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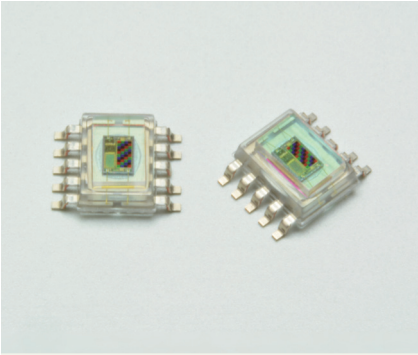
Color sensors



S13683-03DT/-04DS

I²C interface-compatible color sensor

The S13683-03DT/-04DS is a digital color sensor that supports the I²C (inter-integrated circuit) interface. It is sensitive to red (λ=615 nm), green (λ=530 nm), and blue (λ=460 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 light, and correction channel**
- **Correction channel**
  The channels detect incident light that does not pass the filter.
  The product subtracts the correction channel output with internal processing to obtain high accuracy RGB data.
- **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.**
- **With internal infrared-cut filter**
- **Wide dynamic range (Low gain: 1 to 10 k*lx*)**
- **Standard packing state**
  S13683-03DT: reel
  S13683-04DS: stick

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**

Absolute maximum ratings

Parameter	Symbol	Condition	Value	Unit
Supply voltage	Vdd	Ta=25 °C	-0.3 to +4.5	V
Output current	Io	Ta=25 °C	±10	mA
Power dissipation	P	Ta=25 °C	300	mW
Operating temperature	Topr	No dew condensation*1	-40 to +85	°C
Storage temperature	Tstg	No dew condensation*1	-40 to +105	°C
Soldering temperature*2	Tsol		240 (once)	°C

*1: When there is a temperature difference between a product and the surrounding area in high humidity environment, dew condensation may occur on the product surface. Dew condensation on the product may cause deterioration in characteristics and reliability.
*2: Reflow soldering, IPC/JEDEC J-STD-020 MSL 5a, see P. 10
Note: Exceeding the absolute maximum ratings even momentarily may cause a drop in product quality. Always be sure to use the product within the absolute maximum ratings.

Recommended operating conditions (Ta=25 °C unless otherwise noted)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Supply voltage	Vdd		2.25	-	3.63	V
I^2C bus pull-up voltage*3	Vbus	Rp=2.2 kΩ	1.65	-	Vdd + 0.5	V
High level input voltage (SDA, SCL)*4	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	V
Low level input voltage (SDA, SCL)*4	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	V
Bus capacitance (SDA, SCL)	Cbus		-	-	400	pF

*3: For details, see the I^2C specifications, "The I^2C-BUS SPECIFICATION VERSION 2.1".
*4: Vdd - Vbus<1.2 V
Operation is not guaranteed if this condition is not met.

Electrical and optical characteristics

■ Sensor section [Ta=25 °C, Vdd=Vbus=3.3 V, A light source, unless otherwise noted (initial setting: low gain, integration time: 546 ms/ch)]*5

Parameter		Symbol	Condition		Min.	Typ.	Max.	Unit
Spectral response range*6		λ	Blue			400 to 540		nm
			Green			455 to 630		
			Red			575 to 660		
Peak sensitivity wavelength		λp	Blue		-	460	-	nm
			Green		-	530	-	
			Red		-	615	-	
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	-	-
Photosensitivity	Low gain	Sbl	Blue	Initial setting	2.0	3.8	5.6	counts/*lx*
		Sgl	Green		4.7	8.7	12.7	
		Srl	Red		6.8	12.4	18.0	
		Scol	Correction ch		-	3.0	-	
		Sbl	Blue	Initial setting*6	2.8	3.8	4.8	
		Sgl	Green		6.5	8.7	11.0	
		Srl	Red		8.6	12.4	16.2	
		Scol	Correction ch		-	3.0	-	
Red/Blue sensi. ratio	Low gain	Srl/Sbl	Initial setting Same chip		2.4	3.2	4.0	-
Red/Green sensi. ratio		Srl/Sgl			1.05	1.4	1.75	
Blue/Green sensi. ratio		Sbl/Sgl			0.33	0.44	0.55	
Photosensitivity	High gain	Sbh	Blue	Integration time 546 ms/ch	22.0	40.0	58.0	counts/*lx*
		Sgh	Green		47.0	86.0	125.0	
		Srh	Red		67.0	122.0	177.0	
		Scoh	Correction ch		-	30.0	-	
		Sbh	Blue	Integration time 546 ms/ch*7	30.0	40.0	50.0	
		Sgh	Green		64.5	86.0	107.5	
		Srh	Red		85.0	122.0	159.0	
		Scoh	Correction ch		-	30.0	-	
Red/Blue sensi. ratio	High gain	Srh/Sbh	Integration time 546 ms/ch Same chip		2.25	3.0	3.75	-
Red/Green sensi. ratio		Srh/Sgh			1.05	1.40	1.75	
Blue/Green sensi. ratio		Sbh/Sgh			0.35	0.47	0.59	

