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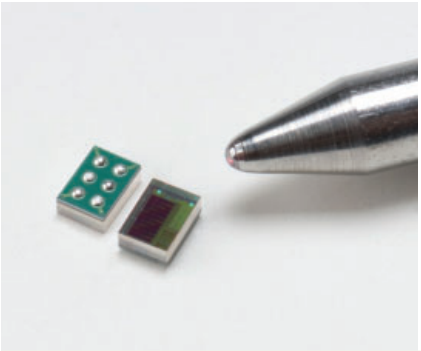
Color sensor



S11059-01WT

I²C interface-compatible color sensor

The S11059-01WT is a color sensor that supports the I²C (inter-integrated circuit) interface. It is sensitive to red (λ=615 nm), green (λ=530 nm), blue (λ=460 nm), and infrared (λ=855 nm) light, and outputs detected results as 16-bit digital data for each color. The photodiode for each color is automatically switched sequentially to perform measurements. The sensitivity and integration time can be adjusted so that light measurements can be performed over a wide range.

Features

- **I²C interface compatible**
- **Sequential measurements of red, green, blue, and infrared light**
- **2-step sensitivity switching (sensitivity ratio 1 : 10)**
- **Sensitivity adjustment by setting the integration time**
- **Low voltage (2.5 V or 3.3 V) operation**
- **Low current consumption: 75 µA typ.**
- **Small package (WL-CSP: wafer level-chip size package)**
- **Internal infrared-cut filter**
- **Wide dynamic range (Low gain: 1 to 10 k*lx*)**

Applications

- **LCD backlight adjustment for cell phones, notebook PC, etc.**
- **Energy-saving sensor for large-size TV, etc.**
- **Various types of light detection or color adjustment**

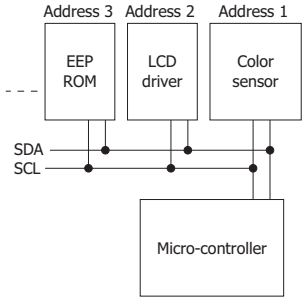
Feature 01 I²C interface-compatible to allow direct connection to micro-controller

The sensor supports the I²C interface and so can exchange data with the micro-controller using two signal lines jointly usable with other devices. The digital output makes it easy to install into electronic devices such as cell phones and flat-panel TVs whose micro-controller is compatible with the I²C interface. The sensor supports I²C Fast mode (400 kHz) and operates on 2.25 to 3.63 V.

Feature 02 WL-CSP makes the device even smaller and highly reliable

The WL-CSP measures only 1.18 × 1.68 × 0.58 mm and lead-free reflow solder (260 °C) can be used.

Connection example of I²C interface



SDA: serial data
SCL: serial clock

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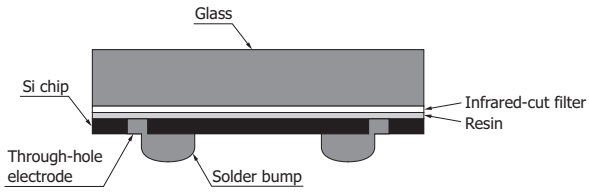
Cross section of WL-CSP



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Absolute maximum ratings (Ta=25 °C)

Parameter	Symbol	Value	Unit
Supply voltage	Vdd	-0.3 to +6	V
Load current	Io	±10	mA
Power dissipation	P	100	mW
Operating temperature	Topr	-40 to +85	°C
Storage temperature	Tstg	-40 to +100	°C
Reflow soldering conditions *1	Tsol	Peak temperature 260 °C, 3 times	-

*1: Moisture absorption and reflow conditions: JEDEC J-STD-020D LEVEL2a

Recommended operating conditions

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Supply voltage	Vdd		2.25	-	3.63	V
I^2C bus pull-up voltage	Vbus	Rp *2=2.2 kΩ	1.65	-	Vdd + 0.5	V
High level input voltage (SDA, SCL)	Vih	Vbus≥2.25 V, Vdd>2.75 V	0.7Vbus	-	Vdd + 0.5	V
		Vbus<2.25 V, Vdd≤2.75 V	0.8Vbus	-	Vdd + 0.5	
Low level input voltage (SDA, SCL)	Vil	Vbus≥2.25 V, Vdd>2.75 V	-0.5	-	0.2Vbus	V
		Vbus<2.25 V, Vdd≤2.75 V	-0.5	-	0.3Vbus	
Bus capacitance (SDA, SCL)	Cbus		-	-	400	pF

*2: Pull-up resistor value is determined by Cbus and Vbus.

