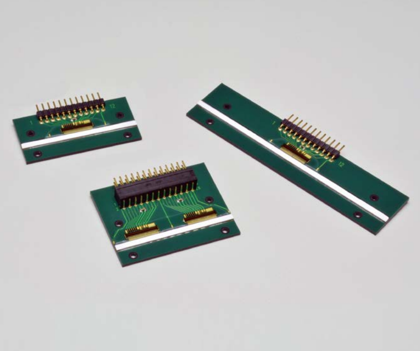
Photodiode arrays with amplifiers



S13885-128G/-256G, S13886-128G

Photodiode arrays combined with signal processing IC for X-ray detection

The S13885/S13886 series are photodiode arrays with amplifiers having a phosphor sheet attached to the photosensitive area for X-ray detection. Improvement in the signal processing IC chip has achieved higher sensitivity compared to the previous products (S11865/S11866 series). The signal processing IC chip is formed by CMOS process and incorporates a timing generator, shift register, charge amplifier array, clamp circuit and hold circuit, making the external circuit configuration simple. A long and narrow image sensor can be configured by arranging multiple arrays in a row.

Features

- **Data rate: 1 MHz max.**
- **Element pitch: 3 types available**
  S13885-128G: 0.4 mm pitch × 128 ch
  S13885-256G: 0.2 mm pitch × 256 ch
  S13886-128G: 0.8 mm pitch × 128 ch
- **3.3 V power supply operation**
- **Simultaneous integration method by using a charge amplifier array**
- **Low dark current due to zero-bias photodiode operation**
- **Integrated clamp circuit allows low noise and wide dynamic range.**
- **Integrated timing generator allows operation at two different pulse timings.**
- **Detectable energy range: 30 k to 100 keV**

Applications

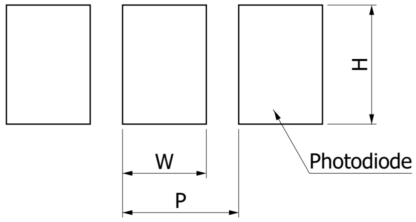
- **Line sensors for X-ray detection**
- **Long and narrow line sensors**

Structure

Parameter	Symbol*1	S13885-128G	S13885-256G	S13886-128G	Unit
Element pitch	P	0.4	0.2	0.8	mm
Element width	W	0.3	0.1	0.7	mm
Element height	H	0.6	0.3	0.8	mm
Number of elements	-	128	256	128	-
Effective area length	-	51.2	51.2	102.4	mm
Board material	-	Glass epoxy			-

*1: Refer to following figure.

Enlarged drawing of photosensitive area



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Absolute maximum ratings (Ta=25 °C unless otherwise noted)

Parameter	Symbol	Value	Unit
Supply voltage	Vdd	-0.3 to +4.2	V
Reference voltage	Vref	-0.3 to +4.2	V
Photodiode voltage	Vpd	-0.3 to +4.2	V
Gain selection terminal voltage	Vgain	-0.3 to +4.2	V
Master/slave selection voltage	Vms	-0.3 to +4.2	V
Clock pulse voltage	V(CLK)	-0.3 to +4.2	V
Reset pulse voltage	V(RESET)	-0.3 to +4.2	V
External start pulse voltage	V(EXTSP)	-0.3 to +4.2	V
Operating temperature[2]	Topr	-5 to +60	°C
Storage temperature[2]	Tstg	-10 to +70	°C

[2] No dew condensation
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.

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 terminal voltage (Ta=25 °C)

Parameter		Symbol	Min.	Typ.	Max.	Unit
Supply voltage		Vdd	3.0	3.3	3.6	V
Reference voltage		Vref	Vdd - 1.0	Vdd - 0.8	Vdd - 0.6	V
Photodiode voltage		Vpd	-	Vref	-	V
Gain selection terminal voltage	High gain	Vgain	Vdd - 0.25	Vdd	Vdd + 0.25	V
	Low gain		0	-	0.25	V
Master/slave selection voltage	High level[3]	Vms	Vdd - 0.25	Vdd	Vdd + 0.25	V
	Low level[4]		0	-	0.25	V
Clock pulse voltage	High level	V(CLK)	Vdd - 0.25	Vdd	Vdd + 0.25	V
	Low level		0	-	0.25	V
Reset pulse voltage	High level	V(RESET)	Vdd - 0.25	Vdd	Vdd + 0.25	V
	Low level		0	-	0.25	V
External start pulse voltage	High level	V(EXTSP)	Vdd - 0.25	Vdd	Vdd + 0.25	V
	Low level		0	-	0.25	V

[3] Parallel
[4] Serial at 2nd or later stages

Electrical characteristics [Ta=25 °C, Vdd=3.3 V, V(CLK)=V(RESET)=3.3 V]

Parameter		Symbol	Min.	Typ.	Max.	Unit
Clock pulse frequency[5]		f(CLK)	40	-	4000	kHz
Line rate[6]	S13885/S13886-128G	LR	-	-	7568	lines/s
	S13885-256G		-	-	3844	
Output impedance		Zo	-	3	-	kΩ
Current consumption	S13885/S13886-128G	Ic	-	36	-	mA
	S13885-256G		-	72	-	
Charge amplifier feedback capacitance	High gain	Cf	-	0.125	-	pF
	Low gain		-	0.25	-	

[5] Video data rate is 1/4 of f(CLK).
[6] The values depend on the clock pulse frequency.

