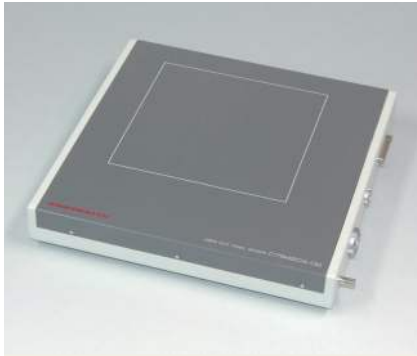


# Flat panel sensor



C7942CA-22

## Large photodiode area (120 × 120 mm)

The C7942CA-22 is a compact, lightweight digital X-ray image sensor developed as a key device for non-destructive inspection, biochemical imaging, and X-ray microscopy. High-resolution, high-definition digital X-ray images can be acquired in real time.

### Features

- 2400 × 2400 pixels
- 12-bit digital output
- High-speed imaging: 2 frames/s (single operation)  
9 frames/s (4 × 4 binning)
- Low noise and wide dynamic range

### Applications

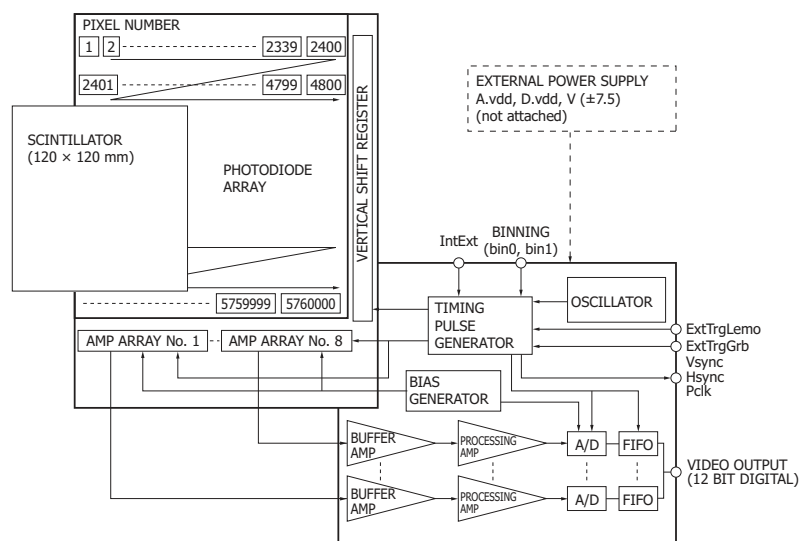
- Non-destructive inspection (off-line only)
- Digital X-ray photography

### Configuration

The C7942CA-22 is comprised of a sensor board and a control board. Mounted on the sensor board is a CMOS image sensor chip made up of a two-dimensional photodiode array, row-scanning vertical shift register, and 8 charge amplifier arrays. Each charge amplifier array has a horizontal shift register and consists of 300 ch charge amplifiers with CDS circuit.

A CsI scintillator plate is mounted on the two-dimensional photodiode array. X-rays incident on the scintillator are converted to fluorescence, which then enters the two-dimensional photodiode array where electric charge is accumulated in each pixel according to the light intensity. The accumulated charge on each row is sequentially selected by the row-scanning vertical shift register, transferred to the amplifiers through the data line, and converted to a voltage signal. Then an analog signal is sent out from each amplifier array by scanning the horizontal shift register.

The control board converts the analog signal into a 12-bit digital signal, which is then sent to a frame grabber board as a 12-bit parallel output through one port.



Note: Signals are read out in order of pixel number.

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## Structure

Parameter	Specifications	Unit
Pixel size	50 × 50	μm
Photodiode area	120 × 120	mm
Number of pixels	2400 × 2400	pixels
Number of active pixels	2240 × 2344	pixels
Readout	Charge amplifier array	-
Video output (Data1-12)	RS-422 (differential), 12-bit	-
Output data rate	15.15	MHz
Synchronous signal (Vsync, Hsync, Pclk)	RS-422 (differential)	-
bin0/1, ExtTrgGrb, ExtTrgLemo, IntExt	TTL	-
Scintillator	CsI	-

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

Parameter	Symbol	Value	Unit
Supply voltage for digital circuitry (+5 V)	D.vdd	+6.0	V
Supply voltage for analog circuitry (+5 V)	A.vdd	+6.0	V
Supply voltage for analog circuitry (±7.5 V)	V(±7.5)	±12	V
Input voltage (bin0/1, ExtTrgGrb, ExtTrgLemo, IntExt)	Vin	0 to 6.0	V
Operating temperature*1	Topr	0 to +40	°C
Storage temperature*1	Tstg	-10 to +60	°C
Incident X-ray energy	-	100	kVp
Total warranty dose*2	D	1 (8730)	MR (Gy)

\*1: No 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.

