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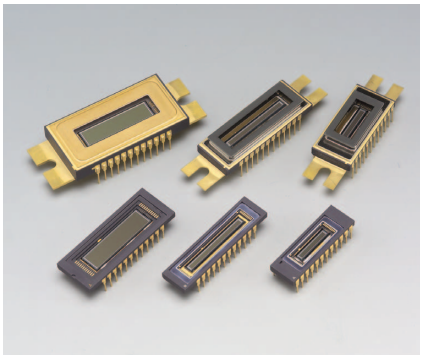
CCD area image sensors



S9970/S9971 series

Low dark signal, low readout noise front-illuminated FFT-CCD

The S9970/S9971 series are families of FFT-CCD image sensors specifically designed for low-light-level detection in scientific applications. The S9970/S9971 series offer lower dark current and lower readout noise than the S7010/S7011 series that have been marketed. By using the binning operation, the S9970/S9971 series can be used as a linear image sensor having a long aperture in the direction of the device length. This makes the S9970/S9971 series ideally suited for use in spectrophotometry. The binning operation offers significant improvement in S/N and signal processing speed compared with conventional methods by which signals are digitally added by an external circuit. The S9970/S9971 series also feature low noise and low dark signal (MPP mode operation). This enables low-light-level detection and long integration time, thus achieving a wide dynamic range.
The S9970/S9971 series have an effective pixel size of 24 × 24 µm and are available in image areas ranging from 12.288 (H) × 1.44 (V) mm^2 (512 × 60 pixels) up to a large image area of 24.576 (H) × 6.048 (V) mm^2 (1024 × 252 pixels). The S9970/S9971 series are pin compatible with the S7010/S7011 series. (Operating conditions are a little bit changed from the S7010/S7011 series.)

Features

- **Low dark signal: 10 e^-/pixel/s typ. (0 °C, MPP mode)**
- **Low readout noise: 4 e^-rms typ.**
- **512 (H) × 60 (V) to 1024 (H) × 252 (V) pixel format**
- **Pixel size: 24 × 24 µm**
- **Line/pixel binning**
- **100% fill factor**
- **Wide dynamic range**
- **MPP operation**

Applications

- **Fluorescence spectrometers, ICP**
- **Raman spectrometers**
- **Industrial inspection requiring**
- **Semiconductor inspection**
- **DNA sequencers**
- **Low-light-level detection**

Selection guide

Type no.	Cooling	Number of total pixels	Number of active pixels	Image size [mm (H) × mm (V)]	Applicable multichannel detector head
S9970-0906	Non-cooled	532 × 64	512 × 60	12.288 × 1.440	C7020
S9970-1006		1044 × 64	1024 × 60	24.576 × 1.440	
S9970-1007		1044 × 128	1024 × 124	24.576 × 2.976	
S9970-1008		1044 × 256	1024 × 252	24.576 × 6.048	
S9971-0906	One-stage TE-cooled	532 × 64	512 × 60	12.288 × 1.440	C7021
S9971-1006		1044 × 64	1024 × 60	24.576 × 1.440	
S9971-1007		1044 × 128	1024 × 124	24.576 × 2.976	
S9971-1008		1044 × 256	1024 × 252	24.576 × 6.048	C7025

Structure

Parameter	S9970 series	S9971 series
Pixel size	24 (H) × 24 (V) µm	
Vertical clock phase	2-phase	
Horizontal clock phase	2-phase	
Output circuit	One-stage MOSFET source follower	
Package	24-pin ceramic DIP (refer to dimensional outlines)	
Window*1	Quartz glass	S9971-0906/-1006/-1007: sapphire S9971-1008: AR-coated sapphire

*1: Temporary window type (ex. S9970-0906N) and UV coat type (ex. S9970-0906UV) are available upon request.
(On the temporary window type, a window is temporarily attached by tape to protect the CCD chip and wires.)

Absolute maximum ratings (Ta=25 °C)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Operating temperature	Topr		-50	-	+50	°C
Storage temperature	Tstg		-50	-	+70	°C
Output transistor drain voltage	V_{OD}		-0.5	-	+25	V
Reset drain voltage	V_{RD}		-0.5	-	+18	V
Test point (vertical input source)	V_{ISV}		-0.5	-	+18	V
Test point (horizontal input source)	V_{ISH}		-0.5	-	+18	V
Test point (vertical input gate)	V_{IG1V}, V_{IG2V}		-15	-	+15	V
Test point (horizontal input gate)	V_{IG1H}, V_{IG2H}		-15	-	+15	V
Summing gate voltage	V_{SG}		-15	-	+15	V
Output gate voltage	V_{OG}		-15	-	+15	V
Reset gate voltage	V_{RG}		-15	-	+15	V
Transfer gate voltage	V_{TG}		-15	-	+15	V
Vertical shift register clock voltage	V_{P1V}, V_{P2V}		-15	-	+15	V
Horizontal shift register clock voltage	V_{P1H}, V_{P2H}		-15	-	+15	V
Maximum current*2	Imax	Tc*3=Th*4=25 °C	1.5	1.5	3.0	A
Maximum voltage	Vmax	Tc*3=Th*4=25 °C	4.4	8.8	3.6	V
Thermistor power dissipation	Pd_th		-	-	7.6	mW

*2: If the current is greater than Imax, the heat absorption begins to decrease due to the Joule heat. It should be noted that this value is not a damage threshold. To protect the thermoelectric cooler and maintain stable operation, the supply current should be less than 60% of this maximum current.
*3: Temperature of cool side of thermoelectric cooler
*4: Temperature of hot side of thermoelectric cooler
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.

Operating conditions (MPP mode, Ta=25 °C)

Parameter		Symbol	Min.	Typ.	Max.	Unit
Output transistor drain voltage		V_{OD}	18	20	22	V
Reset drain voltage		V_{RD}	11.5	12	12.5	V
Output gate voltage		V_{OG}	1	3	5	V
Substrate voltage		V_{SS}	-	0	-	V
Test point (vertical input source)		V_{ISV}	-	V_{RD}	-	V
Test point (horizontal input source)		V_{ISH}	-	V_{RD}	-	V
Test point (vertical input gate)		V_{IG1V}, V_{IG2V}	-8	0	-	V
Test point (horizontal input gate)		V_{IG1H}, V_{IG2H}	-8	0	-	V
Vertical shift register clock voltage	High	V_{P1VH}, V_{P2VH}	0	4	6	V
	Low	V_{P1VL}, V_{P2VL}	-9	-8	-7	
Horizontal shift register clock voltage	High	V_{P1HH}, V_{P2HH}	0	4	6	V
	Low	V_{P1HL}, V_{P2HL}	-9	-8	-7	
Summing gate voltage	High	V_{SGH}	0	4	6	V
	Low	V_{SGL}	-9	-8	-7	
Reset gate voltage	High	V_{RGH}	0	4	6	V
	Low	V_{RGL}	-9	-8	-7	
Transfer gate voltage	High	V_{TGH}	0	4	6	V
	Low	V_{TGL}	-9	-8	-7	
External load resistance		R_L	20	22	24	kΩ

