Photobit®
Behind Every Great Digital Image™

PB-R006
Photobit® TrueColor™ Processor for CMOS Image Sensors

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Printed in the United States of America.

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Photobit® TrueColor™ Processor for CMOS Image Sensors

January 2000 (Version 1.3)

Product Specification

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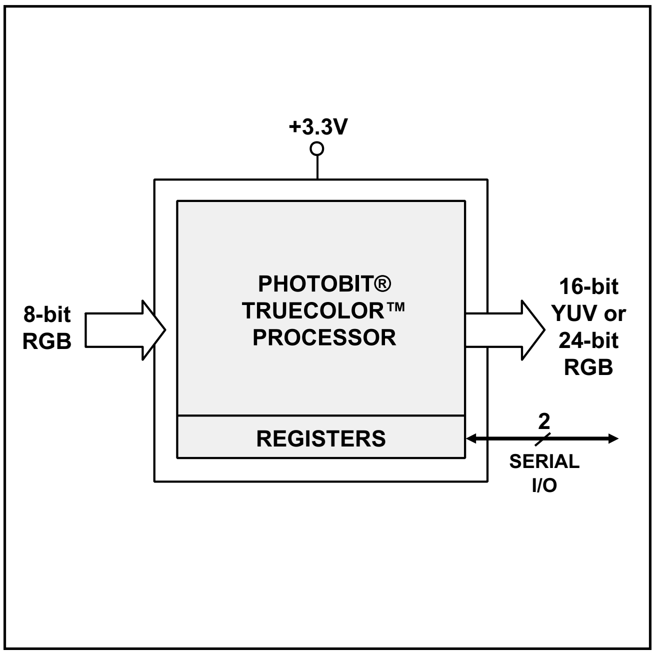


1.0 Introduction

1.1 Features

- Standard Bayer RGB color interpolation
- Fully programmable color correction
- Fully programmable gamma correction
- Wide range of aperture correction
- 16-bit YUV (CCIR 601 standard) video out
- 16-bit YUV (pseudo-CCIR 656) video out
- 24-bit RGB video out
- VGA resolution at up to 30 frames per second
- Internal white balance measurement engine
- Compatibility with all Photobit® CIF-size and VGA-format CMOS image sensors

Designed as a digital signal processor (DSP) for CMOS image sensors, the PB-R006 Photobit® TrueColor™ Processor performs standard Bayer RGB color interpolation, color correction, gamma correction, and a wide range of aperture correction.

It may be used as a companion to Photobit's PB-0100/PB-0101 (CIF-size) or PB-0300 (VGA-format) image sensors, as well as non-Photobit chips, to produce a complete CMOS color video chip set that avoids the need for a separate DSP or microprocessor to do color processing or the need to write specialized color-correction algorithms.

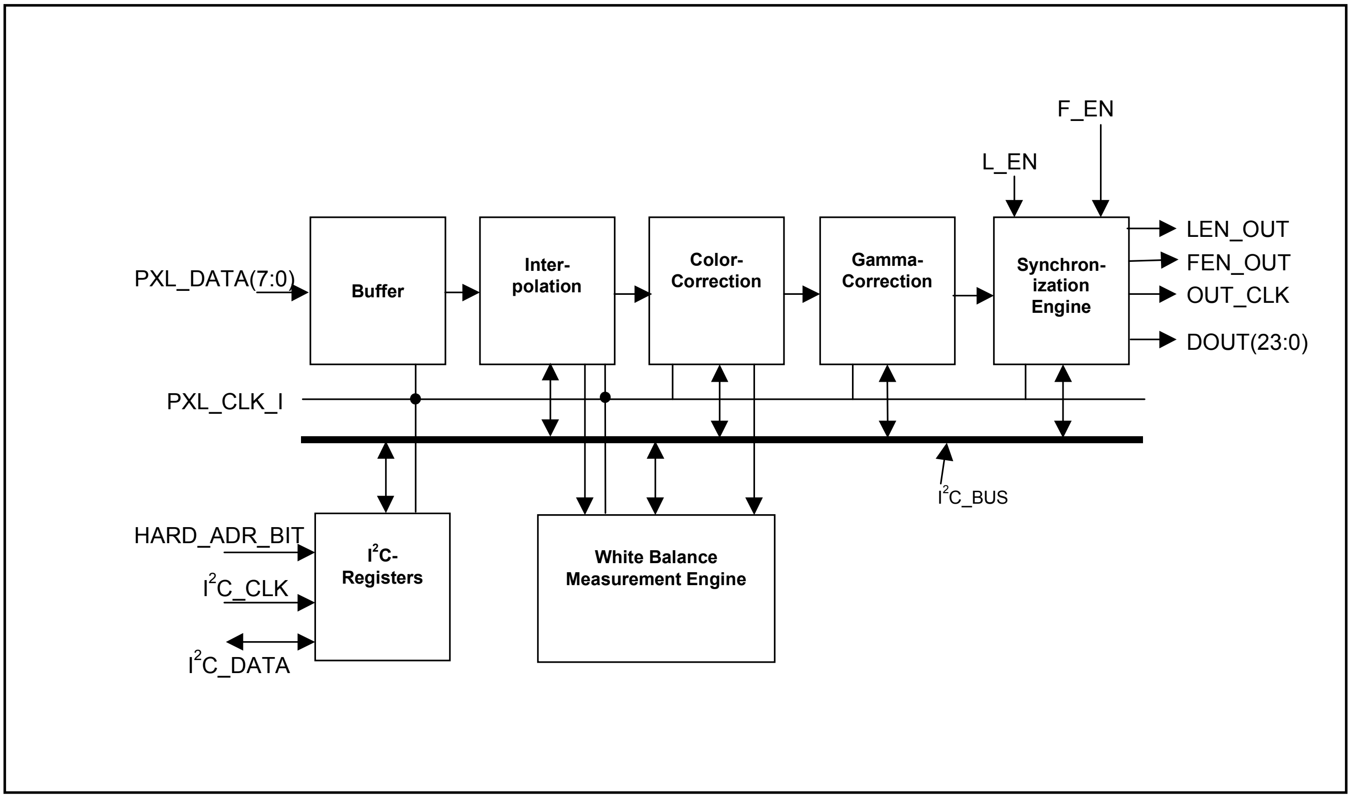
The input to the PB-R006 is 8-bit Bayer RGB color. Processing is performed in real time with a user-selectable window of either 5 x 5 or 3 x 3 pixels. Three (3) output formats are available: 24-bit RGB, 16-bit CCIR601 YUV, and pseudo-CCIR656 YUV.

1.2 Top-Level Specification

Processing Functions	Standard Bayer RGB color interpolation Fully programmable color correction Fully programmable gamma correction Wide range of aperture correction
Processing Rate	Real-time (30 frames per second) up to VGA (640 x 480) resolution, sensor sync-controlled
Frame Rate	Up to 60 fps, sensor controlled
Interpolation Window Size	5 x 5 or 3 x 3 pixels, user-selectable
Input	8-bit Bayer RGB (continuous or burst, with selectable starting color)
Output Formats	24-bit RGB 16-bit CCIR601 YUV 16-bit pseudo-CCIR656 YUV Phase-changeable clock delay
Interface	Two-wire serial interface
Clock Speed	24 MHz
Operating Temperature	-5°C to +70°C
Power Dissipation	120mW
Power Supply	+3.3V
Supply Current	35mA
Package	100-pin MQFP

2.0 Electrical

2.1 Functional Block Diagram



2.2 Signal Path

The processor's signal path consists of eleven (11) main modules:

- Input buffer
- Color-interpolation and aperture-correction block
- Color-correction engine
- Gamma-correction engine
- RGB-to-YUV transformer, or delay module
- Frame formatter and CCIR 656 engine
- Output formatter
- Clock generator
- Measurement engine for white balance
- Register settings module
- I^2C engine

The input buffer module formats the data inputs for the color-interpolation and aperture-correction block. The values in Registers 5 and 6 determine the size of the color-interpolation window and the degree of aperture correction to be performed on the pixels.

After color interpolation, 24-bit data is available for each pixel, i.e. 8 bits for Red, 8 bits for Green, and 8 bits for Blue. This data is passed along to the color-correction module. (To bypass the color-correction and gamma-correction engines, the user can set Bit 4 of Register 6 to 1.) The color-correction coefficients are controlled through settings in Registers 2 to 4 and 8 to 17.

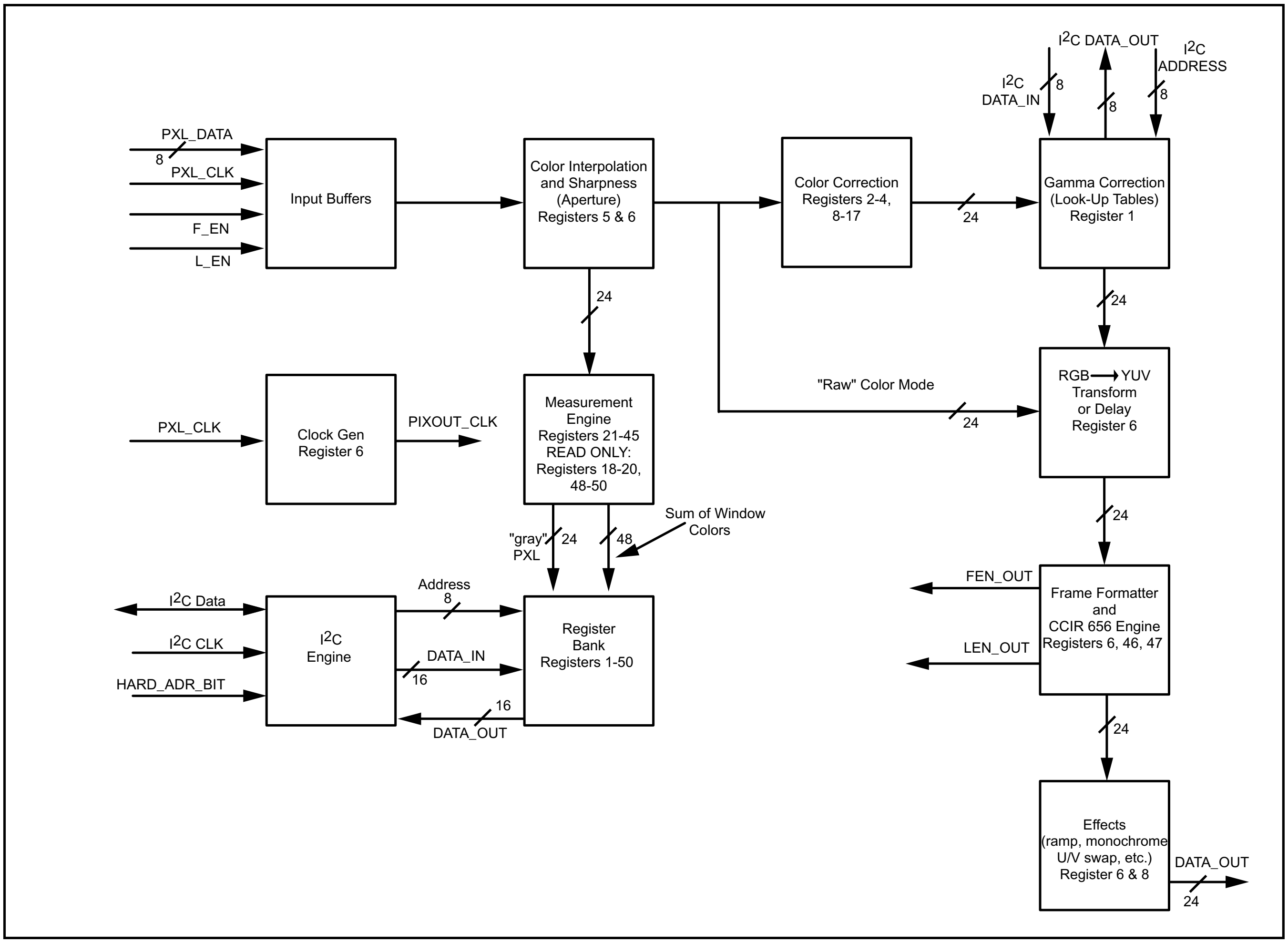
After color correction, the pixel data is sent to the gamma-correction module, which contains three look-up tables. The user can program the values in the tables through the I^2C. Register 1 settings determine access to the look-up tables. The gamma-correction module matches the values of the incoming pixel data and replaces them with the programmed values in the look-up tables. The new values are then passed to the RGB-to-YUV transformer.

