AELML : 6fh : 84h]

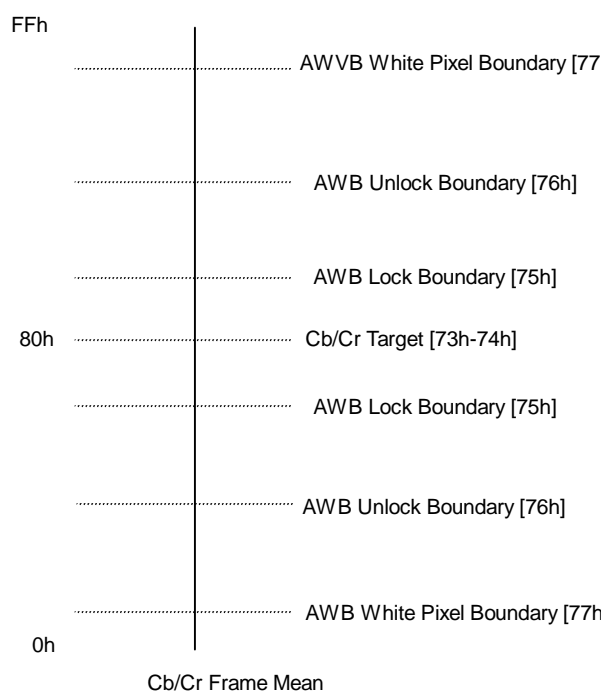
7	6	5	4	3	2	1	0
AE Integration Time Limit Low							
1	0	0	0	0	1	0	0

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 1/8sec with SCF set to 25Mhz

$$12.5\text{Mhz} / 8 = 1,562,500 = 17\text{d}784$$

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 [AWBM : 70h : 41h]

7	6	5	4	3	2	1	0
reserved	Full Window	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	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.	

AWB Speed	(Fast)11 - 10 - 01 - 00(slow)
AWB On	Auto White Balance Control Enabled

AWB Mode Control 2 [AEM2 : 71h : 02h]

7	6	5	4	3	2	1	0
reserved				AWB Low Speed	AWB Subsampling mode	AWB Analog Gain Control	AWB Digital Gain control
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 Subsampling 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
AWB Digital Gain Control	AWB updates Cb/Cr digital gain registers(79h,7ah) in order to reach optimum white balance state

Cb Target [CBTGT : 73h : 80h]

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

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

Cr Target [CRTGT : 74h : 80h]

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

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

AWB Lock Boundary [AWBLB : 75h : 2h]

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 [AWBUB : 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 [AWBWPB : 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.

Y Digital Gain [YGAIN : 78h : 40h]

7	6	5	4	3	2	1	0
Y Digital Gain							
0	1	0	0	0	0	0	0

The register represents the current Y digital gain value (1/64 resolution) in Digital Gain block, and is updated every frame by AE logic when AE digital gain update mode is active.

Cb Digital Gain [CBGAIN : 79h : 40]

7	6	5	4	3	2	1	0
Cb Digital Gain							
0	1	0	0	0	0	0	0

The register represents the current Cb digital gain value (1/64 resolution) in Digital Gain block, and is updated every frame by AWB logic when AWB digital gain update mode is active.

Cr Digital Gain [AWBSCLB : 7ah : 40h]

7	6	5	4	3	2	1	0
Cr Digital Gain							

0	1	0	0	0	0	0	0
---	---	---	---	---	---	---	---

The register represents the current Cr scaling value(1/64 resolution) in Digital Gain block, and is updated every frame by AWB logic when AWB digital gain update mode is active.

AE Status [AEST : 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

AWB Status [AWBST : 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

Y Frame Mean [YFMEAN : 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.

Cb Frame Mean [CBFMEAN : 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.

Cr Frame Mean [CRFMEAN : 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.

$$AE \text{ Lock Boundary} < (Y \text{ Frame Mean} - AE \text{ Target}) < AE \text{ Unlock Boundary.}$$

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.

$$AE \text{ Lock Boundary} < (AE \text{ Target} - Y \text{ Frame Mean}) < AE \text{ Unlock Boundary.}$$

Integration-Scan Offset High [ISOFSH : 82h : RO]

7	6	5	4	3	2	1	0
Integration-Scan Offset High							
RO	RO	RO	RO	RO	RO	RO	RO

Integration-Scan Offset Middle [ISOFSM : 83h : RO]

7	6	5	4	3	2	1	0
Integration-Scan Offset Middle							
RO	RO	RO	RO	RO	RO	RO	RO

Integration-Scan Offset Low [ISOFSH : 84h : RO]

7	6	5	4	3	2	1	0
Integration-Scan Offset Low							
RO	RO	RO	RO	RO	RO	RO	RO

The register represents time offset between integration plane and scan plane. The value should be the same as the value specified by integration time register(63h – 65h).

AWB Luminance High Boundary [AWBLUHI : 8ah : c8h]

7	6	5	4	3	2	1	0
AWB Luminance High Boundary							
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 Low Boundary [AWBLULO : 8bh : 0ah]

7	6	5	4	3	2	1	0
AWB Luminance Low Boundary							
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 [AWBNO : 8ch : 02h]

7	6	5	4	3	2	1	0
AWB Valid Number							
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 : 0h]

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

Dark Bad Pixel Concealment	10	Dark Bad Pixel Concealment is always performed.
----------------------------	----	---

Mode	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 : 13h]

7	6	5	4	3	2	1	0
Dark Bad Integration Time High							
0	0	0	1	0	0	1	1

Dark Bad Integration Time Middle [DPCINTM : 92h : 12h]

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

Dark Bad Integration Time Low [DPCINTL : 93h : d0h]

7	6	5	4	3	2	1	0
Dark Bad Integration Time Low							
1	1	0	1	0	0	0	0

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 Bad G Threshold [DPCGTH : 94h : 0ch]

7	6	5	4	3	2	1	0
Dark Bad G Threshold							
0	0	0	0	1	1	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 Bad C Threshold [DPCGTH : 95h : 0ch]

7	6	5	4	3	2	1	0
Dark Bad C Threshold							
0	0	0	0	1	1	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.

