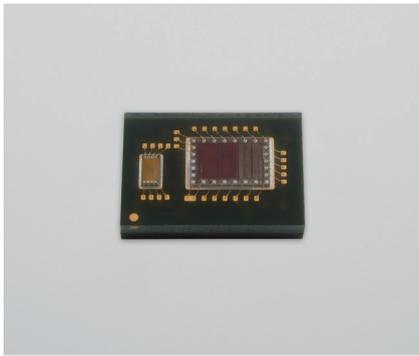


# Photo IC for rangefinder



S13021-01CT

## One channel distance measurement photo IC for indirect TOF (time-of-flight)

The S13021-01CT is a distance measurement device using the indirect TOF method. It integrates Hamamatsu's CMOS sensor and signal processing circuit. The sensor outputs signals proportional to the time for the pulse-modulated light to reflect by the target object and return. The output value can be used to calculate the distance to the target object. The S13021-01CT runs on low voltage (3.3 V) and supports I<sup>2</sup>C interface and SPI.

### Features

- Low voltage operation (3.3 V)
- I<sup>2</sup>C interface/SPI compatible
- Built-in 16-bit A/D converter

### Applications

- Distance measurement
- Presence or absence of objects

### Structure

Parameter	Specification	Unit
Photosensitive area	0.4 × 0.4	mm
Package	Glass epoxy	-
Seal material	Epoxy resin	-

### Absolute maximum ratings (Ta=25 °C)

Parameter	Symbol	Value	Unit
Supply voltage	Vdd	-0.3 to +4.6	V
Load current	Io	±10	mA
Power dissipation	P	100	mW
Operating temperature	Topr	-25 to +65	°C
Storage temperature	Tstg	-40 to +85	°C
Reflow soldering conditions*1	Tsol	Peak temperature 240 °C , 1 time	-

\*1: JEDEC level 5a

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

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Supply voltage	Vdd(A) Vdd(D)		-	3.3	-	V
I <sup>2</sup> C bus pull-up voltage*2	Vbus	Rp=2.2 kΩ	-	Vdd(D)	-	V
High level input voltage	Vih		0.7Vdd(D)	-	-	V
Low level input voltage	Vil		-	-	0.2Vdd(D)	V
Bus capacitance	Cbus	SDA, SCL	-	-	400	pF
Clock frequency	Fclk	CLK	-	50	-	MHz
Resolution	-		-	16	-	bit

\*2: The pull-up resistance is determined by the Cbus and Vbus values.

### Electrical and optical characteristics [Ta=25 °C, Vdd(A)=Vdd(D)=3.3 V, CLK=50 MHz]

#### ■ Sensor area

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Spectral response range	λ		-	440 to 1000	-	nm
Peak sensitivity wavelength	λp		-	800	-	nm
Current consumption	Icc		-	9.3	-	mA
Photosensitivity*3	RES		-	15600	-	digit/μW·s
Output value*4	Vor	When dark	-6000	0	+6000	digit
Output value	Vsat	Saturated	-32768	-	-	digit
Sensitivity ratio*5	SR		-	1.0	-	-

\*3: Monochromatic wavelength source (λ=850 nm)

\*4: Output value right after reset in dark state

\*5: Output ratio of Vout1 (VTX1=3 V, VTX2=VTX3=0 V) to Vout2 (VTX2=3 V, VTX1=VTX3=0 V)

#### ■ I<sup>2</sup>C area

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
I <sup>2</sup> C address*6	-	7-bit	0x2A, 0x2B, 0x2C, 0x2D			-
I <sup>2</sup> C clock frequency	fclk	-	1	-	400	kHz
SDA, SCL High level output voltage	Voh	Rp=2.2 kΩ	0.8Vbus	-	-	V
SDA, SCL Low level output voltage	Vol	Rp=2.2 kΩ	0	-	0.4	V
Input terminal capacitance	Ci		-	-	20	pF
SDA, SCL output fall time*7	tf	Rp=2.2 kΩ Cp=400 pF	-	-	250	ns

\*6: I<sup>2</sup>C address

Add_sel1	Add_sel2	I <sup>2</sup> C address
Low	Low	0x2A
Low	High	0x2B
High	Low	0x2C
High	High	0x2D

\*7: The SCL and SDA output fall times are determined by the time constant defined by Cbus × Rp. I<sup>2</sup>C interface (SDA, SCL) timing complies with "The I<sup>2</sup>C-bus specification version 2.1".

■ SPI area

Only the data output function is used for the SPI.