Depending on the value of Bit 4 in Register 6, the RGB-to-YUV transformer (or delay module) obtains the pixel data values from either the color-interpolation and aperture-correction block or the gamma-correction module. Bit 0 of Register 6 determines whether the data is converted to YUV or just delayed.

After the RGB values are converted to YUV, or delayed, the data is passed on to the frame formatter and CCIR 656 engine. The frame size can be controlled through Registers 46 and 47. If the user wants the data in CCIR 656 format, then bit 7 of Register 6 is set to 1.

Finally the data is sent to the output formatter module. The settings in Registers 6 and 8 determine the various effects, such as ramp, monochrome, U/V swap, etc.

2.2 Signal Path (continued)



2.3 I²C Description

Registers are written to and read from the PB-R006 through the I²C bus. The PB-R006 is an I²C slave. The PB-R006 is controlled by the I²C clock (I²C_CLK), which is driven by the I²C master. Data is transferred into and out of the PB-R006 through the I²C data (I²C_DATA) line. The I²C_DATA line is pulled up to 3.3V off-chip by a 1.5Ω resistor. Either the slave or master device can pull the I²C_DATA line down; the I²C protocol determines which device is allowed to pull the I²C_DATA line down at any given time.

Protocol

The I²C bus defines several different transmission codes, as follows:

- a Start bit
- the slave device 8-bit address
- an (no) Acknowledge bit
- an 8-bit message
- a Stop bit

Sequence

A typical read or write sequence begins by the master sending a start bit. After the start bit, the master sends the slave device's 8-bit address. The last bit of the address determines if the request will be a read or a write, where a 0 indicates a write and a 1 indicates a read. The slave device acknowledges its address by sending an acknowledge bit back to the master.

If the request was a write, the master then transfers the 8-bit register address to which a write should take place. The slave sends an acknowledge bit to indicate that the register address has been received. The master then transfers the data 8 bits at a time, with the slave sending an acknowledge bit after each 8 bits. The PB-R006 uses 16-bit data for its internal registers, thus requiring two 8-bit transfers to write to one register. After 16 bits are transferred, the register address is automatically incremented, so that the next 16 bits are written to the next register address. The master stops writing by sending a start or stop bit.

A typical read sequence is executed as follows. First the master sends the write-mode slave address and 8-bit register address just as in the write request. The master then sends a start bit and the read-mode slave address. The master then clocks out the register data 8 bits at a time. The master sends an acknowledge bit after each 8-bit transfer. The register address is auto-incremented after every 16 bits is transferred. The data transfer is stopped when the master sends a no-acknowledge bit.

Bus Idle State

The bus is idle when both the data and clock lines are HIGH. Control of the bus is initiated with a Start bit, and the bus is released with a Stop bit. Only the master can generate the start and stop bits.

Start Bit and Stop Bit

The start bit is defined as a HIGH to LOW transition of the data line while the clock line is HIGH. The stop bit is defined as a LOW to HIGH transition of the data line while the clock line is HIGH.

Slave Address

The 8-bit address of an I²C device consists of 7 bits of address and 1 bit of direction. A 0 in the LSB of the address indicates write mode, and a 1 shows read mode.

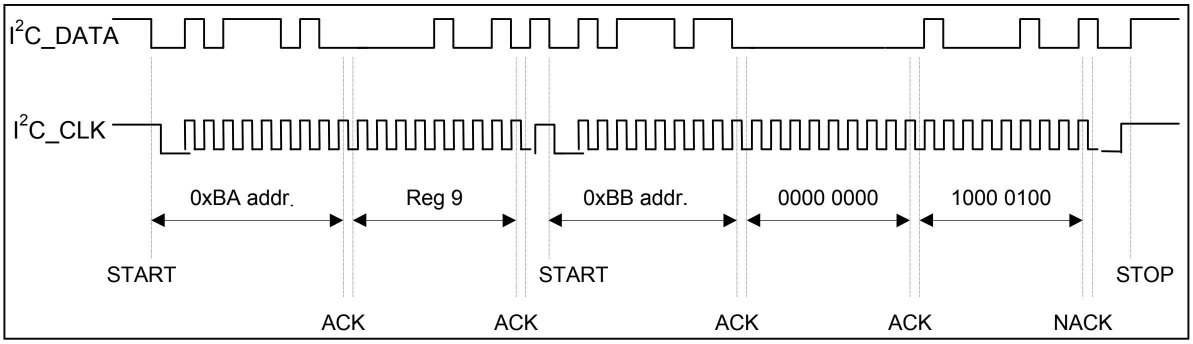
Data Bit Transfer

One data bit is transferred during each clock pulse. The I²C clock pulse is provided by the master. The data must be stable during the HIGH of the I²C clock. It can only change when the clock is LOW. Data is transferred 8 bits at a time, followed by an acknowledge bit.

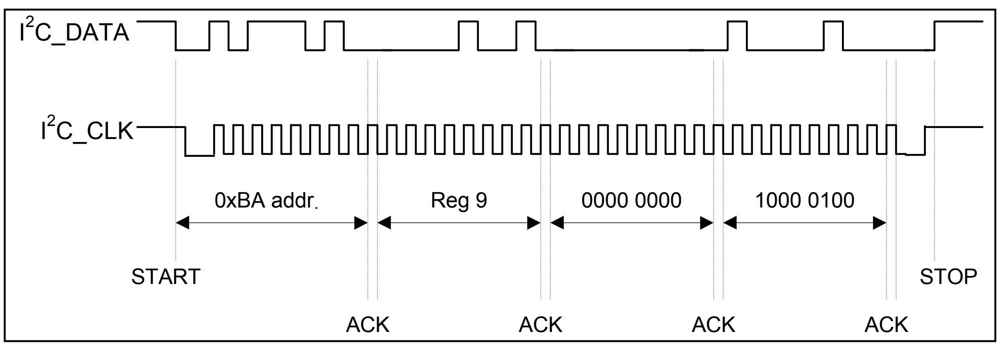
Acknowledge Bit and No-Acknowledge Bit

The master generates the acknowledge clock pulse. The transmitter (which is the master when writing, or the slave when reading) releases the data line, and the receiver indicates an acknowledge bit by pulling the data line low during the acknowledge clock pulse. The no-acknowledge bit is generated when the data line is not pulled down by the receiver during the acknowledge clock pulse. A no-acknowledge bit is used to terminate a read sequence.

2.3 I²C Description (continued)



Timing Example: a Write to I²C Register 9 with the value 132. The PB-R006 drives the I²C_DATA line low during acknowledge clock pulses (ACK).

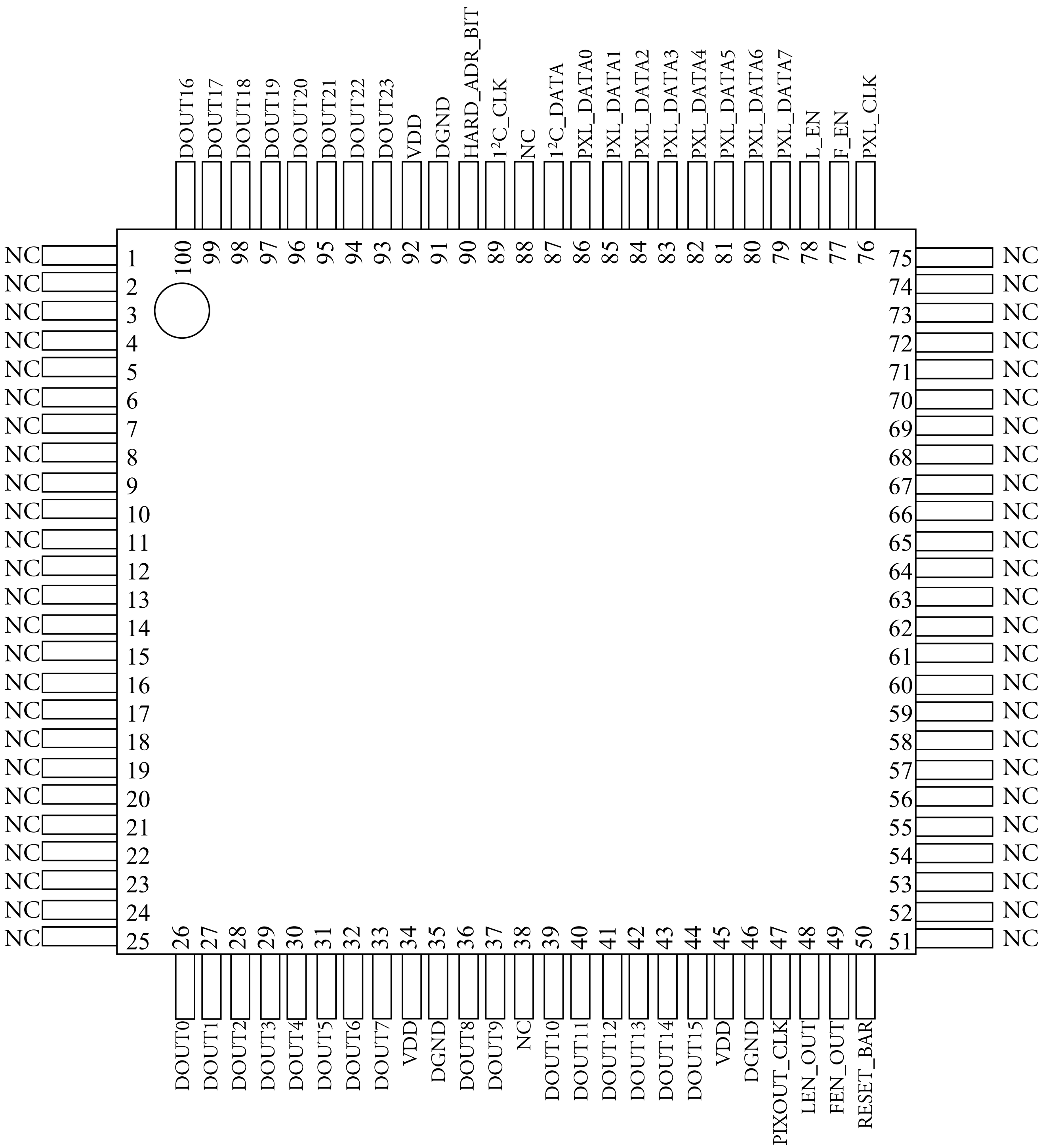


Timing Example: a Read from I²C Register 9 that returns the value of 132. The PB-R006 drives the I²C_DATA line low during the first three acknowledge clock pulses (ACK). I²C_DATA is driven low by the master during the fourth acknowledgement clock pulse.The fifth pulse is a no-acknowledge (NACK) from the master (I²C_DATA is not driven low).