Frame Timing

For clear description of frame timing, clocks' acronym and relation are reminded in here again.

< Clock Acronym Definition >

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

< Clock Frequency Relation >

MCF : MCF	DCF : MCF/Clock Division	
SCF : DCF/2	ICF	SCF for 3x3 interpolation, SCF/2 for 1/4 subsampling mode SCF/4 for 1/16 subsampling mode
VCF : ICF for 16bit output, ICF*2 for 8bit output	LCF : 1/(HBLANK Period + HSYNC Period)	

HBLANK Period : HBLANK Time register value * (1/SCF)

HSYNC Period : HSYNC Active Time

< Frame Time Calculation >

Core Frame Time is

$$(\text{IDLE SLOT} + \text{Video Height} * \text{LCP})$$

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. 3x3 Color Interpolation Timing

3x3 Color Interpolation Frame Timing Related Parameters			
Master Clock Frequency(MCF)	20Mhz	Divided Clock Frequency(DCF)	MCF/1 = 20Mhz
Sensor Clock Frequency(SCF)	DCF/2 = 10Mhz	Sensor Clock Period(SCP)	1/10Mhz = 100ns
Window Width	640	Window Height	480
HBLANK Value	208	VBLANK Value	8
VSYNC Mode	Line Mode	Line Clock Period(LCP)	848 SCPs
Output Bus Width	8bit	VGA Video Output Frequency	SCF * 2 = 20Mhz

Final Video Output Size	640x480	.	.
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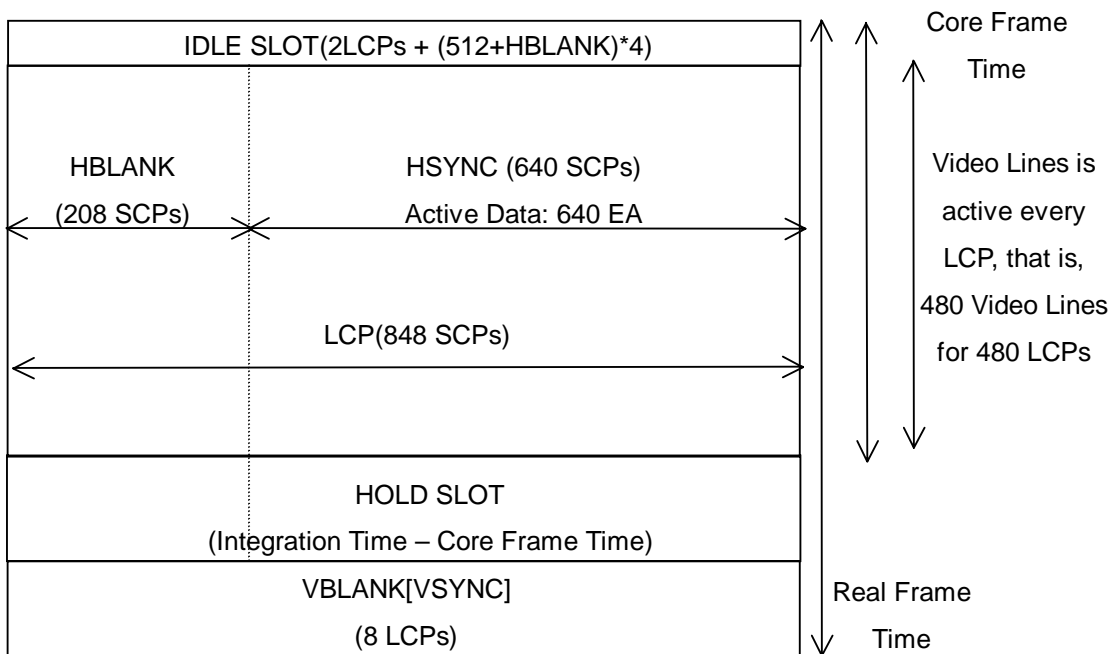
If Integration Time < Core Frame Time, Real Frame Time is

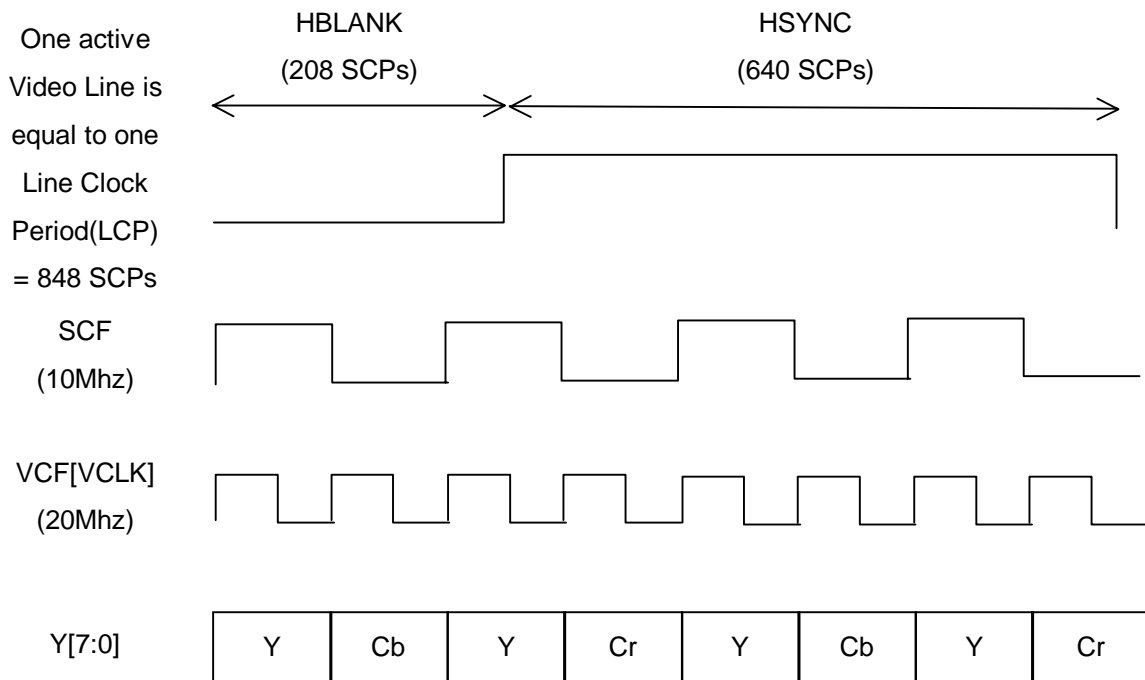
$$2 * (208 + 640) \text{ SCPs} + 480 * (208 + 640) \text{ SCPs} + 8 * (208 + 640) \text{ SCPs} = 415520 \text{ SCPs} = 0.041552\text{sec}$$