*5: Provide light shielding so that no light enters from anywhere other than the top surface of the filter.
*6: Relative sensitivity=more than 10%
*7: 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	0.7 Vbus	-	-	V
	Low level	Vol	Rp=2.2 kΩ	0	-	0.4	V
Input/output terminal capacitance		Ci		-	-	20	pF
SDA/SCL output fall time*8		tf	Rp=2.2 kΩ, Cp=400 pF	-	-	250	ns

*8: 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 (correction ch)	Output data (correction ch, MSB)							
0A		Output data (correction ch, 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 S11059-02DT 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. S11059-02DT measurement result is stored in these registers when the I²C command is changed to read mode. The values are kept until the next measurement 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

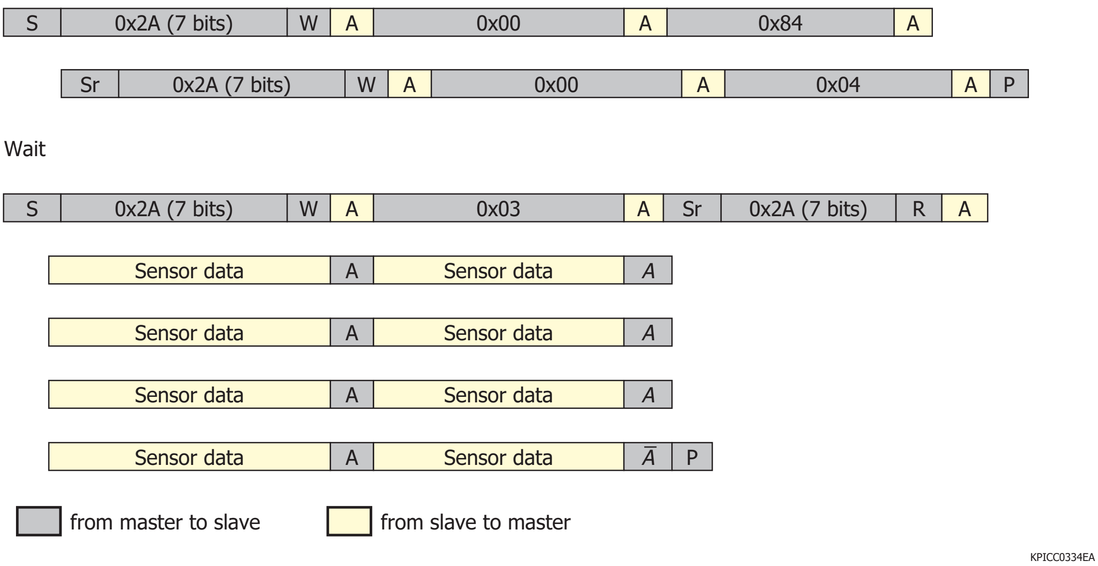
Condition 1: Initial setting [manual setting mode, low gain, Tint=00 (175 μs), integration time 546 ms/ch (0x0C30 is set in manual timing register)]