Electrical and optical characteristics [Ta=25 °C, Vdd=3.3 V, V(CLK)=V(RESET)=3.3 V, Vgain=3.3 V (high gain), 0 V (low gain)]

Parameter		Symbol	S13885-128G			S13885-256G			S13886-128G			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Peak sensitivity wavelength[7]		λp	-	720	-	-	720	-	-	720	-	nm
Dark output voltage[8]	High gain	V_D	-	0.02	0.2	-	0.02	0.2	-	0.02	0.2	mV
	Low gain		-	0.01	0.1	-	0.01	0.1	-	0.01	0.1	
Saturation output voltage		Vsat	Vref - 1.0	Vref - 0.7	-	Vref - 1.0	Vref - 0.7	-	Vref - 1.0	Vref - 0.7	-	V
Saturation exposure[7] [9]	High gain	Pin_sat	-	0.3	0.4	-	1.8	2.3	-	0.1	0.13	mlx · s
	Low gain		-	0.6	0.8	-	3.6	4.5	-	0.2	0.26	
Photosensitivity[7] [9]	High gain	Sw	4800	6000	-	800	1000	-	14080	17600	-	V/lx · s
	Low gain		2400	3000	-	400	500	-	7040	8800	-	
Photoresponse nonuniformity[10]	3 channels from both ends	PRNU	-	-	-55, +10	-	-	-70, +10	-	-	-35, +10	%
	All channels excluding 3 channels from both ends		-	-	±10	-	-	±10	-	-	±10	
Readout noise[11]	High gain	Nread	-	1.0	1.5	-	0.6	0.9	-	1.7	2.6	mV rms
	Low gain		-	0.6	0.9	-	0.4	0.6	-	1.0	1.5	
Output offset voltage[12]		Voffset	-	Vref	-	-	Vref	-	-	Vref	-	V

*7: Measured without phosphor sheet

*8: Integration time ts=1 ms

*9: Measured with a 2856 K tungsten lamp

*10: Photoresponse nonuniformity (PRNU) is the output nonuniformity that occurs when the photosensitive area is uniformly illuminated by X-ray (tube voltage: 70 kV) which is approx. 50% of the saturation level. PRNU is defined as follows:

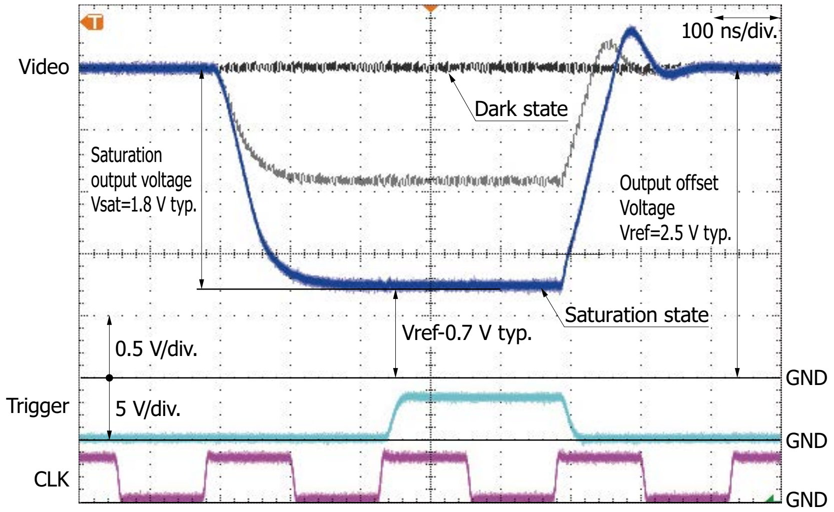
$$PRNU = \Delta X/X \times 100\ [\%]$$

X: average output of all elements, ΔX: difference between X and the maximum or minimum output, whichever is larger.

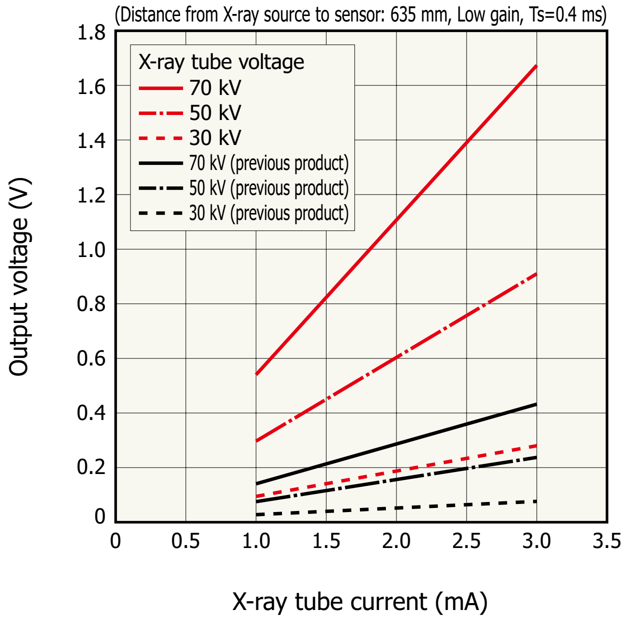
*11: Video data rate=1 MHz, dark state, ts=1 ms

*12: Video output is negative-going output with respect to the output offset voltage.