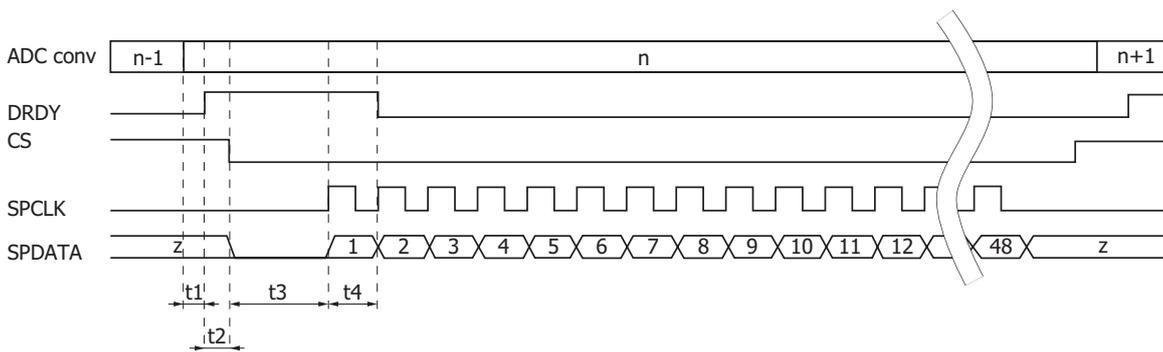
Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
SPI clock frequency	fspi-clk		-	-	10	MHz
High level output voltage	Voh		0.8Vdd(D)	-	-	V
Low level output voltage	Vol		0	-	0.2Vdd(D)	V
High level input voltage	Vih		0.7Vdd(D)	-	-	V
Low level input voltage	Vil		-	-	0.3Vdd(D)	V

■ SPI data format

Number of readout bits	1-16	17-32	33-40	41	42-48
Description	Ch1 data	Ch2 data	Ndata_counter Which iteration the data was read out	Dark frame Operation flag 1: Dark frame 0: LED light emission frame	Dummy data All zeros

MSB first for all data  
For Ch1 data, the first bit is the MSB, and the 16th bit is the LSB.

■ SPI timing chart



KPIC0277EA

Period	Description	Min.	Max.
t1	From the completion of ADC conversion to the rising edge of DRDY	One internal CLK cycle 0.33 μs	-
t2	From the rising edge of DRDY to the falling edge of CS	10 ns	-
t3	From the falling edge of CS to the first rising edge of SPCLK	10 ns	-
t4	From the first rising edge of the CPCLK to the falling edge of DRDY	One SPCLK cycle 10 ns	-

When readout data is ready, DRDY is set to "assert (high)."

After DRDY is set to "assert (high)," transmission is started on the microcontroller side.

The microcontroller first sets CS to "assert (low)," and then sends SPCLK.

When CS=low, data is output from SPDATA in sync with SPCLK when it is received.

As SPDATA transitions on the rising edge of SPCLK, SPDATA is acquired on the falling edge of SPCLK.

Total of 8-bit × 6=48 pieces of data can be read out.

In the end, the microcontroller sets CS to "negate (high)."

DRDY is set to "negate (low)" on the second rising edge of SPCLK. When data readout is ready again, it is set to "assert (high)."

I<sup>2</sup>C register map

Hex	Function	7	6	5	4	3	2	1	0	
0x00	Sensor control	abc_reset	abc_sleep	fixed value						
0x01	Output data	Data1								
0x02		Data2								
0x03										
0x04										
0x05	Analog control	fixed value							r_seq_	dark_frame
0x06										
0x07										
0x08		fixed value								
0x09										
0x0A		Ndata_counter								
0x0B										
0x0C		fixed value								
0x0D										
0x0E	Distance measurement control	Nlight								
0x0F		Ndata								
0x10		VTX1								
0x11		VTX2								
0x12		VTX3								
0x13										
0x14		led_num								
0x15		l_trig_offset				fixed value				
0x16										
0x17	pres_width									
0x18										

Fixed value registers are operation settings for rangefinder.