■ 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 (Correction ch: MSB)		X	X	X	X	X	X	X	X	*A*	Correction ch data output
Data read out (Correction ch: LSB)		X	X	X	X	X	X	X	X	$\bar{A}$	P

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

■ Format



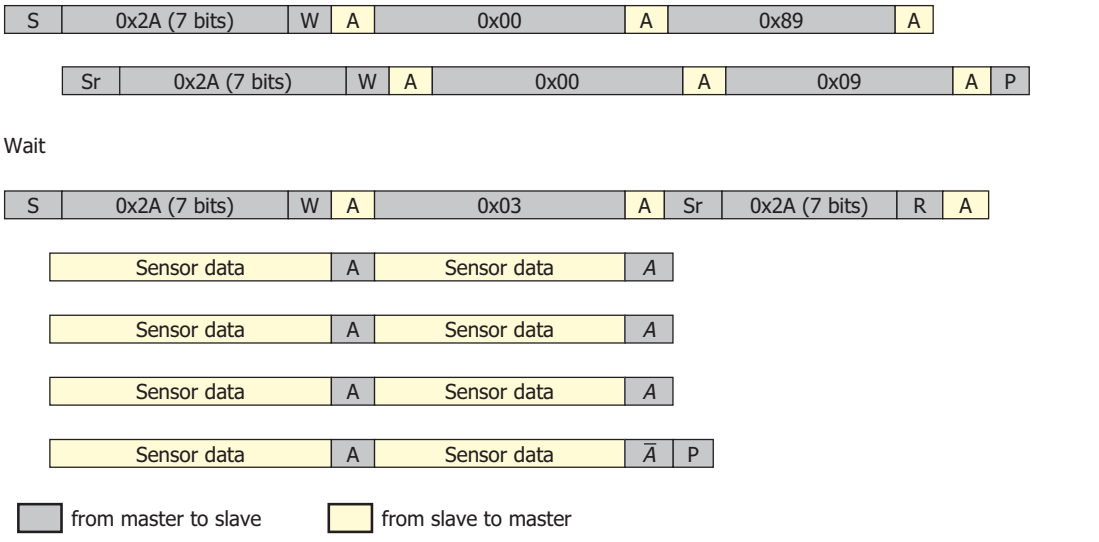
Condition 2 [fixed period mode, high gain, Tint=01 (1.4 ms), integration time 1.4 ms/ch]

■ 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 (Correction ch: MSB)		X	X	X	X	X	X	X	X	*A*	Correction ch data output
Data read out (Correction ch: 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



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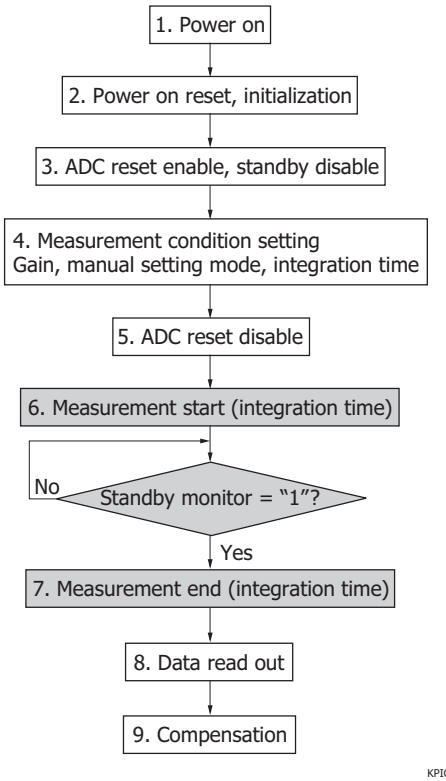
Compensation method for sensitivity variation



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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)