Output waveform of one element



X-ray output example (S13885-128G)



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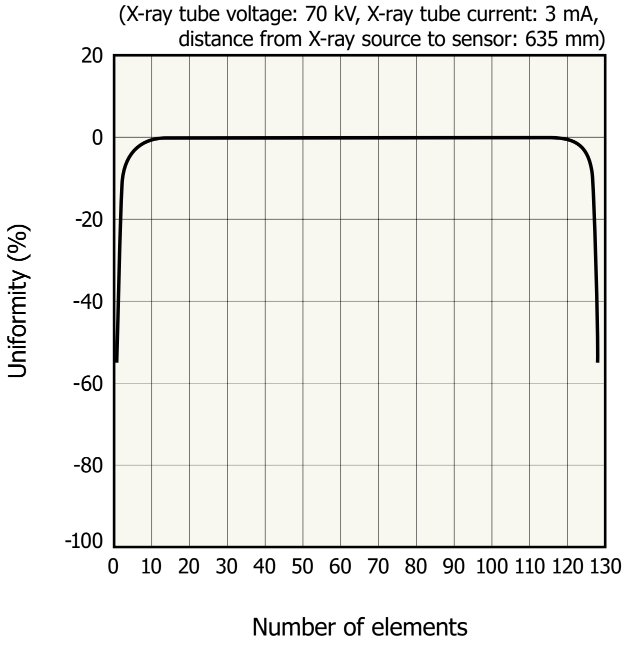
Uniformity example of X-ray output (S13885-128G)



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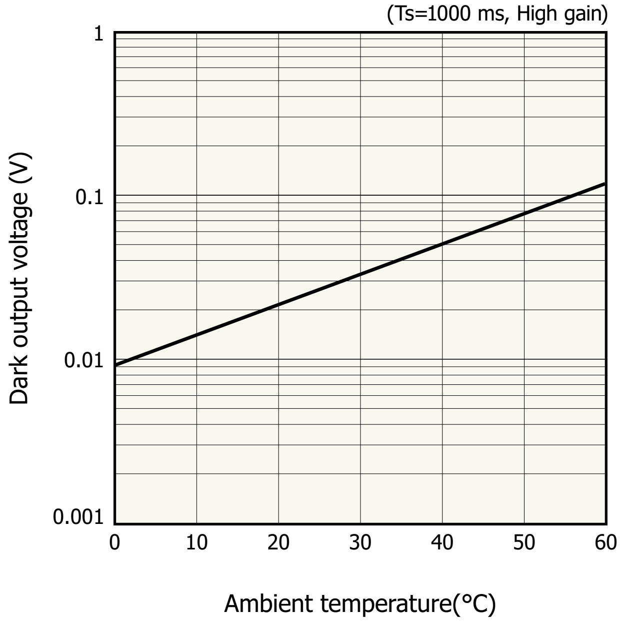
Dark output voltage vs. ambient temperature (typical example)



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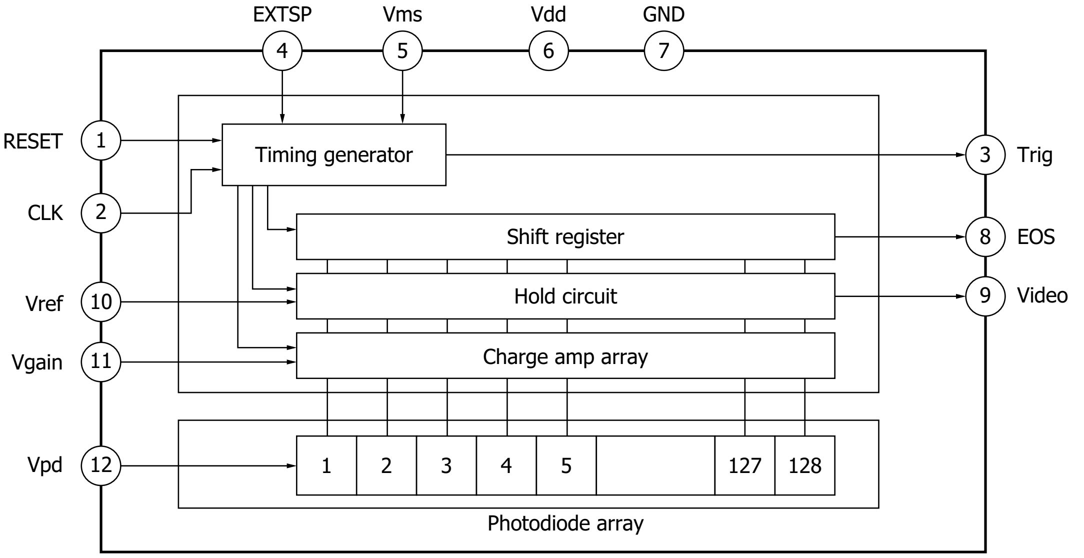
Block diagram