Electrical and optical characteristics

■ Sensor section [Ta=25 °C, Vdd=3.3 V, A light source, unless otherwise noted (initial setting: low gain, integration time: 546 ms/ch)]

Parameter		Symbol	Condition		Min.	Typ.	Max.	Unit
Spectral response range *3		λ	Blue			400 to 540		nm
			Green			455 to 630		
			Red			575 to 660		
			Infrared, more than 700 nm			785 to 885		
Peak sensitivity wavelength		λp	Blue		-	460	-	nm
			Green		-	530	-	
			Red		-	615	-	
			Infrared, more than 700 nm		-	855	-	
Current consumption	Operating mode	Idd	E=0 lx (dark state), excluding output current		30	75	150	μA
	Standby mode	Idds			0.1	1.0	3.0	
Dark count		Sd	E=0 lx (dark state)		-	-	5	counts
Gain ratio		rg	High gain/Low gain		-	10	-	-
Photo sensitivity	Low gain	Sbl	Blue	Initial setting	2.01	3.35	4.69	counts/lx
		Sgl	Green		4.57	7.61	10.66	
		Srl	Red		5.69	9.48	13.28	
		Sirl	Infrared		-	1.66	-	
		Sbl	Blue	Initial setting *4	2.51	3.35	4.19	
		Sgl	Green		5.71	7.61	9.52	
		Srl	Red		7.11	9.48	11.85	
		Sirl	Infrared		-	1.66	-	
Red/Blue sensi. ratio	Low gain	Srl/Sbl	Initial setting Same chip		2.12	2.83	3.54	-
Red/Green sensi. ratio		Srl/Sgl			0.93	1.25	1.56	
Blue/Green sensi. ratio		Sbl/Sgl			0.33	0.44	0.55	
Photo sensitivity	High gain	Sbh	Blue	Integration time: 546 ms/ch	19.0	31.7	44.4	counts/lx
		Sgh	Green		45.7	76.2	106.7	
		Srh	Red		56.7	94.5	132.4	
		Sirh	Infrared		-	15.3	-	
		Sbh	Blue	Integration time: 546 ms/ch *4	23.8	31.7	39.7	
		Sgh	Green		57.2	76.2	95.3	
		Srh	Red		70.9	94.5	118.2	
		Sirh	Infrared		-	15.3	-	
Red/Blue sensi. ratio	High gain	Srh/Sbh	Integration time: 546 ms/ch Same chip		2.24	2.98	3.73	-
Red/Green sensi. ratio		Srh/Sgh			0.93	1.24	1.55	
Blue/Green sensi. ratio		Sbh/Sgh			0.31	0.42	0.52	

*3: Relative sensitivity=more than 10%

*4: Integration time is measured and corrected. See "Compensation method for sensitivity variation". Integration time measurement accuracy is 0.36%.

■ I²C section (Ta=25 °C, Vdd=3.3 V, unless otherwise noted)

Parameter		Symbol	Condition	Min.	Typ.	Max.	Unit
I²C address		ADDR	7 bits		0x2A (0101010)		
I²C clock frequency		fclk		1	-	400	kHz
SDA, SCL output voltage	High level	Voh	Rp=2.2 kΩ	0.7Vbus	-	-	V
	Low level	Vol	Rp=2.2 kΩ	0	-	0.4	V
Input/output terminal capacitance		Ci		-	-	20	pF
SDA/SCL output fall time *5		tf	Rp=2.2 kΩ, Cp=400 pF	-	-	250	ns

*5: SCL/SDA output rise time is determined by a time constant of Cbus × Rp.
Note: The I²C interface (SDA, SCL) timings conform to the "I²C bus specification version 2.1".

Register map

Adrs	Function	bit							
		7	6	5	4	3	2	1	0
00	Control	ADC reset 1: Reset 0: Operation	Standby function 1: Standby mode 0: Operating mode	Standby function monitor	-	Gain selection 1: High gain 0: Low gain	Integration mode 1: Manual setting mode 0: Fixed period mode	Integration time setting (00) 87.5 µs, (01) 1.4 ms (10) 22.4 ms, (11) 179.2 ms	
01	Manual timing register	Integration time manual setting register (MSB)							
02		Integration time manual setting register (LSB)							
03	Sensor data register (red)	Output data (red, MSB)							
04		Output data (red, LSB)							
05	Sensor data register (green)	Output data (green, MSB)							
06		Output data (green, LSB)							
07	Sensor data register (blue)	Output data (blue, MSB)							
08		Output data (blue, LSB)							
09	Sensor data register (infrared)	Output data (infrared, MSB)							
0A		Output data (infrared, LSB)							