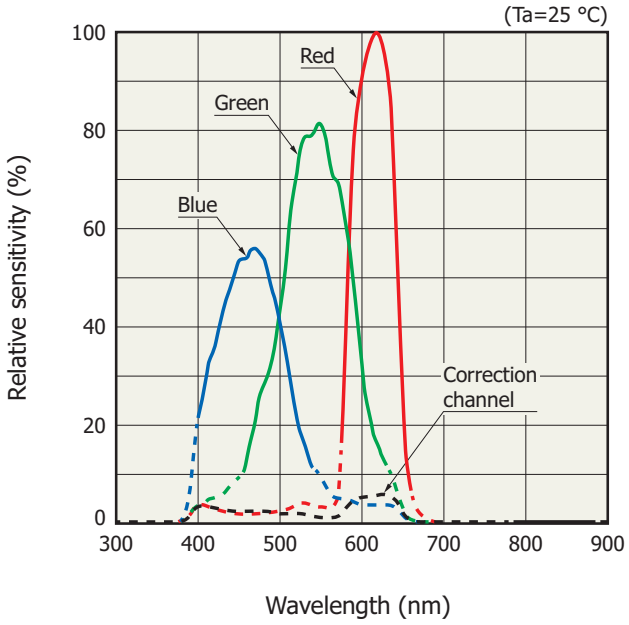
Measurement accuracy of integration time

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 calculated 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 (typical example)



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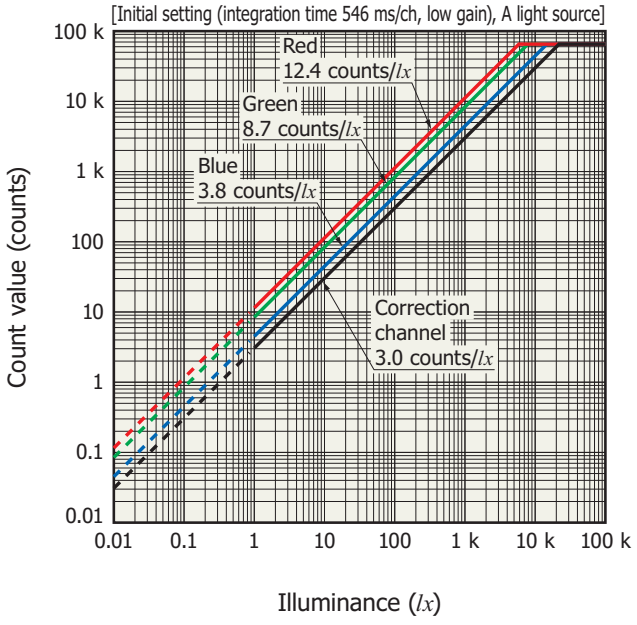
Count value vs. illuminance (typical example)



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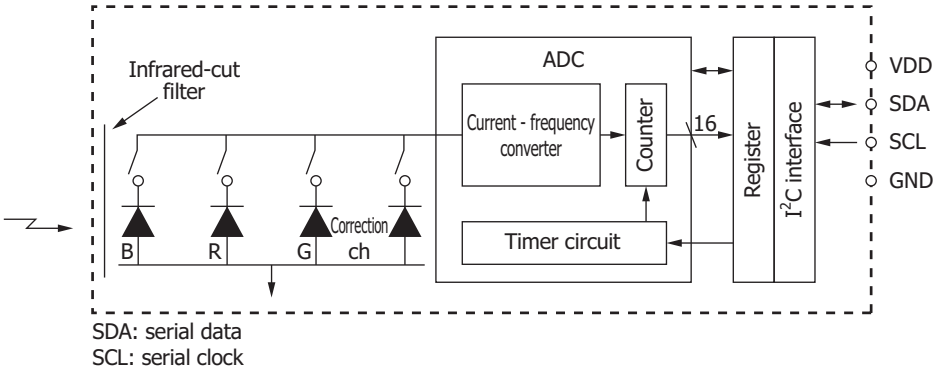
Block diagram