S13885-128G, S13886-128G



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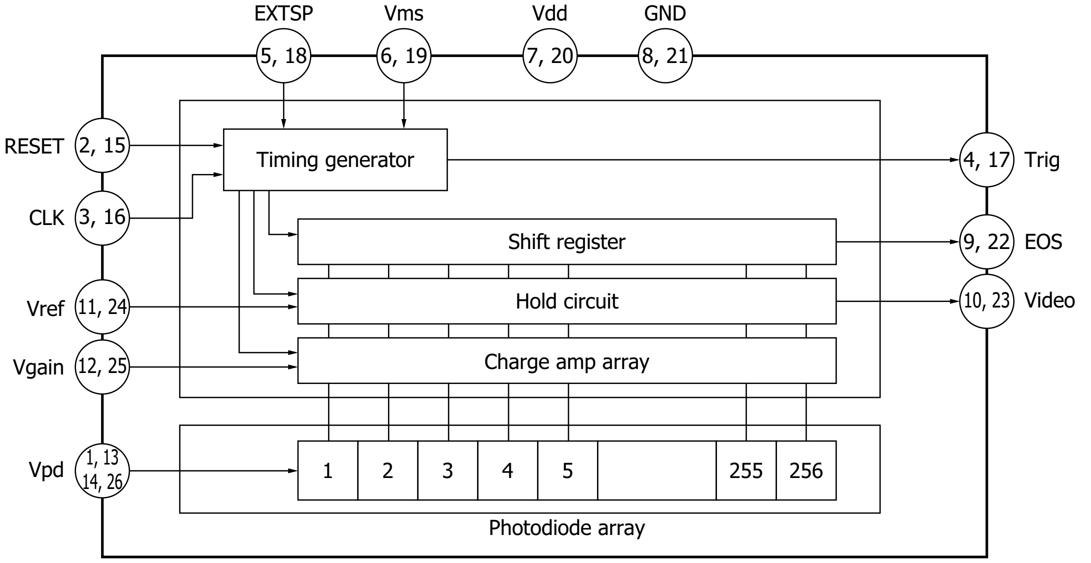
S13885-256G



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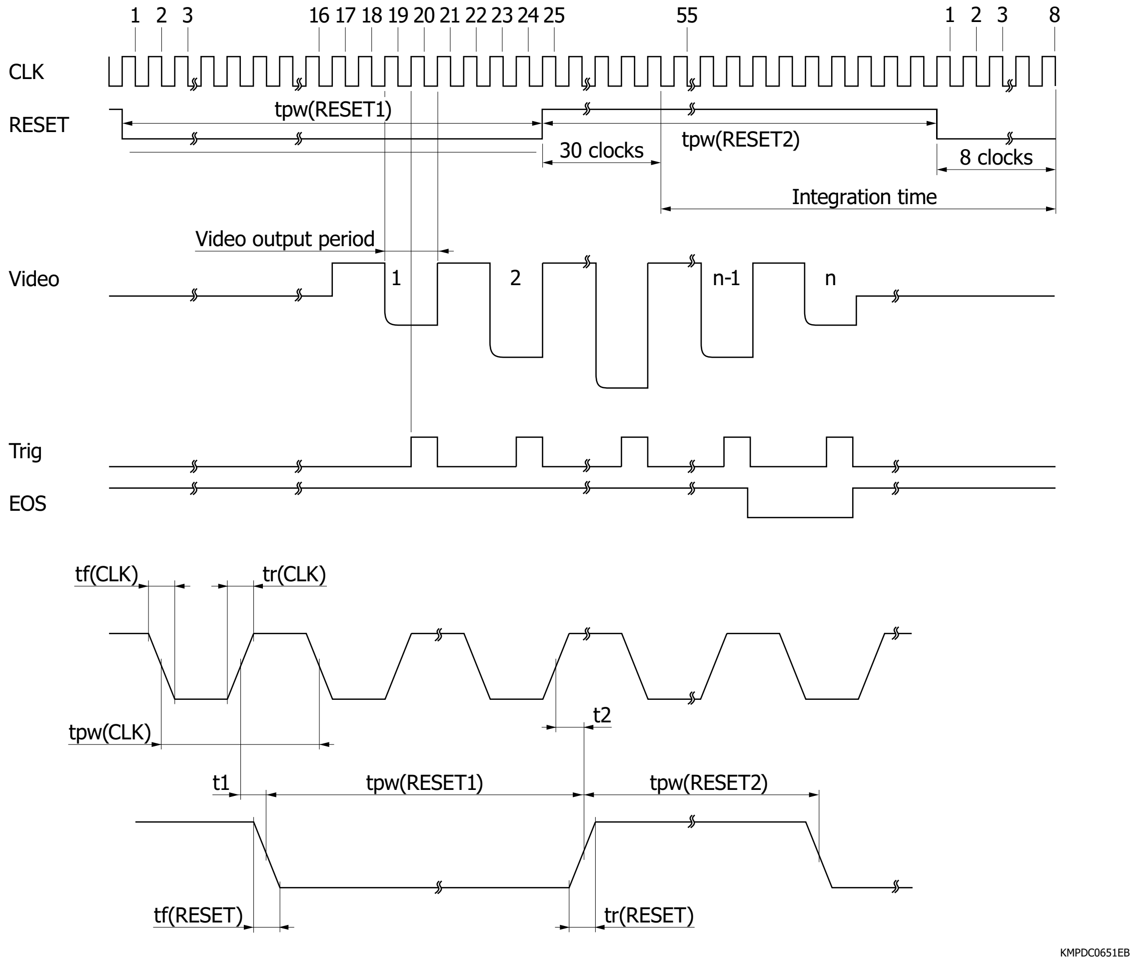
Timing chart

