

CMOS Image Sensor(CIS) Image Signal Processor

Preliminary Specification

Document Title

CMOS Image Sensor(CIS) Image Signal Processor

Revision History

<u>Revision No.</u>	<u>History</u>	<u>Draft Date</u>	<u>Remark</u>
0.0	Initial Draft	November 28, 2002	Preliminary

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CMOS Image Sensor(CIS) Image Signal Processor

GENERAL DESCRIPTION

The S5C7322X is highly integrated single chip CIS(CMOS image sensor) image signal processor, fabricated by SAMSUNG 0.35um CMOS technology. The processor is input a digital data of the CIS output in a camera system which uses a CIS and produces the luminance signal and the chrominance signal. It has built-in CalmRISC16 core, the RISC core for the AE/AWB function.

- 1) For the signal processing of the camera using the CIS, the processor separates the luminance signal and the chrominance signal using built-in 4H delay line and generates the luminance signal and the color difference signal by image signal processing. It calculates intensity using the luminance signal element for AE which is the main facility of the camera. It also detects the white color information and delivers that information to RISC core for AWB.
- 2) Using the built-in CalmRISC16 core the analog gain for AE and the coefficient for high-shutter speed control are calculated. These are output to CIS and each R/G/B gains for AWB are calculated to output to RGB Matrix Block.
- 3) The processor supports the composite image signal of ITU-R656 format.
- 4) The processor supports the I2C bus interface.

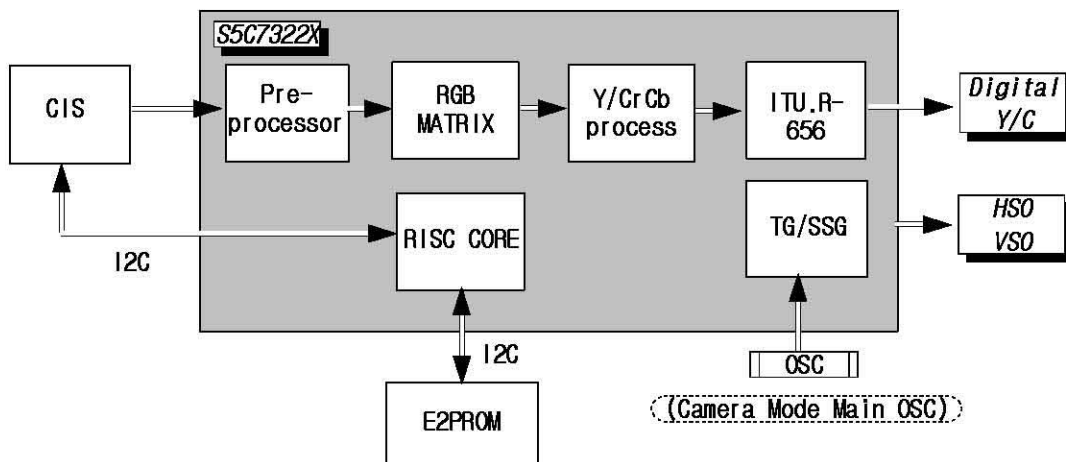
FEATURE

- Effective Resolution : 640X480, VGA
- CIS white defect detection and correction
- Built-in digital clamp function
- 4-line processing using 3-line memory
- Luminance/chrominance signal processing of Bay-array structure
- Color correction
- Luminance/chrominance signal processing of improved SNR
- Built-in arithmetic function for the AE/AWB
- Auto exposure
- Auto white balance
- Digital Y/Cr/Cb and Sync signals output of 4:2:2 ITU-R.656 format which is 8 bits
- γ compensation using partial linear interpolation for each of the degree, R, G and B.
- Built-in I2C bus interface
- Built-in self test pattern generator

PROCESS TECHNOLOGY AND PACKAGE

Process : 0.35 um Silicon GATE 4 Metals 2.8 V CMOS Technology(L35)
PKG : 48-ELP-0707

FUNCTIONAL BLOCK DIAGRAM



The preprocess block which accepts the 10-bit CIS outputs performs ADC delay compensation, digital clamping, CIS defect detection and correction function. This block executes RGB matrix signal processing for the R/G/B signal generation, luminance signal edge enhancement and chrominance signal processing, consecutively. And then it outputs the digital Y/C output through output pins. The oscillator for the above-mentioned camera mode is constructed by main X-TAL only which operates at 24.54MHz.

EACH MODE FREQUENCY

Mode		VGA	QVGA	QQVGA	CIF	QCIF		
Item								
X-tal		24.54MHz						
CIS section		12.27MHz	3.06MHz	3.06MHz	3.06MHz	3.06MHz	12.27MHz	3.06MHz
Signal process section		12.27MHz	3.06MHz	3.06MHz	3.06MHz	3.06MHz	12.27MHz	3.06MHz
Y/C Signal output		24.54MHz	6.03MHz	6.03MHz	6.03MHz	6.03MHz	24.54MHz	6.03MHz
I2C BUS		400kHz						
CIS	Model	S5K433LX						
	Read Area	× 1	× 1	× 2	× 1	× 2	× 5/3	× 5/3
	Effective Pixel	640 × 480	320 × 240	320 × 240	160 × 120	160 × 120	352 × 288	176 × 144
	Frame Rate	30	30	30	100	100	30	30

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Rating	Unit
VDD	DC Supply Voltage	-0.3 to 3.8	V
VIN	DC Input Voltage	3.3V I/O -0.3 to VDD +0.3	
IIN	DC Input Current	±10	mA
I _{latch}	Latch-up Current	±200	mA
TSTG	Storage Temperature	-40 to 125	°C

RECOMMENDED OPERATING CONDITIONS

Symbol	Parameter	Rating	Unit
VDD	DC Supply Voltage	2.55 to 3.05	V
TA	Commercial Temperature Range	0 to 70	°C

1) 0°C ~ +70°C : Function and AC, DC specification satisfied.

ELECTROSTATIC CHARACTERISTICS

Item	Electrostatic Level			Unit
	Pin Number	Target	Reference Product	
Human Body Model	ALL	±2000V ↑	-	V
Machine Model		±200V ↑		V
CDM	ALL	±500V ↑		V
	I-test	±100mA ↑		mA
Latch-Up	Power	V _{dd} max × 1.5 ↑		V

RECOMMENDED DC OPERATING CONDITIONS

$V_{DD}=2.8\pm 0.25V$, $T_A=0$ to $70^\circ C$

Item	Symbol	Condition	Min	Typ	Max	Unit	Remark	
Supply Voltage	V_{DD}	-	2.55	2.8	3.05			
Input voltage	High level	V_{IH}	2.0	-	-		*1, *2	
	Low level	V_{IL}	-	-	0.8			
Output voltage	High level	V_{OH}	$I_{OH} = -1mA$	0.8 V_{DD}	-	-	V	*3
			$I_{OH} = -2mA$					*4
			$I_{OH} = -4mA$					*5, *7
			$I_{OH} = -8mA$					*6
	Low level	V_{OL}	$I_{OL} = 1mA$	-	-	0.2 V_{DD}	V	*3
			$I_{OL} = 2mA$					*4
			$I_{OL} = 4mA$					*5, *7
			$I_{OL} = 8mA$					*6
Input Current	High Level	I_{IH}	$V_{IN} = V_{DD}$	-10	-	10	μA	*1
	High level (Pull-Down)			10	30	60		*2
	Low Level			I_{IL}	$V_{IN} = V_{SS}$	-10		-
Opreating Current	I_{DD}	-	-	30	-	mA	-	
Static Current	I_{SS}	-	-	100	-	mA	-	

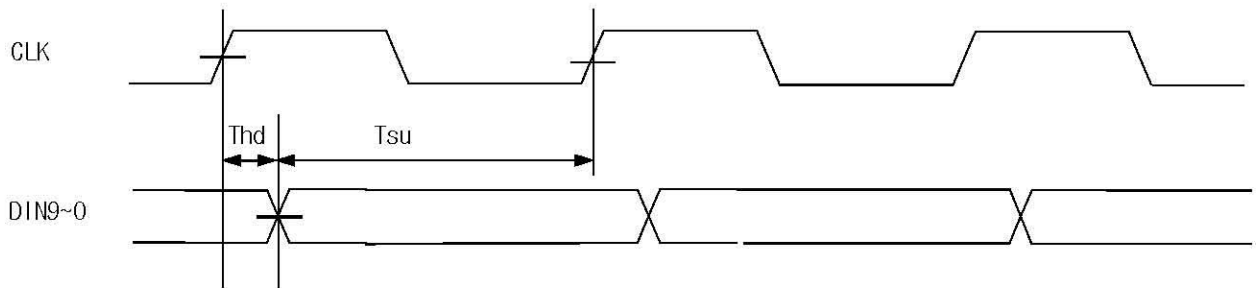
[REMARK]

- *1 : #1, #2, #3, #4, #5, #26, #27, #28, #29, #30, #37, #38, #39, #40, #41, #44, #45, #46, #47, #48
- *2 : #8, #9, #10, #11, #33, #34, #35
- *3 : #36
- *4 : #25
- *5 : #13, #14
- *6 : #12, #15, #16, #17, 20, #21, #22, #23, #24
- *7 : #27, #28, #29, #30