Adrs 00 bit 7: Asserting this bit to "1", the ADC block is reset. The register data is not reset. To start the operation, set this bit to "0".
Adrs 00 bit 6: Asserting this bit to "1" the device goes into standby mode. The ADC block stops its operation. The register data is not reset. To start the operation, set this bit to "0".
Adrs 00 bit 5: This monitors auto standby function. "1" means standby mode. This is read only.
Adrs 00 bit 3: Gain selection bit. "1" is high gain mode and "0" is low gain mode. This bit is selecting the photodiode area. The size ratio of high gain photodiode area and low gain photodiode area is 10 : 1. Therefore the gain ratio is 10 times from low to high.
Adrs 00 bit 2: Asserting this bit to "1", the device goes into manual setting mode. Deasserting this bit to 0, goes into fixed period mode. In manual setting mode, the S11059-01WT automatically goes to standby mode after a measurement is made. In fixed period mode, measurements are continuously repeated.
Adrs 00 bit 1,0: These bits select the period of internal basis clock. The period is equal to integration time per color in fixed period mode. "00" is 87.5 us, "01" is 1.4 ms, "10" is 22.4 ms, "11" is 179.2 ms. In manual setting mode, "00" is 175 µs, "01" is 2.8 ms, "10" is 44.8 ms, "11" is 368 ms. The integration time per color is set to multiple value (Adrs 01 & 02) with the period.
Adrs 01 & 02: This is a multiple value setting in manual setting mode, and can be set to a minimum of 0x0000 and a maximum of 0xFFFF (65535). This is used to set how far to expand the integration time per color which specified by "Integration time setting" (Tint). For example, if you want to set the integration time per color to 546 ms, set 175 µs by Tint="00" and then set this register to N=3120 (0xC30).

Mode	Manual timing register (Adrs 01 & 02)	Integration time setting (Tint)			
		00	01	10	11
Fixed period mode	Disabled	87.5 µs	1.4 ms	22.4 ms	179.2 ms
Manual setting mode	N	175 × N µs	2.8 × N ms	44.8 × N ms	358.4 × N ms

Adrs 03 to 0A: These bytes are register for sensor data. S11059-01WT measurement result is stored in these registers when the I²C command is changed to read mode. The values are kept until next read cycle.

Initial setting [Low gain, manual setting mode, Tint=00 (175 µs), integartion time 546 ms/ch]

Adrs	Function	bit								Hex
		7	6	5	4	3	2	1	0	
00	Control	1	1	1	-	0	1	0	0	0xE4
01	Manual timing register	0	0	0	0	1	1	0	0	0x0C
02		0	0	1	1	0	0	0	0	0x30

Program example

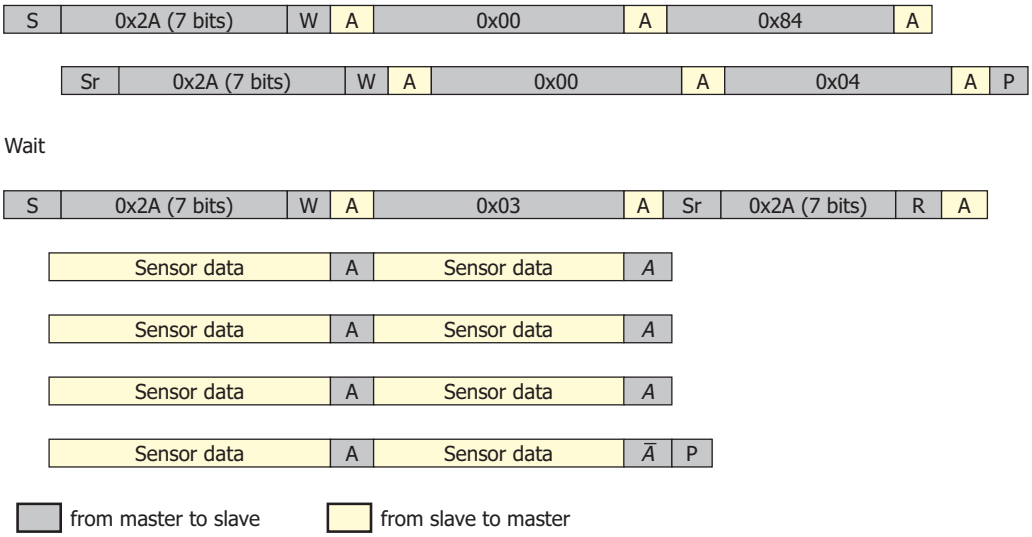
Condition 1: Initial setting [manual setting mode, low gain, Tint=00 (175 µs), integration time 546 ms/ch (0x0C30 is set in manual timing register)]