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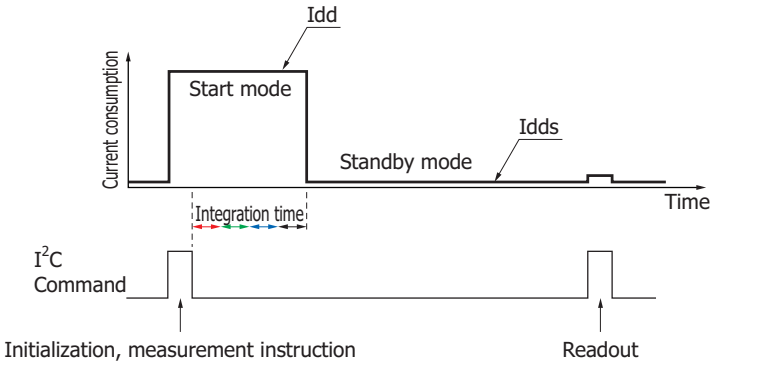
Timing chart of standby function



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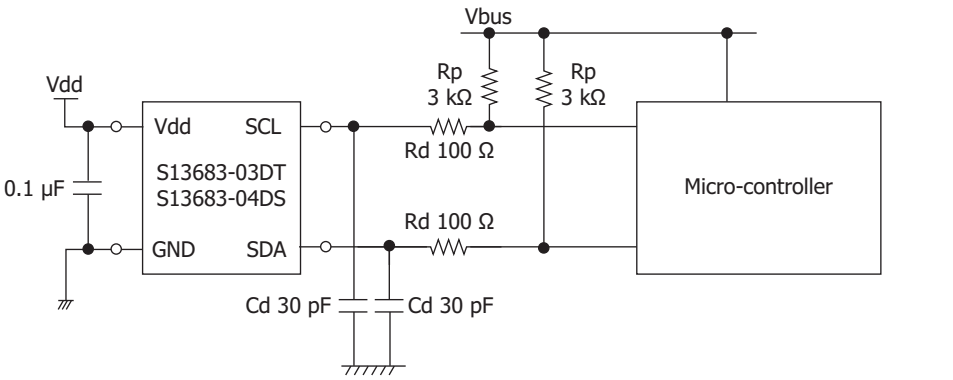
Connection example



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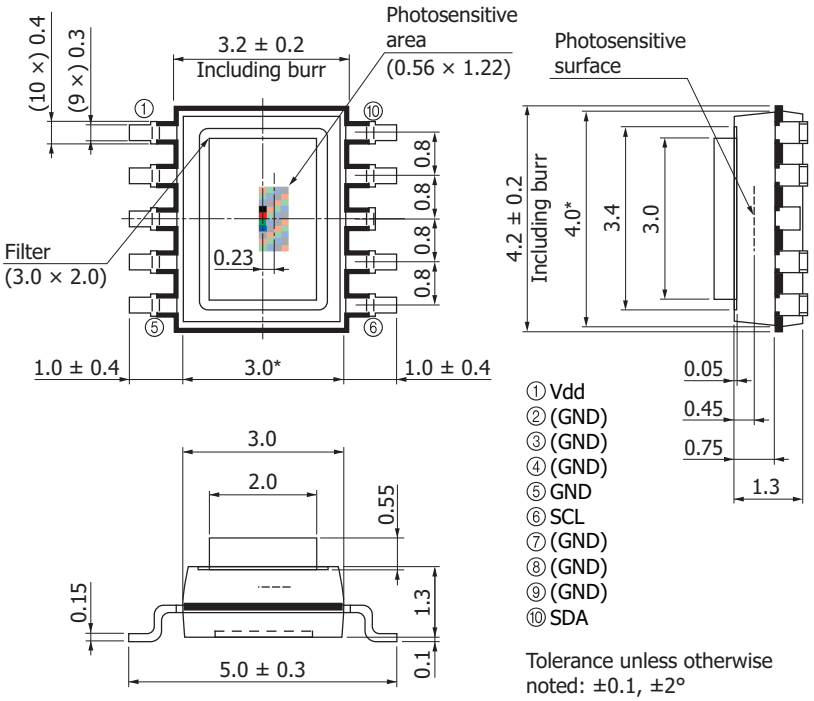
Dimensional outline (unit: mm)