Electrical characteristics (Ta=25 °C)

Parameter		Symbol	Min.	Typ.	Max.	Unit
Signal output frequency		fc	-	0.1	1	MHz
Vertical shift register capacitance	S9970/S9971-0906	C_{P1V}, C_{P2V}	-	750	-	pF
	S9970/S9971-1006		-	1500	-	
	S9970/S9971-1007		-	3000	-	
	S9970/S9971-1008		-	6000	-	
Horizontal shift register capacitance	S9970/S9971-0906	C_{P1H}, C_{P2H}	-	100	-	pF
	S9970/S9971-1006		-	180	-	
	S9970/S9971-1007		-	180	-	
	S9970/S9971-1008		-	180	-	
Summing gate capacitance		C_{SG}	-	7	-	pF
Reset gate capacitance		C_{RG}	-	7	-	pF
Transfer gate capacitance	S9970/S9971-0906	C_{TG}	-	60	-	pF
	S9970/S9971-1006		-	100	-	
	S9970/S9971-1007		-	100	-	
	S9970/S9971-1008		-	100	-	
Transfer efficiency*5		CTE	0.99995	0.99999	-	-
DC output level		Vout	12	15	18	V
Output impedance		Zo	-	5	-	kΩ
Power dissipation*6		P	-	15	-	mW

*5: Charge transfer efficiency per pixel, measured at half of the full well capacity
*6: Power dissipation of the on-chip amplifier plus load resistance

Electrical and optical characteristics (Ta=25 °C, unless otherwise noted)

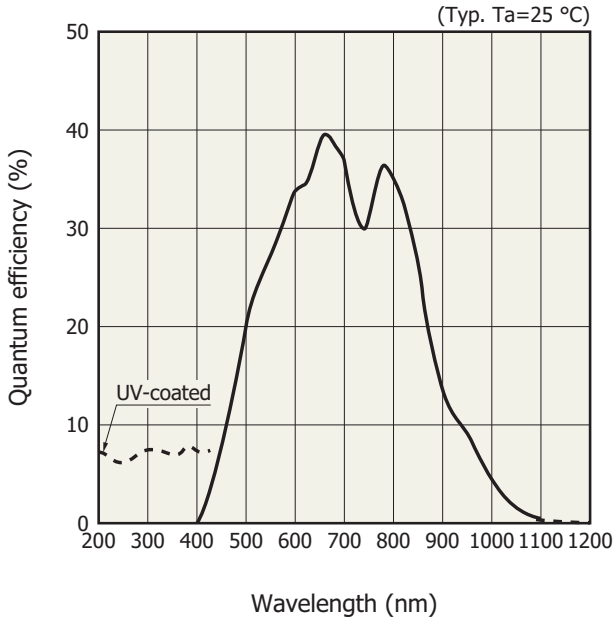
Parameter		Symbol	Min.	Typ.	Max.	Unit
Saturation output voltage		Vsat	-	Fw × Sv	-	V
Full well capacity	Vertical	Fw	150	300	-	ke^-
	Horizontal		300	600	-	
CCD node sensitivity*7		Sv	-	3.5	-	$\mu V/e^-$
Dark current (MPP mode)*8	+25 °C	DS	-	200	3000	e^-/pixel/s
	0 °C		-	10	150	
Readout noise*9		Nr	-	4	18	e^- rms
Dynamic range*10	Line binning	DR	75000	150000	-	-
	Area scanning		37500	75000	-	-
Spectral response range		λ	-	400 to 1100	-	nm
Photoresponse nonuniformity*11		PRNU	-	-	±10	%
Blemish	Point defects*12	-	-	-	0	-
	Cluster defects*13		-	-	0	
	Column defects*14		-	-	0	

*7: V_{OD}=20 V , Load resistance=22 kΩ
*8: Dark current nearly doubles for every 5 to 7 °C increase in temperature.
*9: -40 °C, operating frequency is 80 kHz.
*10: Dynamic range (DR) = Full well capacity / Readout noise
*11: Measured at one-half of the saturation output (full well capacity) using LED light (peak emission wavelength: 560 nm)

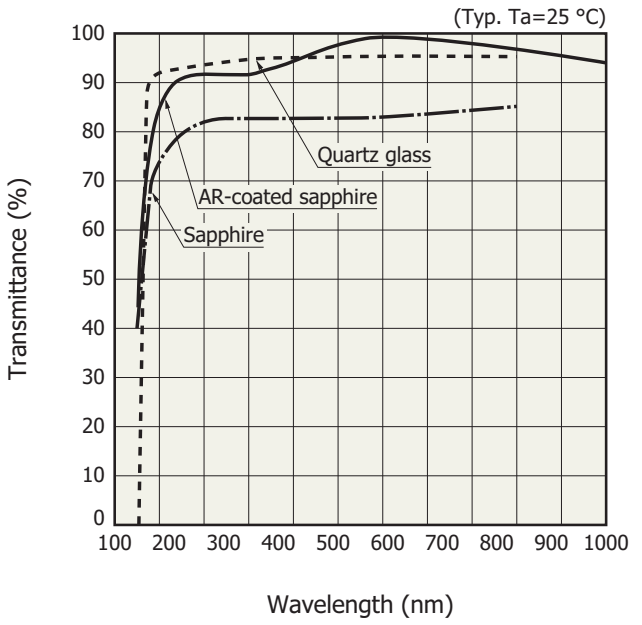
$$\text{Photoresponse nonuniformity} = \frac{\text{Fixed pattern noise (peak to peak)}}{\text{Signal}} \times 100\ [\%]$$

*12: White spots
Pixels that generate dark current higher than 3% of the saturation (measured at 0 °C, Ts=1 s)
Black spots
Pixels whose sensitivity is lower than one-half of the average pixel output (measured with uniform light producing one-half of the saturation charge)
*13: 2 to 9 contiguous defective pixels
*14: 10 or more contiguous defective pixels