Command

Action		Data body								Ack	Remark
Address call (0x2A)	S	0	1	0	1	0	1	0	W	A	7-bit address
Register call (0x00)		0	0	0	0	0	0	0	0	A	Calls control byte
Register write (0x84)		1	0	0	0	0	1	0	0	A	ADC reset, standby disabled
Address call (0x2A)	Sr	0	1	0	1	0	1	0	W	A	Restart, address
Register call (0x00)		0	0	0	0	0	0	0	0	A	Calls control byte
Register write (0x04)		0	0	0	0	0	1	0	0	A	P ADC reset disabled, bus release
Wait longer than integration time (>2184 ms)											
Address call (0x2A)	S	0	1	0	1	0	1	0	W	A	7-bit address
Register call (0x03)		0	0	0	0	0	0	1	1	A	Calls output data byte
Address call (0x2A)	Sr	0	1	0	1	0	1	0	R	A	Changes to read mode
Data read out (R: MSB)		X	X	X	X	X	X	X	X	*A*	Red data output
Data read out (R: LSB)		X	X	X	X	X	X	X	X	*A*	
Data read out (G: MSB)		X	X	X	X	X	X	X	X	*A*	Green data output
Data read out (G: LSB)		X	X	X	X	X	X	X	X	*A*	
Data read out (B: MSB)		X	X	X	X	X	X	X	X	*A*	Blue data output
Data read out (B: LSB)		X	X	X	X	X	X	X	X	*A*	
Data read out (Infrared: MSB)		X	X	X	X	X	X	X	X	*A*	Infrared data output
Data read out (Infrared: LSB)		X	X	X	X	X	X	X	X	$\overline{A}$	P

S=Start condition, Sr=Restart condition, A=Acknowledge, *A*=Acknowledge by host, P=Stop condition, R=Read mode (1), W=Write mode (0), $\overline{A}$=not acknowledge

Format



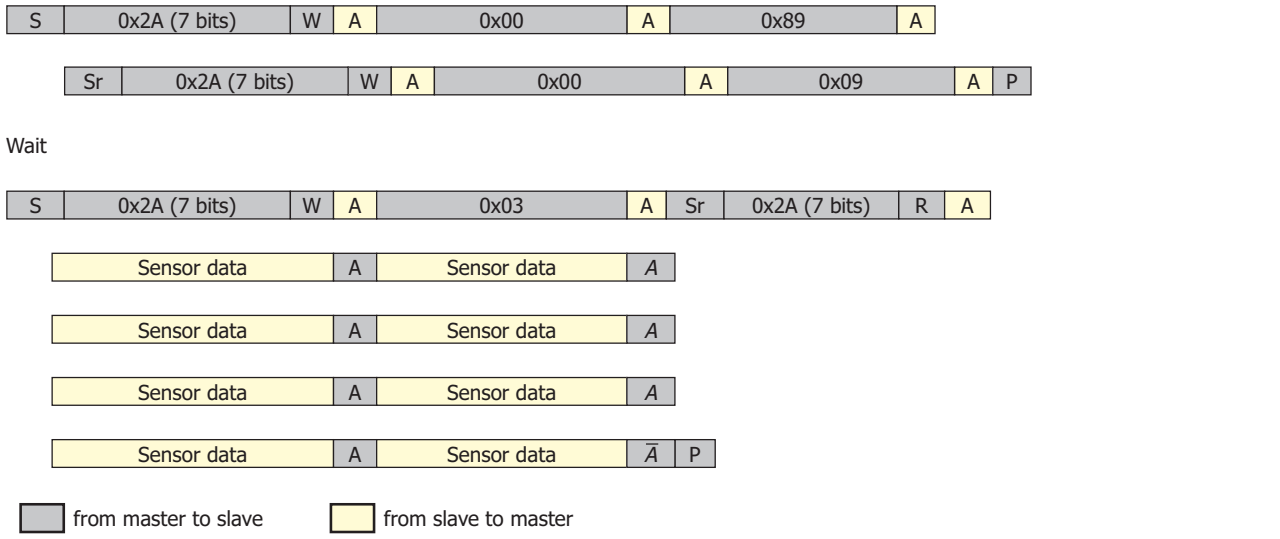
Condition 2 [fixed period mode, high gain, Tint=01 (1.4 ms), integration time 1.4 ms/ch]