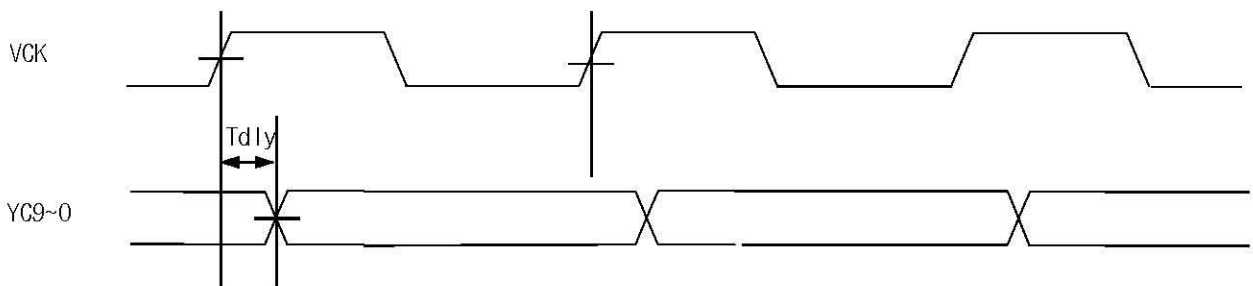
AC CHARACTERISTICS

VSS = 0V, VDD = 2.8V ± 0.25, Ta=0~70°C

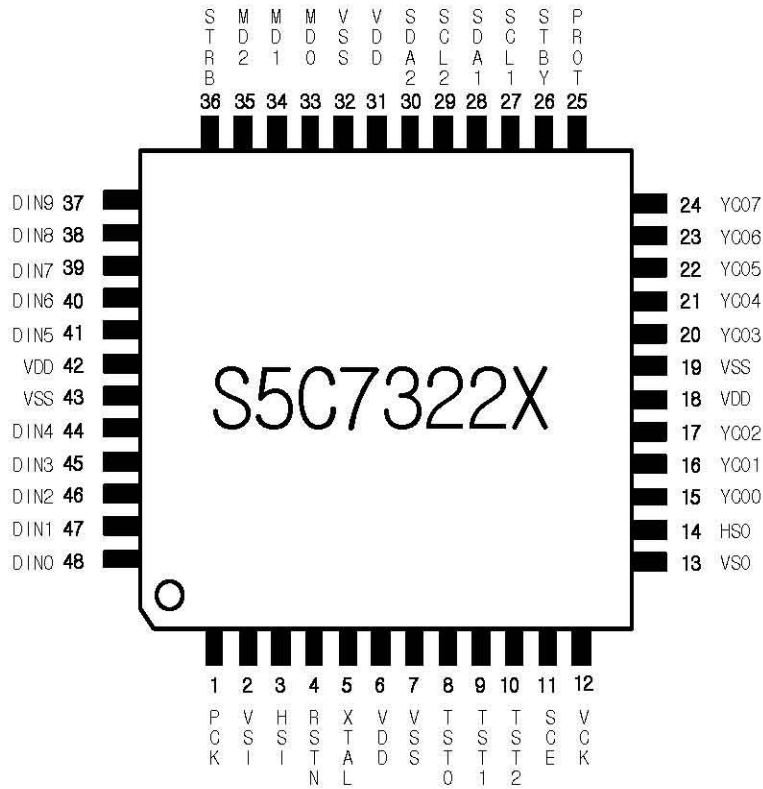
Item	Signal	Symbol	Characteristics			Unit	Remark
			Min	Typ	Max		
Input Data Setup Time	DIN9~DIN0	Tsu	5	-	-	ns	VDD=2.8V ± 0.25 Ta=0~70°C
Input Data Hold Time	DIN9~DIN0	Thd	5	-	50	ns	VDD=2.8V ± 0.25 Ta=0~70°C



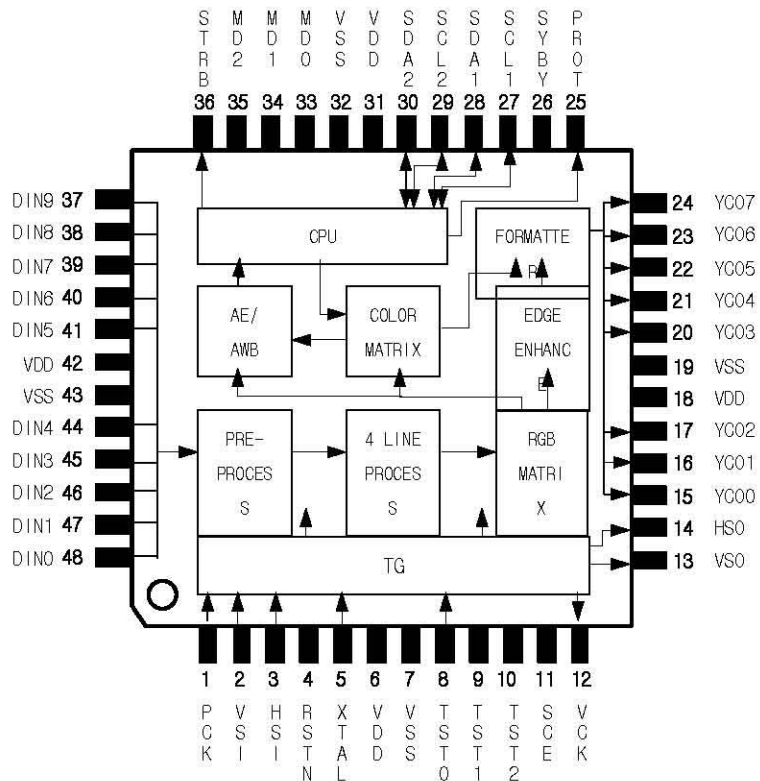
Item	Signal	Symbol	Characteristics			Unit	Remark
			Min	Typ	Max		
Output Data Delay Time	YC9~YC0	Tdly	0.5	-	3	ns	VDD=2.8V ± 0.25 Ta=0~70°C



PIN CONFIGURATION



BLOCK DIAGRAM



PIN DESCRIPTION

Pin #	Name	I/O	Description
1	PCK	I	Pixel Clock Input from CMOS Image Sensor
2	VSI	I	Vertical Sync Input from CMOS Image Sensor
3	HSI	I	Horizontal Sync Input from CMOS Image Sensor
4	RSTN	I	Master Reset
5	XTAL	I	X'tal Input
6	VDD	P	Power
7	VSS	G	Ground
8	TST0	I	Test Mode Selection 0
9	TST1	I	Test Mode Selection 1
10	TST2	I	Test Mode Selection 2
11	SCE	I	Scan Test Path Enable Signal
12	VCK	O	Main Clock Output for Video Module
13	VSO	O	Vertical sync Output to Video Module
14	HSO	O	Horizontal sync Output to Video Module
15	YCO0	O	Image Data Output 0 (LSB)
16	YCO1	O	Image Data Output 1
17	YCO2	O	Image Data Output 2
18	VDD	P	Power
19	VSS	G	Ground
20	YCO3	O	Image Data Output 3
21	YCO4	O	Image Data Output 4
22	YCO5	O	Image Data Output 5
23	YCO6	O	Image Data Output 6
24	YCO7	O	Image Data Output 7 (MSB)

PIN DESCRIPTION (Continued)

Pin #	Name	I/O	Description
25	PROT	O	Protection Signal
26	STBY	I	Stand-by Mode ('0' : Stand-by Mode, '1' : Normal Mode)
27	SCL1	I/O	Serial Clock Inout1 for I2C Bus
28	SDA1	I/O	Serial Address & Data1 Inout for I2C Bus
29	SCL2	I/O	Serial Clock Inout2 for I2C Bus
30	SDA2	I/O	Serial Address & Data Inout2 for I2C Bus
31	VDD	P	Power
32	VSS	G	Ground
33	MD0	I	Mode Selection 0
34	MD1	I	Mode Selection 1
35	MD2	I	Mode Selection 2
36	STRB	O	Strobe Signal Output to CMOS Image Sensor for Single Frame Capture
37	DIN9	I	Data Input from CMOS Image Sensor 9 (MSB)
38	DIN8	I	Data Input from CMOS Image Sensor 8
39	DIN7	I	Data Input from CMOS Image Sensor 7
40	DIN6	I	Data Input from CMOS Image Sensor 6
41	DIN5	I	Data Input from CMOS Image Sensor 5
42	VDD	P	Power
43	VSS	G	Ground
44	DIN4	I	Data Input from CMOS Image Sensor 4
45	DIN3	I	Data Input from CMOS Image Sensor 3
46	DIN2	I	Data Input from CMOS Image Sensor 2
47	DIN1	I	Data Input from CMOS Image Sensor 1
48	DIN0	I	Data Input from CMOS Image Sensor 0 (LSB)

I2C INTERFACE

The I2C is an industry standard serial interface. The I2C contains a serial two-wire half duplex interface that features bi-directional operation, master or slave mode. The SDA and SCL are the bi-directional data and clock pins, respectively. These pins are open-drain type ports and will require a pull-up resistor to VDD. The image sensor uses the I2C bus to write or read one register byte per I2C cycle. The I2C bus interface is composed of following parts : START signal, 7-bit slave device address transmission followed by a read/write bit, an acknowledgement signal from the slave, 8-bit data transfer followed by an acknowledgement signal and STOP signal. The SDA bus line may only be changed while SCL is low. The data on the SDA bus line is valid on the high-to-low transition of SCL.