Spectral response (without window)*15

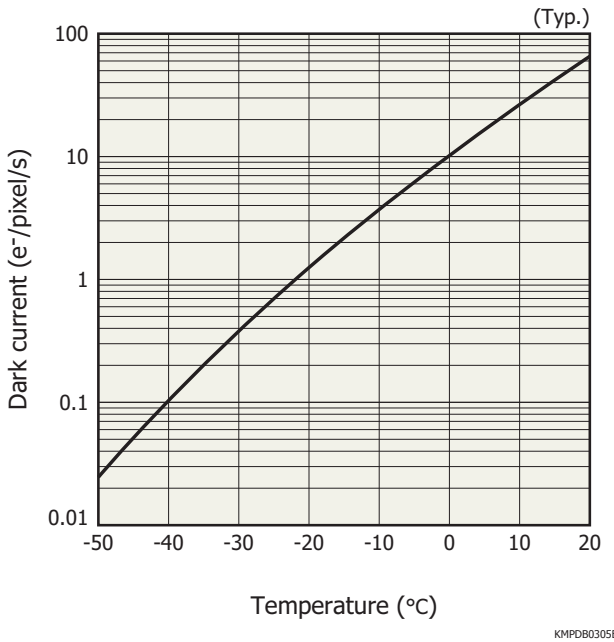


Spectral transmittance characteristics of window material



*15: Spectral response with sapphire or AR-coated sapphire is decreased according to the spectral transmittance characteristic of window material.

Dark current vs. temperature

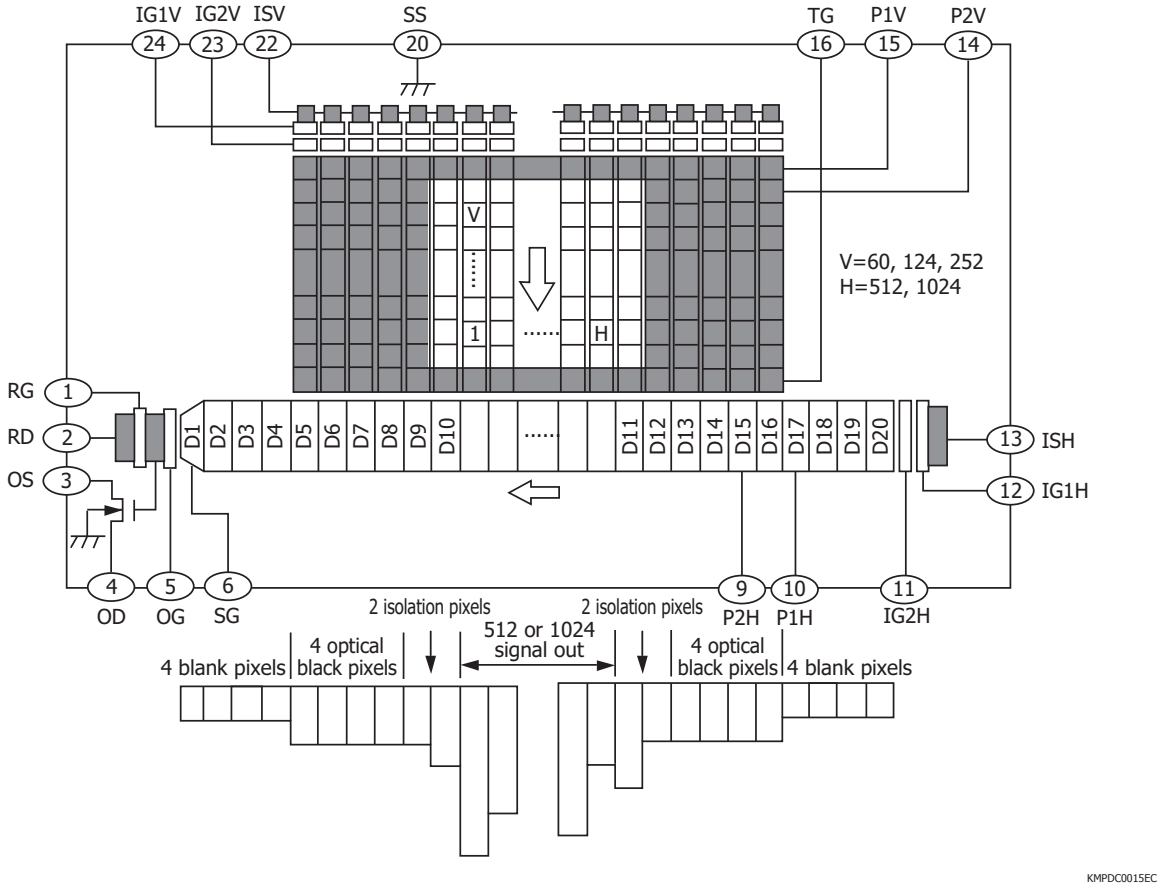


Window material

Type no.	Window material
S9970 series	Quartz glass*16 (option: window-less)
S9971-0906/-1006/-1007	Sapphire*17 (option: window-less)
S9971-1008	AR-coated sapphire*17 (option: window-less)

*16: Resin sealing
*17: Hermetic sealing

Device structure (conceptual drawing of top view in dimensional outlines)



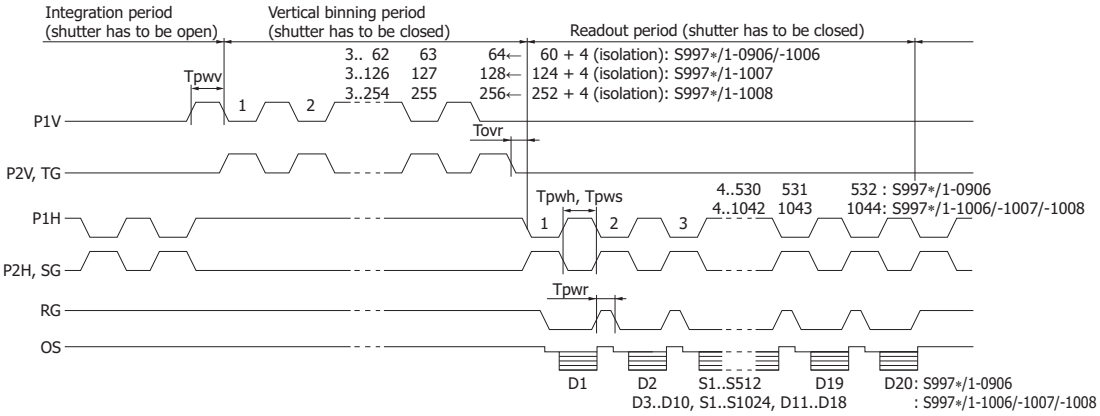
Pixel format

Left ← Horizontal direction → Right						
Blank	Optical black	Isolation	Effective	Isolation	Optical black	Blank
4	4	2	512 or 1024	2	4	4

Top ← Vertical direction → Bottom		
Isolation	Effective	Isolation
2	60, 124 or 252	2