■ Command

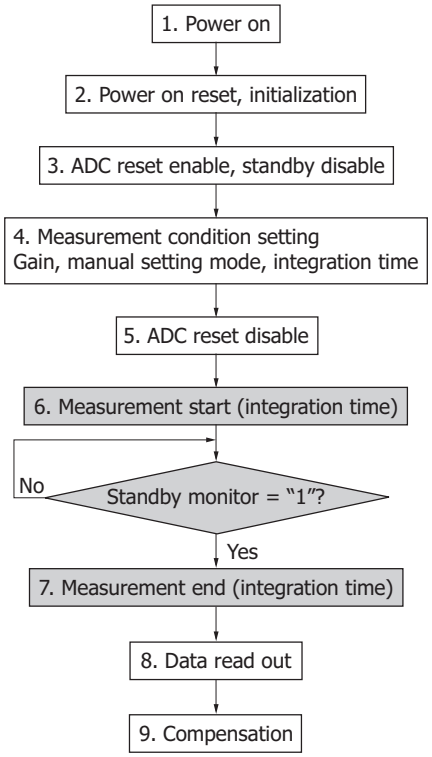
Action		Data body								Ack	Remark
Address call (0x2A)	S	0	1	0	1	0	1	0	W	A	7-bit address
Register call (0x00)		0	0	0	0	0	0	0	0	A	Calls control byte
Register write (0x89)		1	0	0	0	1	0	0	1	A	ADC reset, standby disabled
Address call (0x2A)	Sr	0	1	0	1	0	1	0	W	A	7-bit address
Register call (0x00)		0	0	0	0	0	0	0	0	A	Calls control byte
Resistor write (0x09)		0	0	0	0	1	0	0	1	A	P ADC reset disabled, bus release
Wait longer than integration time (> 5.6 ms). Within this period, repeat measurement is continued.											
Address call (0x2A)	S	0	1	0	1	0	1	0	W	A	7-bit address
Register call (0x03)		0	0	0	0	0	0	1	1	A	Calls output data byte
Address call (0x2A)	Sr	0	1	0	1	0	1	0	R	A	Changes to read mode
Data read out (R: MSB)		X	X	X	X	X	X	X	X	*A*	Red data output
Data read out (R: LSB)		X	X	X	X	X	X	X	X	*A*	
Data read out (G: MSB)		X	X	X	X	X	X	X	X	*A*	Green data output
Data read out (G: LSB)		X	X	X	X	X	X	X	X	*A*	
Data read out (B: MSB)		X	X	X	X	X	X	X	X	*A*	Blue data output
Data read out (B: LSB)		X	X	X	X	X	X	X	X	*A*	
Data read out (Infrared: MSB)		X	X	X	X	X	X	X	X	*A*	Infrared data output
Data read out (Infrared: LSB)		X	X	X	X	X	X	X	X	$\overline{A}$	P

S=Start condition, Sr=Restart condition, A=Acknowledge, *A*=Acknowledge by host, P=Stop condition, R=Read mode(1), W=Write mode(0), $\overline{A}$=not acknowledge

■ Format



Compensation method for sensitivity variation



Sensitivity variation can be decreased using the compensation coefficient which is calculated from the integration time measurement result. Explanation of compensation method is shown as follows.

Integration time measurement method

In case of integration time measurement, it is necessary to set manual setting mode. The integration time measurement starts after "ADC reset" disabled. To measure the finishing integration time (measurement) Tmeas, check "Standby monitor" bit until it becomes to "1".

Compensation method

The sensitivity compensation that used integration time is as follows:

$$K = \frac{Tset}{Tmeas}$$

$$S' = S \cdot K$$

K : compensation coefficient
Tset : integration time (setting)
Tmeas: integration time (measurement)
S : photo sensitivity (measurement)
S' : photo sensitivity (compensation)