START Signal

When no master device is engaging two bus lines (SCL, SDA), the bus lines are at logical "1". A master may initiate communication by sending a START signal which is defined as a high-to-low transition of SDA while SCL is high. Then, all slaves on the bus wake up to communication.

Slave Address Transmission

After the START signal, the slave address and read/write bit is transmitted by the master. The 7-bit address for the image sensor is 001001b starting with the MSB. The read/write bit following the 7-bit address tells the slave the direction of data transfer. (1: read transfer, the slave sends the data to the master, 0: write transfer, the master sends the data to the slave)

Acknowledgment

Only one slave which has an address sent by the master sends back an acknowledge bit. This is done by pulling the SDA bus line low at the 9th SCL. If the master receives an acknowledge, it is said that successful slave addressing has been achieved.

Data Transfer

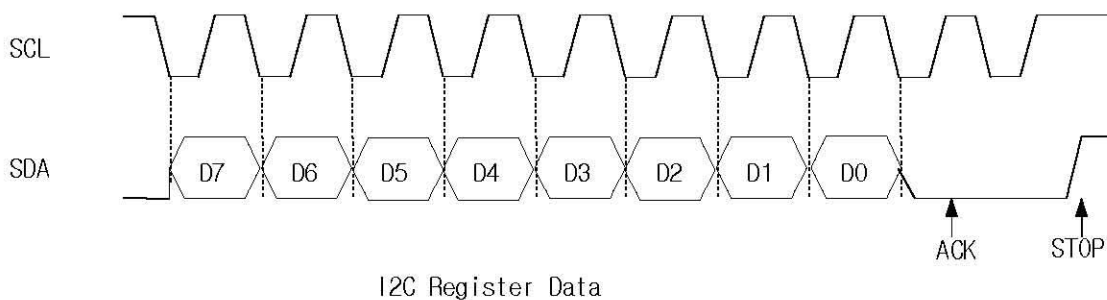
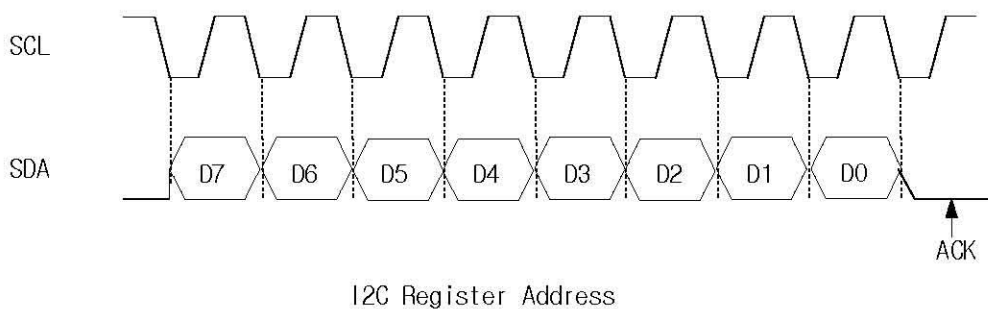
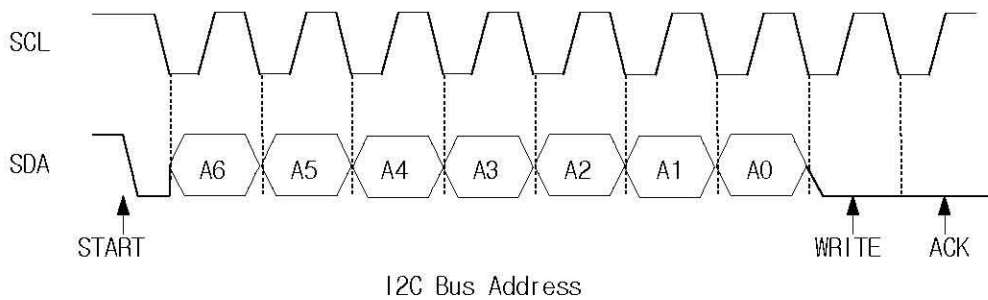
After successful slave addressing, data transfer is proceeding between the master and the slave in a direction specified by the read/write bit, the MSB being transferred first. The first data byte of data is the register address to be read or written. Each data byte is 8bits long and has to followed by an acknowledge bit, which signals from the receiving device.

STOP Signal

The master can terminate the communication by generating a STOP signal. A STOP signal is defined as a low-to-high transition of SDA while SCL is high.

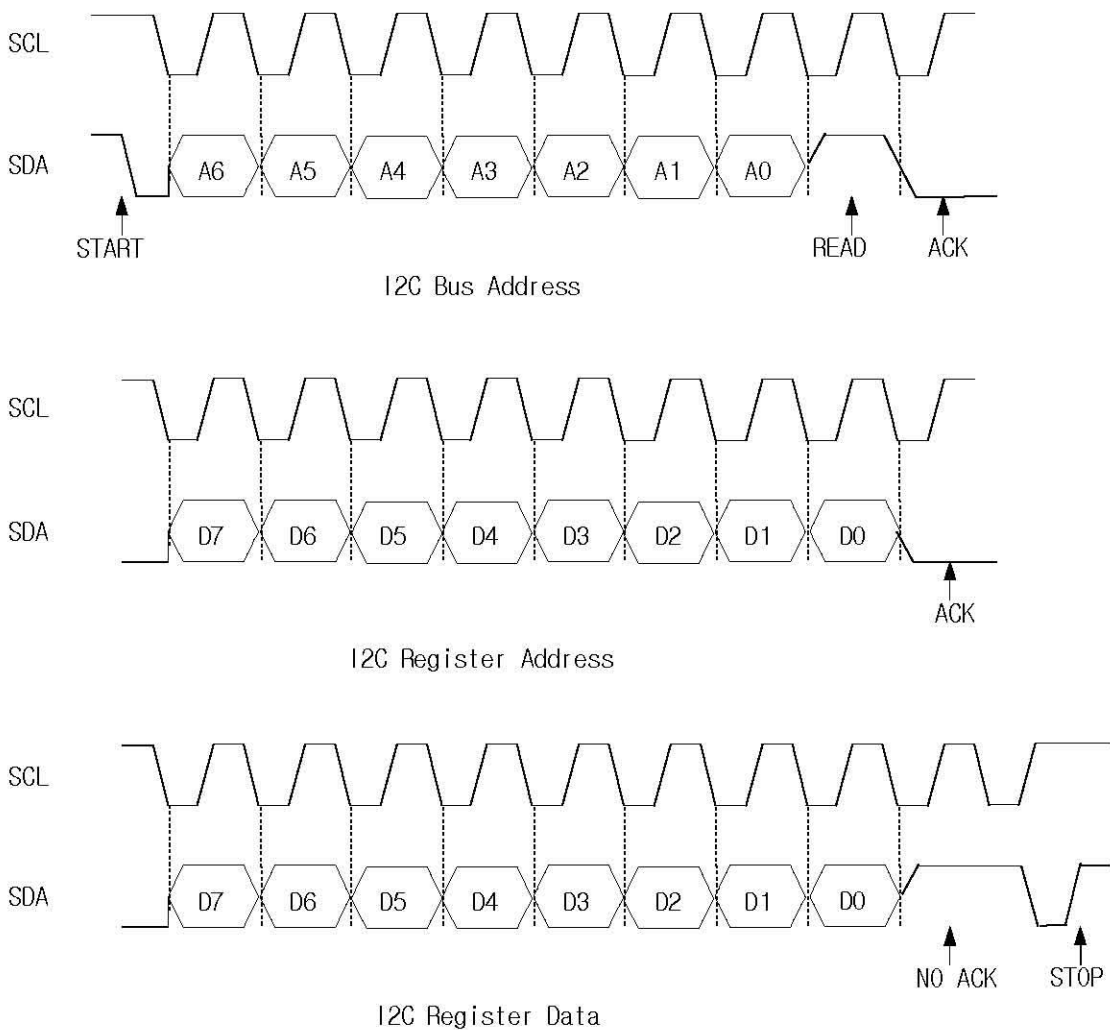
Write Operation Timing

- A. Master transmits a START signal.
- B. Master transmits the device slave address with "write" indicated (binary : 00100010b).
- C. After the device receives slave address, it sends acknowledgment by forcing the SDA bus line low during the 9th clock.
- D. Master transmits the register address.
- E. After the device slave receives register address, it sends acknowledgement by forcing the SDA bus line low during the 9th clock.
- F. Master transmits the data to be written at the previously received register address.
- G. After the device receives the data to be written, it sends acknowledgement by forcing the SDA bus line low during the 9th clock.
- H. Master transmits STOP signal to end the write cycle.



Read Operation Timing

1. Master transmits a START signal
2. Master transmits the S5K711CX slave address with "read" indicated (binary : 00100011b)
3. After S5K711CX slave receives slave address, slave sends acknowledgment by forcing the SDA bus line low during the 9th clock.
4. Master transmits the register address.
5. After S5K711CX slave receives register address, slave sends acknowledgment by forcing the SDA bus line low during the 9th clock.
6. S5K711CX transmits the data to be read at the previously received register address.
7. Master does not send an acknowledgment.
8. Master transmits STOP to end the read cycle.