Timing chart

Line binning



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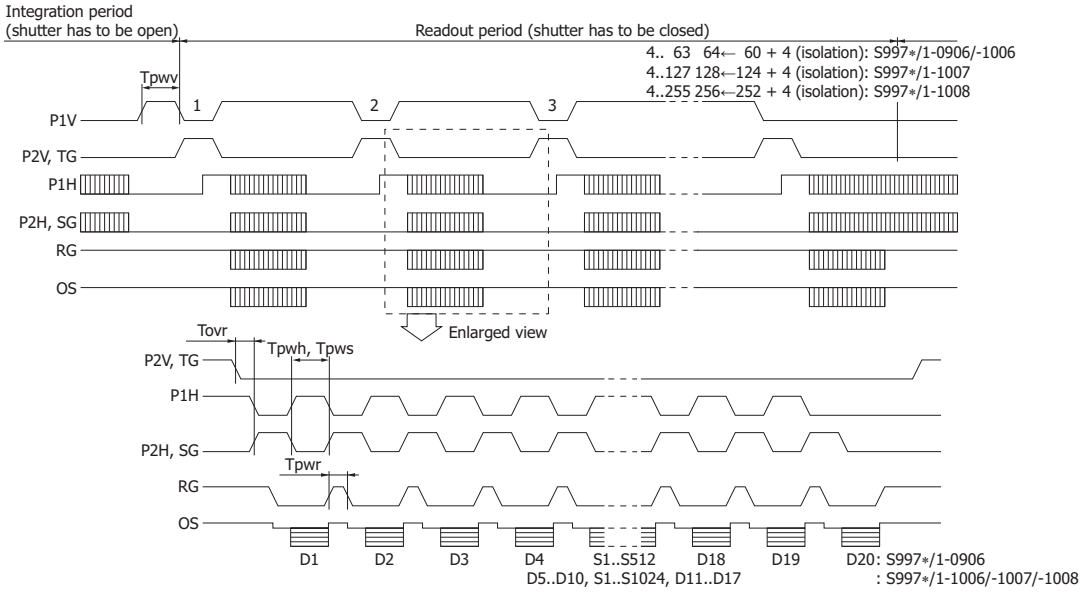
Area scanning (large full well mode)



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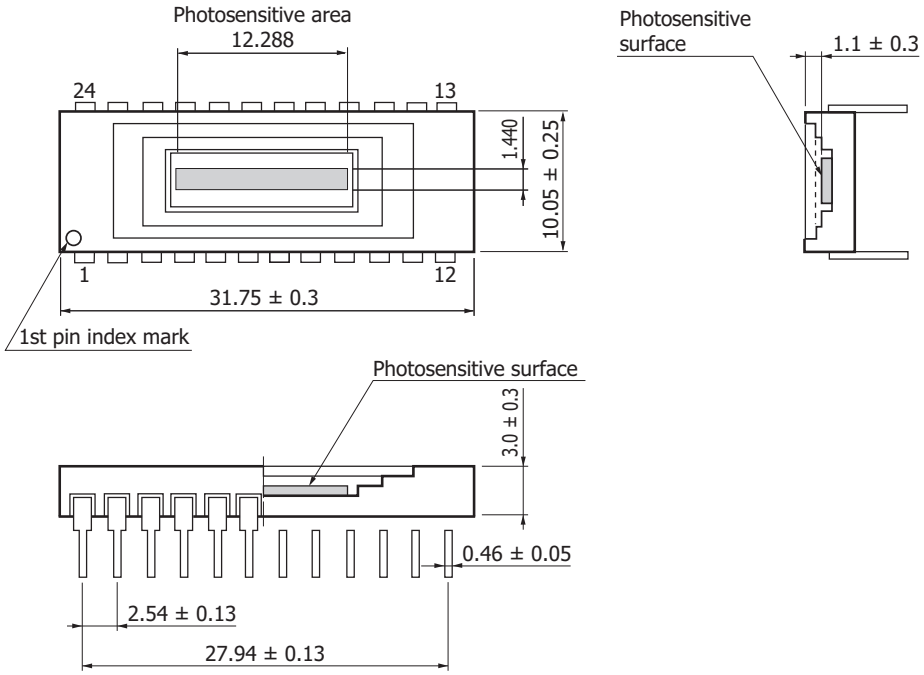
Parameter			Symbol	Min.	Typ.	Max.	Unit
P1V, P2V, TG	Pulse width*18	S9970/S9971-0906	Tpwv	1.5	4.5	-	µs
		S9970/S9971-1006		3.0	9.0	-	
		S9970/S9971-1007		6.0	18	-	
		S9970/S9971-1008		12	36	-	
	Rise and fall times		Tprv, Tpfv	200	-	-	ns
P1H, P2H	Pulse width		Tpwh	500	5000	-	ns
	Rise and fall times*18		Tprh, Tpfh	10	-	-	ns
	Duty ratio		-	-	50	-	%
SG	Pulse width		Tpws	500	5000	-	ns
	Rise and fall times		Tprs, Tpfs	10	-	-	ns
	Duty ratio		-	-	50	-	%
RG	Pulse width		Tpwr	100	500	-	ns
	Rise and fall times		Tprr, Tpfr	5	-	-	ns
TG - P1H	Overlap time		Tovr	3	6	-	µs

*18: Symmetrical clock pulses should be overlapped at 50% of maximum amplitude.

Dimensional outlines (unit: mm)

S9970-0906



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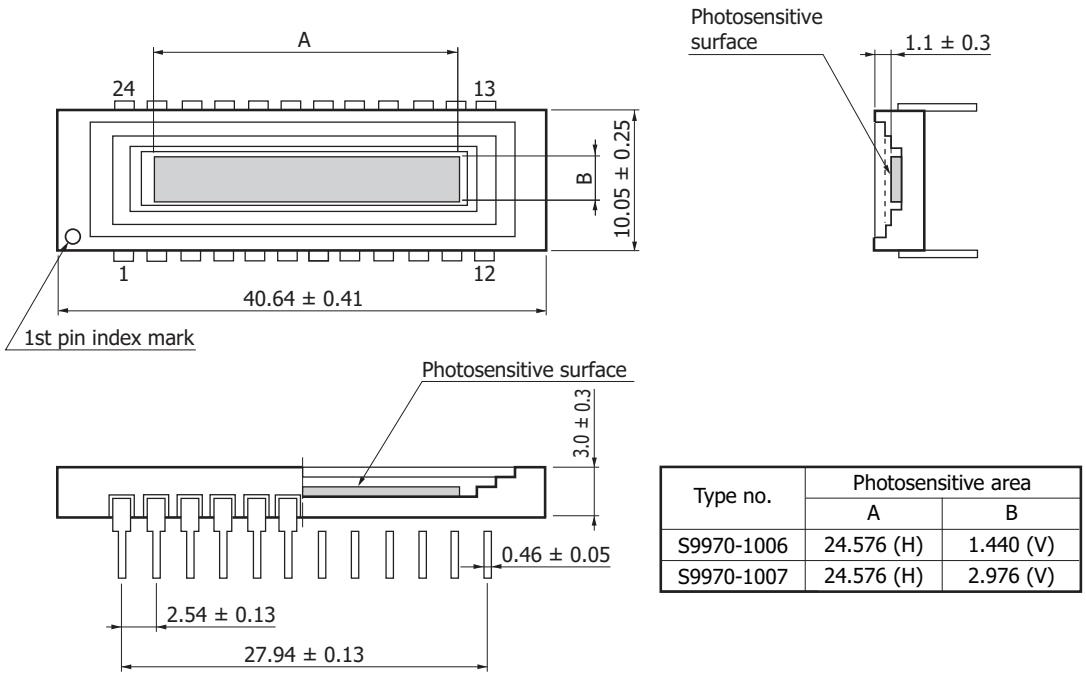
S9970-1006/-1007