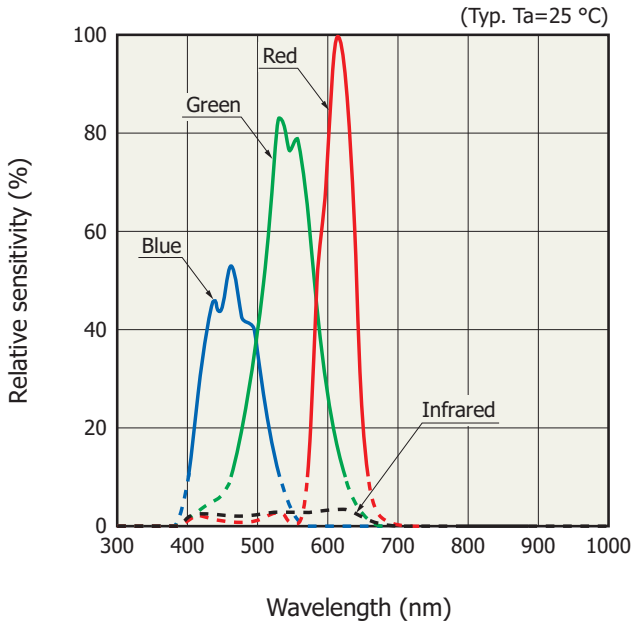
Measurement accuracy of integration time

The measurement minimum resolution of Tmeas is defined by the looping duration (Tunit). In case of default setting, the Tset is 2184 ms and assuming the Tunit to 7.8 ms, the accuracy of integration time is calulated by following formula.

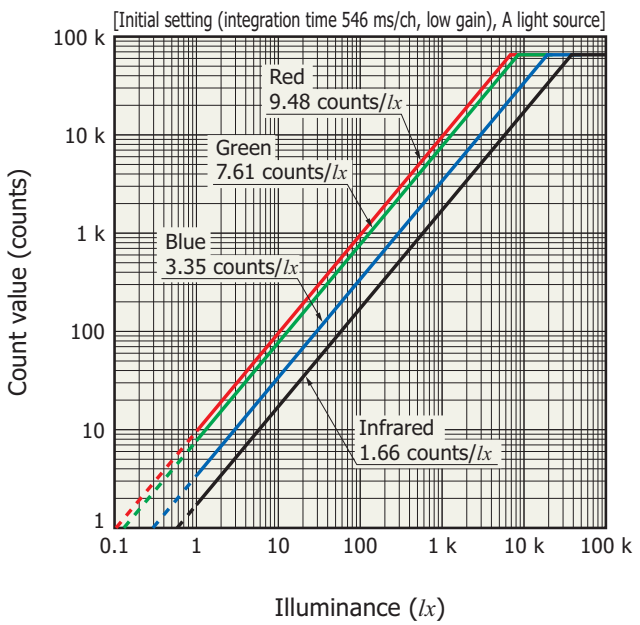
$$\frac{Tunit}{Tset} \times 100 = \frac{7.8}{2184} \times 100 = 0.36\%$$

The specification of compensated sensitivity is defined as 0.36% accuracy.

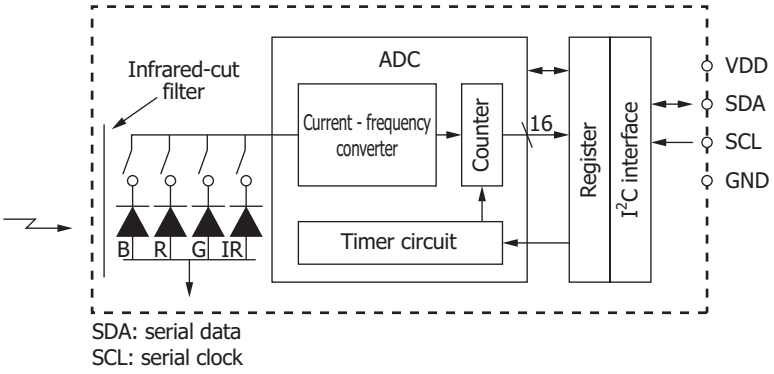
Spectral response



Count value vs. illuminance (typical example)



Block diagram



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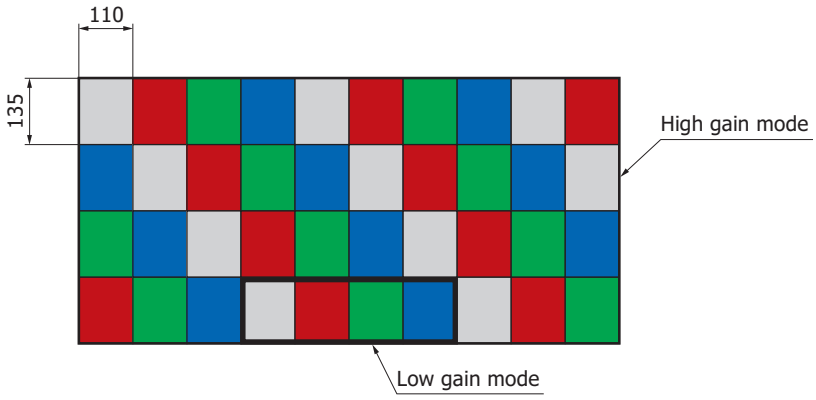
Details of active area (unit: µm)