else Real Frame Time is

$$\text{Integration Time} * \text{SCPs} + 8 * (208 + 640) \text{ SCPs.}$$

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

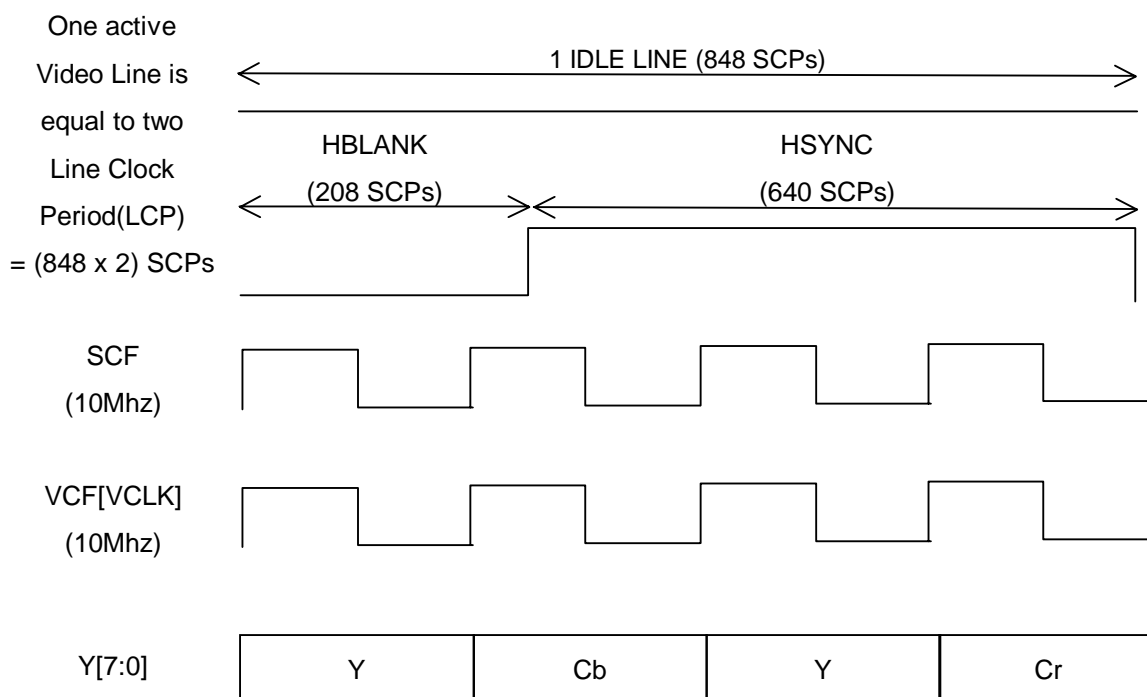
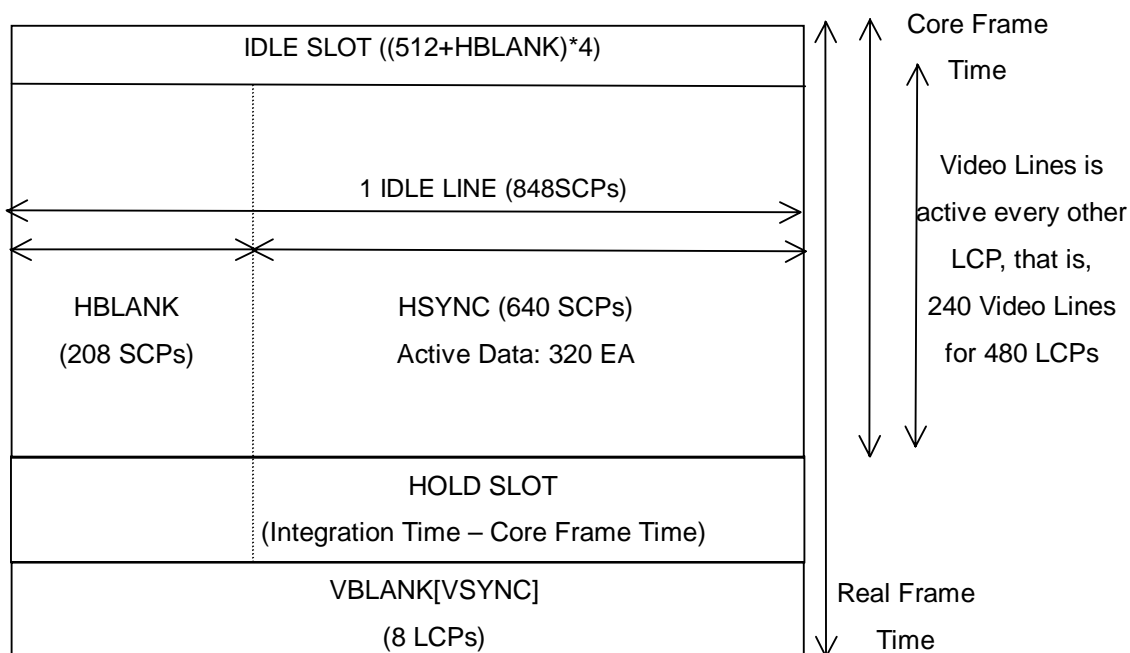