## ■ Register table

Mode	Register address	bit	Name	Description	Remarks
Global control	0x00	7	abc_reset	1: ADC reset on The internal register is reset to its initial condition, and operation is stopped. Operation starts when ADC reset is set to ON once and then set to OFF. 0: ADC reset off	
ADC result	0x01	[7:0]	ch1[15:8]	ADC output result on the data1 side, 16-bit	Read only
	0x02	[7:0]	ch1[7:0]	Signed 16-bit integer with the most significant bit being the sign bit	
	0x03	[7:0]	ch2[15:8]	ADC output result on the data2 side, 16-bit	
	0x04	[7:0]	ch2[7:0]	Signed 16-bit integer with the most significant bit being the sign bit	
	0x05	0	r_seq_dark_frame	Light frame (with L_trig) or dark frame (without L_trig) 1: Dark frame 0: Light frame	Read only
	0x0A	[7:0]	Ndata_counter	Which data readout iteration this is counted from immediately after pixel reset when in rangefinder mode	Read only
Rangefinder	0x0E	[7:0]	Nlight[15:8]	LED emission count	
	0x0F	[7:0]	Nlight[7:0]	Minimum value: 1	
	0x10	[7:0]	Ndata[7:0]	Setting of how many times (N) to repeat the readout after pixel reset (Pres)	
	0x11	[7:0]	VTX1[7:0]	VTX1 pulse width setting Minimum value: 1 In unit of 20 ns for CLK=50 MHz	
	0x12	[7:0]	VTX2[7:0]	VTX2 pulse width setting Minimum value: 1 In unit of 20 ns for CLK=50 MHz	
	0x13	[7:0]	VTX3[15:8]	The low period of VTX3 is calculated automatically from VTX1 and VTX2.	
	0x14	[7:0]	VTX3[7:0]	The high period can be set to 2 + (VTX3 - 1) CLK. Minimum VTX3 value: 1 In unit of 20 ns for CLK=50 MHz	
	0x15	[7:0]	led_num[7:0]	LED light emission pulse width Minimum value: 1 In unit of 20 ns for CLK=50 MHz	
	0x16	[7:4]	lt_offset[3:0]	LED light emission pulse timing adjustment Minimum value: 1 Same timing as VTX1 when the value is 1 The timing can be adjusted to a faster setting.	
	0x17	[7:0]	pres_width[15:8]	Specifies the PD reset length	
0x18	[7:0]	pres_width[7:0]	Minimum value: 1		

- Default I<sup>2</sup>C register value  
Change the  values in the register.

ADC\_RESET must be set to 1 once and then changed to 0.

Default value

	7	6	5	4	3	2	1	0
0 0x00	0	0	-	0	0	0	0	0
1 0x01	-	-	-	-	-	-	-	-
2 0x02	-	-	-	-	-	-	-	-
3 0x03	-	-	-	-	-	-	-	-
4 0x04	-	-	-	-	-	-	-	-
5 0x05	1	0	0	0	0	-	-	-
6 0x06	0	1	0	1	0	0	0	0
7 0x07	0	1	0	0	1	1	0	0
8 0x08	1	0	0	0	0	1	1	0
9 0x09	1	0	0	0	0	0	0	0
10 0x0A	-	-	-	-	-	-	-	-
11 0x0B	0	0	0	1	0	0	0	0
12 0x0C	0	0	0	0	0	0	0	0
13 0x0D	0	0	0	0	0	0	0	0
14 0x0E	0	0	0	0	0	0	0	0
15 0x0F	0	0	0	0	0	0	0	0
16 0x10	0	0	0	0	0	0	0	1
17 0x11	0	0	0	0	0	0	0	1
18 0x12	0	0	0	0	0	0	0	1
19 0x13	0	0	0	0	0	0	0	1
20 0x14	0	0	0	0	0	0	0	0
21 0x15	0	0	0	0	0	0	0	1
22 0x16	0	0	0	0	0	0	0	1
23 0x17	0	0	0	1	0	0	1	1
24 0x18	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	1

