Application Note 5330

Introduction

This application note describes the programming of the ADJD-S311-CR999 and ADJD-S371-QR999 in color sensing application. An application example, color LED grouping, reflective sensing and a typical circuit is also provided in this note.

Serial interface protocol.

The programming is done through the serial interface. The serial interface protocol details are described in the datasheet. The device address consists of the most significant 7-bit slave device address and a R/W bit. The 7-bit slave device address is 74H or decimal 116. Thus, the device address for writing is E8H and for reading is E9H. The dataflow diagram for the serial communication is as follows.

For Write, S [Dw] a [R] a [Vw] a P

For Read, S [Dw] a [R] a Sr [Dr] a [Vr] n P

KEY Description

S Start transition from host controller

a Acknowledge bit from device

n Not acknowledge bit sent by host controller to device

Sr Repeat start transition

P Stop transition from host controller

[Dw] ADJD-S311/S371 device write address byte = E8H

[Dr] ADJD-S311/S371 device read address byte = E9H

[R] Device register address byte in the write or read operation

[Vw] Value to write to device register address 'R'

[Vr] Value to read from device register address 'R'

Example:

a) To write a gain setting, 0AH to CAP_RED register (address 06H), the datagram is S [E8] a [06] a [0A] a P

b) To read GSSR register (address 00H), the datagram is S [E8] a [00] a Sr [E9] a [Vr] n P

Key:

S - Start transition

a - Acknowledge bit receive from device

n - Not acknowledge bit send to device

Sr - Repeat start transition

P - Stop transition

[E8] - ADJD-S311/S371 device write address byte = E8H

[E9] - ADJD-S311/S371 device read address byte = E9H

[00] – GSSR is bit 0 of CTRL register address = 00H

[06] – CAP_RED register address = 06H

[0A] – Gain setting 0AH to write to CAP_RED register

[Vr] - Byte value read from device

Programming

Before the ADJD-S311/S371 can be used, a one time sensor gain optimization routine is done so that the digital values ranges from 0 to 1000. Figure 1 show the flowchart to obtain the optimum digital values. Figure 2 show the typical sensor operation flowchart after the sensor gain settings has been obtained.

Sensor Gain Optimization Procedure

This procedure selects gain settings to optimize the digital value. The optimized digital value should never exceed 1000 in normal sensor operation.

1. First perform an external power on reset. Wait 10us for the reset sequence to be completed.
2. Write sensor gain registers, CAP_RED, CAP_GREEN, CAP_BLUE and CAP_CLEAR to select the number of capacitor. The values must range from 00H to 0FH. A higher capacitance value will result in lower sensor output.
3. Write sensor gain registers, INT_RED, INT_GREEN, INT_BLUE and INT_CLEAR to select the integration time. The integration time registers is a 12-bit registers, the values is range from 0 to 4095. A higher value in integration time will generally result in higher sensor digital value if the capacitance gain registers have the same value.

   Example:

   To select 2500 in integration time for red channel:

      Convert decimal 2500 to binary, which is 100111000100_2.

      Write the lowest 8-bit, C4H to INT_RED_LO (address 0AH).

      Write the highest 4-bit, 09H to INT_RED_HI (address 0BH).
4. Acquire sensor digital values by writing 01H to CTRL register (address 00H). Then read CTRL register. When the value is 00H, the sensor digital values are read from the sample data registers (address 40H to 47H). If these sensor digital values are not optimum, do another iteration loop consisting of step 2, 3 and 4.
5. If the sensor digital values obtained in step 4 are optimum, a check is done to ensure that the sensor digital values will never exceed 1000. This is done by selecting running condition or any operating case which the sensor will give maximum value in

   a) red, green and blue channel, or

   b) any of the red, green or blue channels.

   Step 4 is performed again to obtain sensor digital values for these operating cases. If the check shows that the sensor digital values do not exceed 1000, then the sensor gain optimization procedure is completed. The sensor operation procedure can be done or the device can be put to sleep mode.