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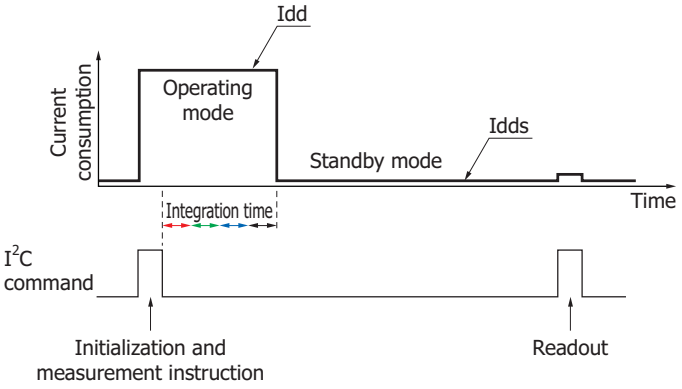
Timing chart of standby function



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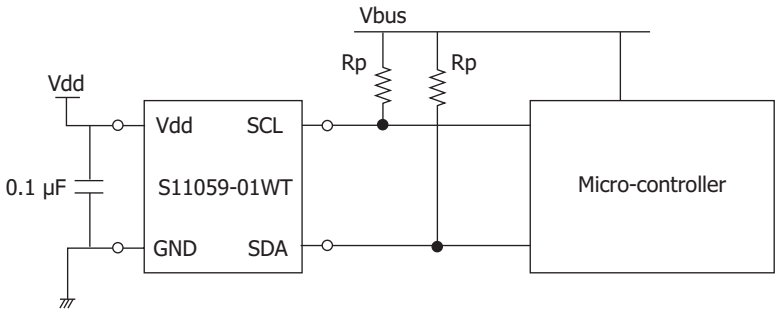
Connection example



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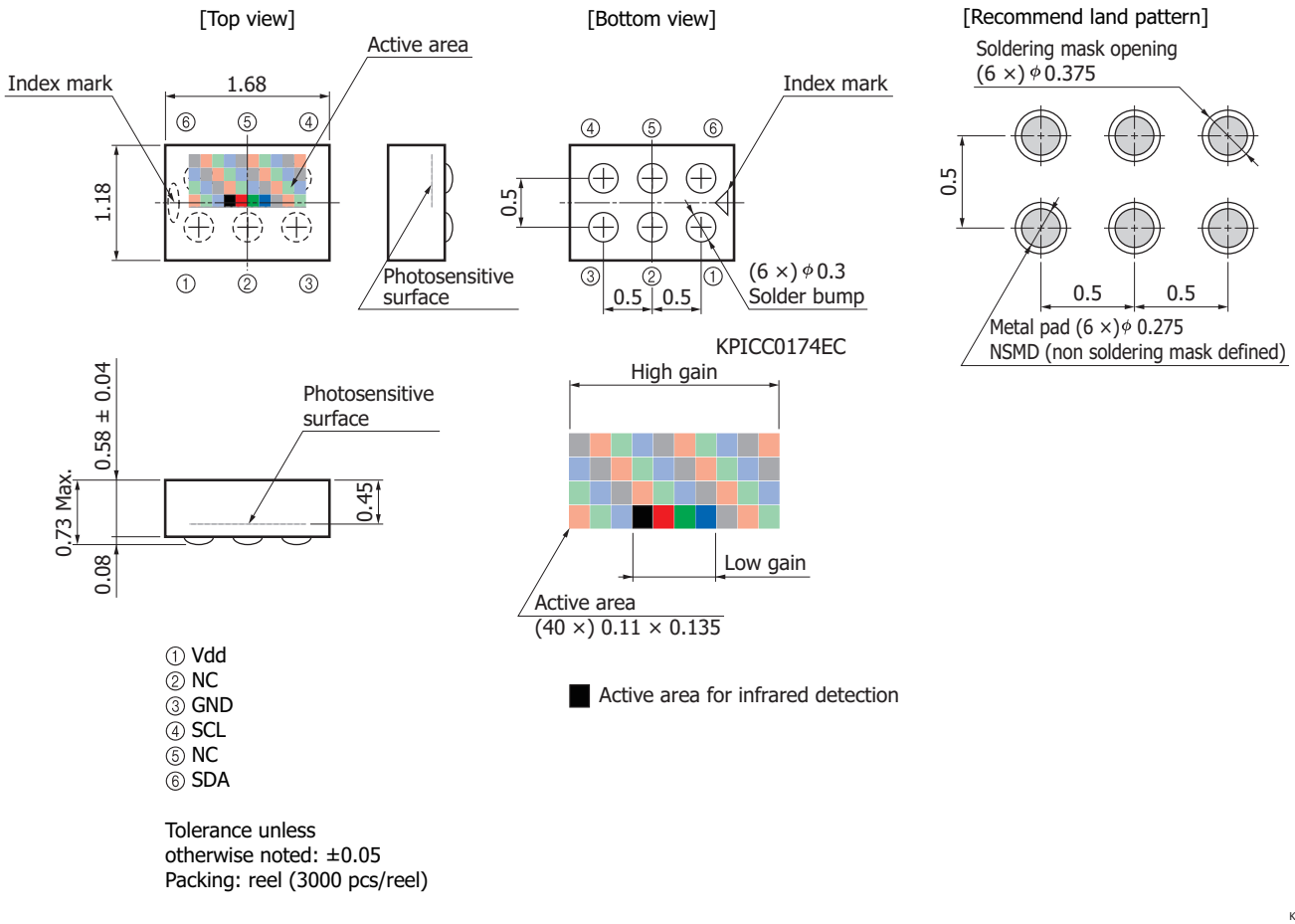
Dimensional outline (unit: mm)