SYSTEM FUNCTIONAL DESCRIPTION

PREPROCESS

The preprocess module executes ADC delay adjust, digital clamp, CCD defect detection and correction. The execution of these function is as follows :

- ADC Delay Adjust
- Digital Clamp
- White Defect Detection
- Defect Correction

R/G/B MATRIX

The R/G/B matrix is a frequency conversion memory block. In the DVC mode it accomplishes the function to change a sampling ratio of the output frequency about the input frequency. This goal is achieved by the address control when we generate the Read Address and the Write Address using 1H Delay Line which is a input buffer.

- Adaptive R/G/B Interpolation by 4-Line Processing
- R/G/B Color Correction
- Gamma Compensation Using the Partial Linear Approximation
- Luminance Signal Generation
- Color Suppression (Highlight, Edge Suppress) Coefficient Generation

EDGE ENHANCEMENT

For the edge enhancement using the output of the luminance signal details tasks following are performed.

- Horizontal Edge Enhancement
- Vertical Edge Enhancement
- Non-linear Characteristic Process after the Edge Enhancement
- Noise Slice
- Level Clip
- Detail Enhancement
- High-Light Enhancement Control
- Gain Control of the luminance

COLOR MATRIX

Color difference signals(R-Y,B-Y) for the composite image signal are generated by using R/G/B output.

- White and Black Adjust
- Color Difference Signal Generation
- Hue Adjust
- Gain Control of the Color Difference Signal
- High Luminance/Edge Color Suppression

OPTICAL DETECTOR

This block accepts the luminance signal and the R/G/B signal to generate the data for AE(Auto Exposure) and AWB(Auto White Balance) to the given window area and outputs that data to the RISC core. And it generates the Window Pulse to display each window area of AE and AWB.

- 1-Field Luminance Signal Integration for the AE in the Window1 Area
- 1-Field Luminance Signal Integration for the AE in the Window2 Area
- Luminance Level Clip Count for the AE in the Window2 Area
- 1-Field R, G, B Signal Integration for the AWB in the Window Area

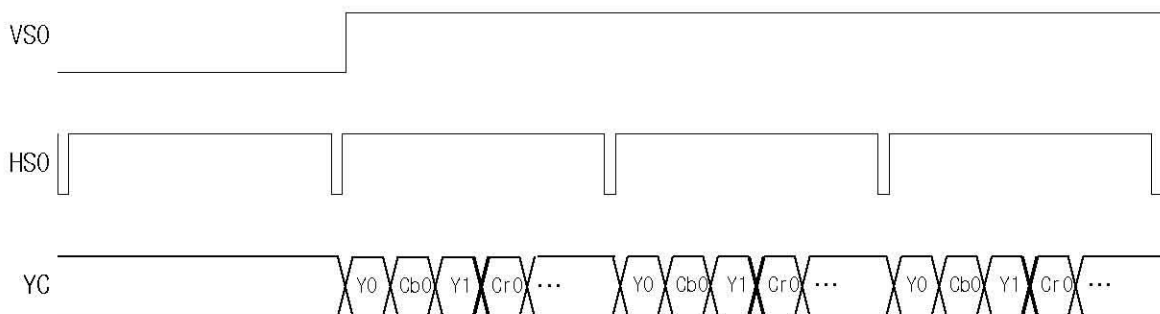
RISC CORE

This block receives the data for Auto Exposure(AE) from the optical detector block and generates Analog Gain and High-Shutter Coefficients from it. These results are output to the CIS. White balance coefficient is produced from the data for Auto White Balance(AWB) and is output to the Color Matrix block.

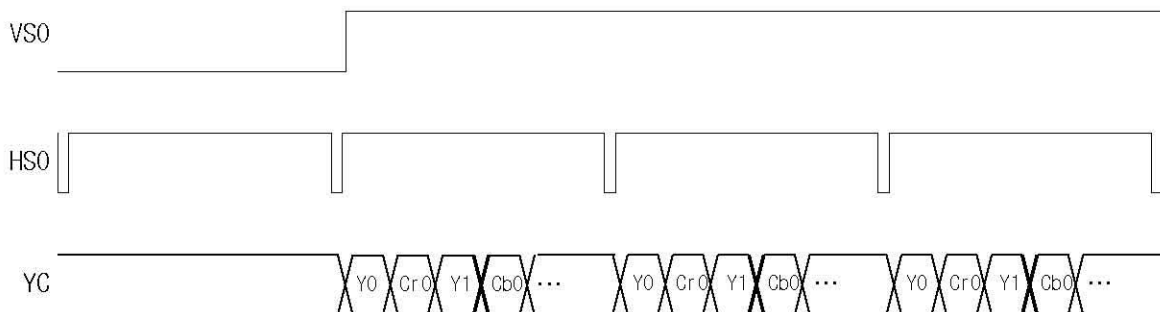
- Auto Exposure
- Auto White Balance
- I2C Bus Interface

VIDEO OUTPUT TIMING DIAGRAM

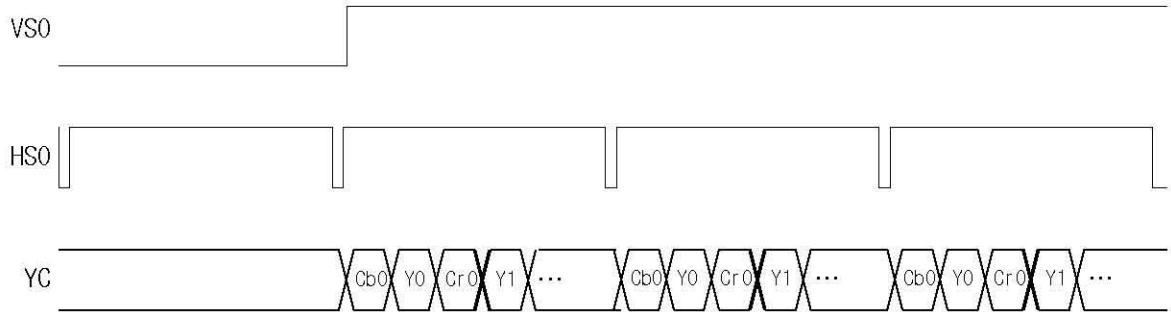
YCrCb Format 1 (Y/Cb/Y/Cr)



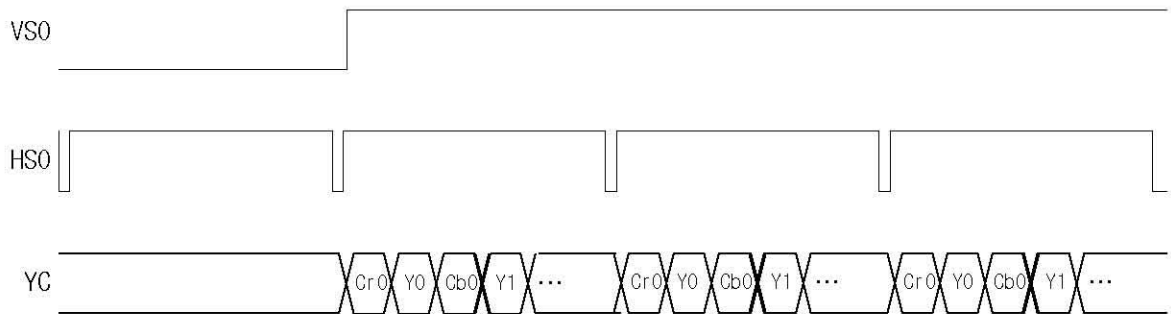
YCrCb Format 2 (Y/Cr/Y/Cb)



YCrCb Format 3 (Cb/Y/Cr/Y)

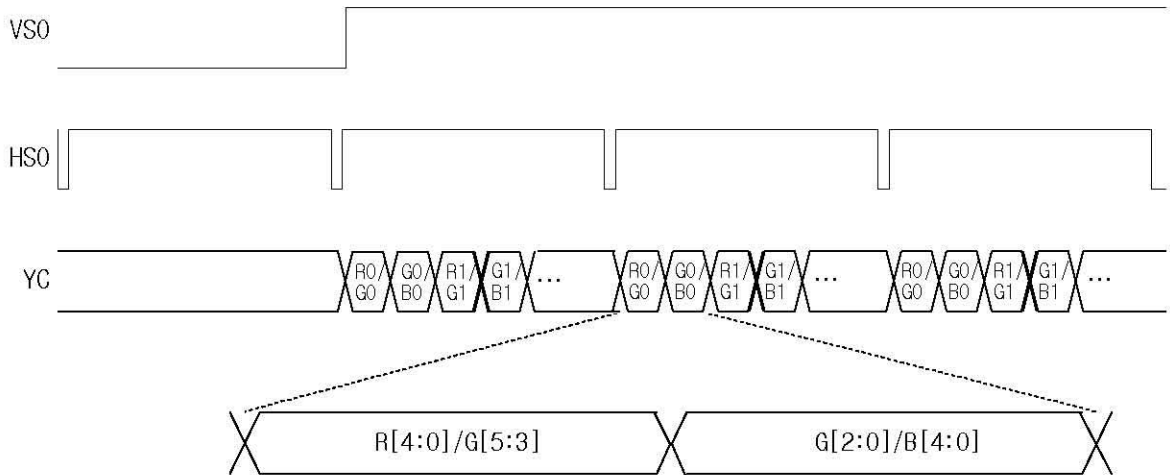


YCrCb Format 4 (Cr/Y/Cb/Y)