Type no.	Photosensitive area	
	A	B
S9970-1006	24.576 (H)	1.440 (V)
S9970-1007	24.576 (H)	2.976 (V)

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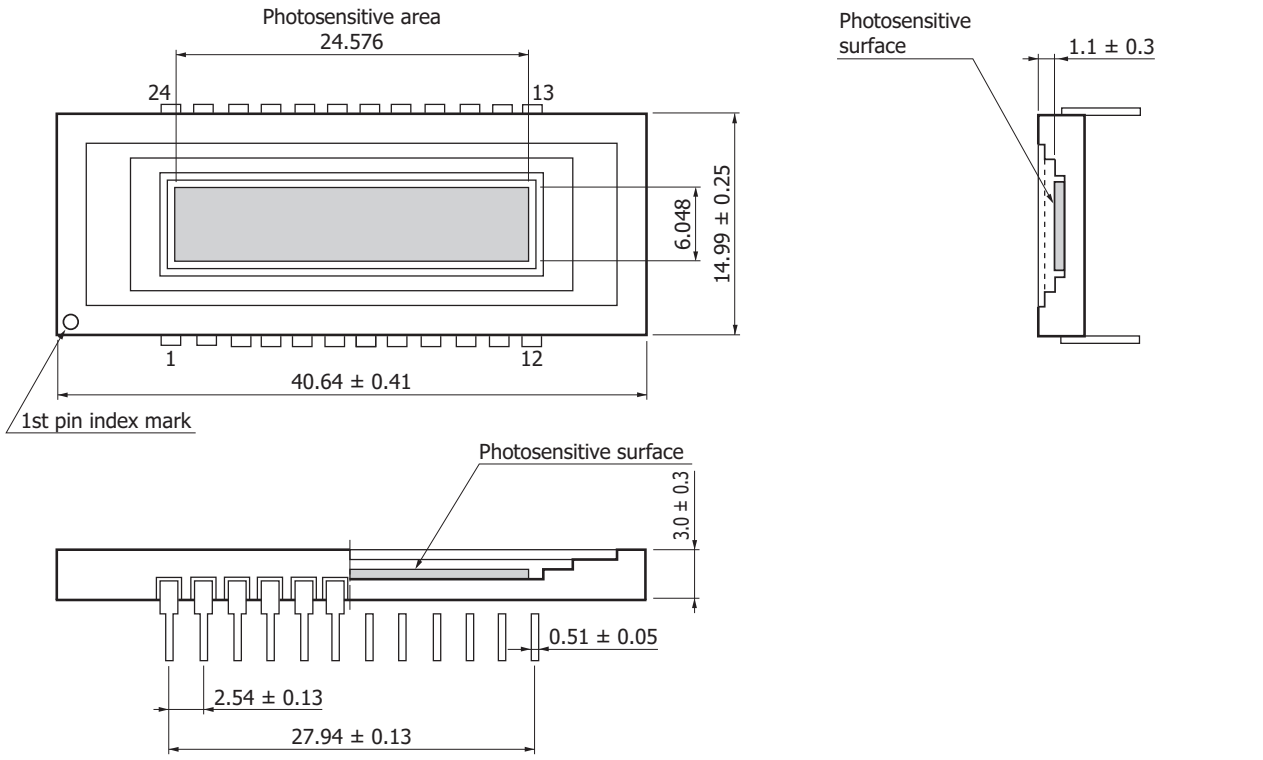
S9970-1008



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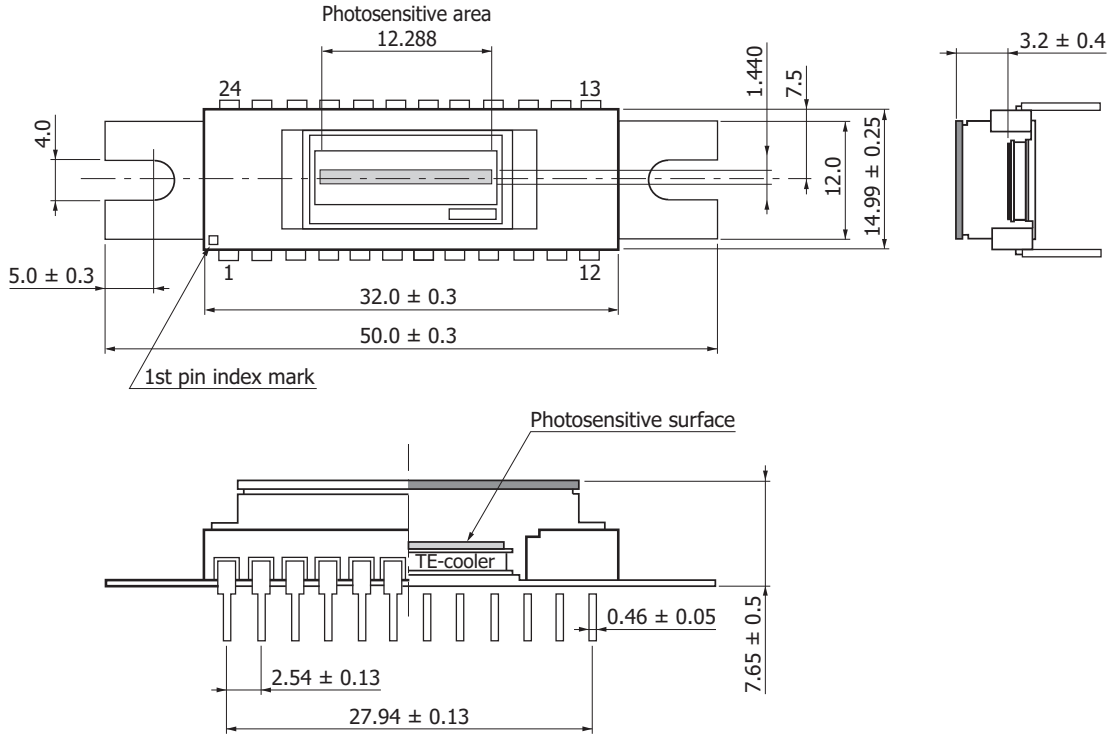
S9971-0906