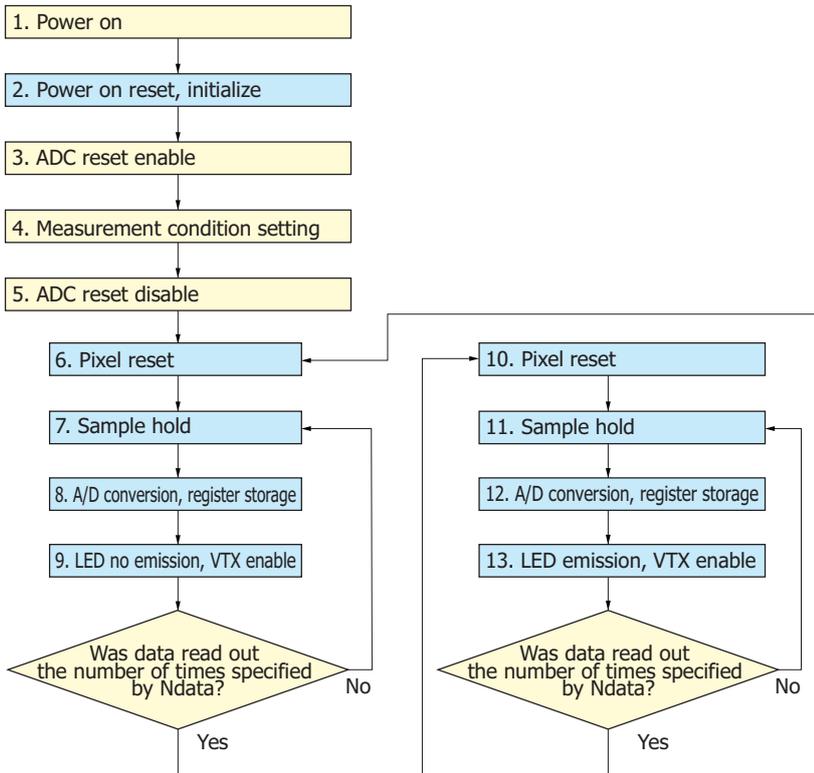
Rangefinder mode

	7	6	5	4	3	2	1	0
0 0x00	0	0	-	0	1	1	1	1
1 0x01	-	-	-	-	-	-	-	-
2 0x02	-	-	-	-	-	-	-	-
3 0x03	-	-	-	-	-	-	-	-
4 0x04	-	-	-	-	-	-	-	-
5 0x05	1	0	0	0	1	-	-	-
6 0x06	1	1	0	0	0	0	1	1
7 0x07	1	1	0	0	1	1	0	0
8 0x08	1	0	0	0	0	1	1	0
9 0x09	1	0	0	0	0	0	0	0
10 0x0A	0	0	0	1	0	0	0	0
11 0x0B	0	0	0	0	0	0	0	0
12 0x0C	0	0	0	0	0	0	0	0
13 0x0D	1	0	0	0	0	0	0	0
14 0x0E	0	0	0	0	0	0	0	0
15 0x0F	0	0	0	0	0	0	0	0
16 0x10	0	0	0	0	0	0	0	1
17 0x11	0	0	0	0	0	0	0	1
18 0x12	0	0	0	0	0	0	0	1
19 0x13	0	0	0	0	0	0	0	1
20 0x14	0	0	0	0	0	0	0	0
21 0x15	0	0	0	0	0	0	0	1
22 0x16	0	0	0	0	0	0	0	1
23 0x17	0	0	0	1	0	0	1	1
24 0x18	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	1

Register address	Hexadecimal notation	Binary notation
0x00	0x0F	0000 1111
0x05	0x88	1000 1000
0x06	0xC3	1100 0011
0x07	0xCC	1100 1100
0x0D	0x80	1000 0000

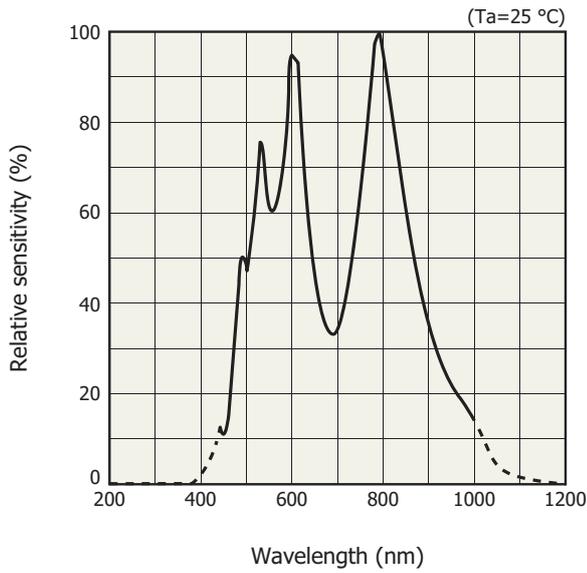
ADC\_RESET must be changed as follows: 0→1→0.