2.4 Pin Descriptions

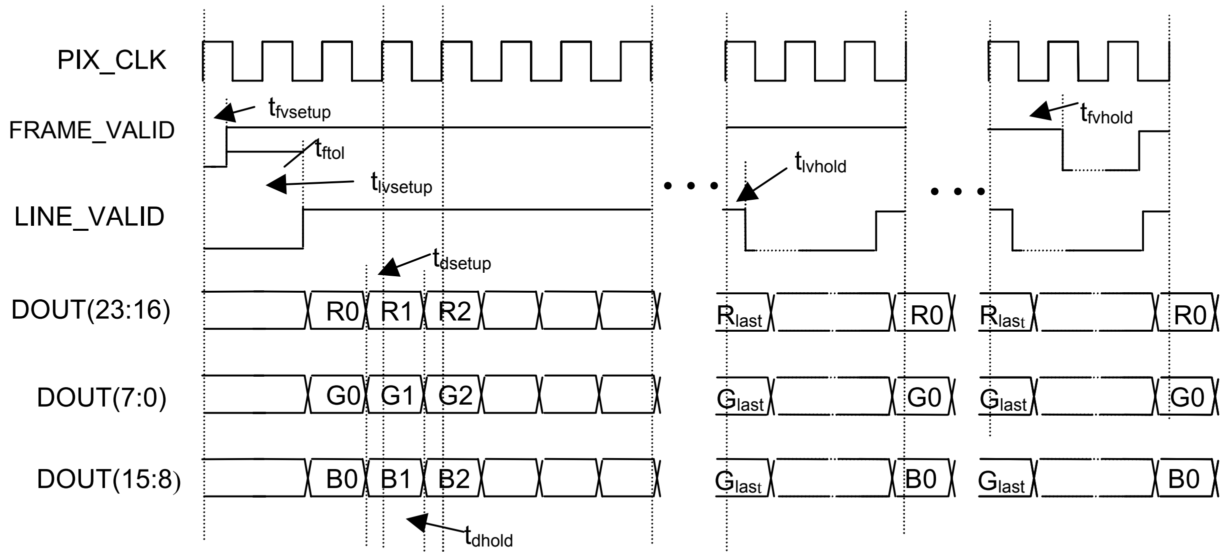
Pin	Name	Description	Direction
26	DOUT0	Green0 or Y0 or Y0/U0 or Y0/V0, depending on register settings, Default = Y0, LSB	OUT
27	DOUT1	Green1 or Y1 or Y1/U1 or Y1/V1, depending on register settings, Default = Y1	OUT
28	DOUT2	Green2 or Y2 or Y2/U2 or Y2/V2, depending on register settings, Default = Y2	OUT
29	DOUT3	Green3 or Y3 or Y3/U3 or Y3/V3, depending on register settings, Default = Y3	OUT
30	DOUT4	Green4 or Y4 or Y4/U4 or Y4/V4, depending on register settings, Default = Y4	OUT
31	DOUT5	Green5 or Y5 or Y5/U5 or Y5/V5, depending on register settings, Default = Y5	OUT
32	DOUT6	Green6 or Y6 or Y6/U6 or Y6/V6, depending on register settings, Default = Y6	OUT
33	DOUT7	Green7 or Y7 or Y7/U7 or Y7/V7, depending on register settings, Default = Y7, MSB	OUT
34	VDD	Power, Typ. 3.3V	POWER
35	DGND	Ground, Typ. 0V	GND
36	DOUT8	Blue0 or V0/U0 or U0/V0, depending on register settings, Default = V0/U0, LSB	OUT
37	DOUT9	Blue1 or V1/U1 or U1/V1, depending on register settings, Default = V1/U0	OUT
39	DOUT10	Blue2 or V2/U2 or U2/V2, depending on register settings, Default = V2/U2	OUT
40	DOUT11	Blue3 or V3/U3 or U3/V3, depending on register settings, Default = V3/U3	OUT
41	DOUT12	Blue4 or V4/U4 or U4/V4, depending on register settings, Default = V4/U4	OUT
42	DOUT13	Blue5 or V5/U5 or U5/V5, depending on register settings, Default = V5/U5	OUT
43	DOUT14	Blue6 or V6/U6 or U6/V6, depending on register settings, Default = V6/U6	OUT
44	DOUT15	Blue7 or V7/U7 or U7/V7, depending on register settings, Default = V7/U7, MSB	OUT
45	VDD	Power, Typ. 3.3V	POWER
46	DGND	Ground, Typ. 0V	GND
47	PIXOUT_CLK	Pixel Clock Out, either PXL_CLK or PXL_CLK/2 depending on register settings. Default = PXL_CLK	OUT
48	LEN_OUT	Line Valid Out, active high or active low depending on register settings.Default = active high	OUT
49	FEN_OUT	Frame Valid Out, active high or active low depending on register settings.Default = active high	OUT
50	RESET_BAR	Asynchrounous reset in, active low	IN
76	PXL_CLK	Pixel clock in, Maximum 24 MHz	IN
77	F_EN	Frame Valid in, active high	IN
78	L_EN	Line Valid in, active high	IN
79	PXL_DATA7	Pixel7 value, MSB	IN
80	PXL_DATA6	Pixel6 value	IN
81	PXL_DATA5	Pixel5 value	IN
82	PXL_DATA4	Pixel4 value	IN
83	PXL_DATA3	Pixel3 value	IN
84	PXL_DATA2	Pixel2 value	IN
85	PXL_DATA1	Pixel1 value	IN
86	PXL_DATA0	Pixel0 value	IN
87	I2C_DATA	I2C_DATA IN/OUT	IN/OUT
89	I2C_CLK	I2C_CLK	IN
90	HARD_ADR_BIT	Hard Address Bit for I2C address, the address is either B9, B8 for HARD_ADR_BIT=1, or 91,90 for HARD_ADR_BIT=0.	IN
91	DGND	Ground, typ 0V	GND
92	VDD	Power, typ 3.3 V	POWER
93	DOUT23	Red7 or U7/V7 or V7/U7, depending on register settings, Default = U7/V7, MSB	OUT
94	DOUT22	Red6 or U6/V6 or V6/U6, depending on register settings, Default = U6/V6	OUT
95	DOUT21	Red5 or U5/V5 or V5/U5, depending on register settings, Default = U5/V5	OUT
96	DOUT20	Red4 or U4/V4 or V4/U4, depending on register settings, Default = U4/V4	OUT
97	DOUT19	Red3 or U3/V3 or V3/U3, depending on register settings, Default = U3/V3	OUT
98	DOUT18	Red2 or U2/V2 or V2/U2, depending on register settings, Default = U2/V2	OUT
99	DOUT17	Red1 or U1/V1 or V1/U1, depending on register settings, Default = U1/V1	OUT
100	DOUT16	Red0 or U0/V0 or V0/U0, depending on register settings, Default = U0/V0, LSB	OUT
1-25, 38, 51-75, 88	NC	Not connected	

2.4.1 Pin-Out Diagram



2.5 Output Format and Timing

MODE 1: 24-BIT RGB COLOR OUTPUT



PIX_CLK = max. 24 MHz

$t_{fvsetup}$ = / setup time for FRAME_VALID before rising edge of PIX_CLK / = 20 ns

t_{fvhold} = / hold time for FRAME_VALID after rising edge of PIX_CLK / = 20 ns

$t_{lvsetup}$ = / setup time for LINE_VALID before rising edge of PIX_CLK / = 30 ns

t_{lvhold} = / setup time for LINE_VALID after rising edge of PIX_CLK / = 30 ns

t_{dsetup} = / setup time for DOUT before rising edge of PIX_CLK / = 25 ns

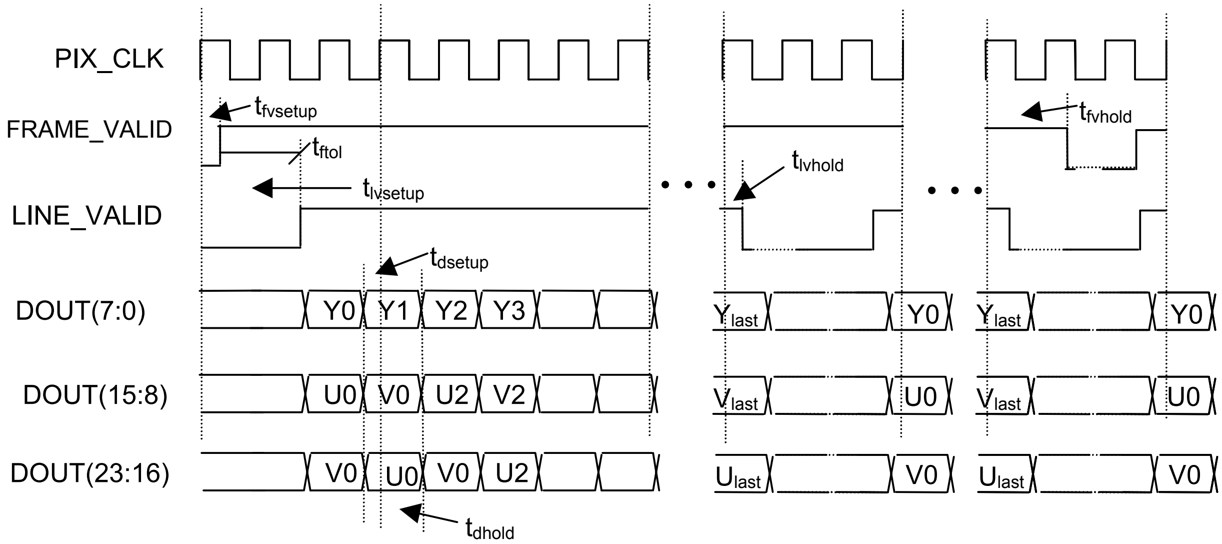
t_{dhold} = / setup time for DOUT after rising edge of PIX_CLK / = 60 ns

t_{ftol} = / FRAME VALID to LINE VALID time / = 13.2μs

2.5 Output Format and Timing (continued)

MODE 2: 16-BIT CCIR601 YUV OUTPUT

U/V order for DOUT (15:8) and V/U order for DOUT (23:16). Order can be changed by toggling Bit 1 of Register 6.