2. 1/4 Subsampling Timing

1/4 Subsampling Frame Timing Related Parameters			
Master Clock Frequency(MCF)	20Mhz	Divided Clock Frequency(DCF)	MCF/1 = 20Mhz
Sensor Clock Frequency(SCF)	DCF/2 = 10Mhz	Sensor Clock Period(SCP)	1/10Mhz = 100ns
Window Width	640	Window Height	480
HBLANK Value	208	VBLANK Value	8
VSYNC Mode	Line Mode	Line Clock Period(LCP)	848 * 2 SCPs
Output Bus Width	8bit	SIF Video Output Frequency	SCF * 1 = 10Mhz
Final Video Output Size	320x240		

In 1/4 subsampling mode, valid video data is produced every other line, i.e. for 480 LCPs, active video lines are 240. HSYNC active time is equal to HSYNC active time of 3x3 color interpolation mode, but video clock frequency is half of 3x3 color interpolation mode's to produce half size output in horizontal direction.

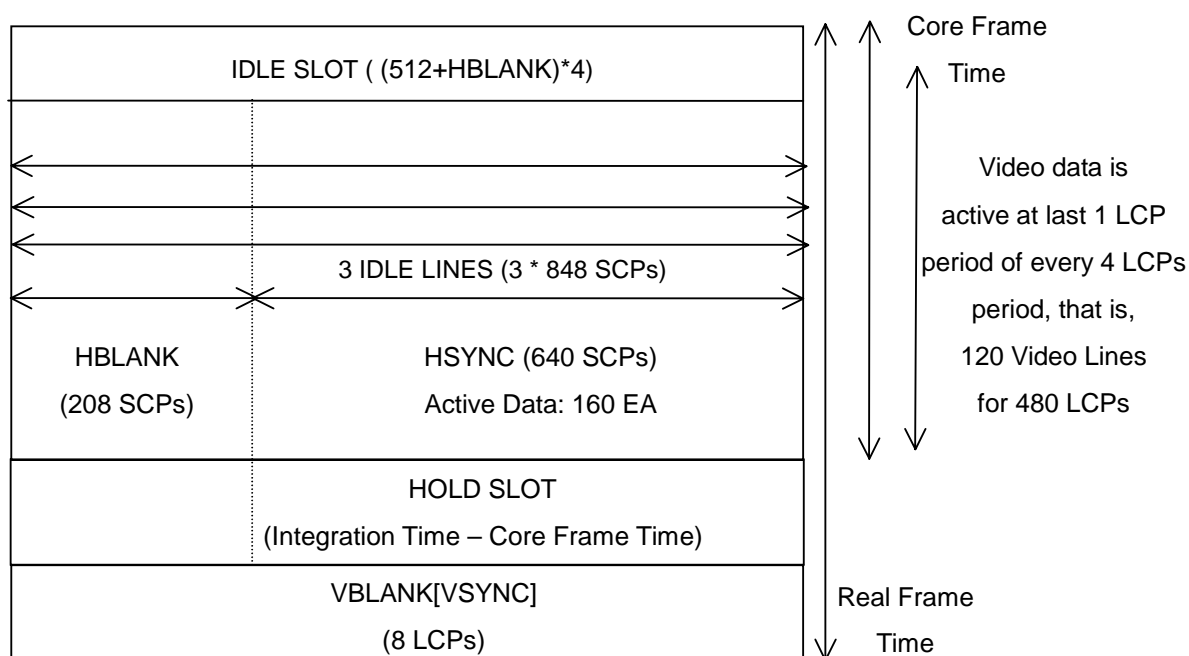


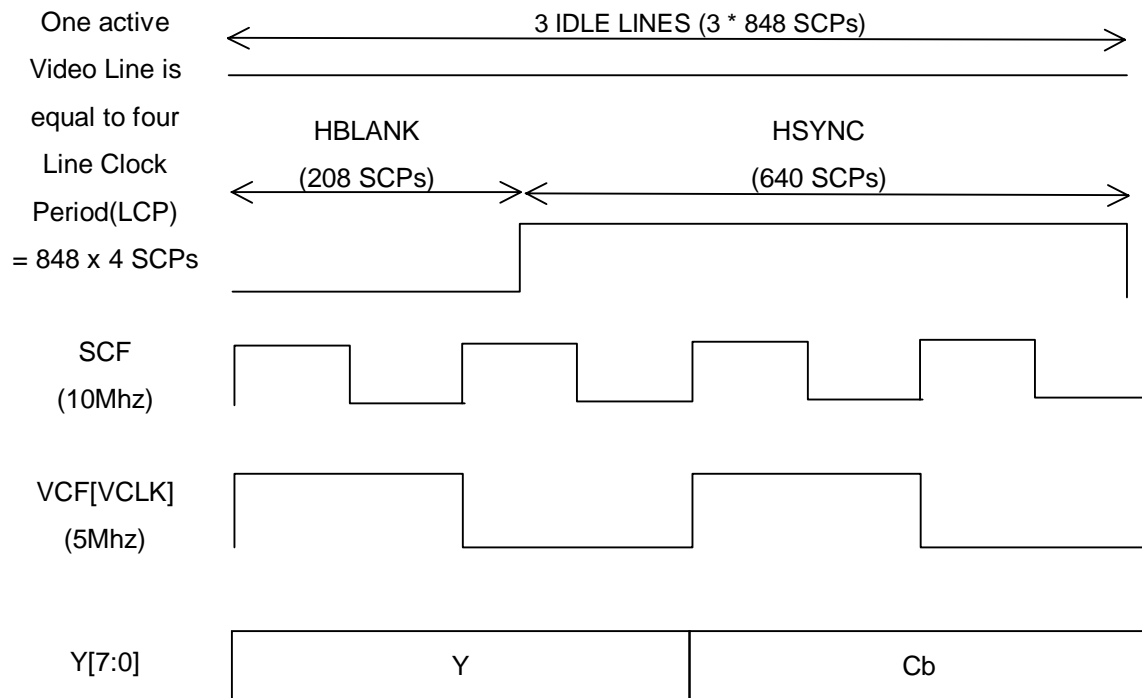
3. 1/16 Subsampling Timing

1/16 Subsampling Frame Timing Related Parameters			
Master Clock Frequency(MCF)	20Mhz	Divided Clock Frequency(DCF)	MCF/1 = 20Mhz
Sensor Clock Frequency(SCF)	DCF/2 = 10Mhz	Sensor Clock Period(SCP)	1/10Mhz = 100ns

Window Width	640	Window Height	480
HBLANK Value	208	VBLANK Value	8
VSYNC Mode	Line Mode	Line Clock Period(LCP)	848 * 4 SCPs
Output Bus Width	8bit	QSIF Video Output Frequency	SCF / 2 = 5Mhz
Final Video Output Size	160x120		

In 1/16 subsampling mode, valid video data is produced every four line, i.e. for 480 LCPs, active video lines are 120. HSYNC active time is equal to HSYNC active time of 3x3 color interpolation mode, but video clock frequency is a quarter of 3x3 color interpolation mode's to produce a quarter size output in horizontal direction.