\*2: Incident X-ray energy 100 kVp or less

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.

## Specifications [Ta=25 °C, A.vdd= 5.0 V, D.vdd= 5.0 V, V(±7.5)= ±7.5 V]

Parameter	Symbol	Min.	Typ.	Max.	Unit
Frame rate (single operation)	Sf(int)	1.9	2	-	frames/s
Frame rate (2 × 2 binning)	-	-	4	-	frames/s
Frame rate (4 × 4 binning)	-	-	9	-	frames/s
Frame rate external (single operation)	Sf(ext)	-	Sf(int) to 0.1	-	frames/s
Noise (rms)*2	N(rms)	-	1100	-	electrons
Saturation charge	Csat	-	2.2	-	M electrons
Sensitivity*3	S	20 (2.3)	25 (2.9)	-	LSB/mR (LSB/μGy)
Resolution*4	Reso	6	8	-	line pairs/mm
Dynamic range	-	-	2000	-	-
Defect line*5	-	-	-	20	lines
Blemish*6	-	-	-	600	μm
Non-uniformity of sensitivity*6	-	-	-	4	%
Defect cluster*6	-	-	Not allowed		-
Bright line output adjacent to a defect line*6	-	-	-	120	%
Output offset*6	-	-	65	200	LSB

\*2: Internal trigger mode, single operation

\*3: at 80 kVp without filter

\*4: Spatial frequency at CTF=5 %

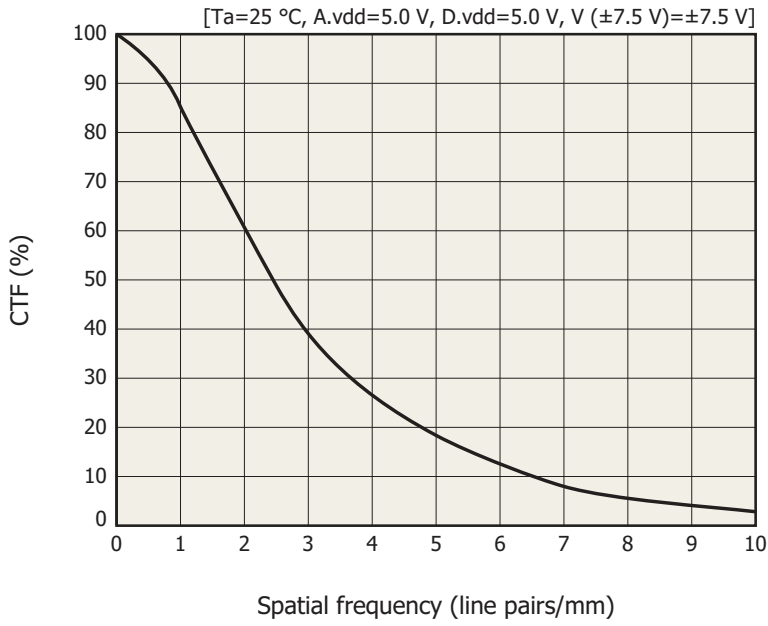
\*5: A defect line is a horizontal or vertical line containing 4 or more cosecutive pixels located at the opposite side of an amplifier array or a shift register, that produce 1/8 of the average sensitivity of the surrounding pixels. Adjacent defective lines are not allowed in the vertical or horizontal directions.