PIX_CLK = max. 24 MHz

$t_{fvsetup}$ = / setup time for FRAME_VALID before rising edge of PIX_CLK / = 20 ns

t_{fvhold} = / hold time for FRAME_VALID after rising edge of PIX_CLK / = 20 ns

$t_{lvsetup}$ = / setup time for LINE_VALID before rising edge of PIX_CLK / = 30 ns

t_{lvhold} = / setup time for LINE_VALID after rising edge of PIX_CLK / = 30 ns

t_{dsetup} = / setup time for DOUT before rising edge of PIX_CLK / = 25 ns

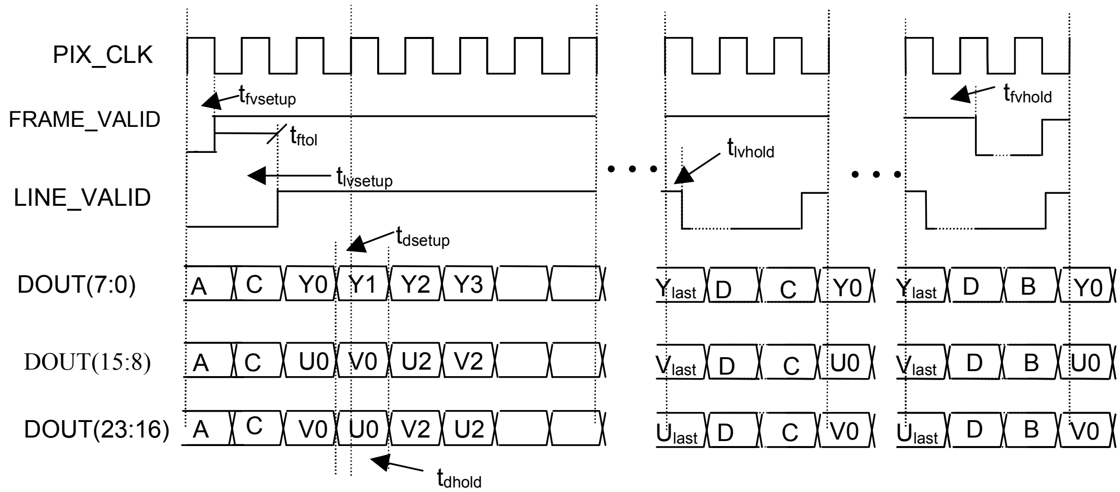
t_{dhold} = / setup time for DOUT after rising edge of PIX_CLK / = 60 ns

t_{ftol} = / FRAME VALID to LINE VALID time / = 13.2μs

2.5 Output Format and Timing (continued)

MODE 3: PSEUDO-CCIR656 YUV OUTPUT

Embedded sync signals for companion chips that does YUV = >RGB, or YUV = >NTSC, a subset of the CCIR 656 standard. DOUT (15:0) has the order of U/V and DOUT (23:16) has the order of V/U. The order can be changed by toggling Bit 1 of Register 6.



PIX_CLK = max. 24 MHz

$t_{fvsetup}$ = / setup time for FRAME_VALID before rising edge of PIX_CLK / = 20 ns

t_{fvhold} = / hold time for FRAME_VALID after rising edge of PIX_CLK / = 20 ns

$t_{lvsetup}$ = / setup time for LINE_VALID before rising edge of PIX_CLK / = 30 ns

t_{lvhold} = / setup time for LINE_VALID after rising edge of PIX_CLK / = 30 ns

t_{dsetup} = / setup time for DOUT before rising edge of PIX_CLK / = 25 ns

t_{dhold} = / setup time for DOUT after rising edge of PIX_CLK / = 60 ns

t_{ftol} = / FRAME_VALID to LINE_VALID time/ = 13.2 µs

A = /FRAME START WORD / = FF0000A0

B = / FRAME END WORD / = FF0000B0

C = /LINE START WORD / = FF000080

D = /LINE END WORD / = FF000090

2.6 Registers

2.6.1 Register Programming Example

On power-up and after reset, the PB-R006 comes up in a default mode of non-stretch YUV output with uncorrected color. ('Non-stretch' is where PIXEL CLOCK IN has the same frequency as PIXEL CLOCK OUT.) The following steps may be taken to obtain color-corrected images:

1. Program the color-correction matrix registers.
2. Program the gamma-correction look-up tables.
3. Program the sensor operating mode to suit the particular application.
4. Enable color-corrected output.
5. Program the measurement engine parameters for dynamic white balance. (This step, which is optional, requires white balance software.)

SET COLOR-CORRECTION MATRIX REGISTERS

$$\begin{bmatrix} R^{corrected} \\ G^{corrected} \\ B^{corrected} \end{bmatrix} = \begin{bmatrix} K1 & K2 & K3 \\ K4 & K5 & K6 \\ K7 & K8 & K9 \end{bmatrix} \bullet \begin{bmatrix} R^{raw} \\ G^{raw} \\ B^{raw} \end{bmatrix}$$

☞ Determine the signs for the 9 color correction coefficients (K1,..., K9)

☞ Program Register 2 with the signs of K1,..., K9
Set corresponding bit to "1" if the sign is negative, otherwise set to "0"

☞ Select the scaling factor for the various coefficients
For color correction, coefficient K1
a. Choose the largest scaling factor (16, 32, 64, 128, 256), Sc, such that (larger scaling factor gives better accuracy)
Sc * K1 < 256
b. Program bits 0-2 of Register 3 with the corresponding scaling factor.
"000" for 16
"001" for 32
"010" for 64
"011" for 128
"100" for 256
c. Repeat a, b for K2, ..., K9. For K6, ..., K9, program the corresponding bits in Register 4 instead of Register 3.

☞ Program the magnitude of the coefficients after scaling into Registers 9-17.
For color correction coefficient K1,
a. Round (Sc*K1) to the nearest integer
b. Convert the integer to its binary value
c. Program Register 9 with the corresponding binary value
d. Repeat a, b, c for K2, ..., K9. For part c, the Register 9 will be Register 10-17 for K2-K9 respectively.

PB-0100 COLOR-CORRECTION MATRIX

$$\begin{bmatrix} 8.726 & -4.089 & -1.186 \\ -1.127 & 2.992 & -0.765 \\ -0.373 & -2.658 & 4.695 \end{bmatrix}$$

PB-0300 COLOR-CORRECTION MATRIX

$$\begin{bmatrix} 2.105 & -0.443 & -0.035 \\ -0.388 & 1.407 & 0.032 \\ -0.037 & -1.480 & 3.969 \end{bmatrix}$$

This example refers to a Photobit PB-0300 CMOS image sensor operating under fluorescent illumination in non-stretch YUV output mode. It assumes a start from the reset condition.

(Note: color-correction matrices depend on the system optics as well as illumination, so the matrix of this example, below, should be adjusted to render optimal color for the actual application.)

$$\begin{bmatrix} R^{corrected} \\ G^{corrected} \\ B^{corrected} \end{bmatrix} = \begin{bmatrix} 2.105 & -0.443 & -0.035 \\ -0.388 & 1.407 & 0.032 \\ -0.037 & -1.480 & 3.969 \end{bmatrix} \bullet \begin{bmatrix} R^{raw} \\ G^{raw} \\ B^{raw} \end{bmatrix}$$

2.6.2 Register Programming Example (continued)

☞ Program signs of the color-correction coefficients in R2 as follows:
R2 ⇐ "0000000011100110"$_2$ = 230_{10}

☞ Program the scaling values in R3 and R4 as follows:
R3 ⇐ "0011100100100010"$_2$ = 14626_{10}
R4 ⇐ "0000010011100100"$_2$ = 1252_{10}

☞ Program magnitudes of the color-correction coefficients in R9 through R17 as follows:
R9 ⇐ "0000000010000111"$_2$ = 135_{10}
R10 ⇐ "0000000001110010"$_2$ = 114_{10}
R11 ⇐ "0000000000001001"$_2$ = 9_{10}
R12 ⇐ "0000000001100100"$_2$ = 100_{10}
R13 ⇐ "0000000010110100"$_2$ = 180_{10}
R14 ⇐ "0000000000001000"$_2$ = 8_{10}
R15 ⇐ "0000000000001001"$_2$ = 9_{10}
R16 ⇐ "0000000010111101"$_2$ = 189_{10}
R17 ⇐ "0000000011111110"$_2$ = 254_{10}

SET GAMMA-CORRECTION LOOK-UP TABLES

Gamma correction compensates for the voltage-intensity non-linearities of monitors. Many VGA monitors have partial gamma compensation built in, while other display types, including many NTSC receivers, provide no gamma correction.

For monitors having partial gamma correction, gamma values to be programmed into the PB-R006 are in the range of 0.9 to 0.6. For gamma-uncompensated displays, values of 0.5 to 0.4 are appropriate.

The contents of the gamma look-up tables to be programmed into the chip are determined according to the following formula (values are rounded):

$$Gamma(pxl\_value) = \left\lceil 255 \cdot \left[\frac{pxl\_value}{255} \right]^{gamma\_value} \right\rceil^{ceil} \quad where\ pxl\_value = 1,\ldots,255$$

A gamma value of 0.8 corresponds to the following contents for the 255 locations of the look-up table:

1, 3, 5, 7, 9, 10, 12, 14, 15, 17, 19, 20, 22, 23, 25, 26, 27, 29, 30, 31, 33, 34, 35, 37, 38, 39, 41, 42, 43, 44, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 165, 166, 167, 168, 169, 170, 171, 172, 172, 173, 174, 175, 176, 177, 178, 179, 180, 180, 181, 182, 183, 184, 185, 186, 186, 187, 188, 189, 190, 191, 192, 192, 193, 194, 195, 196, 197, 198, 198, 199, 200, 201, 202, 203, 204, 204, 205, 206, 207, 208, 209, 209, 210, 211, 212, 213, 214, 214, 215, 216, 217, 218, 219, 219, 220, 221, 222, 223, 224, 224, 225, 226, 227, 228, 229, 229, 230, 231, 232, 233, 233, 234, 235, 236, 237, 238, 238, 239, 240, 241, 242, 242, 243, 244, 245, 246, 246, 247, 248, 249, 250, 250, 251, 252, 253, 254, 254.

In general, the user will want to program the same gamma-correction values in the Red, Green, and Blue gamma-correction tables. The programming sequence is as follows:

☞ Select the Red look-up table address space by programming value 2 in R1.
R1 ⇐ "0000000000000010"$_2$ = 2_{10}

☞ Program the values listed in the above table in consecutive addresses from 2 through 255. Note that addresses 0 and 1 should not be programmed, because pixel values of 0 and 1 are remapped into pixel value 2. Also, address location 1 always addresses R1 and allows for address space switching.