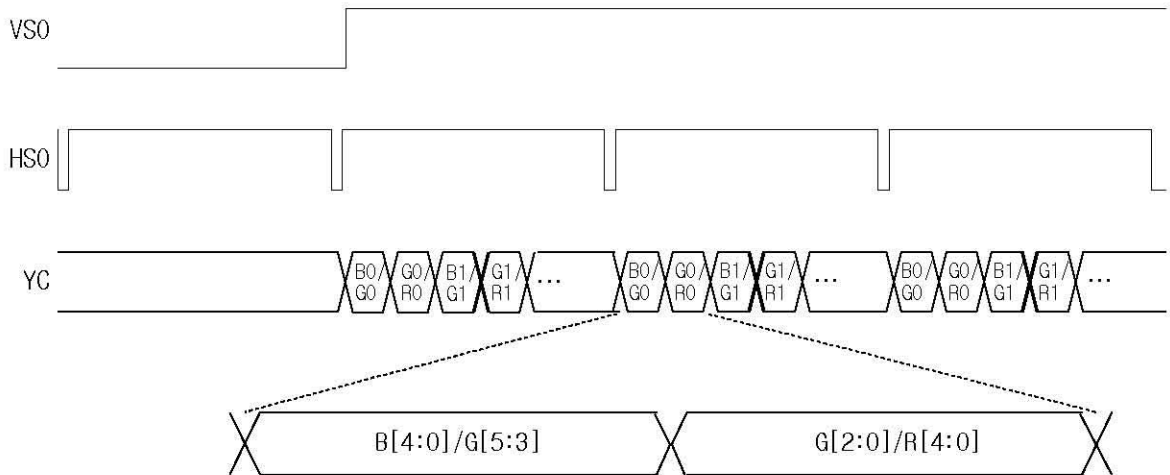
R/G/B Format 1 (R/G/B)

R : G : B = 5Bits : 6Bits : 5Bits

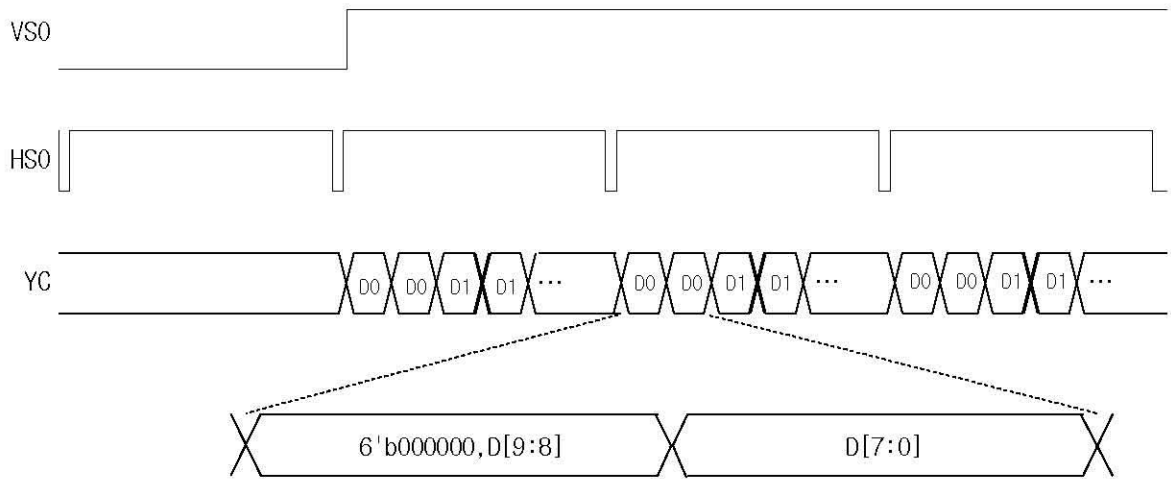


R/G/B Format 2 (B/G/R)

B : G : R = 5Bits : 6Bits : 5Bits



CIS Raw Format

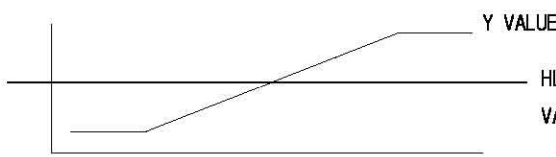
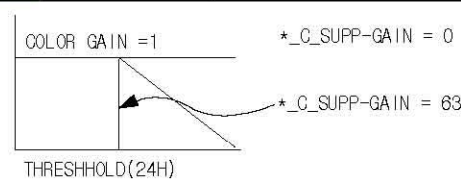


REGISTER MAP

Address	DATA							Default
00	Timing Generator Command							
	TCMD[7:0]							81
	INT_HVS	MCK_DIV[1:0]	SCK_INV	VSO_INV	HSO_INV	VSI_INV	HSI_INV	
	0 : Use SYNC out of ISP	10 : CIS 8 CLK division process → ISP 4 CLK division process	0 : Red signal at the SCK HIGH	0 : Out VSO signal directly	0 : Out HSO signal directyl	0 : Out CIS vertical signal directly	0 : Out CIS horizontal signal directly	
	1 : Use SYNC out of CIS	01 : CIS 4 CLK division process → ISP 2 CLK division process Default : Process the same CLK division with CIS CLK	1 : Green signal at the SCK HIGH	1 : Invert VSO signal	1 : Invert HSO signal	1 : Invert CIS vertical signal	1 : Invert CIS HORIZONTAL SIGNAL	
HSO,VSO : H/V signal considered ISP total delay into the encoder								
01	Preprocessor Command							
	PCOMMAND1[7:0]							00
	-	HMIR_DEALY[1:0]	AD_DELAY[1:0]	CLP_EN	PTEST	THRESH_O		
		AD Delay reselect for CIS 10 : AD_DELAY 10 11 : AD_DELAY 00 Default : OUT AD_DELAY directly	AD clock delay 00 : 1 CLK 01 : 2 CLK 10 : 3 CLK 11 : 4 CLK	0 : Normal 1 : Digital clamp ON	Defect generate enable 0 : OFF 1 : ON	Threshold value display 0 : OFF 1 : ON		
02	CLAMP_OFFSET							
	POFFSET[7:0]							00
	Offset value in CLAMP operation (-128 ---- 127 : 2's compliment)							
03	DUMMY							
	--							
	--							
04	DUMMY							
	--							
	--							
05	DUMMY							
	--							
	--							
06	DUMMY							
	--							
	--							

Address	DATA							Default
07	DUMMY							
08	Detection Window Horizontal Start							00
	PWIN_H_START[7:0]							
Window horizontal start point for defect detection (× 4)								
09	Detection Window Horizontal End							00
	PWIN_H_END[7:0]							
Window horizontal end point for defect detection (× 4)								
0A	Detection Window Vertical Start							00
	PWIN_V_START[7:0]							
Window vertical start point for defect detection (× 2)								
0B	Detection Window Vertical End							00
	PWIN_V_END[7:0]							
Window vertical end point for defect detection (× 2)								
0C	DUMMY							
0D	Horizontal Clamp Start Point							01
	CLP_H_START[7:0]							
Horizontal start point of the optical black region of the CIS (× 1)								
0E	Vertical Clamp Start Point							
	CLP_H_START[9:8]			CLP_V_START[5:0]				
Vertical start point of the optical black region of the CIS (× 2)								
0F	Threshold Value To Search The Defect Pixel Position							00
	PTHRESH1[7:0]							
Threshold value to judge the white defect								
10	CR & CB							04
	CRCB_SEL_ADRS[7:0]							
	-	-	-	-	OUT_SEL[1:0]	YC_SEL	CRCB_SEL	
	-	-	-	-	00 : ITU656 FORMAT	0 : Y	0 : CB	
	-	-	-	-	01 : ITU601 FORMAT	1 : C	1 : CR	
				10 : R/G/B FORMAT				
				11 : CIS OUTPUT				
11	GAMMA SELECT & PIXEL SEQUENCE CHANGE							10
	RCONTROL_ADRS[7:0]							
	BW	RGB_LIN	GAM_SEL	RH_CONT	RV_CONT	RCS_DLY[2:0]		
	0 : BW CIS 1 : Color CIS	0 : ADM algorithm 1 : 3-Line linear algorithm	Gamma correction method 0 : NEW 1 : OLD	Horizontal pixel arrangement 0 : SCK 1 : ~SCK	Vertical pixel arrangement 0 : ID 1 : ~ID	000: -1 MCK 100: 0 MCK 001: -2 MCK 101: 1 MCK 010: -3 MCK 110: 2 MCK 011: -4 MCK 111: 3 MCK		