\*6: See P. 7, 8, "Description of terms"

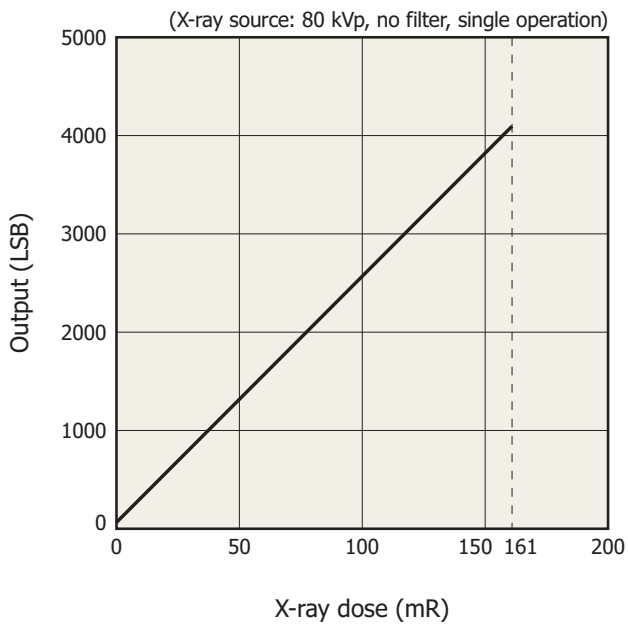
\*7: Average of all effective pixels in single operation at Sf(int)

Note: X-ray energy range is 20 k to 100 kVp.

**Resolution**



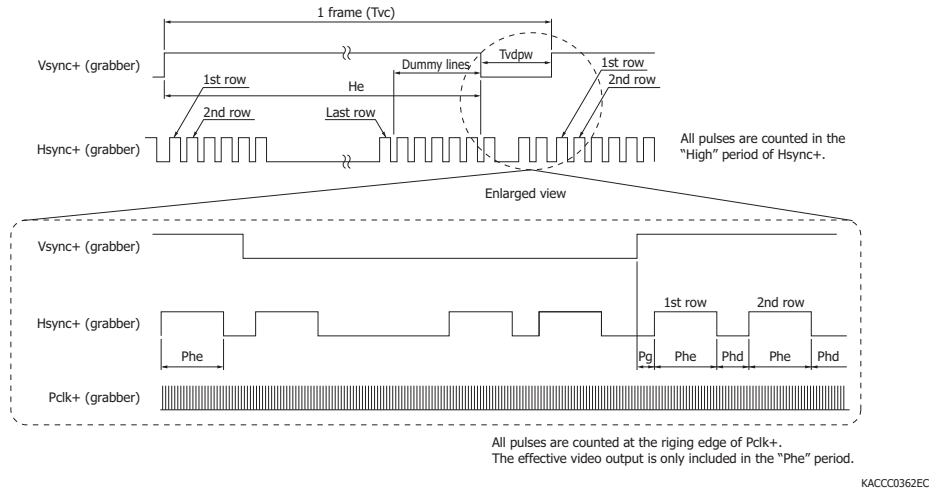
**Output vs. X-ray dose**



**Timing chart**

Internal trigger mode

To acquire images through a frame grabber board, write parameters in the software program or parameter file by referring to the following timing chart and description.



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Parameter		Count		
		Single operation (1 × 1)	2 × 2 binning	4 × 4 binning
He	Effective line	2344	1172	586
	Dummy line	56	28	14
Phe	Effective pixel	2240	1120	560
	Dummy pixel	160	80	40
Phd		526	1726	2326
Pg		21	21	21

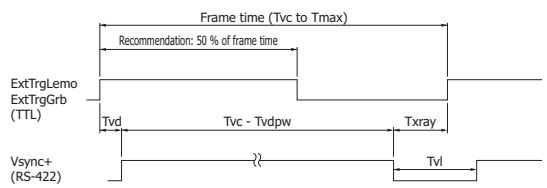
Note: "He" is the Hsync count. Phe, Phd and Pg are the Pclk count.

External trigger mode

To acquire images in external trigger mode, input an external trigger pulse as shown below. When the time Tvd has passed after the rising edge of the external trigger pulse, synchronous signals and video signals are obtained.

When used in synchronization with a pulsed X-ray source, X-rays should be irradiated during the T<sub>xray</sub> period.