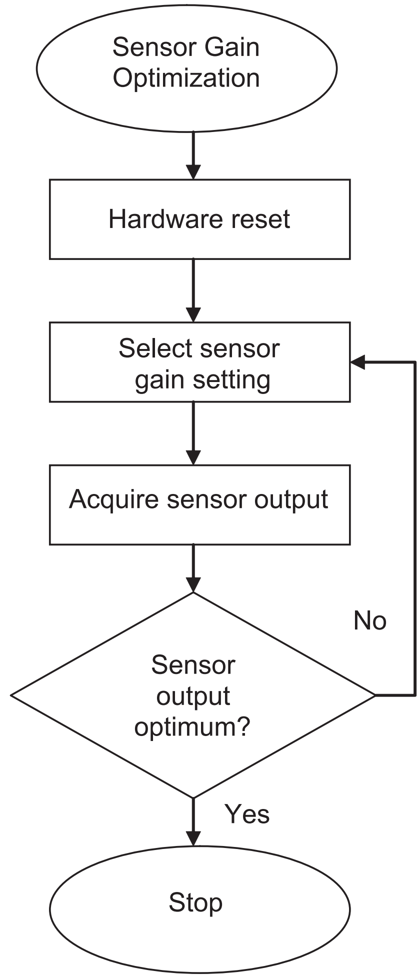

Figure 1. Sensor gain optimization flow chart

Sensor Operation Procedure.

1. First perform an external power on reset. Wait 10us for the reset sequence to be completed.
2. Write sensor gain registers, CAP_RED, CAP_GREEN, CAP_BLUE and CAP_CLEAR with values obtained from the previous sensor gain optimization procedure.
3. Write sensor gain registers, INT_RED, INT_GREEN, INT_BLUE and INT_CLEAR with values obtained from the previous sensor gain optimization procedure.
4. Acquire offsets in normal operating environment. The light source for color sensing must be turned off. The offsets are acquired by writing 02H to CTRL register. The offset values are stored in offset data registers (address 72H, 73H, 74H, 75H). By writing 01H to CONFIG register (address 01H), all digital values of the sensor will automatically trim the offsets.
5. Now the sensor is ready to read colors. Sensor digital values can be acquired by writing 01H to CTRL register (address 00H). Read CTRL register. When the value in CTRL register is 00H, sensor digital values are acquired in sensor sample data registers.

   Repeat step 5 for more sensor readings. If there are no more colors to read, the device can be put to sleep mode.

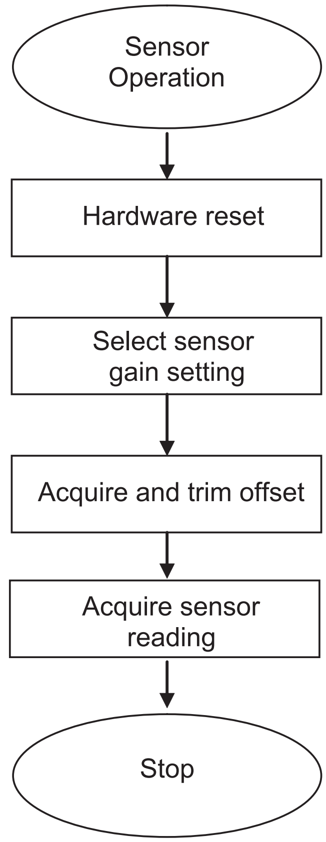

Figure 2. Sensor operation flow chart

Color LED grouping example

An example in transmission color sensing is provided for illustration. LED lamps of three colors, red, green and blue are to be grouped into three colors depending on its light source color. The LED lamps are lighted one by one and grouped according to its color. Refer to figure 3 for an illustration of the setup. The filter-coated photodiode array of the color sensor converts the incident light into digital R, G and B reading. Since all three outputs increase linearly with increasing light intensity, the sensor can measure both color and total intensity of the light.

The sensor readings obtained in step 5 of sensor operation procedure is processed to yield color information which control the binning. The LED is grouped as follows:

a) Red bin if red channel digital value is the highest value.

b) Green bin if green channel digital value is the highest value.

c) Blue bin if blue channel digital value is the highest value.

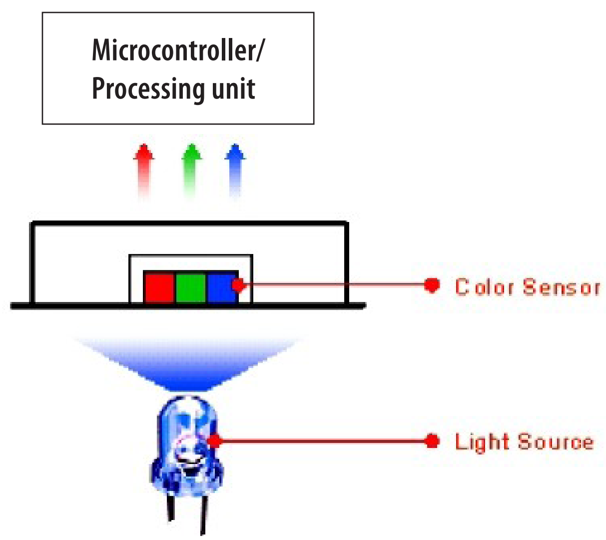

Figure 3. Illustration of LED test setup

The typical circuit for the color sensor application is shown in Fig.4.