## Flowchart



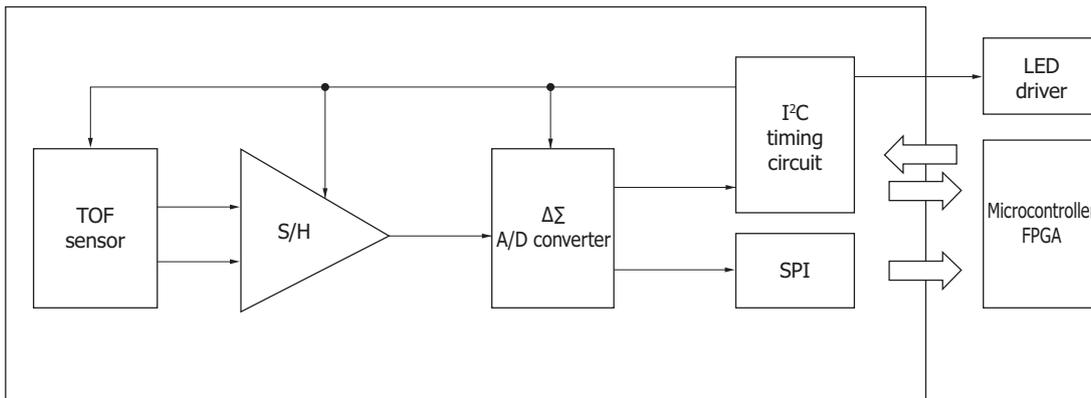
Yellow indicates operations performed by the user, and blue the product's internal operation. When the IC receives power and CLK, the built-in power-on reset circuit operates to set all registers to their initial conditions (2). To enter measurement conditions, enter commands via the I<sup>2</sup>C bus. To write to registers, the ADC reset bit must be asserted (reset) once (I<sup>2</sup>C command 0x00:8F) (3). After setting the conditions (4), ADC reset is deasserted (released) to start measuring (I<sup>2</sup>C command 0x00:0F) (5). In operation mode, sampling (output measurement when dark) and data saving are performed first. Then, the first light emission occurs. After repeating the sampling and data-saving operations, the data is read out. Further, the measurement count is taken, and the procedure returns to pixel reset and repeats measurements. During this repetition, if ADC reset or ADC sleep is performed with an I<sup>2</sup>C command, the product stops its operation.

**Spectral response (typical example)**



KPICB0198EA

**Block diagram**

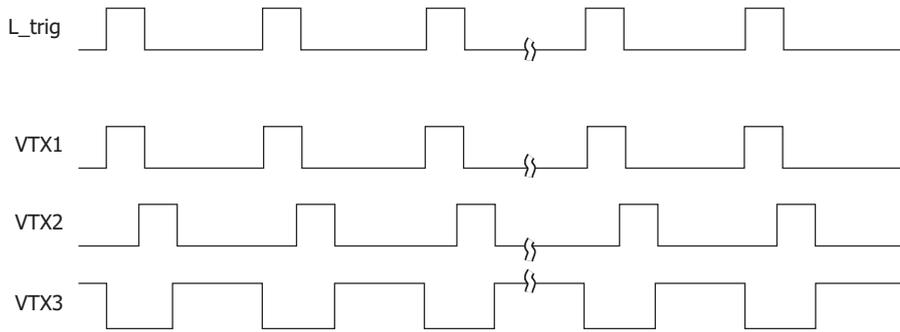


KPIC00314EA

**Operation timing**

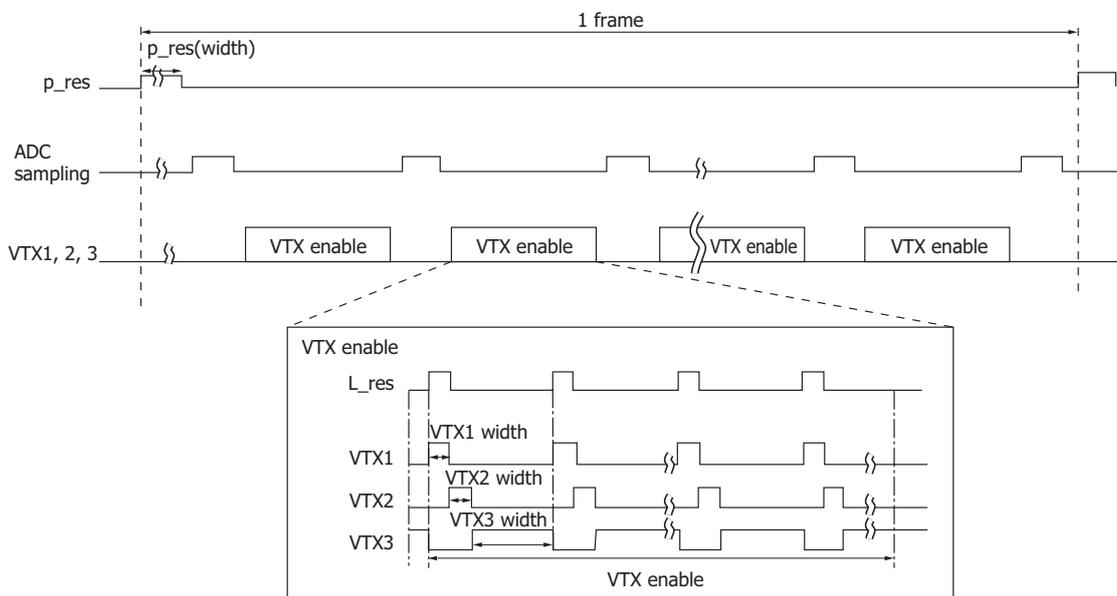
■ L\_trig timing

L\_trig is a pulse signal synchronized to VTX1.