Tolerance unless otherwise noted: ±0.1, ±2°
Shaded area indicates burr.
Chip position accuracy with respect to package dimensions marked*
X, Y≤±0.2, θ≤±2°

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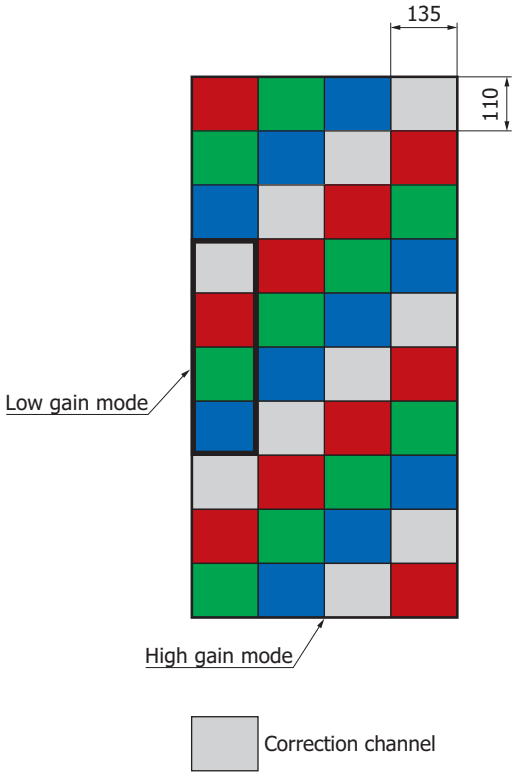
Details of photosensitive area (unit: μm)



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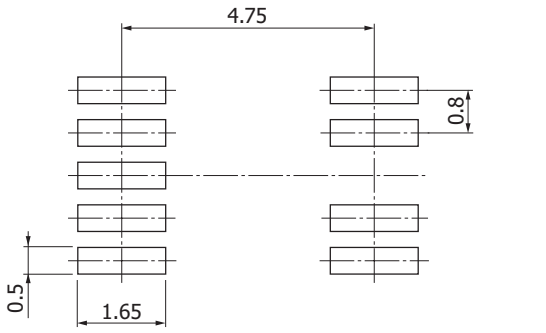
Recommended land pattern (unit: mm)



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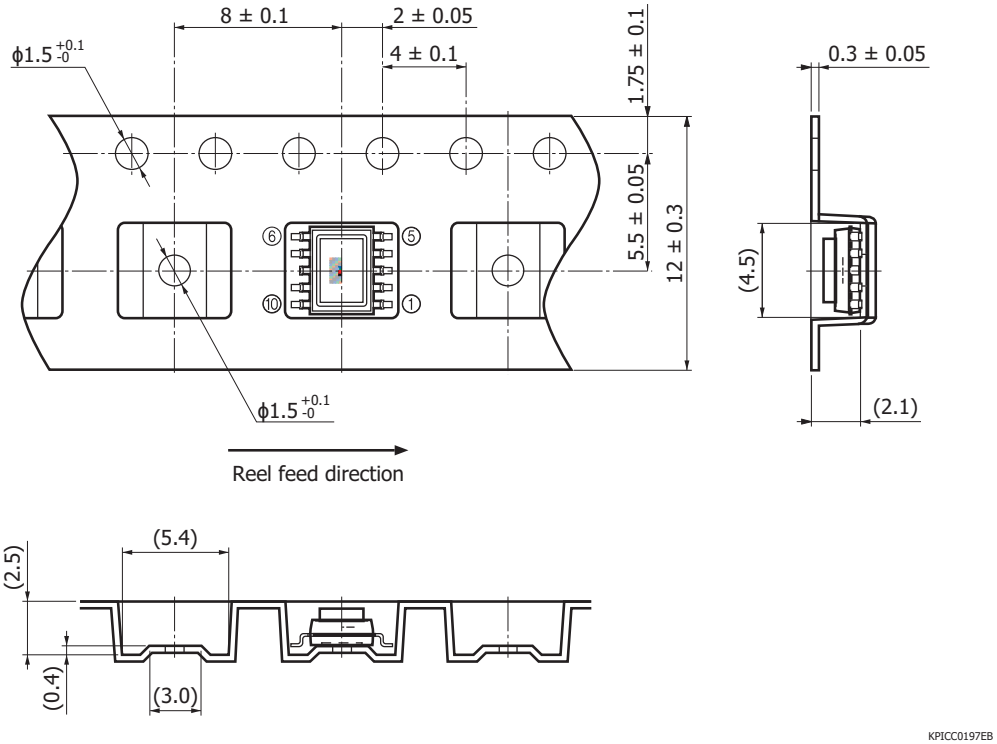
Reel packing specifications (S13683-03DT)