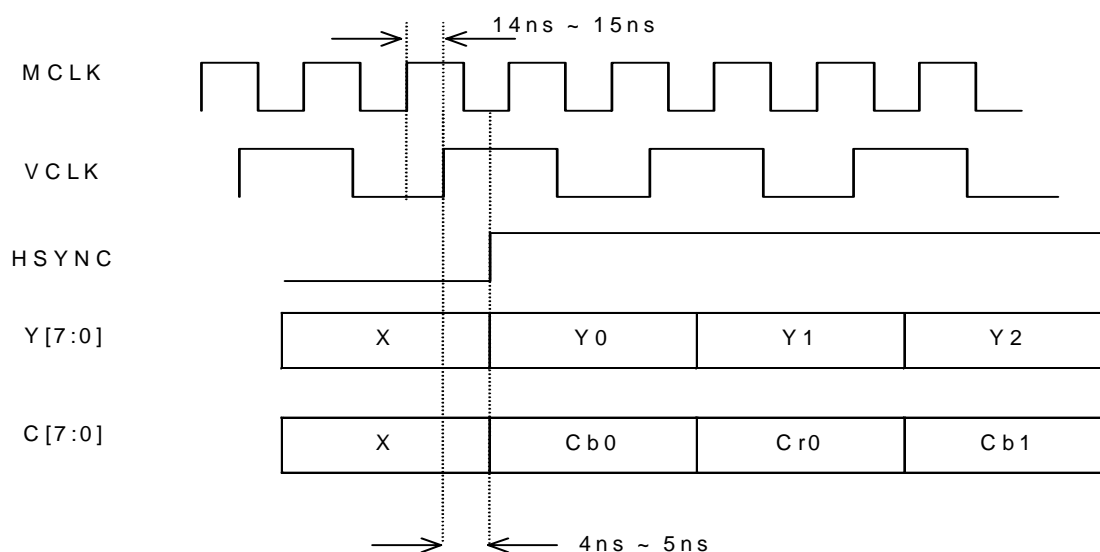
Anti-Banding Configuration

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	SCF / (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.

Data Output Timing and Interface



As specified in the above data output timing diagram, the timing margin between video clock pin (VCLK) and data pins (Y[7:0] or C[7:0]) is about 4ns ~ 5ns. This margin may be sufficient or not according to how much video clock and data pins are delayed internally in the backend chip, respectively. To safely latch the data output in the backend chip, it is recommended that data be latched at negative edge of VCLK. The above timing margin diagram represents 16bit output interface, but is also valid for 8bit output interface.

Output Data Format

Output Format is controlled by configuring Output Format register[31h]. Configurable options are specified again for your reference.

Output Format [OUTFMT : 31h : 39h]

7	6	5	4	3	2	1	0
reserved	reserved	Cb First	Y First	8 Bit Output	reserved	YCbCr 4:4:4	YCbCr 4:2:2
0	0	1	1	1	0	0	1

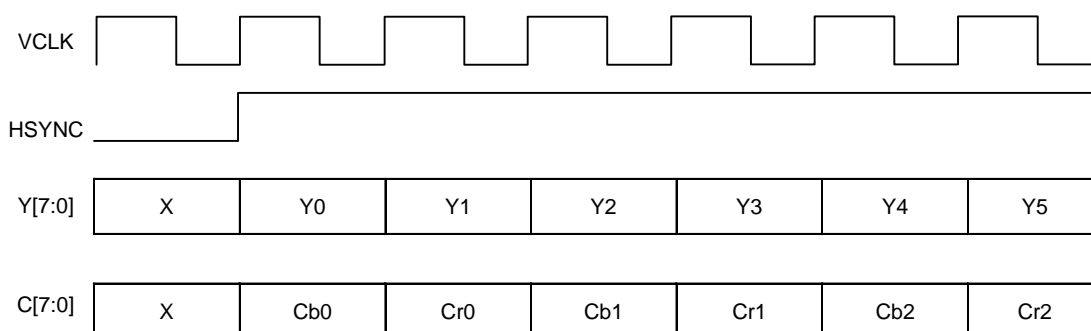
Cb First	Cb pixel in front of Cr pixel in 16bit or 8bit video data output modes
Y First	Y pixel in front of Cb and Cr pixels in 8bit video output mode. This option is meaningful only with 8bit output mode.
8 Bit Output	Image Data is produced only in Y[7:0]. C[7:0] should be discarded