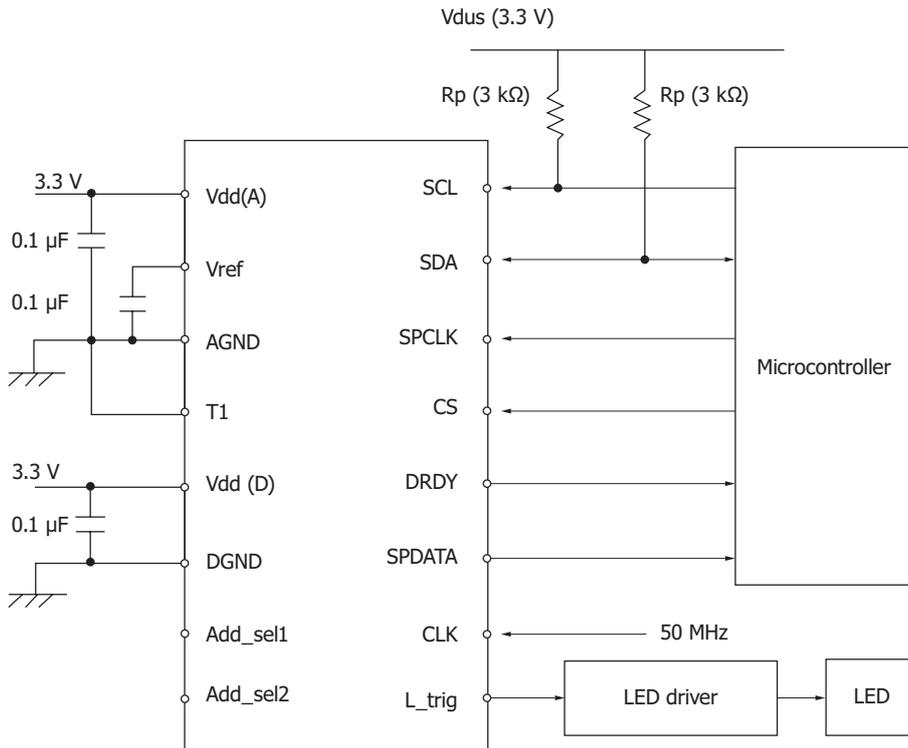
KPIC0279EA

■ Timing chart



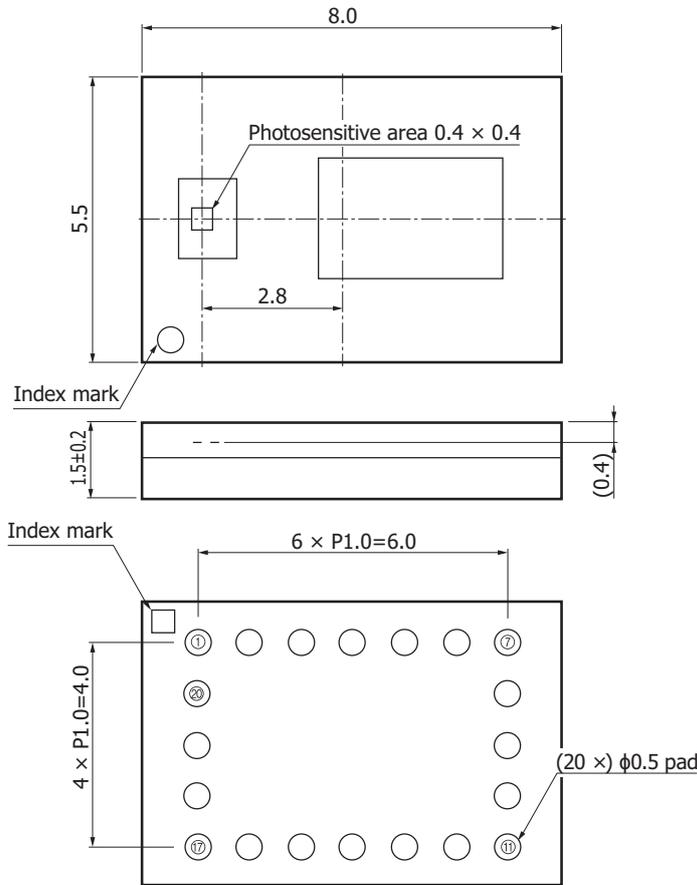
KPIC0280EA

**Operating circuit example**



KPIC0281EA

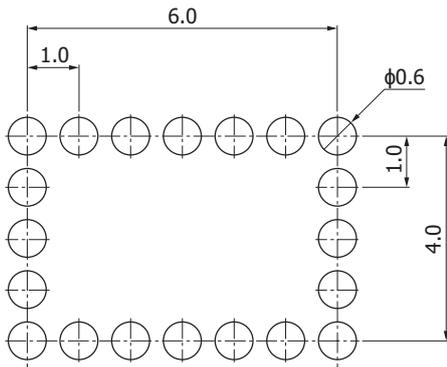
**Dimensional outline (unit: mm)**



Tolerance unless otherwise noted:  $\pm 0.1$   
 Chip position accuracy with respect to package dimensions marked \*  
 $X, Y \leq \pm 0.2, \theta \leq \pm 0.2$   
 Values in parentheses indicate reference values.

KP1CA0099EA

**Recommended land pattern (unit: mm)**



KPIC0283EA

## Pin connections

Pin no.	Symbol	I/O	Function	Description
1	Vdd(A)	I	Power supply	Analog supply voltage
2	Vref	I	Analog	Internal reference voltage
3	AGND	I	Power supply	Analog ground
4	T1	-	-	Test terminal