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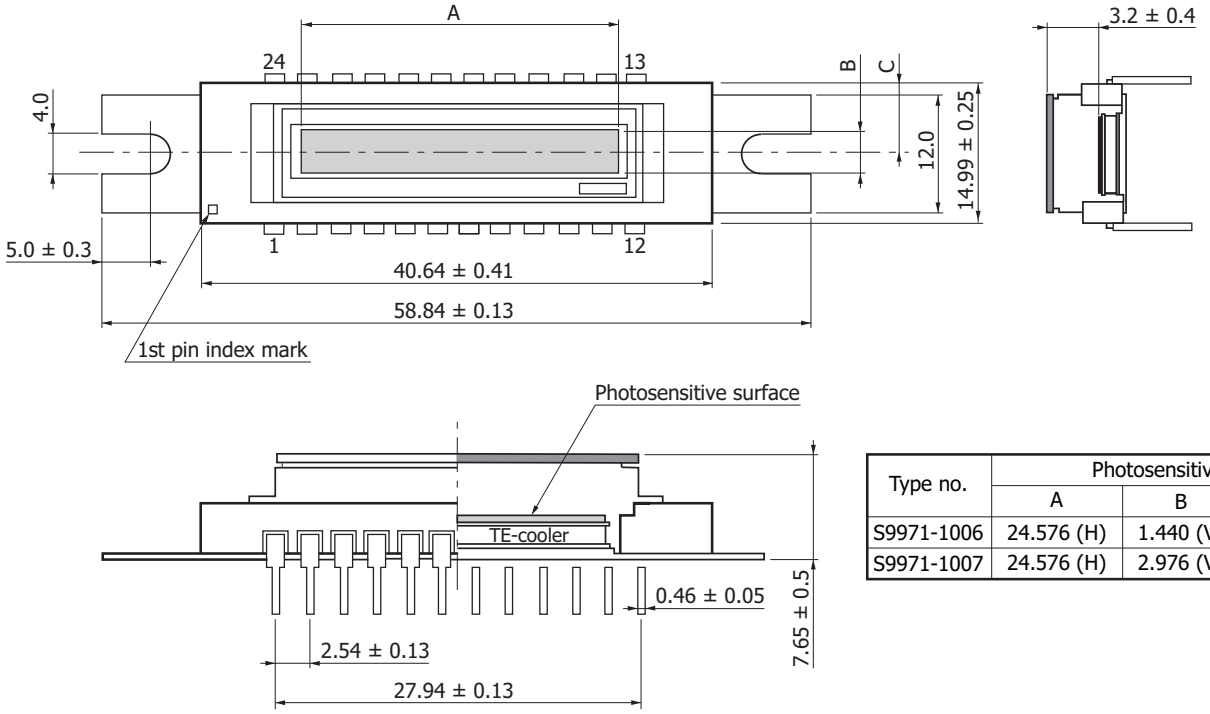
S9971-1006/-1007



Type no.	Photosensitive area		
	A	B	C
S9971-1006	24.576 (H)	1.440 (V)	7.5
S9971-1007	24.576 (H)	2.976 (V)	7.1

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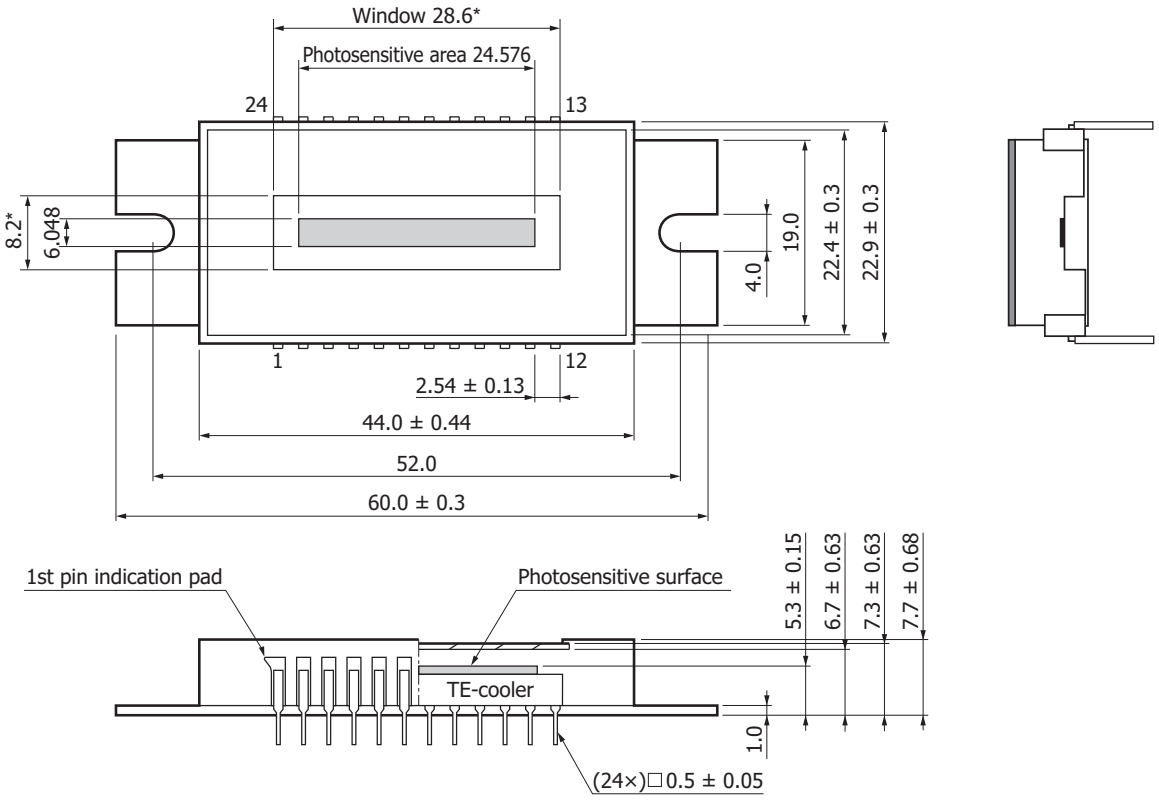
S9971-1008