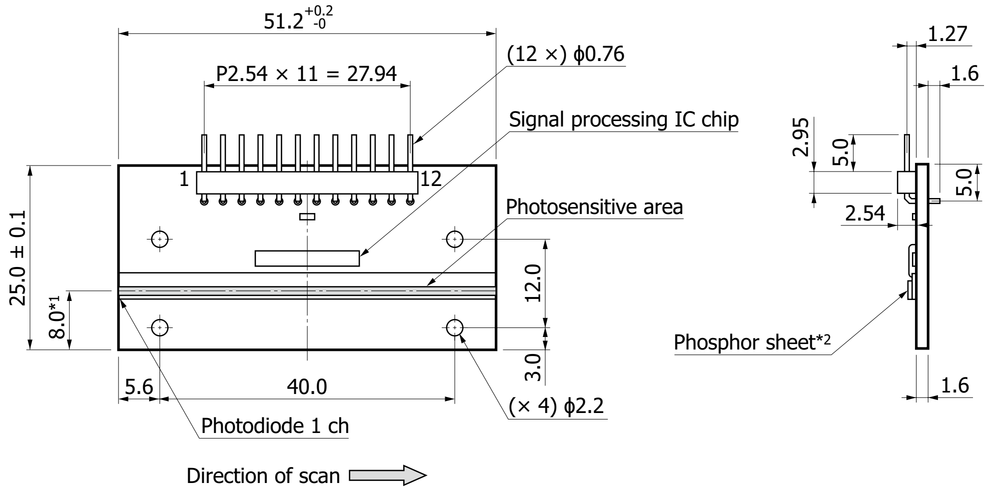


Parameter	Symbol	Min.	Typ.	Max.	Unit
Clock pulse width	tpw(CLK)	250	-	25000	ns
Clock pulse rise/fall times	tr(CLK), tf(CLK)	0	20	30	ns
Reset pulse width 1	tpw(RESET1)	25	-	-	CLK
Reset pulse width 2	tpw(RESET2)	40	-	-	CLK
Reset pulse rise/fall times	tr(RESET), tf(RESET)	0	20	30	ns
Clock pulse-reset pulse timing 1	t1	-20	0	20	ns
Clock pulse-reset pulse timing 2	t2	-20	0	20	ns

1. The internal timing circuit starts operation at the falling edge of CLK immediately after a RESET pulse goes low.
2. When the falling edge of this CLK is counted as 1 clock, the video signal of the 1st channel appears between 18.5 clocks and 20.5 clocks. Subsequent video signals appear every 4 clocks.
3. The trigger pulse for the 1st channel rises at a timing of 19.5 clocks and then rises every 4 clocks. The rising edge of each trigger pulse is the recommended timing for data acquisition.
4. Signal charge integration time equals [the high period of a RESET pulse - 22 clocks]. The charge integration starts at the fall of the 30th clock after the rise of the RESET pulse and ends at the fall of the 8th clock after the fall of the RESET pulse. After the RESET pulse next changes from high to low, signals integrated within this period are sequentially read out as time-series signals by the shift register operation. The rise and fall of a RESET pulse must be synchronized with the rise of a CLK pulse, but the rise of a RESET pulse must be set outside the video output period. One cycle of RESET pulses cannot be set shorter than the time equal to [16.5 + 4 × N (number of elements)] clocks.
5. The video signal after an EOS signal output becomes a high impedance state, and the video output will be indefinite.