5	CLK	I	Digital	Master clock input
6	SPCLK	I	Digital	SPI clock
7	DRDY	O	Digital	Negative data standby output 0: Not standby 1: Data standby
8	SPDATA	O	Digital	SPI data output
9	CS	I	Digital	Negative chip selection input 0: Selected 1: Not selected
10	SDA	I/O	Digital	I <sup>2</sup> C data (SDA)
11	SCL	I	Digital	I <sup>2</sup> C clock (SCK)
12	L_trig	O	Digital	Optical pulse trigger
13	Add_sel1	I	Digital	I <sup>2</sup> C address switch flag
14	Add_sel2	I	Digital	I <sup>2</sup> C address switch flag
15	DGND	I	Power supply	Digital ground
16	NC	-	-	No connection
17	Vdd(D)	I	Power supply	Digital supply voltage
18	NC	-	-	No connection
19	AGND	I	Power supply	Analog ground
20	NC	-	-	No connection

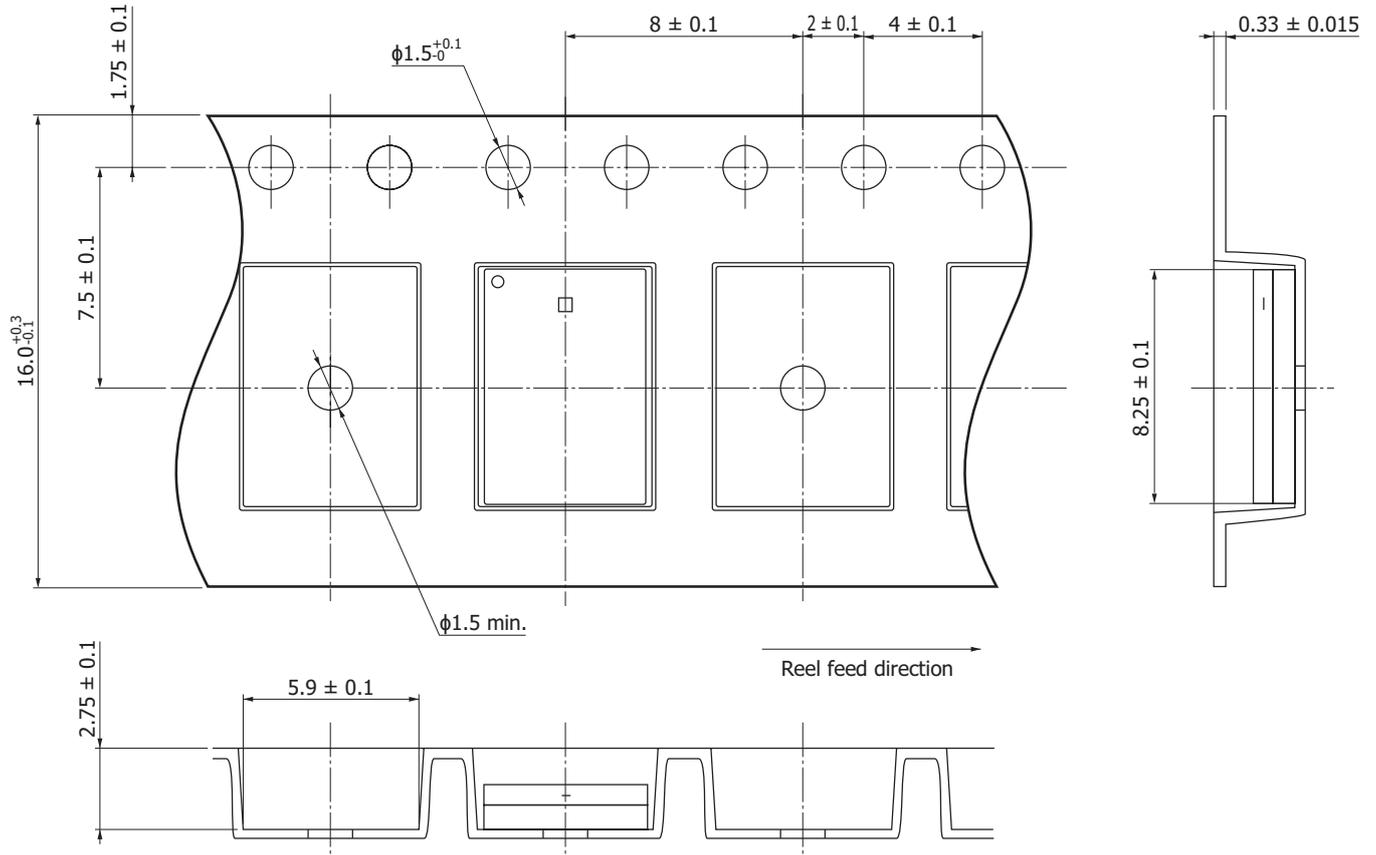
Note: Connect T1 to ground.