2.6.2 Register Programming Example (continued)

☞ Select the Green look-up table address space by programming value 4 in R1.
R1 ⇐ "0000000000000100"$_2$ = 4_{10}

☞ Program the values listed in the above table in consecutive addresses from 2 through 255 as above.

☞ Select the Blue look-up table address space by programming value 8 in R1.
R1 ⇐ "0000000000001000"$_2$ = 8_{10}

☞ Program the values listed in the above table in consecutive addresses from 2 through 255.

☞ De-select the look-up table address space by programming value 1 in R1. (Ignoring this step will result in incorrect color processing because one of the look-up tables will be left multiplexed to the I^2C engine instead of the image pipeline.)
R1 ⇐ "0000000000000001"$_2$ = 1_{10}

PROGRAM SENSOR OUTPUT MODE

To select color-corrected non-stretch YUV output, program value 3 into mode control register R6:
R6 ⇐ "0000000000000011"$_2$ = 3_{10}

ADJUST OUTPUT COLOR PHASE

Due to possible variations in the propagation delay between valid data and the rising edge of the pixel clock in different hardware configurations, it may be necessary to adjust the color phase by programming values from "00" through "11" into the LSBs of R8 until the proper color phase is achieved. This trial-and-error process is usually performed only once for each hardware configuration.

The above steps are the minimum programming required to achieve a color-corrected image. Other registers may also be programmed to modify the PB-R006's default operation, according to the register descriptions. For example, image sharpness may be increased by programming R5.

2.6.2 Register Descriptions

This section contains the complete list of user registers.

Register Address	Register Name	Function	Read/Write Control
01 hex (1 decimal)	R1	Look -Up Table Select Register	RW

Default Contents = 0001 hex (control registers selected):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Description:

This register controls the address space for I^2C communications. No more than one bit should be set at any time.

Bit 0: Don't care

Bit 1: Enables I^2C access to Control Registers (R2 through R50)

Bit 2: Enables I^2C access to Red Gamma Look-Up Table (R/W)

Bit 3: Enables I^2C access to Green Gamma Look-Up Table (Write only)

Bit 4: Enables I^2C access to Blue Gamma Look-Up Table (Write only)

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
02 hex (2 decimal)	R2	Sign of coefficients of Color Correction Matrix Register	RW

Default Contents = 00EE hex (off-diagonal coefficients negative):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	0

Description:
This register specifies the signs of 9 color correction coefficients
Negative sign is specified by setting corresponding bit
Bit 0: Don't care (sign of K9 is assumed to be always positive)
Bit 1: Sign of K8
Bit 2: Sign of K7
Bit 3: Sign of K6
Bit 4: Don't care (sign of K5 is assumed to be always positive)
Bit 5: Sign of K4
Bit 6: Sign of K3
Bit 7: Sign of K2
Bit 8: Don't care (sign of K1 is assumed to be always positive)
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
03 hex (3 decimal)	R3	Scaling of color correction coefficients K1 through K5 Register	RW

Default Contents = 0000 hex (all coefficients are multiplied by 16):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies scaling of color correction coefficients K1 through K5. All coefficients are loaded as 8-bit unsigned integers. The scaling scheme allows to accommodate fractional coefficients in range from 0.004 through 15.93. Prior to loading, fractional coefficients are multiplied by either 16, 32, 64, 128 or 256 and rounded to nearest integer. For maximum accuracy scaling factor should be selected so that scaled coefficient is as close as possible to (but not exceeding) 255. The minimum allowed scaling factor is 16. The maximum scaling factor is 256. The power of 2 used for scaling in excess of 4 is specified as 3-bit value in R3 and R4. Thus, scaling by 16 is coded as "000", scaling by 32 is coded as "001", scaling by 64 is coded as "010", scaling by 128 is coded as "011" and scaling by 256 is coded as "100". The scaled coefficient values are loaded in R9 through R17 and their signs are specified in R2. For example K2 = -2.3 would be scaled by 64 to 147 and coded as "10010011" in bits 0-7 of R10, "010" in bits 3-5 in R3 and "1" in bit 7 of R2.

Bits 0-2: Scaling of K1
Bits 3-5: Scaling of K2
Bits 6-8: Scaling of K3
Bits 9-11: Scaling of K4
Bits 12-14: Scaling of K5
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
04 hex (4 decimal)	R4	Scaling of color correction coefficients K6 through K9 Register	RW

Default Contents = 0000 hex (all coefficients are multiplied by 16):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies scaling of color correction coefficients K6 through K9
For details see R3;
Bits 0-2: Scaling of K6
Bits 3-5: Scaling of K7
Bits 6-8: Scaling of K8
Bits 9-11: Scaling of K9
Other bits: Don’t care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
05 hex (5 decimal)	R5	Aperture Correction (sharpening gain)	RW

Default Contents = 0005 hex (sharpening gain of 175%):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Description:

This register specifies sharpening gain in the range from 0 to 300%

Bits 0-2:
- "000" - no sharpening
- "001" - 50% sharpening
- "010" - 100% sharpening
- "011" - 125% sharpening
- "100" - 150% sharpening
- "101" - 175% sharpening
- "110" - 200% sharpening
- "111" - 300% sharpening

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
06 hex (6 decimal)	R6	Operating Mode Control Reg.	RW

Default Contents = 0E13 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	1	1	1	0	0	0	0	1	0	0	1	1

Description:

This register specifies the operating mode of PB-R006

Bit 0: "1" - YUV output; "0" - RGB output

Bit 1: Toggles U/V order in CCIR601 16-bit YUV mode

Bit 2: Delays output by one pxl_clk (valid only in YUV "stretch" mode when PIXOUT_CLK frequency = 1/2 of PXL_CLK frequency)

Bit 3: Stretch mode control; "1" - stretches active video 2 times across horizontal Blanking (PIXOUT_CLK = ½ PXL_CLK); "0" - PIXOUT_CLK = PXL_CLK; Note: "stretch" mode requires horizontal blanking time of the imager to be longer than horizontal active.

Bit 4: "1" - outputs "raw" color bypassing color and gamma correction: in this mode the output video can be seen without loading color matrix and gamma look-up tables; "0" - normal color processing

Bit 5: "1" - line_valid_out is active low; "0" - line_valid_out is active high

Bit 6: "1" - frame_valid_out is active low; "0" - frame_valid_out is active high

Bit 7: "1" -synchronization codes similar to CCIR656 are embedded in the image

Bit 8: "1" - Color interpolation is performed on 3x3 neighborhood; "0" - interpolation is performed on 5x5 neighborhood

Bit 9: "1" - aperture correction is applied at all pixels; "0" - aperture correction is applied at green pixels locations only

Bit 10: "1" - Existing Green pixels are used as-is (higher resolution and noise); "0" - all Green pixels are interpolated

Bit 11: "1" - Existing Red and Blue pixels are used as-is (higher resolution and noise); "0" - all Red and Blue pixels are interpolated

Bit 12: "1" - small aperture corrections (< 6) are attenuated by a factor of 2 (reduces noise amplification)

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
07 hex (7 decimal)	R7	Software Reset	W

Default Contents = 0000 hex (no reset):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register resets all other registers to defaults, resets all pixel counters and suspends output of R006. This register must be cleared by the I^2C host to resume operation.

Bit 0: "1" - reset state; "0" — operating state

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
08 hex (8 decimal)	R8	Output Format Control Register	RW

Default Contents = 0002 hex (standard video output):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Description:
This register specifies the operating mode of PB-R006
Bit 0: Toggles the assumptions about Bayer CFA (horizontal shift); “0” — row containing Blue comes first; “1” — row with Red comes first
Bit 1: Toggles the assumptions about Bayer CFA (vertical shift); “0” — Green comes first; “1” — Red or Blue comes first
Bit 2: “1” — Blank Red/Cr - color output channel
Bit 3: “1” — Blank Green/Y color output channel
Bit 4: “1” — Blank Blue/Cb — color output channel
Bit 5: “1” — Mutliplexes Green/Y channel on all channels (monochrome mode)
Bit 6: “1” — Produces an intensity ramp on the output
Other bits: Don’t care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
09 hex (9 decimal)	R9	K1 Color Correction Coefficient	RW

Default Contents = 0010 hex (value 1.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Description:
This register specifies the scaled value of color correction coefficient K1. Scaling scheme is described in Register 3.
Bits 0-7: Scaled value of K1
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
0A hex (10 decimal)	R10	K2 Color Correction Coefficient	RW

Default Contents = 0000 hex (value 0.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the scaled value of color correction coefficient K2. Scaling scheme is described in Register 3.
Bits 0-7: Scaled value of K2
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
0B hex (11 decimal)	R11	K3 Color Correction Coefficient	RW

Default Contents = 0000 hex (value 0.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies the scaled value of color correction coefficient K3. Scaling scheme is described in Register 3.

Bits 0-7: Scaled value of K3

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
0C hex (12 decimal)	R12	K4 Color Correction Coefficient	RW

Default Contents = 0000 hex (value 0.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies the scaled value of color correction coefficient K4. Scaling scheme is described in Register 3.

Bits 0-7: Scaled value of K4

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
0D hex (13 decimal)	R13	K5 Color Correction Coefficient	RW

Default Contents = 0010 hex (value 1.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Description:
This register specifies the scaled value of color correction coefficient K5. Scaling scheme is described in Register 3.
Bits 0-7: Scaled value of K5
Other bits: Don’t care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
0E hex (14 decimal)	R14	K6 Color Correction Coefficient	RW

Default Contents = 0000 hex (value 0.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the scaled value of color correction coefficient K6. Scaling scheme is described in Register 3.
Bits 0-7: Scaled value of K6
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
0F hex (15 decimal)	R15	K7 Color Correction Coefficient	RW

Default Contents = 0000 hex (value 0.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies the scaled value of color correction coefficient K7. Scaling scheme is described in Register 3.

Bits 0-7: Scaled value of K7

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
10 hex (16 decimal)	R16	K8 Color Correction Coefficient	RW

Default Contents = 0000 (value 0.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies the scaled value of color correction coefficient K8. Scaling scheme is described in Register 3.

Bits 0-7: Scaled value of K8

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
11 hex (17 decimal)	R17	K9 Color Correction Coefficient	RW

Default Contents = 0010 hex (value 1.0):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Description:

This register specifies the scaled value of color correction coefficient K9. Scaling scheme is described in Register 3.

Bits 0-7: Scaled value of K9

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
12 hex (18 decimal)	R18	Red Component of Pixel found by White Balance Measurement Engine	R

Default Contents = 00000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the value of red component of pixel found by Measurement Engine in accordance with criteria specified in Registers 22 through 45. This register is updated during vertical blanking. Also see description given for Register 22.
Bits 0-7: Red component value
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
13 hex (19 decimal)	R19	Green Component of Pixel found by White Balance Measurement Engine	R
	Default Contents =	0000 hex:	

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies the value of green component of pixel found by Measurement Engine in accordance with criteria specified in Registers 22 through 45. This register is updated during vertical blanking. Also see description given for Register 22.