YCbCr 4:4:4	YCbCr 24bit data for a pixel is produced with 16bit output mode. With color space conversion disabled, RGB 24bit data for a pixel is produced in this mode. This mode is meaningful only with 16bit output mode.
YCbCr 4:2:2	YCbCr data for a pixel is produced with 8/16 output mode

Output timings for general configurations are described below. Slot named as "X" means that it is has no meaningful value and should be discarded.

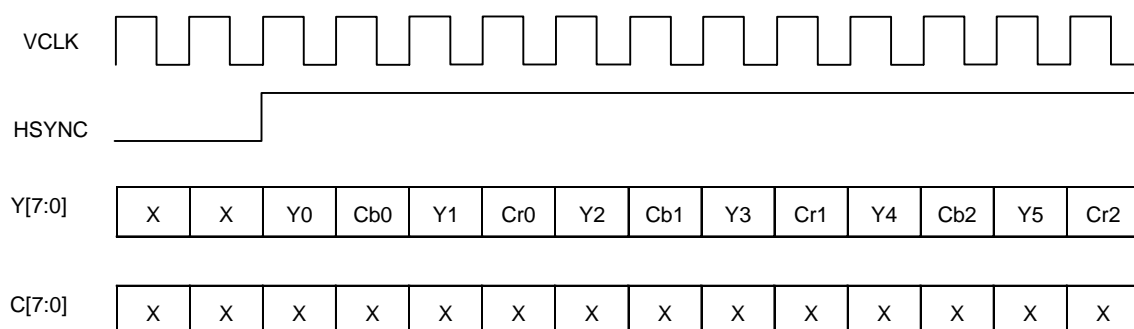
1. YCbCr 4:2:2 with 16bit output

Register bit configurations: 16bit output, Cb First, YCbCr 4:2:2



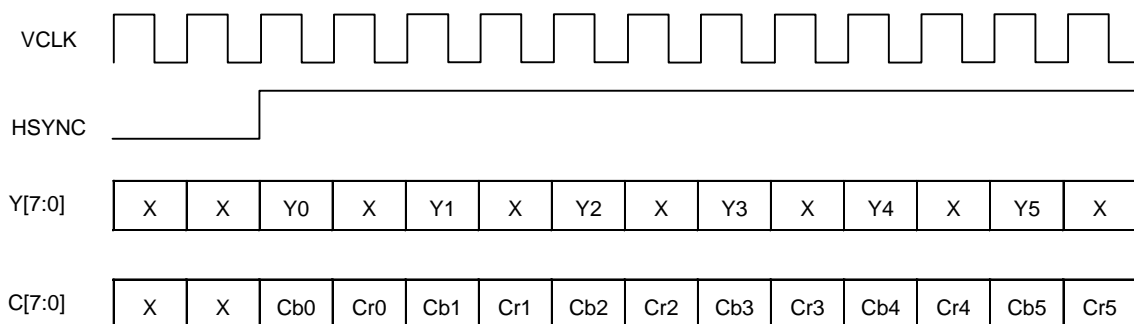
2. YCbCr 4:2:2 with 8bit output

Register bit configurations: 8bit output, Y First, Cb First, YCbCr 4:2:2



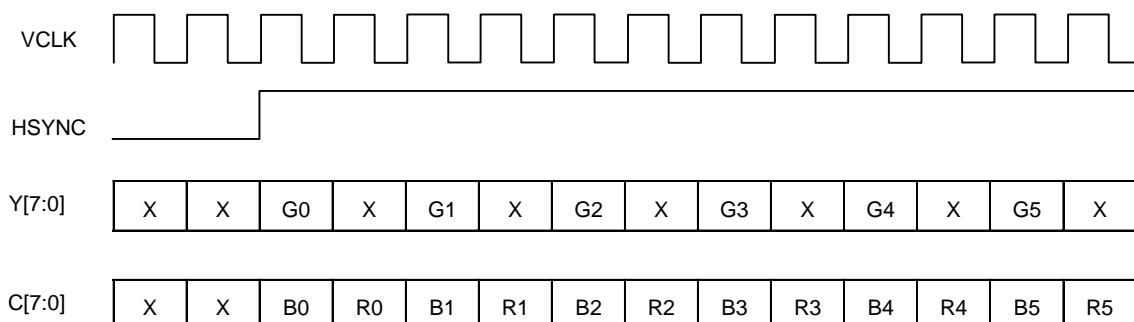
3. 24bit YCbCr 4:4:4 output

Register bit configurations : 8bit output, Y First, Cb First, YCbCr 4:4:4, and color space conversion enabled



4. 24bit RGB 4:4:4 output

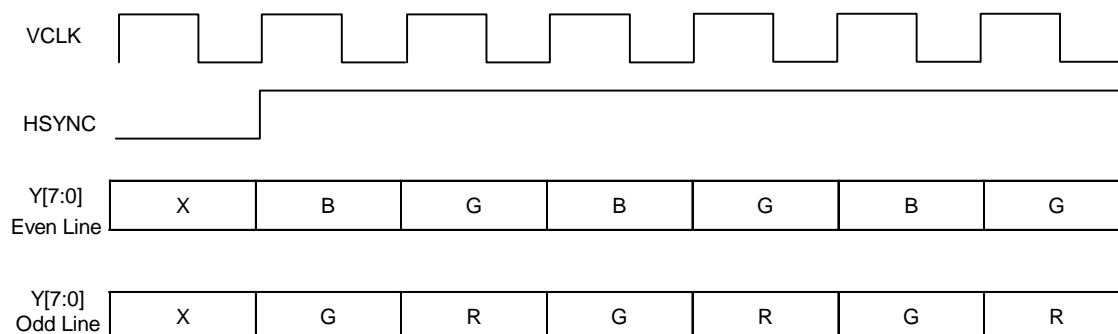
Register bit configurations : 8bit output, Y First, Cb First, YCbCr 4:4:4, and color space conversion disabled