Standard packing specifications

Reel

Dimensions	Hub diameter	Tape width	Material	Electrostatic characteristics
330 mm	100 mm	16 mm	PS	Conductive

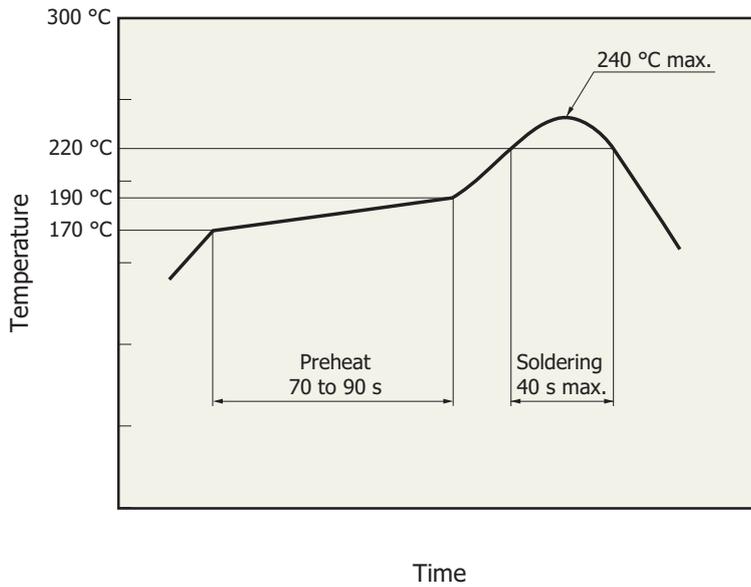
Embossed tape (unit: mm, material: PS, conductive)



KPIC0282EA

Packing quantity  
1000 pcs/reel

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

**Measured example of temperature profile with our hot-air reflow oven for product testing**

KPICB0171EA

- 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. When you set reflow soldering conditions, check that problems do not occur in the product by testing out the conditions in advance.

**Related information**

[www.hamamatsu.com/sp/ssd/doc\\_en.html](http://www.hamamatsu.com/sp/ssd/doc_en.html)

- Precautions
  - Disclaimer
  - Surface mount type products

## Evaluation kit for photo IC for rangefinder (S13021-01CT)

An evaluation kit for understanding the operating principle of Hamamatsu's S13021-01CT photo IC for rangefinder is available. Contact us for detailed information.



Information described in this material is current as of May 2018.

Product specifications are subject to change without prior notice due to improvements or other reasons. This document has been carefully prepared and the information contained is believed to be accurate. In rare cases, however, there may be inaccuracies such as text errors. Before using these products, always contact us for the delivery specification sheet to check the latest specifications.

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