■ Reel (conforms to JEITA ET-7200)

Outer diameter	Hub diameter	Tape width	Material	Electrostatic characteristics
ϕ254 mm	ϕ80 mm	12 mm	PS (polystyrene)	Conductive

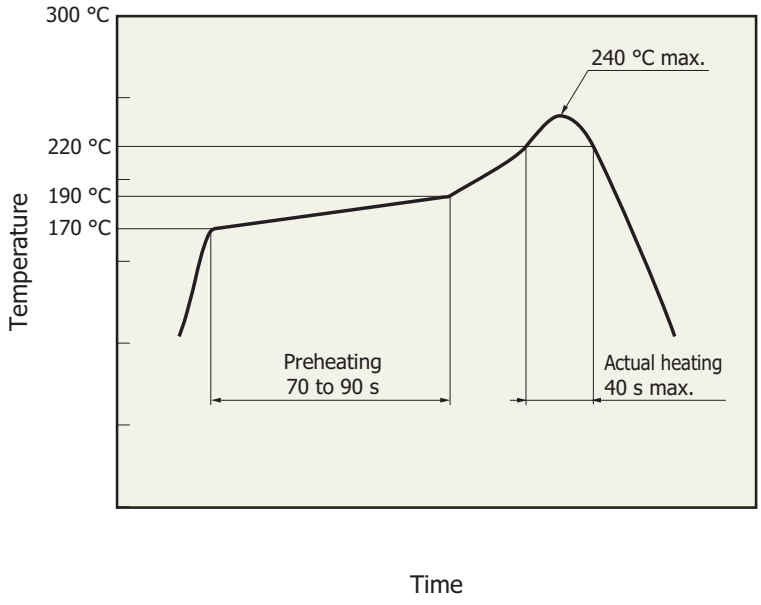
■ Embossed tape (unit: mm, material: PS, conductive)



■ Packing quantity
1500 pcs/reel

■ Packing type
Reel and desiccant in moisture-proof packaging (vacuum-sealed)

Recommended soldering condition



· This product supports lead-free soldering. After unpacking, store it in an environment at a temperature of 30 °C or less and a humidity of 60% or less, and perform soldering within 24 hours.
· The effect that the product receives during reflow soldering varies depending on the circuit board and reflow oven that are used. Before actual reflow soldering, check for any problems by testing out the reflow soldering methods in advance.

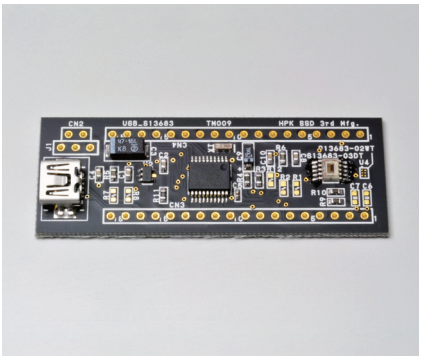
Related information

www.hamamatsu.com/sp/ssd/doc_en.html

■ Precautions
· Disclaimer
· Surface mount type products

Evaluation kit for color sensors C15701-01

An evaluation kit [60 mm (H) × 21.5 mm (V)] is available for the S13683-03DT/-04DS color sensors (with S13683-03DT/-04DS). Contact us for detailed information.



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