Bayer Data Format

SCTRA[1:0] 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

Register Write Sequences

One Byte Write

S	22H	A	01H	A	03H	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: 03H [Video Mode : CIF]
- *7. Read: acknowledge from sensor
- *8. Drive: I2C stop condition

Multiple Byte Write using Auto Address Increment

S	22H	A	6aH	A	51H	A	61H	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: 6aH [sub-address]
- *5. Read: acknowledge from sensor
- *6. Drive: 51H [AE Integration Step High]
- *7. Read: acknowledge from sensor
- *8. Drive: 61H [AE Integration Step Low]
- *9. Read: acknowledge from sensor
- *10. Drive: I2C stop condition

Register Read Sequence

S	22H	A	50H	A	S	23H	A	Data of 50H	A	P
*1	*2	*3	*4	*5	*6	*7	*8	*9	*10	*11

Read "Reset Level Control" register from HV7131GP

- *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: 50H [sub-address]
- *5. Read: acknowledge from sensor
- *6. Drive: I²C 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 Control Value" 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.
V _{dpp}	Digital supply voltage	Volts	-0.3	7.0
V _{app}	Analog supply voltage	Volts	-0.3	7.0
V _{ipp}	Input signal voltage	Volts	-0.3	7.0
T _{op}	Operating Temperature	°C	-10	50
T _{st}	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
V _{dd}	Internal operation supply voltage	Volt	2.6	3.0		
V _{ih}	Input voltage logic "1"	Volt	2.0	3.0	6.5	

V_{il}	Input voltage logic "0"	Volt	0	0.8	6.5	
V_{oh}	Output voltage logic "1"	Volt	2.15		60	at $I_{oh} = -1\text{mA}$
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		

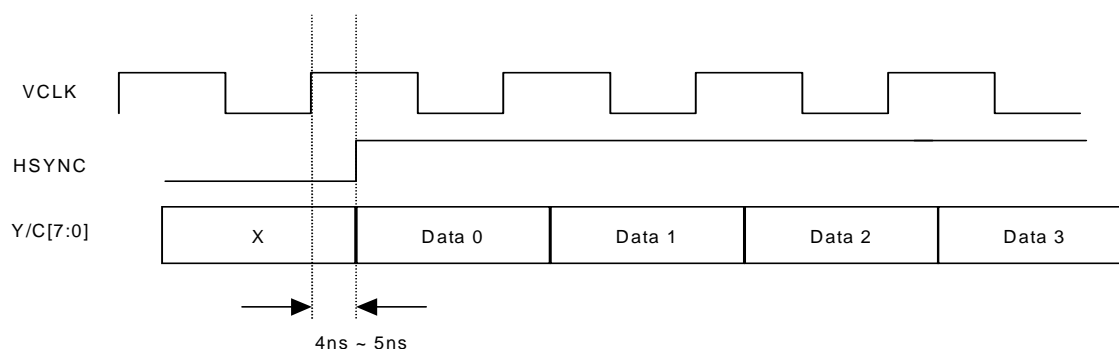
AC Operating Conditions

Symbol	Parameter	Max Operation Frequency	Units	Notes
MCLK	Main clock frequency	25	MHz	1,2
SCK	I ² C clock frequency	400	KHz	3

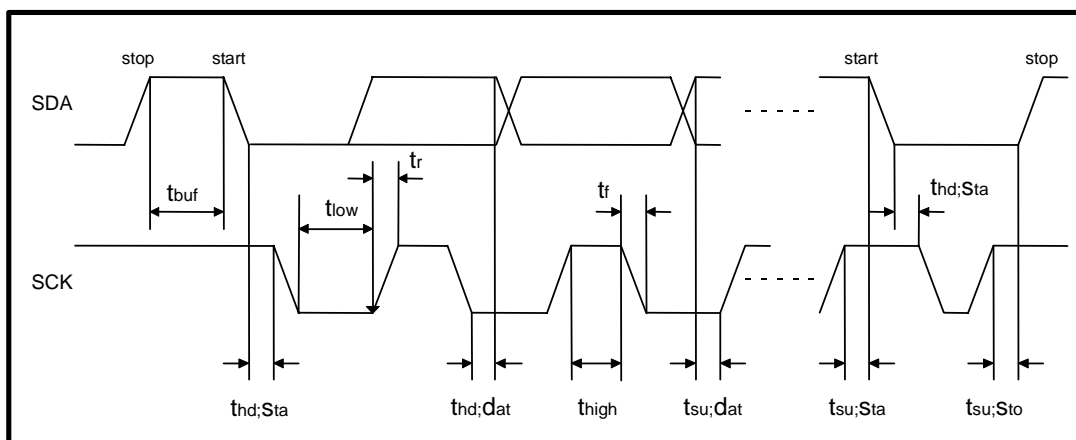
1. MCLK may be divided by internal clock division logic for easy integration with high speed video codec system.
2. Frame Rate : 30 frames/sec at 25Mhz, HBLANK = 208, VBLANK = 8
3. SCK is driven by host processor. For the detail serial bus timing, refer to I2C chip interface section

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 ² C bus must be free before a new transmission can start	t_{buf}	1.2	-	us
Hold time for a START	$t_{hd;Sta}$	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	$t_{su;Sta}$	1.2	-	us
Data hold time	$t_{hd;Dat}$	1.3	-	us
Data setup time	$t_{su;Dat}$	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	$t_{su;Sto}$	1.2	-	us
Capacitive load of SCK/SDA	C_b	-	-	pf

Electro-Optical Characteristics

Parameter	Units	Min.	Typical	Max.	Note
Sensitivity	mV / lux·sec		1500		
Dark Signal	mV/lux·sec		200		
Dark Shading	mV/sec		TBD		
Output Signal Shading	%		60		
Output Saturation Signal	mV		1000		
Power Consumption (Normal Mode)	mW		86		30f/s, 2.8V
	mW		68		15f/s, 2.8V
Power Down	mW		0.336		

- Color temperature of light source: 3200K / IR cut-off filter (CM-500S, 1mm thickness) is used.