* Size of window that guarantees the transmittance in the "Spectral transmittance characteristics of window material" graph

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Pin connections

Pin no.	S9970 series		S9971 series		Remark (standard operation)
	Symbol	Description	Symbol	Description	
1	RG	Reset gate	RG	Reset gate	
2	RD	Reset drain	RD	Reset drain	+12 V
3	OS	Output transistor source	OS	Output transistor source	R_L=22 kΩ
4	OD	Output transistor drain	OD	Output transistor drain	+20 V
5	OG	Output gate	OG	Output gate	+3 V
6	SG	Summing gate	SG	Summing gate	Same timing as P2H
7	-		Th1	Thermistor	
8	-		Th2	Thermistor	
9	P2H	CCD horizontal register clock-2	P2H	CCD horizontal register clock-2	
10	P1H	CCD horizontal register clock-1	P1H	CCD horizontal register clock-1	
11	IG2H	Test point (horizontal input gate-2)	IG2H	Test point (horizontal input gate-2)	0 V
12	IG1H	Test point (horizontal input gate-1)	IG1H	Test point (horizontal input gate-1)	0 V
13	ISH	Test point (horizontal input source)	ISH	Test point (horizontal input source)	Shorted to RD
14	P2V	CCD vertical register clock-2	P2V	CCD vertical register clock-2	
15	P1V	CCD vertical register clock-1	P1V	CCD vertical register clock-1	
16	TG*16	Transfer gate	TG*19	Transfer gate	Same timing as P2V
17	-		-		
18	-		P-	TE-cooler-	
19	-		P+	TE-cooler+	
20	SS	Substrate (GND)	SS	Substrate (GND)	GND
21	-		-		
22	ISV	Test point (vertical input source)	ISV	Test point (vertical input source)	Shorted to RD
23	IG2V	Test point (vertical input gate-2)	IG2V	Test point (vertical input gate-2)	0 V
24	IG1V	Test point (vertical input gate-1)	IG1V	Test point (vertical input gate-1)	0 V

*19: TG is an isolation gate between vertical register and horizontal register. In standard operation, the same pulse as P2V should be applied to TG.

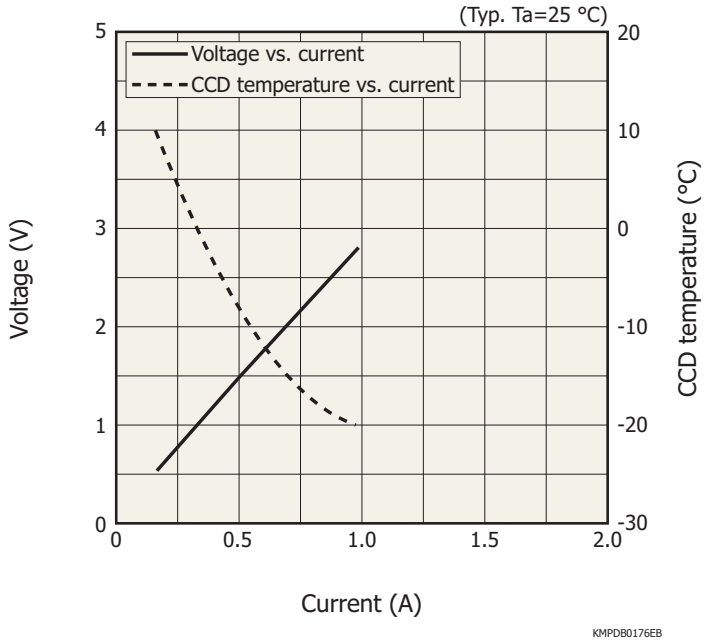
Specifications of built-in TE-cooler (Typ.)

Parameter	Symbol	Condition	S9971-0906	S9971-1006/-1007	S9971-1008	Unit
Internal resistance	Rint	Ta=25 °C	2.8	6.0	1.2	Ω
Maximum heat absorption*20	Qmax		3.4	6.7	5.1	W
Maximum temperature of hot side	-		70			°C

*20: This is a heat absorption when the maximum current is supplied to the TE-cooler.

TE-cooler characteristics

S9971-0906



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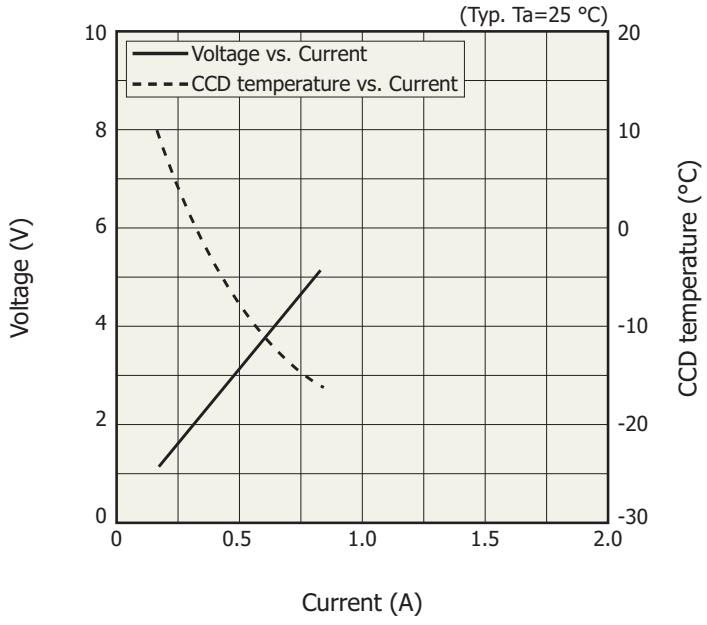
S9971-1006/-1007



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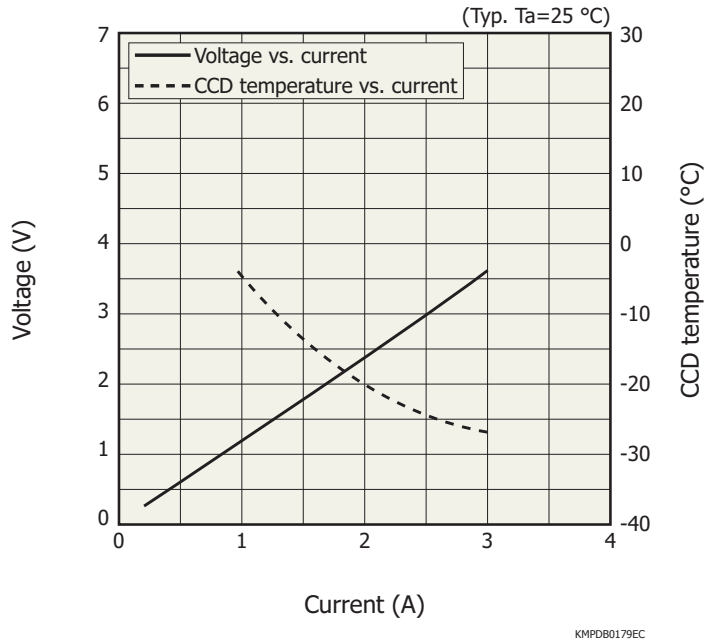
S9971-1008