Dimensional outlines (unit: mm)

S13885-128G



Tolerance unless otherwise noted: ±0.2

*1: Distance from board bottom to photosensitive area center
Board: G10 glass epoxy
Connector: PRECI-DIP DURTAL 800-10-012-20-001101

*2: Phosphor sheet specifications
- Material: Gd_2O_2S: Tb
- Phosphor thickness: 300 μm typ.
- Detectable energy range: 30 k to 100 keV

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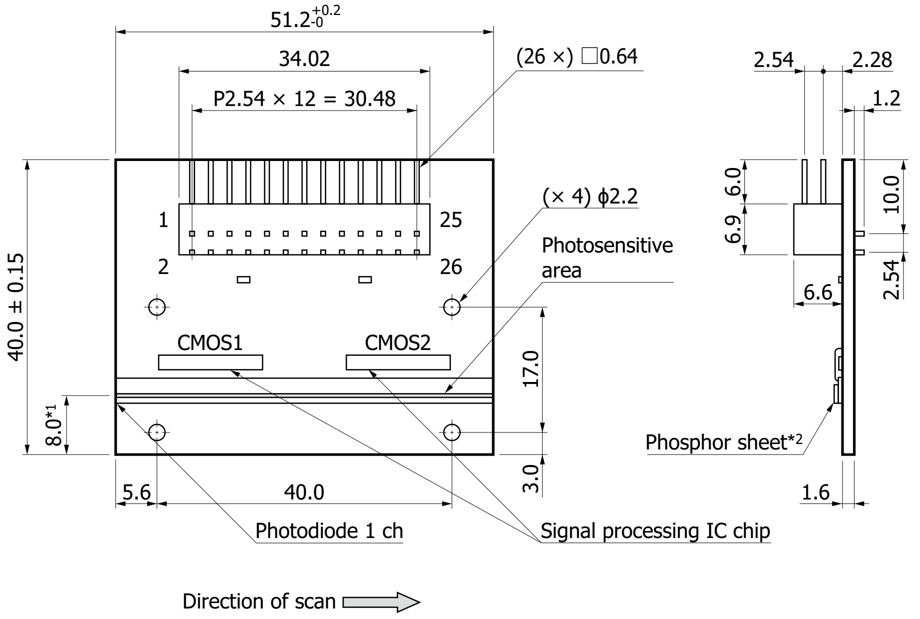
S13885-256G



Tolerance unless otherwise noted: ±0.2

*1: Distance from board bottom to photosensitive area center
Board: G10 glass epoxy
Connector: JAE (Japan Aviation Electronics Industry, Limited) PS-26PE-D4LT1-PN1

*2: Phosphor sheet specifications
- Material: Gd_2O_2S: Tb
- Phosphor thickness: 300 μm typ.
- Detectable energy range: 30 k to 100 keV

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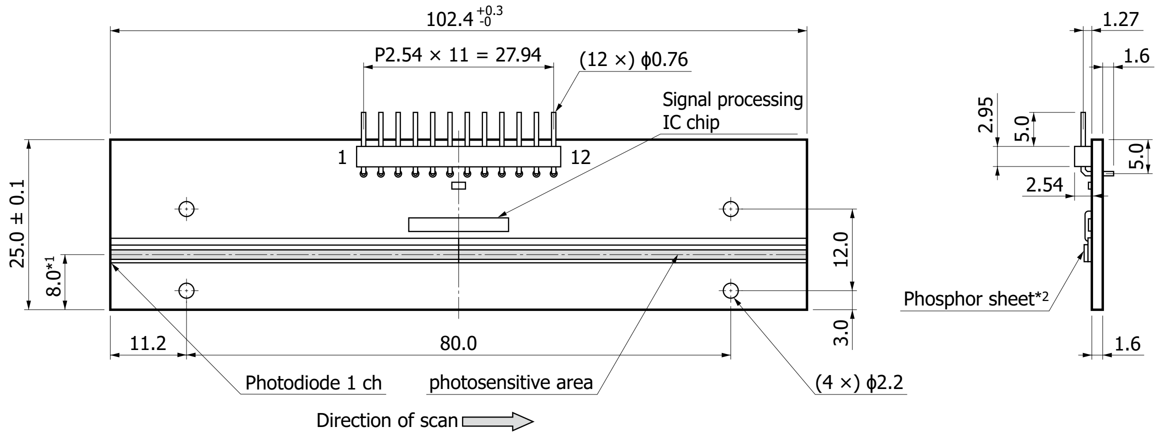
S13886-128G



Tolerance unless otherwise noted: ±0.2

*1: Distance from board bottom to photosensitive area center
Board: G10 glass epoxy
Connector: PRECI-DIP DURTAL 800-10-012-20-001101

*2: Photodiode array with phosphor sheet
- Material: Gd_2O_2S:Tb
- Phosphor thickness: 300 µm typ.
- Detectable energy range: 30 k to 100 keV

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Pin connections

S13885-128G, S13886-128G

Pin no.	Symbol	Name	Note
1	RESET	Reset pulse	Pulse input
2	CLK	Clock pulse	Pulse input
3	Trig	Trigger pulse	Positive-going pulse output
4	EXTSP	External start pulse	Pulse input
5	Vms	Master/slave selection voltage	Voltage input
6	Vdd	Supply voltage	Voltage input
7	GND	Ground	
8	EOS	End of scan	Negative-going pulse output
9	Video	Video output	Negative-going output from Vref
10	Vref	Reference voltage	Voltage input
11	Vgain	Gain selection terminal voltage	Voltage input
12	Vpd	Photodiode voltage	Voltage input