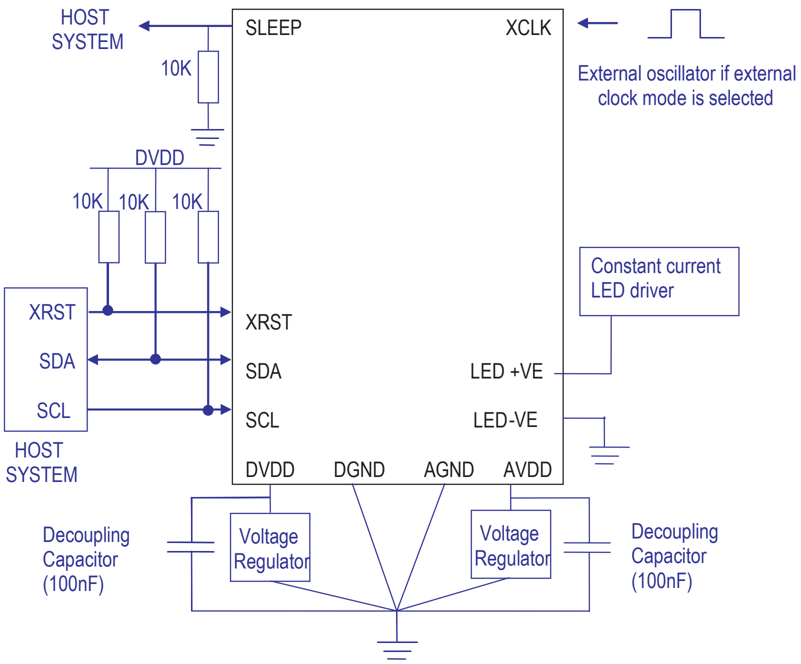

Figure 4. Typical color sensor circuit diagram

Reflective Color Sensing

By definition of reflective sensing, the color sensor detects light reflected from a surface or an object. The sensor module is designed in such a way that both the light source and the color sensor are placed closed to the target surface/object. Light coming from the LED is bounced off a surface/object and measured by the sensor. For a given light source, the color of light reflected off a surface/object is a function of the surface/object color. For example, white light incident onto a red surface is reflected as red. Since any color is uniquely represented by its R, G and B components, the sensor module effectively measures the color of a surface/object by converting the R, G and B components of the reflected light to digital values. By interpreting these digital values, the color of the surface can be determined. In addition, given that the outputs increase linearly with the intensity of reflected light, the sensor also measures the reflectivity of a surface/ object where the clear channel could be use for this purpose.