Bits 0-7: Green component value

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
14 hex (20 decimal)	R20	Blue Component of Pixel found by White Balance Measurement Engine	R

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies the value of blue component of pixel found by Measurement Engine in accordance with criteria specified in Registers 22 through 56. This register is updated during vertical blanking. Also see description given for Register 22.

Bits 0-7: Blue component value

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
15 hex (21 decimal)	R21	White Balance Measurement Engine Marker Control	RW

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register controls whether or not the pixel found by Measurement Engine is displayed in the image as a red 2x2 square marker.
Bit 0: "1" enable marker display; "0" disable marker display
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
16 hex (22 decimal)	R22	Lower limit on Red component for White Balance Measurement Engine Control	RW

Default Contents = 0014 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0

Description:

One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfieds the set of thresholds specified in Registers 22 through 45. This register specifies the lower limit of the red component of pixel to be identified by the Measurement Engine.

Bits 0-7: Lower limit of red component for pixel to be identified by White Balance Measurement Engine.

Other bits: Don’t care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
17 hex (23 decimal)	R23	Upper limit on Red component for White Balance Measurement Engine Control	RW

Default Contents = 00DC hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0

Description:

One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfieds the set of thresholds specified in Registers 22 through 45. This register specifies the upper limit of the red component of pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of red component for pixel to be identified by White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
18 hex (24 decimal)	R24	Lower limit on Green component for White Balance Measurement Engine	RW

Default Contents = 0014 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0

Description:
One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfies the set of thresholds specified in Registers 22 through 45. This register specifies the lower limit of the green component of pixel to be identified by the Measurement Engine.
Bits 0-7: Lower limit of green component for pixel to be identified by White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
19 hex (25 decimal)	R25	Upper limit on Green component for White Balance Measurement Engine	RW

Default Contents = 00DC hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0

Description:

One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfies the set of thresholds specified in Registers 22 through 45. This register specifies the upper limit of the green component of pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of green component for pixel to be identified by White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
1A hex (26 decimal)	R26	Lower limit on Blue component for White Balance Measurement Engine	RW

Default Contents = 0014 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0

Description:

One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfies the set of thresholds specified in Registers 22 through 45. This register specifies the lower limit of the blue component of pixel to be identified by the Measurement Engine.

Bits 0-7: Lower limit of blue component for pixel to be identified by WB Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
1B hex (27 decimal)	R27	Upper limit on Blue component for White Balance Measurement Engine	RW

Default Contents = 00DC hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0

Description:

One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfies the set of thresholds specified in Registers 22 through 45. This register specifies the upper limit of the blue component of pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of blue component for pixel to be identified by White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
1C hex (28 decimal)	R28	Lower limit on difference (Green-Red) for White Balance Measurement Engine	RW

Default Contents = 0010 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Description:
This register specifies the lower limit on the (positive) difference between green and red components of the pixel to be identified by the Measurement Engine.
Bits 0-7: Lower limit of (green-red) for pixel to be identified by White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
1D hex (29 decimal)	R29	Upper limit on difference (Green-Red) for White Balance Measurement Engine	RW

Default Contents = 003C hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0

Description:

This register specifies the upper limit on the (positive) difference between green and red components of the pixel to be identified by the Measurement Engine.

Bits 0-7: Lower limit of (green-red) for pixel to be identified by White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
1E hex (30 decimal)	R30	Lower limit on difference (Green-Blue) for White Balance Measurement Engine	RW

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the lower limit on the (positive) difference between green and blue components of the pixel to be identified by the Measurement Engine.
Bits 0-7: Lower limit of (green-blue) for pixel to be identified by White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
1F hex (31 decimal)	R31	Upper limit on difference (Green-Blue) for White Balance Measurement Engine	RW

Default Contents = 00FF hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

This register specifies the upper limit on the (positive) difference between green and blue components of the pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of (green-blue) for pixel to be identified by White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
20 hex (32 decimal)	R32	Lower limit on difference (Red-Blue) for White Balance Measurement Engine	RW

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Description:

This register specifies the upper limit on the (positive) difference between red and blue components of the pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of (red-blue) for pixel to be identified by White Balance Measurement Engine.

Other bits: Don’t care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
21 hex (33 decimal)	R33	Upper limit on difference (Red-Blue) for White Balance Measurement Engine	

Default Contents = 0028hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0

Description:

This register specifies the upper limit on the (positive) difference between red and blue components of the pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of (red-blue) for pixel to be identified by White Balance Measurement Engine.

Other bits: Don’t care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
22 hex (34 decimal)	R34	Lower limit on difference (Red-Green) for White Balance Measurement Engine	RW

Default Contents = 0000 hex,:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the lower limit on the (positive) difference between red and green components of the pixel to be identified by the Measurement Engine.
Bits 0-7: Lower limit of (red-green) for pixel to be identified by White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
23 hex (35 decimal)	R35	Upper limit on difference (Red-Green) for White Balance Measurement Engine	RW

Default Contents = 003C hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0

Description:

This register specifies the upper limit on the (positive) difference between red and green components of the pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of (red-green) for pixel to be identified by White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
24 hex (36 decimal)	R36	Lower limit on difference (Blue-Green) for White Balance Measurement Engine	RW

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the lower limit on the (positive) difference between blue and green components of the pixel to be identified by the Measurement Engine.
Bits 0-7: Lower limit of (blue-green) for pixel to be identified by White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
25 hex (37 decimal)	R37	Upper limit on difference (Blue-Green) for White Balance Measurement Engine	RW

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the upper limit on the (positive) difference between blue and green components of the pixel to be identified by the Measurement Engine.
Bits 0-7: Upper limit of (blue-green) for pixel to be identified by White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
26 hex (38 decimal)	R38	Lower limit on difference (Blue-Red) for White Balance Measurement Engine	RW

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
This register specifies the lower limit on the (positive) difference between blue and red components of the pixel to be identified by the Measurement Engine.
Bits 0-7: Lower limit of (blue-red) for pixel to be identified by White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
27 hex (39 decimal)	R39	Upper limit on difference (Blue-Red) for White Balance Measurement Engine	RW

Default Contents = 0028 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0

Description:

This register specifies the upper limit on the (positive) difference between blue and red components of the pixel to be identified by the Measurement Engine.

Bits 0-7: Upper limit of (blue-red) for pixel to be identified by White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
28 hex (40 decimal)	R40	Weighting of color components for White Balance Measurement Engine	RW

Default Contents = 0035 hex (pixel brightness is defined by default as 1.0*red+1.0*green+4.0*blue):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1

Description:
One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfies the set of thresholds specified in Registers 22 through 45. The "brightness" of the pixel is defined as weighted sum of its color component. The weight of each color component is coded in appropriate two bits of R40. Code "00" correspond to weight of 0.5; code "01" corresponds to weight of 1.0; code "10" corresponds to weight of 2.0 and code "11" corresponds to weight of 4.0; Note: no more than one color component can have the weight of 4.0.
Bits 0-1: Weight of red component
Bits 2-3: Weight of green component
Bits 4-5: Weight of blue component
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
29 hex (41 decimal)	R41	Aperture Limit for pixel to be found by White Balance Measurement Engine	RW

Default Contents = 0003 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Description:

One of the functions of White Balance Measurement Engine is to locate brightest pixel in the image that satisfies the set of thresholds specified in Registers 22 through 45. To avoid "highlights" Measurement Engine disregards pixels with aperture correction values in excess of limit specified in R41; Note: max. value 63

Bits 0-5: Pixels with aperture values above this limit are disregarded by Measurement Engine

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
2A hex (42 decimal)	R42	Left Window Boundary for White Balance Measurement Engine	RW

Default Contents = 0019 hex (left border is column 100):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1

Description:
The Measurement Engine performs search only within the window specified in Registers 42 through 45. NOTE: Programmed values are window boundaries divided by 4.
Bits 0-7: Left window boundary (divided) for White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
2B hex (43 decimal)	R43	Right Window Boundary for White Balance Measurement Engine	RW

Default Contents = 0087 hex (right border is column 540):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1

Description:

The Measurement Engine performs search only within the window specified in Registers 42 through 45. NOTE: Programmed values are window boundaries divided by 4.

Bits 0-7: Right window boundary (divided) for White Balance Measurement Engine.

Other bits: Don’t care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
2C hex (44 decimal)	R44	Top Window Boundary for White Balance Measurement Engine	RW

Default Contents = 0019 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1

Description:
The Measurement Engine performs search only within the window specified in Registers 42 through 45. NOTE: Programmed values are window boundaries divided by 4.
Bits 0-7: Top window boundary (divided) for White Balance Measurement Engine.
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
2D hex (45 decimal)	R45	Bottom Window Boundary for White Balance Measurement Engine	RW

Default Contents = 005F (bottom border is row 380):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1

Description:

The Measurement Engine performs search only within the window specified in Registers 42 through 45. NOTE: Programmed values are window boundaries divided by 4.

Bits 0-7: Bottom window boundary (divided) for White Balance Measurement Engine.

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
2E hex (46 decimal)	R46	Horizontal Frame Size Control	RW

Default Contents = 03FF (by default horizontal window size is equal to that of imager):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1

Description:
The duration of active pulse on the line_valid_out pin can be specified in Register 46. Horizontal active can be as long as horizontal active of the imager or as short as 16 pixels.
NOTE: total line time is not affected by this register.
Bits 0-9: Number of pixels output during horizontal active pulse
Other bit: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
2F hex (47 decimal)	R47	Vertical Frame Size Control	RW

Default Contents = 03FF (by default vertical window size is equal to that of imager):

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1

Description:
The duration of active pulse on the frame_valid_out pin can be specified in Register 47. Vertical active can be as long as vertical active of the imager or as short as 6 lines.
NOTE: total frame time is not affected by this register.
Bits 0-9: Number of pixels output during horizontal active pulse
Other bit: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
30 hex (48 decimal)	R48	Measured Sum of Red components of all pixels within White Balance window	R

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:
White Balance Measurement Engine accumulates the sum of each color component for all pixels within a window specified by Registers 42 through 45.
NOTE: Sum is divided by 2048.
Bits 0-15: Sum of Red components of all pixels within White Balance window divided by 2048
Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
31 hex (49 decimal)	R49	Measured Sum of Green components of all pixels within White BalanceB window	R

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

White Balance Measurement Engine accumulates the sum of each color component for all pixels within a window specified by Registers 42 through 45.

NOTE: Sum is divided by 2048

Bits 0-15: Sum of Green components of all pixels within White Balance window divided by 2048

Other bits: Don't care

2.6.2 Register Descriptions (continued)

Register Address	Register Name	Function	Read/Write Control
32 hex (50 decimal)	R50	Measured Sum of Blue components of all pixels within White Balance window	R

Default Contents = 0000 hex:

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

White Balance Measurement Engine accumulates the sum of each color component for all pixels within a window specified by Registers 42 through 45.

NOTE: Sum is divided by 2048.