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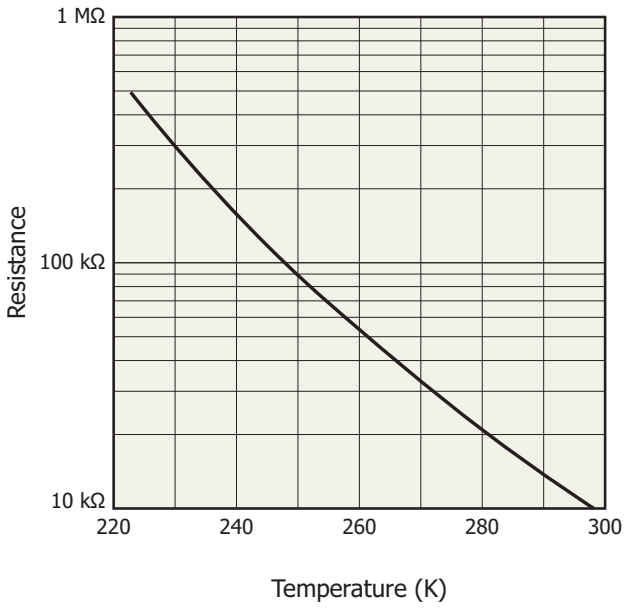
Specifications of built-in temperature sensor

A chip thermistor is built in the same package with a CCD chip, and the CCD chip temperature can be monitored with it. A relation between the thermistor resistance and absolute temperature is expressed by the following equation.

$R_{T1} = R_{T2} \times \exp B_{T1/T2} (1/T1 - 1/T2)$

R_{T1}: resistance at absolute temperature T1 [K]
R_{T2}: resistance at absolute temperature T2 [K]
$B_{T1/T2}$: B constant [K]

The characteristics of the thermistor used are as follows.
R_{298}=10 kΩ
$B_{298/323}$=3450 K



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Precautions (Electrostatic countermeasures)

· Handle these sensors with bare hands or wearing cotton gloves. In addition, wear anti-static clothing or use a wrist strap, in order to prevent electrostatic damage due to electrical charges from friction.
· Avoid directly placing these sensors on a work-desk or work-bench that may carry an electrostatic charge.
· Provide ground lines or ground connection with the work-floor, work-desk and work-bench to allow static electricity to discharge.
· Ground the tools used to handle these sensors, such as tweezers and soldering irons.

It is not always necessary to provide all the electrostatic measures stated above. Implement these measures according to the amount of damage that occurs.

Element cooling/heating temperature gradient rate

When using an external cooler, the element cooling/heating temperature gradient rate should be set at less than 5 K/min.

Multichannel detector head (C7020, C7021, C7025)

Features

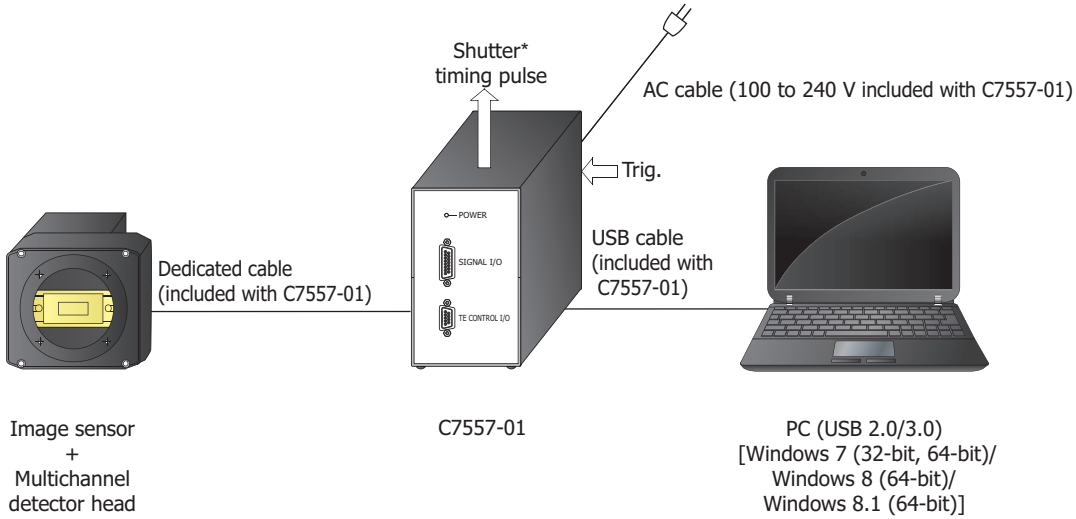
- **C7020: for S9970 series**
  C7021: for S9971-0906/-1006/-1007
  C7025: for S9971-1008
- **Area scanning or full line-binnng operation**
- **Readout frequency: 250 kHz**
- **Readout noise: 20 e^- rms typ.**
- **ΔT=50 °C (ΔT changes by radiation method.)**

Input	Symbol	Value
Supply voltage	V_{D1}	+5 Vdc, 200 mA
	V_{A1+}	+15 Vdc, +100 mA
	V_{A1-}	-15 Vdc, -100 mA
	V_{A2}	+24 Vdc, 30 mA
	V_{D2}	+5 Vdc, 30 mA (C7021, C7025)
	Vp	+5 Vdc, 2.5 A (C7021, C7025)
	V_F	+12 Vdc, 100 mA (C7021, C7025)
Master start	ϕms	HCMOS logic compatible
Master clock	ϕmc	HCMOS logic compatible, 1 MHz

Multichannel detector head controller

Type no.	Interface	Photo	Accessories
C7557-01	USB2.0		· USB cable · Fuse (2.5 A) · Detector head connection cable · AC cable · Software [compatible OS: Windows 7 (32-bit, 64-bit), Windows 8 (64-bit), Windows 8.1 (64-bit)] · Operation manual · MOS adapter

Connection example



* Shutter, etc. are not available.

KACCC0402ED

Related information

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

■ Precautions
· Disclaimer
· Image sensors

HAMAMATSU www.hamamatsu.com

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Cat. No. KMPD1089E09 Jul. 2017 DN