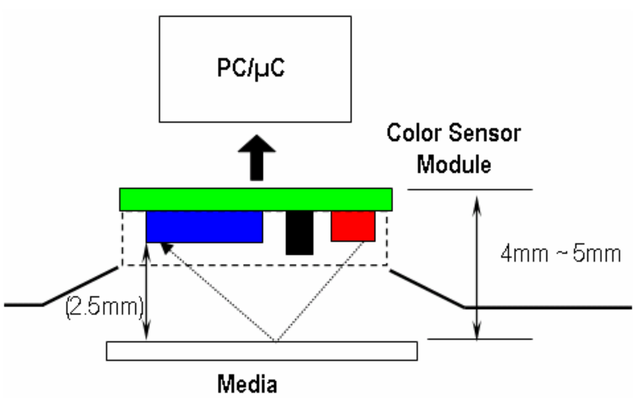

Figure 5. Recommended sensor distance from the media surface

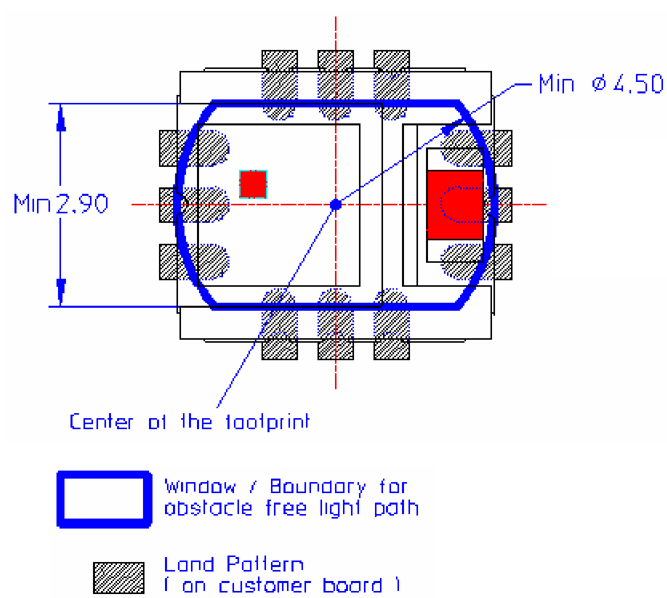

Figure 6. Recommended aperture dimensions with respect to mounting axis for ADJD-S371-QR999

Color Duplication, a Reflective Sensing Example

The figure below shows the block diagram of color duplication application. The white LED illuminates the media while the color sensor will detect the color of the media with the light reflected from the surface. The MCU will then convert this sensor reading to PWM duty cycle that can drive the RGB LED to reproduce the same color as detected.

White Calibration

Before the color sensor can be used for reflective sensing, a one-time white calibration is needed to be done to set the sensor gain to the optimum setting. The white calibration is important to ensure minimal variation between different sensor unit and different LED unit. A white surface is illuminated by LED and detected by sensor with recommended working distance and the microcontroller/tester will perform the calibration.