Address	DATA	Default
12	Horizontal Correlation Threshold	
	RCORTH_H[7:0]	
	Correlation value among the horizontal pixels for the adaptive RGB interpolation	05
13	Vertical Correlation Threshold	
	RCORTH_V[7:0]	
	Correlation value among the vertical pixels for the adaptive RGB interpolation	05
14	R Gain for the R Color Correction	
	RRR_GAIN[7:0]	
	R signal gain for the R signal color correction (X0 ~ X2) See address 1CH	A4
15	G Gain for the R Color Correction	
	RRG_GAIN[7:0]	
	G signal gain for the R signal color correction (X-1 ~ X1) See address 1CH	1D
16	B Gain for the R Color Correction	
	RRB_GAIN[7:0]	
	B signal gain for the R signal color correction (X-1 ~ X1) See address 1CH	1F
17	R Gain for the G Color Correction	
	RGR_GAIN[7:0]	
	R signal gain for the G signal color correction (X-1 ~ X1) See address 1CH	1E
18	G Gain for the G Color Correction	
	RGG_GAIN[7:0]	
	G signal gain for the G signal color correction (X0 ~ X2) See address 1CH	B2
19	B Gain for the G Color Correction	
	RGB_GAIN[7:0]	
	B signal gain for the G signal color correction (X-1 ~ X1) See address 1CH	21
1A	R Gain for the B Color Correction	
	RBR_GAIN[7:0]	
	R signal gain for the B signal color correction (X-1 ~ X1) See address 1CH	24
1B	G Gain for the B Color Correction	
	RBG_GAIN[7:0]	
	G signal gain for the B signal color correction (X-1 ~ X1) See address 1CH	23
1C	B Gain for the B Color Correction	
	RBB_GAIN[7:0]	
	B signal gain for the B signal color correction (X0 ~ X2) $\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{bmatrix} RRR_GAIN & RRG_GAIN & RRB_GAIN \\ RGR_GAIN & RGG_GAIN & RGB_GAIN \\ RBR_GAIN & RBG_GAIN & RBB_GAIN \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$	AD
1D	R Coefficient For The Y Signal	
	RR_COEF[7:0]	
	R coefficient for the Y signal (X0 ~ X1) See address 1FH	4C
1E	G Coefficient For The Y Signal	
	RG_COEF[7:0]	
	G coefficient for the Y signal (X0 ~ X1) See address 1FH	98

Address	DATA				Default
1F	B Coefficient For The Y Signal				
	RB_COEF[7:0]				
	B coefficient for the Y signal (X0 ~ X1) ※ $Y = RR_COEF \times R + RG_COEF \times G + RB_COEF \times B$				1C
20	Y Highlight Color Suppress Reference				
	RHLREF[7:0]				
	Color suppress reference for highlight 				A0
21	Edge Color Suppression Reference				
	REGREF[7:0]				
	Reference value for edge chroma suppress				20
22	C Suppress Gain				
	RHLFALL_ADRS[7:0]				
	-	-	RHLSEL[5]	RHLFALL[4:0]	28
	-	-	0 : OFF 1 : ON	High light color suppress slope	
	 <p style="text-align: center;">$0 \leq (HLFALL \text{ or } EGFALL)/64 < 1.$</p> <p>※ Color suppress coefficient setting <<REGSEL,RHLSEL>> 00 : 6'h3F 01 : Highlight suppress coefficient 10 : Edge suppress coefficient 11 : if HLCS <= EGCS, HLCS else EGCS</p>				
23	C Suppress Gain				
	REGFALL_ADRS[7:0]				
	-	-	REGSEL[5]	REGFALL[4:0]	28
24	Gamma Value 1				
	GM1[7:0]				
	Gamma correction coefficient 1 (Output 8-bit value according to the input 2 ³)				08
25	Gamma Value 2				
	GM2[7:0]				
	Gamma correction coefficient 2 (Output 8-bit value according to the input 2 ⁴)				10
26	Gamma Value 3				
	GM3[7:0]				
	Gamma correction coefficient 3 (Output 8-bit value according to the input 2 ⁵)				20

Address	DATA	Default												
27	Gamma Value 4 GM4[7:0]	40												
	Gamma correction coefficient 4 (Output 8-bit value according to the input 2^6)													
28	Gamma Value 5 GM5[7:0]	80												
	Gamma correction coefficient 5 (Output 8-bit value according to the input 2^7)													
29	Gamma Value 6 GM6[7:0]	00												
	Gamma correction coefficient 6 (Output 8-bit value according to the input 2^8)													
2A	Gamma Value 7 GM7[7:0]	00												
	Gamma correction coefficient 7 (Output 8-bit value according to the input 2^9)													
2B	Gamma Value 8 GM8[7:0]	FF												
	Gamma correction coefficient 8 (Output 8-bit value according to the input 2^{10}) 													
2C	Separate Gamma Value For 10-Bit Gamma Value GM1234H[7:0]	00												
	GM1[9:8] GM2[9:8] GM3[9:8] GM4[9:8]													
2D	Separate Gamma Value For 10-Bit Gamma Value GM5678H[7:0]	1B												
	GM5[9:8] GM6[9:8] GM7[9:8] GM8[9:8]													
2E	Pattern Generation Select Signal PATTERN[7:0]	00												
	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 12.5%; text-align: center;">-</td> <td style="width: 12.5%; text-align: center;">-</td> <td style="width: 25%;">PATTERN[1:0]</td> <td style="width: 12.5%; text-align: center;">-</td> <td style="width: 12.5%; text-align: center;">-</td> <td style="width: 12.5%; text-align: center;">-</td> <td style="width: 12.5%; text-align: center;">-</td> </tr> <tr> <td></td> <td></td> <td>01 : color bar 10 : ramp(horizon) 11 : color blue 00 : same as the preprocessor output</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>		-	-	PATTERN[1:0]	-	-	-	-			01 : color bar 10 : ramp(horizon) 11 : color blue 00 : same as the preprocessor output		
-	-	PATTERN[1:0]	-	-	-	-								
		01 : color bar 10 : ramp(horizon) 11 : color blue 00 : same as the preprocessor output												
2F	DUMMY													

Address	DATA	Default	
30	R Dark Slice		
	CRDS[7:0]	00	
	Dark slice coefficient of the RED signal ($-128 \leq CRDS \leq 127$)		
31	B Dark Slice		
	CBDS[7:0]	00	
	Dark slice coefficient of the BLUE signal ($-128 \leq CBDS \leq 127$)		
32	G Dark Slice		
	CGDS[7:0]	00	
	Dark slice coefficient of the GREEN signal ($-128 \leq CGDS \leq 127$)		
33	RB White Balance		
	CRBWB[7:0]		
	-	-	00
	CRWB[9:8]	CBWB[9:8]	
-	-	RED white balance	BLUE white balance
34	R White Balance		
	CRWB[7:0]	20	
	White balance coefficient of RED signal ($0 \leq CRWB \leq 32$) * SEE ADDR 36		
35	B White Balance		
	CBWB[7:0]	20	
	White balance coefficient of BLUE signal ($0 \leq CBWB \leq 32$) * SEE ADDR 36		
36	G White Balance		
	CGWB[7:0]	40	
	White balance coefficient of GREEN signal ($0 \leq CGWB \leq 4$)		
	* R (Black & White) = $CRWB \times R + CRDS$ ($0 \leq CRWB < 32$, $-128 \leq CRDS \leq 127$)		
G (Black & White) = $CGWB \times G + CGDS$ ($0 \leq CGWB < 4$, $-128 \leq CGDS \leq 127$)			
B (Black & White) = $CBWB \times B + CBDS$ ($0 \leq CBWB < 32$, $-128 \leq CBDS \leq 127$)			
37	(R-G) Gain Control for (R-Y)		
	CRRG[7:0]	59	
	R-G signal coefficient for R-Y signal generation ($-1 \leq CRRG < 1$) * $R-Y = CRRG(R-G) + CRBG(B-G)$ $B-Y = CBRG(R-G) + CBBG(B-G)$		
38	(B-G) Gain Control for (R-Y)		
	CBRG[7:0]	D9	
	B-G signal coefficient for R-Y signal generation ($-1 \leq CBRG < 1$) * SEE ADDR 37		
39	(R-G) Gain Control for (B-Y)		
	CRBG[7:0]	F2	
	R-G signal coefficient for B-Y signal generation ($-1 \leq CRBG < 1$) * SEE ADDR 37		
3A	(B-G) Gain Control for (B-Y)		
	CBBG[7:0]	72	
	B-G signal coefficient for B-Y signal generation ($-1 \leq CBBG < 1$) * SEE ADDR 37		

Address	DATA	Default
Horizontal Blank Rising Edge		
3B	HBLK_RE[7:0]	21
	Horizontal-blank rising edge value setting	
Horizontal Blank Falling Edge		
3C	HBLK_FE[7:0]	A1
	Horizontal-blank falling edge value setting	
Vertical Blank Rising Edge		
3D	VBLK_RE[7:0]	01
	Vertical-blank rising edge value setting	
Vertical Blank Falling Edge		
3E	VBLK_FE[7:0]	E1
	Vertical-blank falling edge value setting	
Separate H/V Blank Value For 10-Bit H/V Blank Value		
3F	HVBLK_RFE[7:0]	21
	HBLK_RE_ADRS[9:8] HBLK_FE_ADRS[9:8] VBLK_RE_ADRS[9:8] VBLK_FE_ADRS[9:8]	
(R-Y)_POSI_GAIN		
40	CRYGP[7:0]	80
	<p>R-Y positive coefficient for R-Y signal gain control ($0 \leq \text{CRYGP} < 2$)</p> <p>※ (R-Y)hue = $\text{CRYG}(\text{R-Y}) + \text{CBYH}(\text{B-Y})$</p> <p>(B-Y)hue = $\text{CRYH}(\text{R-Y}) + \text{CBYG}(\text{B-Y})$ G : Gain Control / H : Hue Control</p> <div style="text-align: center;"> </div>	
(R-Y)_NEGA_GAIN		
41	CRYGN[7:0]	80
	R-Y Negative coefficient for R-Y signal gain control ($0 \leq \text{CRYGN} < 2$)	
(B-Y)_HUE_POSI_GAIN		
42	CRYHP[7:0]	00
	R-Y positive coefficient for B-Y signal hue control ($-1 \leq \text{CRYGP} < -1$)	
(B-Y)_HUE_NEGA_GAIN		
43	CRYHN[7:0]	00
	R-Y Negative coefficient for B-Y signal gain control ($-1 \leq \text{CRYGP} < 1$)	
(B-Y)_POSI_GAIN		
44	CBYGP[7:0]	80
	B-Y positive coefficient for B-Y signal gain control ($0 \leq \text{CBYGP} < 2$)	