Bits 0-15: Sum of Blue components of all pixels within White Balance window divided by 2048

Other bits: Don't care

2.7 Measurement Engine

The PB-R006 Measurement Engine performs a real-time analysis of the portion of the image within a user-specified window, producing the following two results:

- Sums of non-corrected (raw) RGB color values of all pixels within the window
- Raw RGB values for the brightest pixel within the window that satisfies a user-specified set of thresholds

The user must first specify the window of interest by programming the measurement engine as follows: the left window boundary in R42, the right window boundary in R43, the top window boundary in R44, and the bottom window boundary in R45. Window boundaries are programmed in terms of column/row values, divided by 4 (e.g. row 100 is programmed as value 25), and the values take effect immediately.

Once the window of interest is programmed, the raw RGB values of the sum of all pixels in the window can be obtained by reading R48 for Red, R49 for Green, and R50 for the Blue components. The RGB values are measured before aperture-, color-, and gamma-corrections, but after interpolation. R48 through R50 are updated on the falling edge of f_en and represent the sums of all pixels in the window divided by 2048.

Implementers of auto white-balance (AWB) algorithm may find it useful to break the image into a number of sub-images in order to estimate the incident spectra. In that case, to achieve correct readings of the window sums, it is important to insure that at least one full frame has elapsed since the window boundaries were changed.

In some simple white-balance algorithms, the user may designate the brightest pixel as the image element corresponding to white/gray target color. The measurement engine of the PB-R006 outputs the raw RGB components of the brightest pixel within the window of interest in R18 (Red), R19 (Green) and R20 (Blue). The brightest pixel is defined as the one with a maximum weighted sum of its Red, Green, and Blue components, provided that RGB values satisfy the set of thresholds programmed in R22 through R39.

$$\textit{brightest pixel} \quad \max_{\underline{window}} (k_r \; R + k_g \; G + k_b \; B),$$

$$\textit{where } R, G, \textit{and } B \textit{ satisfy conditions in } R22 - R39$$

Weighting coefficients can have values of 0.5, 1.0, 2.0, or 4.0 and are programmed in appropriate bit-fields of R40 (see description of R40 on page 57 for further details). For debugging purposes, the location of the brightest pixel found by the measurement engine can be shown as a red-colored marker in the image by programming 1 into R21.

To implement the closed-loop AWB algorithm, the following steps must be followed:

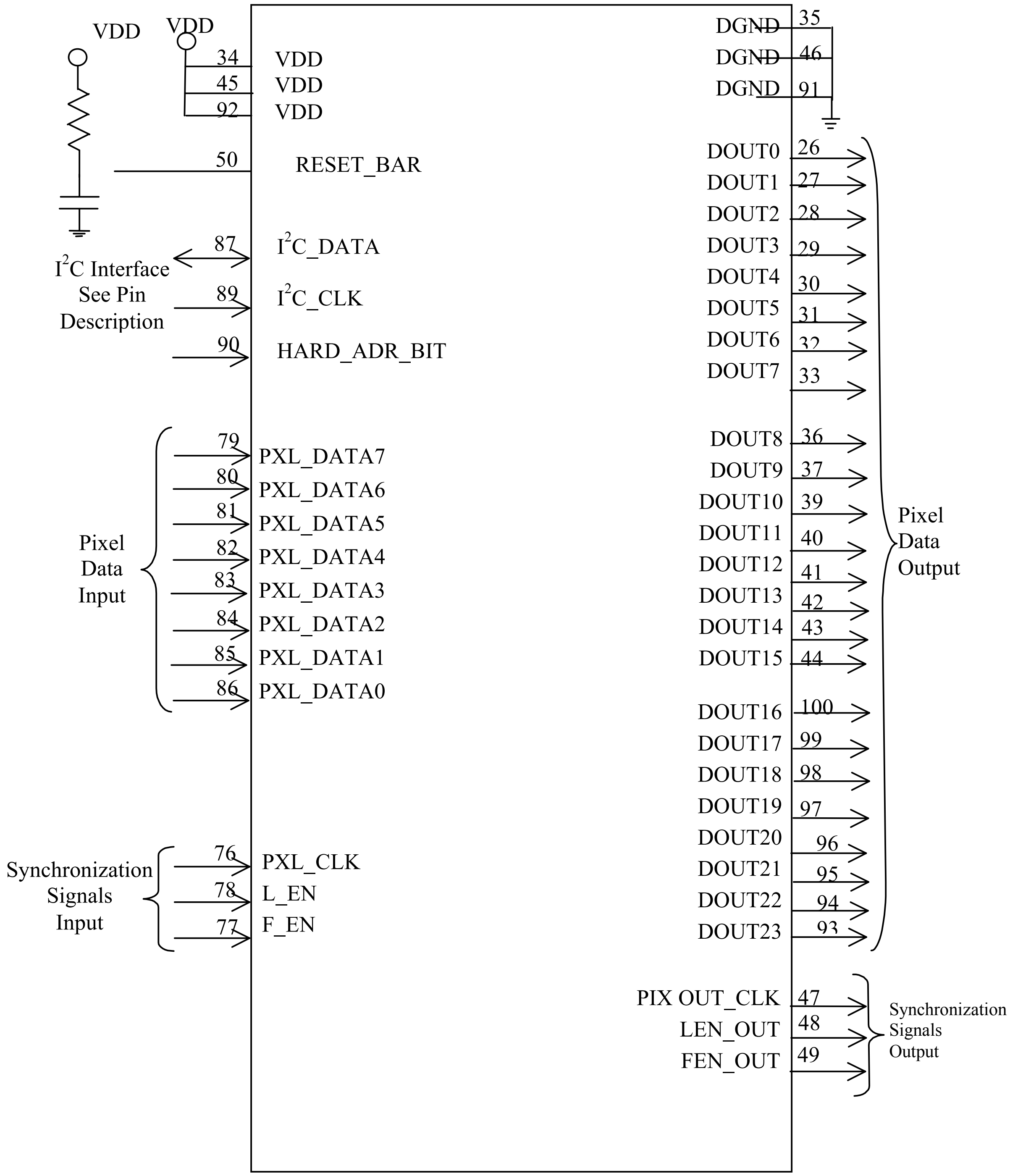
Step 1—The AWB algorithm programs the chip's measurement engine as described above to produce the required statistics.

Step 2—After one frame-time latency, the results are read from R48 through R50 and R18 through R20. (For more sophisticated AWB algorithms, Steps 1 and 2 may need to be repeated to allow for analysis of multiple windows of interest.)

Step 3—Once the necessary statistics have been accumulated, the AWB algorithm computes the necessary adjustments to the color-correction matrix.

Step 4—The AWB algorithm then reprograms the color-correction matrix of the chip, as described in Section 2.6.1. Changes to the individual color channel gains can be achieved by multiplying all elements of the appropriate row of the color matrix by the color gain value.

2.8 Board Connections



2.9 Electrical Specification

AC Electrical Characteristics (Vsupply = 3.3V ± 0.3V; T_A = 0°C to 70°C)

Symbol	Characteristic	Condition	Min.	Typ.	Max.	Unit
Tplh	Data output propogation delay for low to high trans.			20		ns
Tphl	Data output propogation delay for high to low trans.			20		
ns						
Tsetup	Setup time for input to CLK	Vin = Vpwr or Vgnd		5		ns
Thold	Hold time for input to CLK	Vpwr=Min,VOH min		0		ns
PSRR_VDD	Power supply rejection ratio for digital supply	100mV ripple at 9.7 kHz on supply		TBD		dB

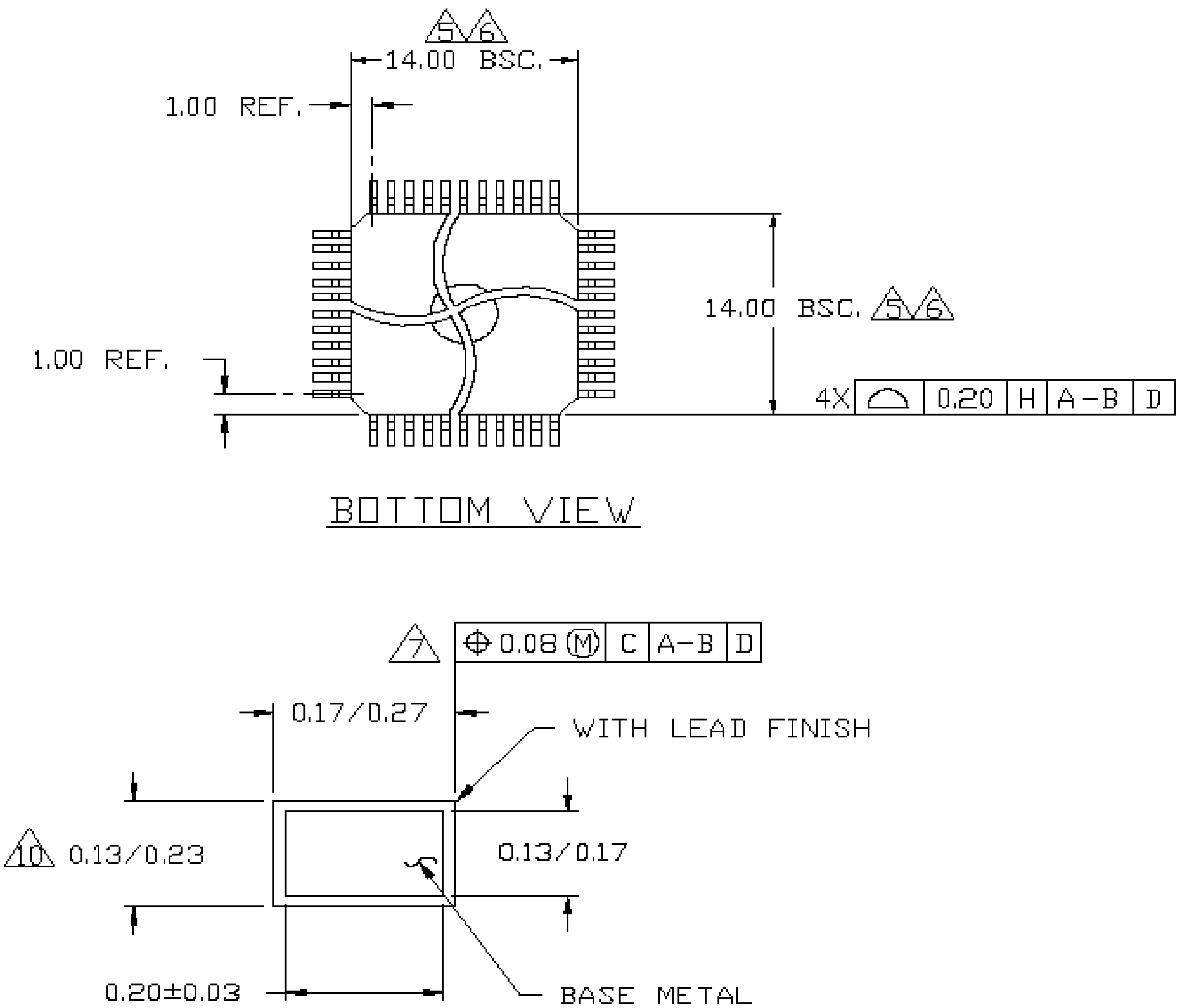
DC Electrical Characteristics (Vsupply = 3.3V ± 0.3V; T_A = 0°C to 70°C)