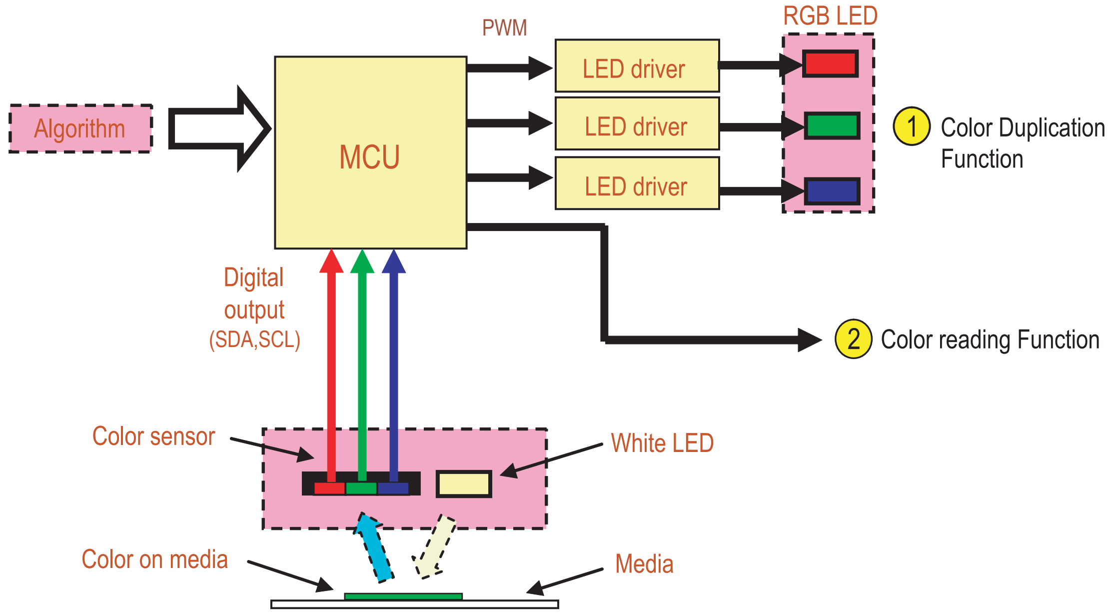

Figure 7. Color duplication block diagram

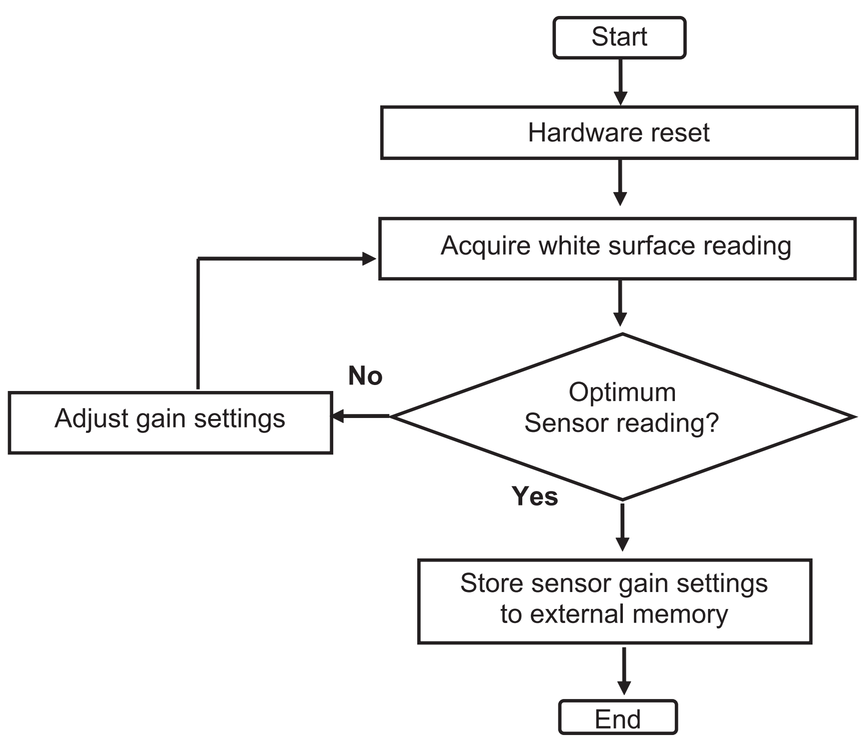

Figure 8. White calibration flow chart

Appendix 1: Sensor registers list

ADD (DEC)	ADD (HEX)	MNEMONIC	RESET	ACCESS	B7	B6	B5	B4	B3	B2	B1	B0
0	0	CTRL	0	R/W	N/A						GOFS	GSSR
1	1	CONFIG	0	R/W	N/A					EXTCLK	SLEEP	TOFS
6	6	CAP_RED	15	R/W	N/A				CAP_RED[3:0]			
7	7	CAP_GREEN	15	R/W	N/A				CAP_GREEN[3:0]			
8	8	CAP_BLUE	15	R/W	N/A				CAP_BLUE[3:0]			
9	9	CAP_CLEAR	15	R/W	N/A				CAP_CLEAR[3:0]			
10	A	INT_RED_LO	0	R/W	INT_RED[7:0]							
11	B	INT_RED_HI	0	R/W					INT_RED[11:8]			
12	C	INT_GREEN_LO	0	R/W	INT_GREEN[7:0]							
13	D	INT_GREEN_HI	0	R/W					INT_GREEN[11:8]			
14	E	INT_BLUE_LO	0	R/W	INT_BLUE[7:0]							
15	F	INT_BLUE_HI	0	R/W					INT_BLUE[11:8]			
16	10	INT_CLEAR_LO	0	R/W	INT_CLEAR[7:0]							
17	11	INT_CLEAR_HI	0	R/W					INT_CLEAR[11:8]			
64	40	DATA_RED_LO	0	R	DATA_RED[7:0]							
65	41	DATA_RED_HI	0	R	N/A						DATA_RED[9:8]	
66	42	DATA_GREEN_LO	0	R	DATA_GREEN[7:0]							
67	43	DATA_GREEN_HI	0	R	N/A						DATA_GREEN[9:8]	
68	44	DATA_BLUE_LO	0	R	DATA_BLUE[7:0]							
69	45	DATA_BLUE_HI	0	R	N/A						DATA_BLUE[9:8]	
70	46	DATA_CLEAR_LO	0	R	DATA_CLEAR[7:0]							
71	47	DATA_CLEAR_HI	0	R	N/A						DATA_CLEAR[9:8]	
72	48	OFFSET_RED	0	R	SIGN_RED	OFFSET_RED[6:0]						
73	49	OFFSET_GREEN	0	R	SIGN_GREEN	OFFSET_GREEN[6:0]						
74	4A	OFFSET_BLUE	0	R	SIGN_BLUE	OFFSET_BLUE[6:0]						
75	4B	OFFSET_CLEAR	0	R	SIGN_CLEAR	OFFSET_CLEAR[6:0]						

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