Address	DATA	Default							
45	(B-Y)_NEGA_GAIN								
	CBYGN[7:0]	80							
	B-Y negative coefficient for B-Y signal gain control ($0 \leq \text{CBYGN} < 2$)								
46	(R-Y)_HUE_POSI_GAIN								
	CBYHP[7:0]	00							
	B-Y positive coefficient for R-Y signal hue control ($-1 \leq \text{CBYHP} < 1$)								
47	(R-Y)_HUE_NEGA_GAIN								
	CBYHN[7:0]	00							
	B-Y negative coefficient for R-Y signal hue control ($-1 \leq \text{CBYHN} < 1$)								
48	C GAIN								
	CGAIN[7:0]	80							
	Color Level Gain : $\times 0 \sim \times 2$								
49	COLOR HUE FIX CONTROL								
	CEFFECT_ADRS[7:0]								
	-	-	-	-	-	-	-	CHUE_FIX	00
								1:Gain = 80(hex) Hue = 0	
								0: Just read directly	
4A	DUMY								
4B	DUMY								
4C	DUMY								
4D	DUMY								
4E	DUMY								
4F	DUMY								
50	AERTURE_NON_LINEAR_CONTROL								
	YNONLIN_ADRS[7:0]								
	YVAPTBKTH[1:0]	YVAPTBKG[1:0]	YHAPTBKTH[1:0]	YHATPBKG[1:0]					AA
	Non-linear control threshold value of the vertical edge enhancement	Non-linear control gain of the vertical edge enhancement	Non-linear control threshold value of the horizontal edge enhancement	Non-linear control gain of the horizontal edge enhancement					
	THRESHOLD [1:0]	Value	GAIN [1:0]	Value					
00	00	00	$\times 0$						
01	16(1.6%)	01	$\times 1/4$						
10	32(3.1%)	10	$\times 1/2$						
11	64(6.3%)	11	$\times 1$						

Address	DATA				Default	
51	Horizontal Edge Enhancement Control					
	YHAPGP[7:0]					
	-	YAPTGAIN_H[1:0]	YHAPTGAIN_P[4:0]			50
	-	High-Frequency Edge Enhancement Filter(H_{HAP}) Gain Coefficient	Horizontal Positive Edge Enhancement Gain : ($X_0 \sim X_1$)			
		YAPTGAIN_H[1:0]	00	01	10	11
	Mode	$2 \times H_{HAP}(Z)$	$4 \times H_{HAP}(Z)$	$8 \times H_{HAP}(Z)$	$10 \times H_{HAP}(Z)$	
$H_{HAP}(Z) = -1 + 2Z^{-1} - Z^{-2}$ ※ For Aperture Filter Characteristics, see address 52 !						
52	Vertical Edge Enhancement Control					
	YVAPGP[7:0]					
	-	YAPTGAIN_L[1:0]	VAPTGAIN_P[4:0]			50
	-	Low-frequency edge enhancement Filter(H_{LAP}) Gain Coefficient	Vertical Positive Edge Enhancement Gain: ($X_0 \sim X_1$)			
		YAPTGAIN_L[1:0]	00	01	10	11
	Mode	$0 \times H_{LAP}(Z)$	$2 \times H_{LAP}(Z)$	$4 \times H_{LAP}(Z)$	$6 \times H_{LAP}(Z)$	
$H_{LAP}(Z) = -1 + 2Z^{-3} - Z^{-4}$ Transfer function of the final edge enhancement filter : $H_{GAP}(Z) = (H_{GHAP}(Z) + H_{GLAP}(Z))$ IF (YAPTGAIN_H,YAPTGAIN_L=0000) : $H_{GAP}(Z)$ ELSE IF (YAPTGAIN_H,YAPTGAIN_L=0001) : $H_{GAP}(Z) / 2$ ELSE IF (YAPTGAIN_H,YAPTGAIN_L=1100 OR 1011 OR 1101 OR 1110 OR 1111) : $H_{GAP}(Z)/8$ ELSE : $H_{GAP}(Z)/4$						
53	H_APERTURE_NEGA_GAIN					
	YHAPGN[7:0]					
	-	-	-	YHAPTGN[4:0]		10
-	-	-	Horizontal Negative-Edge Enhancement Gain ($X_0 \sim X_1$)			
54	V_APERTURE_NEGA_GAIN					
	YVAPGN[7:0]					
	-	-	-	YVAPTGN[4:0]		10
-	-	-	Vertical Negative-Edge Enhancement Gain ($X_0 \sim X_1$)			
55	Highlight Enhancement					
	YHLCLP[7:0]					
	-	-	-	-	YHCLP[3:0]	0A
-	-	-	-	YAPTHLCLP[3:0] : Highlight enhancement clip level : ($7 \sim 127$)		
56	Y Edge Enhancement Clip					
	YAPTCLP[7:0]					
	Edge enhancement clip level (x2) ($0 \sim 510$)				BF	

Address	DATA						Default	
57	Y Highlight enhancement Noise Slice						7F	
	YHLSC[7:0]							
	-	YHLSC[6:0]						
	-	Highlight enhancement noise slice level (0~ 127)						
58	Y Edge Enhancement Noise Slice						00	
	YAPTSC[7:0]							
	-	-	APTSC[5:0]					
	-	-	Edge enhancement noise slice level (0 ~ 63)					
59	Detail Enhancer Threshold & Gain						00	
	YENHANTH[7:0]							
	-	YENHANTH[6:4] → Threshold			-	YENHANG[1:0] → Gain		
	-	000 : 0	100 : 80	-	00 : 1			
	-	001 : 32	101 : 96	-	01 : 1.25			
-	010 : 48	110 : 112	-	10 : 1.5				
-	011 : 64	111 : 128	-	11 : 1.75				
5A	Highlight Enhancement Gain						10	
	YHLGAIN[7:0]							
	-	-	-	HLGAIN[4:0]				
	-	-	-	Highlight enhancement gain (x0 ~ x1)				
5B	Y White Clip						FF	
	YWC[7:0]							
	Y White Clip Level							
5C	Y Gain						80	
	YGAIN[7:0]							
	Y Gain : ×0 ~ ×2							
5D	Y Group Delay						10	
	YGRPDLY[7:0]							
	-	-	-	OZONE_EN	YVAPTSEL[3]	YGRPDLY[2:0]		
	-	-	-	AE/AWB window pulse enable	0 : No LPF used	Y/C group delay match adjust		
	-	-	-	0 : OFF 1 : ON	1 : LPF used	000:0CK Delay		100:-3CK Delay
60	AE Window1 Horizontal Start						23	
	OAEHS_W1[7:0]							
	AE window1 horizontal-start point (x3) (1 ~ 211)							
61	AE Window1 Horizontal End						AF	
	OAEHE_W1[7:0]							
	AE window1 horizontal-end point (x3) (3 ~ 213)							