S13885-256G

Pin no.	CMOS1	Pin no.	CMOS2	Name	Note
1	Vpd	14	Vpd	Photodiode voltage	Voltage input
2	RESET	15	RESET	Reset pulse	Pulse input
3	CLK	16	CLK	Clock pulse	Pulse input
4	Trig	17	Trig	Trigger pulse	Positive-going pulse output
5	EXTSP	18	EXTSP	External start pulse	Pulse input
6	Vms	19	Vms	Master/slave selection voltage	Voltage input
7	Vdd	20	Vdd	Supply voltage	Voltage input
8	GND	21	GND	Ground	
9	EOS	22	EOS	End of scan	Negative-going pulse output
10	Video	23	Video	Video output	Negative-going output from Vref
11	Vref	24	Vref	Reference voltage	Voltage input
12	Vgain	25	Vgain	Gain selection voltage	Voltage input
13	Vpd	26	Vpd	Photodiode voltage	Voltage input

Gain selection terminal voltage setting

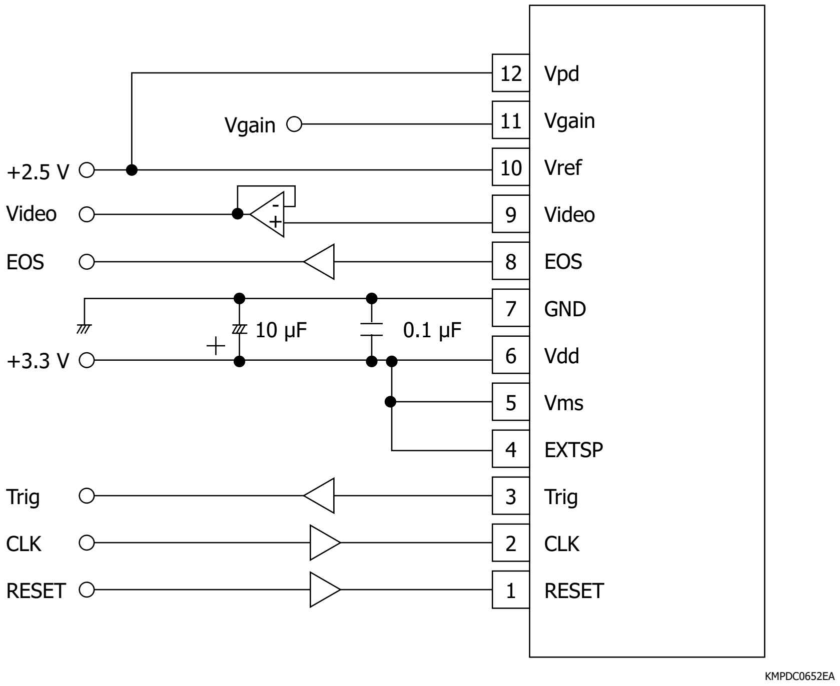
Vdd: High gain (Cf=0.125 pF) GND: Low gain (Cf=0.25 pF)

Setting for each readout method

S13885-128G, S13886-128G

Set to A in the table below in most cases.
To serially read out signals from two or more sensors linearly connected, set the 1st sensor to A and the 2nd or later sensors to B. The CLK and RESET pulses should be shared with each sensor and the video output terminal of each sensor connected together.

■ Connection example (parallel readout)



Note: When making a serial connection with two or more sensors or when connecting the sensor with a long cable, connect a high-impedance amplifier near the sensor if necessary.

Setting	Readout method	Vms	EXTSP
A	All stages of parallel readout, serial readout at 1st sensor	Vdd	Vdd
B	Serial readout at 2nd and later sensors	GND	Preceding sensor EOS is input.

S13885-256G

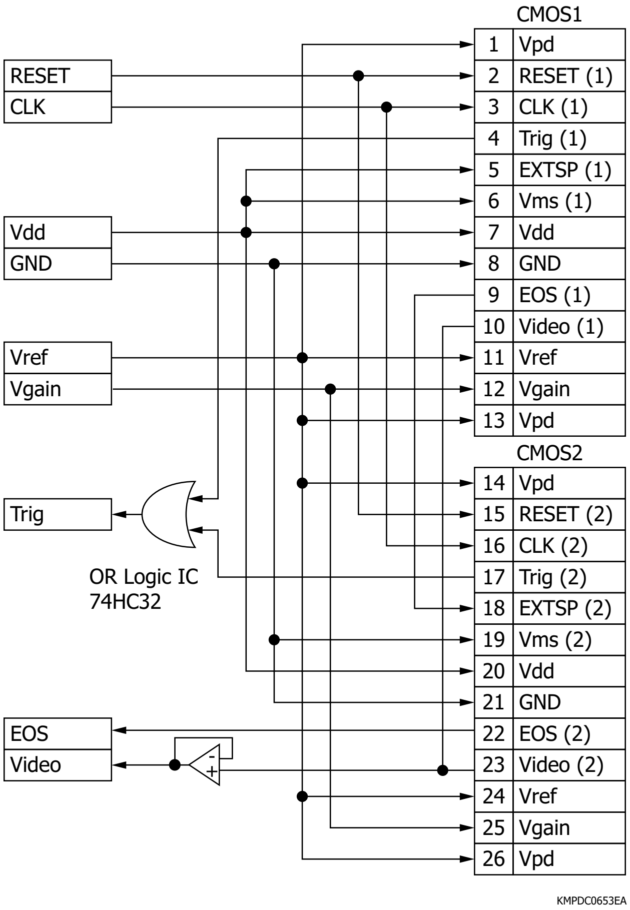
Signals of channels 1 through 128 are output from CMOS1, while signals of channels 129 through 256 are output from CMOS2. The following two readout methods are available.