Symbol	Characteristic	Condition	Min.	Typ.	Max.	Unit
VIH	Input High Voltage		2.0		Vpwr+0.3	V
VIL	Input Low Voltage		-0.3V		0.8	V
IIN	Input Leakage Current, No Pullup Resistor	Vin = Vpwr or Vgnd	-5		5	µA
IOH	Output High Current	Vpwr = Min, VOH min	-3			mA
IOL	Output Low Current	Vpwr = Min, VOL max	3			mA
VOH	Output High Voltage	Vpwr=Min, IOH=-100uA	Vpwr-0.2			V
VOL	Output Low Voltage	Vpwr=Min, IOL=100uA			0.2	V
IOZ	3-State Output Leakage Current	I^2C_Data in High Z, Vout=Vpwr or Vgnd	-10		10	µA
Ipwr	Maximum Quiescent Current	Vin = Vpwr, clock stops	20	30	50	µA
Ioper	Operating Current	Vin = Vpwr, clock running	33	35	37	mA

3.0 Mechanical

3.1 Package Views

Package Outline, 100 Lead MQFP, 14 x 14 mm Body,
1.60/0.15 mm Form, 2.67 mm Thick



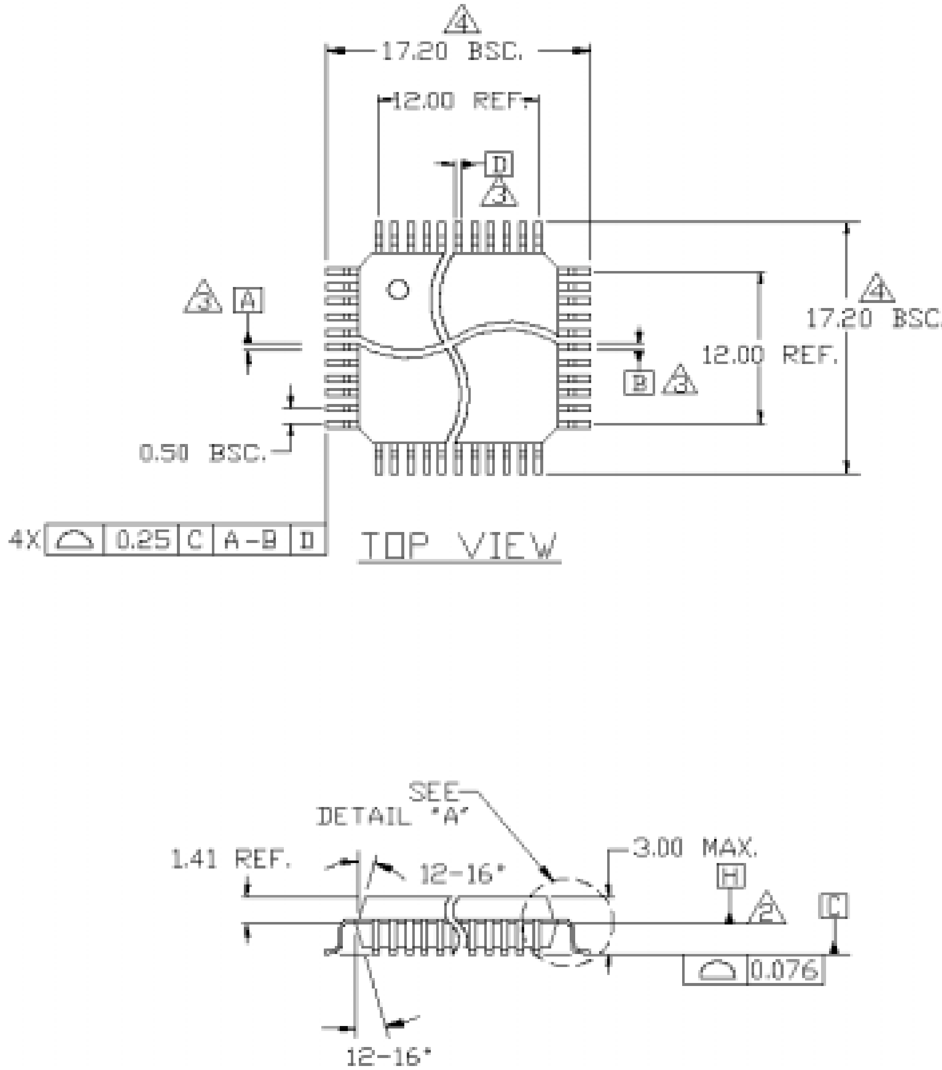
1. ALL DIMENSIONS AND TOLERANCES CONFORM TO ASME Y14.5M-1994.
2. DATUM PLANE H LOCATED AT MOLD PARTING LINE AND COINCIDENT WITH LEAD, WHERE LEAD EXITS PLASTIC BODY AT BOTTOM OF PARTING LINE.
3. DATUMS A-B AND D TO BE DETERMINED WHERE CENTERLINE BETWEEN LEADS EXITS PLASTIC BODY AT DATUM PLANE H.
4. TO BE DETERMINED AT SEATING PLANE C.
5. DIMENSIONS 14.0 OF BOTTOM VIEW DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE MOLD PROTRUSION IS 0.254 MM PER SIDE. THESE DIMENSIONS INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE H.
6. PACKAGE TOP DIMENSIONS ARE SMALLER THAN BOTTOM DIMENSIONS BY 0.20 MM, AND TOP OF PACKAGE WILL NOT OVERHANG BOTTOM OF PACKAGE.
7. DIMENSION 0.17/0.27 OF SECTION "B-B" DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 MM TOTAL IN EXCESS OF THIS DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT.
8. ALL DIMENSIONS ARE IN MILLIMETERS.
9. MAXIMUM ALLOWABLE DIE THICKNESS TO BE ASSEMBLED IN THIS PACKAGE FAMILY IS 0.635 MM.
10. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10 MM AND 0.25 MM FROM THE LEAD TIP.

ALL DIMENSIONS ARE IN MILLIMETERS

3.0 Mechanical (continued)

3.1 Package Views (continued)

Package Outline, 100 Lead MQFP, 14 x 14 mm Body,
1.60/0.15 mm Form, 2.67 mm Thick



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4. TO BE DETERMINED AT SEATING PLANE C.
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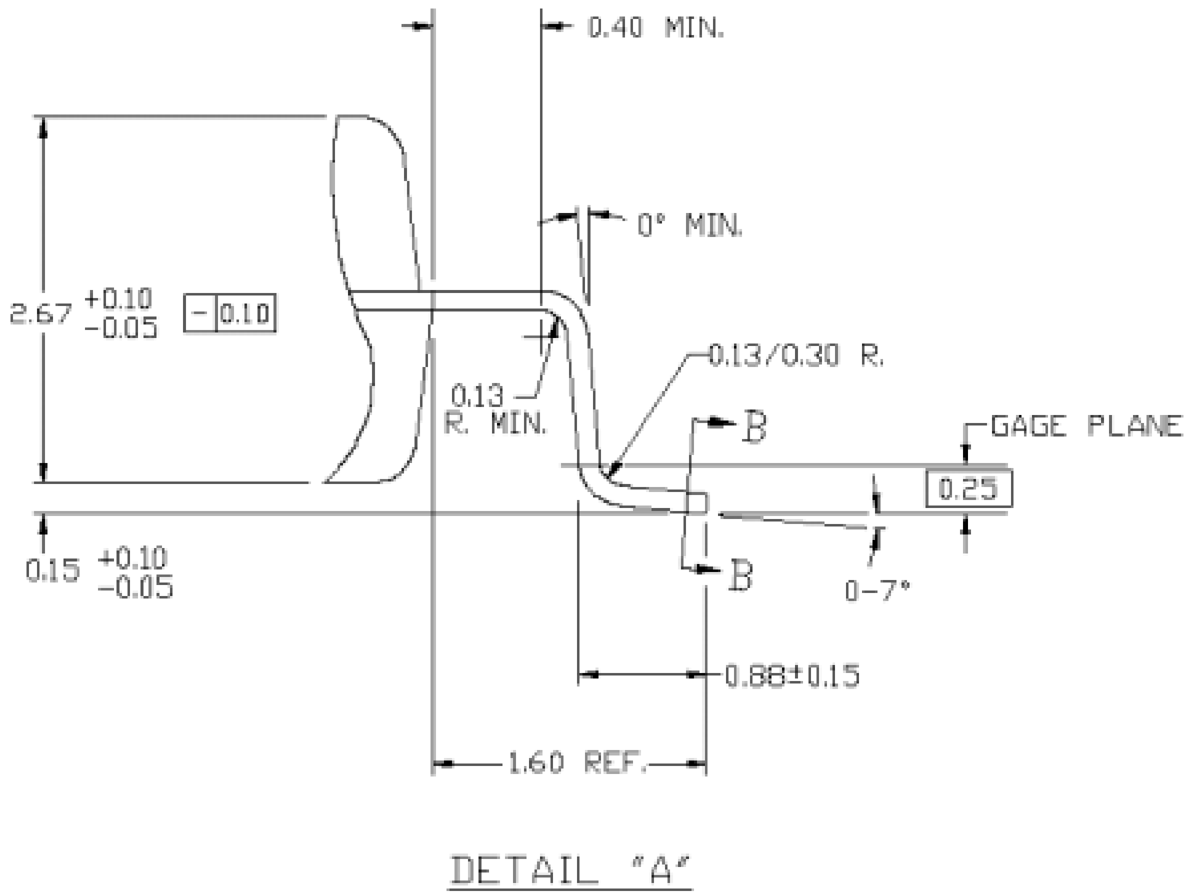
9. MAXIMUM ALLOWABLE DIE THICKNESS TO BE ASSEMBLED IN THIS PACKAGE FAMILY IS 0.635 MM.
10. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10 MM AND 0.25 MM FROM THE LEAD TIP.

ALL DIMENSIONS ARE IN MILLIMETERS

3.0 Mechanical (continued)

3.1 Package Views (continued)

Package Outline, 100 Lead MQFP, 14 x 14 mm Body,
1.60/0.15 mm Form, 2.67 mm Thick



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2. DATUM PLANE H LOCATED AT MOLD PARTING LINE AND COINCIDENT WITH LEAD, WHERE LEAD EXITS PLASTIC BODY AT BOTTOM OF PARTING LINE.
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ALL DIMENSIONS ARE IN MILLIMETERS

4.0 Environmental

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
TSTORAGE	Storage Temperature Range	-40 to 125	C
TLEAD	Maximum Lead Temperature (10-second soldering)	235	C
HUMIDITY	Maximum humidity exposure (@ 85C and 100 hours)	85	%RH