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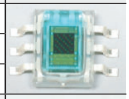
Note: When using this product, please request our technical information (S11059 series) and ensure appropriate design according to the information.

Line-up of RGB color sensors

Type No.	Type	Active area size (mm)	Package (mm)	Peak sensitivity wavelength (nm)		Photo sensitivity						Photo
S9032-02	Photodiode	 ϕ2.0	4 × 4.8 × 1.8^{t} 6-pin (filter 0.75^{t})	B	460	B	0.18 (A/W) [λ=460 nm]					
				G	540	G	0.23 (A/W) [λ=540 nm]					
				R	620	R	0.16 (A/W) [λ=620 nm]					
S9702	Photodiode	 1.0 × 1.0	3 × 4 × 1.3^{t} 4-pin (filter 0.75^{t})	B	460	B	0.18 (A/W) [λ=460 nm]					
				G	540	G	0.23 (A/W) [λ=540 nm]					
				R	620	R	0.16 (A/W) [λ=620 nm]					
S10917-35GT	Photodiode	 1.0 × 1.0	3 × 1.6 × 1.0^{t} COB (on-chip filter)	B	460	B	0.2 (A/W) [λ=460 nm]					
				G	540	G	0.23 (A/W) [λ=540 nm]					
				R	620	R	0.17 (A/W) [λ=620 nm]					
S10942-01CT	Photodiode	 1.0 × 1.0	3 × 1.6 × 1.0^{t} COB (on-chip filter)	*6		B	0.21 (A/W) [λ=460 nm]					
						G	0.25 (A/W) [λ=540 nm]					
						R	0.45 (A/W) [λ=640 nm]					
S9706	Digital Photo IC	 1.2 × 1.2	4 × 4.8 × 1.8^{t} 6-pin (filter 0.75^{t})	B	465	Low	B	0.21 (LSB/lx)	High	B	1.9 (LSB/lx)	
				G	540		G	0.45 (LSB/lx)		G	4.1 (LSB/lx)	
				R	615		R	0.64 (LSB/lx)		R	5.8 (LSB/lx)	
S11059-01WT	I^{2}C interface-compatible color sensor	1.22 × 0.56	1.68 × 1.18 × 0.58^{t} WL-CSP (on-chip filter)	B	460	Low	B	3.35 (counts/lx)	High	B	31.7 (counts/lx)	
				G	530		G	7.61 (counts/lx)		G	76.2 (counts/lx)	
				R	615		R	9.48 (counts/lx)		R	94.5 (counts/lx)	
				IR	855		IR	1.66 (counts/lx)		IR	15.3 (counts/lx)	

*6: Refer to "Spectral response" of "Si photodiode S10942-01CT" datasheet.

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