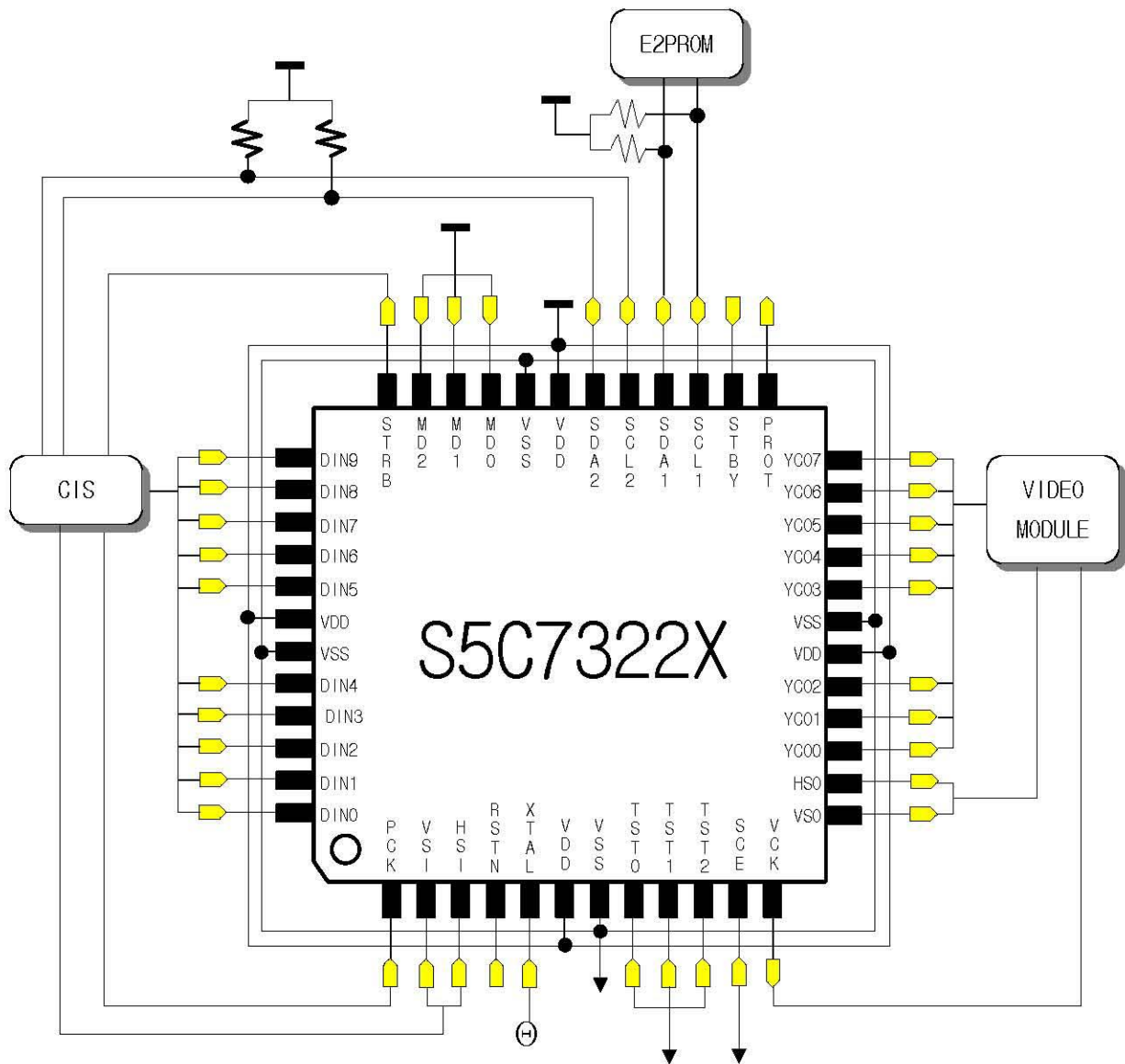
Address	DATA	Default
62	AE Window1 Vertical Start	
	OAEVS_W1[7:0]	0F
	AE window1 vertical-start point (x2)(1 ~ 237)	
63	AE Window1 Vertical End	
	OAEVE_W1[7:0]	C8
	AE window1 vertical-end point (x2)(3 ~ 239)	
64	AE Window2 Horizontal Start	
	OAEHS_W2[7:0]	0A
	AE window2 horizontal-start point (x3)(1 ~ 211)	
65	AE Window2 Horizontal End	
	OAEHE_W2[7:0]	C8
	AE window2 horizontal-end point (x3)(3 ~ 213)	
66	AE Window2 Vertical Start	
	OAEVS_W2[7:0]	05
	AE window2 vertical-start point (x2)(1 ~ 237)	
67	AE Window2 Vertical End	
	OAEVE_W2[7:0]	DC
	AE window2 vertical-end point (x2)(3 ~ 239)	
68	AWB Window Horizontal Start	
	OAWBHS[7:0]	37
	AWB window horizontal-start point (x3)(1 ~ 211)	
69	AWB Window Horizontal End	
	OAWBHE[7:0]	BE
	AWB window horizontal-end point (x3)(3 ~ 213)	
6A	AWB Window Vertical Start	
	OAWBVS[7:0]	14
	AWB window vertical-start point (x2)(1 ~ 237)	
6B	AWB Window Vertical End	
	OAWBVE[7:0]	AA
	AWB window vertical-end point (x2)(3 ~ 239)	
6C	DUMMY	
6D	DUMMY	
6E	DUMMY	
6F	DUMMY	
70	AE Y Signal High Threshold	
	OYH_AE[7:0]	FF
	Y signal high-threshold value for the AE ($0 \leq OYH_AE \leq 255$)	
71	AE Y Signal Low Threshold	
	OYL_AE[7:0]	00
	Y signal low-threshold value for the AE ($0 \leq OYL_AE \leq 255$)	

Address	DATA	Default
72	AWB Y Signal High Threshold	FF
	OYH_AWB[7:0] Y signal high-threshold value for the AWB ($0 \leq \text{OYH_AWB} \leq 255$)	
73	AWB Y Signal Low Threshold	00
	OYL_AWB[7:0] Y signal low-threshold value for the AWB ($0 \leq \text{OYL_AWB} \leq 255$)	
74	AE Clip Counter Threshold	78
	OAECLIP_TH[7:0] Threshold value for the AE clip count ($0 \leq \text{OAECLIP_TH} \leq 255$)	
75	Optical Detector Command	00
	OMODE[7:0] OLPF_SEL OFIL_PASS OYIN_SEL OZONE_SEL[1:0]	
	OLPFSEL : AE Decimation filter selection 0 : [1 1] / 2 1 : [1 2 1] / 4 OFILPASS : AE Decimation filter bypass enable 0 : OFF 1 : ON OYIN_SEL : Y signal input-range selection for the AE 0 : Y[9:2] 1 : Y[7:0] OZONE_SEL : AE/AWB window selection for the display 00 : nothing 01: AE window 1 10: AE window2 11: AWB window	
76	Horizontal Sync Rising Edge	21
	HS_RE[7:0] Rising-edge point setting of the horizontal Sync signal	
77	Horizontal Sync Falling Edge	A1
	HS_FE[7:0] Falling-edge point setting of the horizontal Sync signal	
78	Vertical Sync Rising Edge	01
	VS_RE[7:0] Rising-edge point setting of the vertical Sync signal	
79	Vertical Sync Falling Edge	E1
	VS_FE[7:0] Falling-edge point setting of the vertical Sync signal	
7A	H/V Sync Rising/Falling Edge	00
	HVS_RFE[7:0] HS_RE_ADRS[9:8] HS_FE_ADRS[9:8] VS_RE_ADRS[9:8] VS_FE_ADRS[9:8]	
7B	Horizontal Counter End L	0B
	HCNT_ENDL[7:0] 1H period value setting	
7C	Horizontal Counter End H	03
	HCNT_ENDH[9:8] See address 7BH	

Address	DATA	Default	
7D	Line Memory Hold		
	LM_ADDRL[7:0]	00	
	Vertical point of the line memory hold		
7E	Line Memory Hold Enable		
	LM_ADDRH[7:0]		
	- - - - -	LM_HOLD_ENABLE LM_ADDR[9:8]	00
	- - - - -	0 : Normal 1 : Shutter replace enable	
7F	DUMMY		
80	AE Window1 Data H		
	OAEW1H[7:0]		
	AE accumulated value of the luminance signal in window1 ([23:16])		
81	AE Window1 Data M		
	OAEW1M[7:0]		
	AE Accumulated value of the luminance signal in window1 ([15:8])		
82	AE Window1 Data L		
	OAEW1L[7:0]		
	AE Accumulated value of the luminance signal in window1 ([7:0])		
83	AE Window2 Data H		
	OAEW2H[7:0]		
	AE accumulated value of the luminance signal in window2 ([23:16])		
84	AE Window2 Data M		
	OAEW2M[7:0]		
	AE Accumulated value of the luminance signal in window2 ([15:8])		
85	AE Window2 Data L		
	OAEW2L[7:0]		
	AE Accumulated value of the luminance signal in window2 ([7:0])		
86	AE Clip Counter H		
	OAECLIPH[7:0]		
	AE clip count value (AECLIPCNT [15:8])		
87	AE Clip Counter L		
	OAECLIPL[7:0]		
	AE clip count value (AECLIPCNT [7:0])		
88	DUMMY		
89	DUMMY		
8A	DUMMY		
8B	DUMMY		
8C	DUMMY		
8D	DUMMY		
8E	DUMMY		
8F	DUMMY		

Address	DATA	Default
90	AWB Window B Data H	
	OAWBBH[23:16]	
	Accumulated AWB(B) value in window ([23:16])	
91	AWB Window B Data M	
	OAWBBM[15:8]	
	Accumulated AWB(B) value in window ([15:8])	
92	AWB Window B Data L	
	OAWBBL[7:0]	
	Accumulated AWB(B) value in window ([7:0])	
93	AWB Window G Data H	
	OAWBGH[23:16]	
	Accumulated AWB(G) value in window ([23:16])	
94	AWB Window G Data M	
	OAWBGM[15:8]	
	Accumulated AWB(G) value in window ([15:8])	
95	AWB Window G Data L	
	OAWBGL[7:0]	
	Accumulated AWB(G) value in window ([7:0])	
96	AWB Window R Data H	
	OAWBRH[23:16]	
	Accumulated AWB(R) value in window ([23:16])	
97	AWB Window R Data M	
	OAWBRM[15:8]	
	Accumulated AWB(R) value in window ([15:8])	
98	AWB Window R Data L	
	OAWBRL[7:0]	
	Accumulated AWB(R) value in window ([7:0])	
99	AWB Counter H	
	OAWBCNTH[7:0]	
	Y pixel counter value that is detected in the AWB window (AWB_CNT[15:8])	
9A	AWB Counter L	
	OAWBCNTL[7:0]	
	Y pixel counter value that is detected in the AWB window (AWB_CNT[7:0])	
9B	DUMMY	
9C	DUMMY	
9D	DUMMY	
9E	DUMMY	
9F	DUMMY	

APPLICATION CIRCUIT DIAGRAM



PACKAGE SPEC