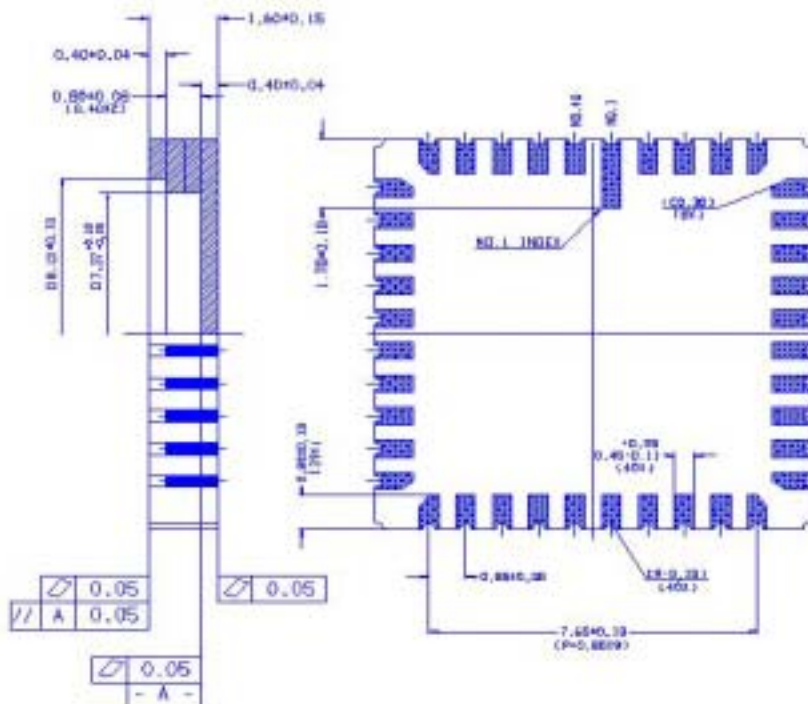
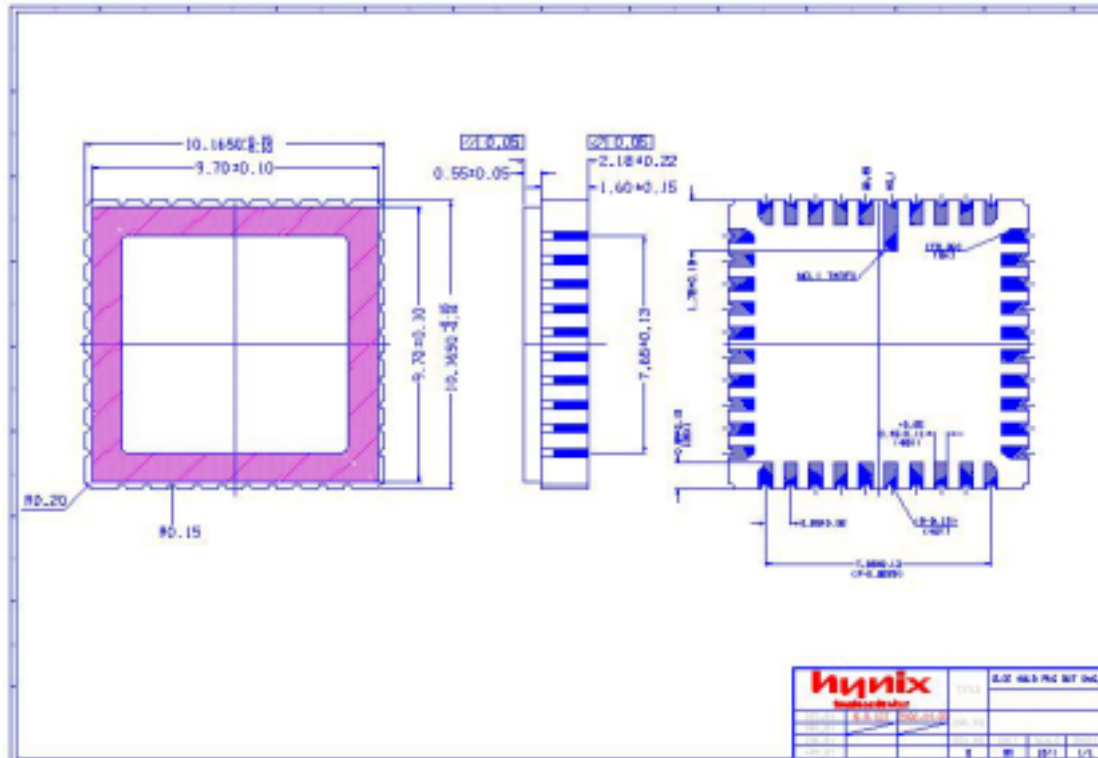
Soldering

Infrared(IR) / Convection solder reflow condition

Parameter	Units	Min.	Typical	Max.	Note
Peak Temperature Range	Celsius	-	230	240	1)

Note: 1) Time within 5 Celsius of actual peak temperature, 10sec

CLCC Package Specification



MEMO

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