(1) Serial readout method
CMOS1 and CMOS2 are connected in serial and the signals of channels 1 through 256 are sequentially read out from one output line. Set CMOS1 as in "A" in the table below, and set CMOS2 as in "B". Use a common CLK for CMOS1 and CMOS2. Likewise, use a common RESET for CMOS1 and CMOS2. Connect the video output terminals to a single line.

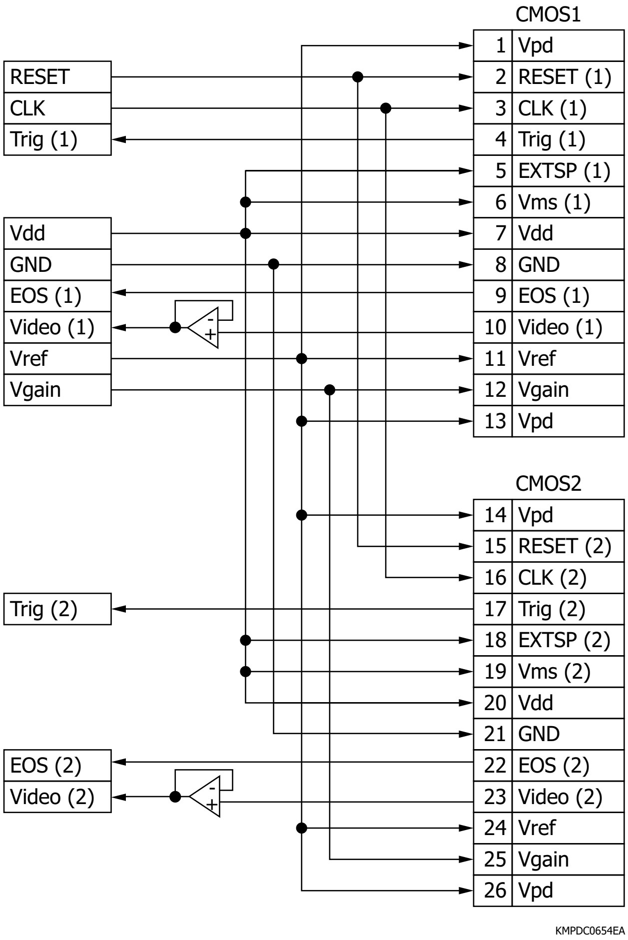
(2) Parallel readout method
128 channel signals are output in parallel respectively from the output lines of CMOS1 and CMOS2. Set both CMOS1 and CMOS2 as in "A" in the table below.

■ Connection examples

- Serial readout method



- Parallel readout method



Note: When making a serial connection with two or more sensors or when connecting the sensor with a long cable, connect a high-impedance amplifier near the sensor if necessary.

Setting	Vms	EXTSP
A	Vdd	Vdd
B	GND	Preceding sensor EOS is input.

Readout circuit

Apply pulse signals that meet the required conditions to the input terminals. Video output should be amplified by an op amp that is connected close to the sensor.

Precautions

(1) The signal processing IC chip is protected against static electricity. However, in order to prevent possible damage to the IC chip, take electrostatic countermeasures such as grounding yourself, as well as workbench and tools. Also protect the IC chip from surge voltages from peripheral equipment.

(2) Gold wires for wire bonding are very thin, so they easily break if subjected to mechanical stress. The signal processing IC chip and wire bonding are covered with resin for protection, but make sure they do not get scratched.
Never touch these portions or the photodiode array chip affixed with the phosphor sheet. Excessive force, if applied, may break the wires or cause malfunction. Blow air to remove dust or debris if it gets on the protective resin. Never wash them with solvent. Signals may not be obtained if dust or debris is left or a scratch is made on the protective resin or the phosphor sheet or if the signal processing IC chip or photodiode array chip is nicked.

(3) The photodiode array characteristics may deteriorate when operated at high humidity, so put it in a hermetically sealed enclosure or case. When installing the photodiode array with amplifier on a board, be careful not to cause the board to warp.

(4) The characteristics of the signal processing IC chip deteriorate if exposed to X-rays. So use a lead shield which is at least 1 mm larger all around than the signal processing IC chip. The 1 mm margin may not be sufficient depending on the incident angle of X-rays. Provide an even larger shield as long as it does not cover the photodiode photosensitive area. Since the optimal shield thickness depends on the operating conditions, calculate it by taking the attenuation coefficient of lead into account.

(5) The sensitivity of the photodiode array chip decreases if continuously exposed to X-rays. The extent of this sensitivity decrease differs depending on the X-ray irradiation conditions.

Related information

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

■ Precautions
· Disclaimer
· Image sensors

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