Mode	40-pin receptacle		2-pin receptacle
	Pin No. 17 (ExtTrgGrb)	Pin No. 37 (IntExt)	Pin No. 1 (ExtTrgLemo)
Internal trigger mode	(Input signal is ignored.)	Low	(Input signal is ignored.)
External trigger mode	Rectangular signal (See the right figure.)	High	High or Open
	High or Open		Rectangular signal (See the right figure.)



Hsync+, Pclk+ and effective video output are the same as internal trigger mode.  
 · Tmax is defined as the reciprocal of the minimum value of Sf(ext).  
 · T<sub>xray</sub> = Frame time - Tvd - (Tvc - Tvdpw)  
 · Tvl = Frame time - (Tvc - Tvdpw)

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(Typ.)

Parameter		Symbol	Single operation	2 × 2 binning	4 × 4 binning	Unit
Vsync	Delay time (only external trigger mode)	Tvd	390	390	390	μs
	Cycle time (internal trigger mode)	Tvc	470	230	117	ms
	Pulse width of Vsync+ in low period (internal trigger mode)	Tvdpw	770	770	770	μs

Note: The numbers of significant figures is two. (except Tvc)

## Accessories

- Power cable (terminated with an FGG.2B.307.CLAD92Z plug at one end and open at the other end; 2 m; see Table 2.)
- External trigger cable (terminated with an FFA.0S.302.CLAC37 plug at one end and open at the other end; 5 m; see Table 3.)
- Earth cable (AWG18; 4 m)

The image acquisition software and image processing libraries are not included with the flat panel sensor.

## System requirements

To operate the C7942CA-22 at full performance, the following system and peripherals are required.

- PC: Prepare a PC that meets the specifications of the frame grabber board while taking the required image processing capability into account.
- Frame grabber board: Monochrome 16 bits or more, pixel clock 16 MHz or more, RS-422 interface synchronous signal
- Power source: A.vdd = +5.0 ± 0.1 V (1000 mA), D.vdd = +5.0 ± 0.1 V (1000 mA), V(±7.5 V) = ±7.5 V ± 0.5 V (±100 mA)
  - The voltages described above are specified at the flat panel sensor side. The impedance of the power cable attached with the flat panel sensor is low enough but it causes 0.1 V approx. drop. Therefore the voltage at the power source side should be set 0.1 V higher than the voltage specified above.
  - Please use a low noise series power supply. (Avoid using a switching power supply.)
  - Install a noise filter on the AC power input line to prevent surges on the AC line.
  - Always ground the ground terminal to avoid the effects of noise from peripheral devices.
- Frame grabber board cable (sold separately, see P. 8.): For synchronous signal, video output and external control (see Table 1.)

[Table 1] Pin assignment of 40-pin receptacle

Pin No.	Signal	Pin No.	Signal
1	Data1+ (LSB)	21	Data1- (LSB)
2	Data2+	22	Data2-
3	Data3+	23	Data3-
4	Data4+	24	Data4-
5	Data5+	25	Data5-
6	Data6+	26	Data6-
7	Data7+	27	Data7-
8	Data8+	28	Data8-
9	Data9+	29	Data9-
10	Data10+	30	Data10-
11	Data11+	31	Data11-
12	Data12+ (MSB)	32	Data12- (MSB)
13	Reserved	33	Reserved
14	Reserved	34	Reserved
15	bin0 (TTL)	35	GND
16	bin1 (TTL)	36	GND
17	ExtTrgGrb (TTL)	37	IntExt (TTL)
18	Vsync+	38	Vsync-
19	Hsync+	39	Hsync-
20	Pclk+	40	Pclk-

Unless otherwise noted, signal level is RS-422.

40-pin receptacle: 10240-52B2PL made by 3M Co. Ltd.

Mating plug: 10140-6000EL made by 3M Co. Ltd.

[Table 2] Power pin assignment and cable color

Pin No.	Color	Signal
1	Brown	+7.5 V
2	Red	Analog GND
3	Orange	-7.5 V
4	Yellow	Analog GND
5	Green	Analog +5 V
6	Blue	Digital GND
7	Purple	Digital +5 V
Shield	-	Analog GND

7-pin power receptacle: ECG.2B.307.CLV made by LEMO S.A.  
Mating power plug: FGG.2B.307.CLAD92Z made by LEMO S.A.

[Table 3] External trigger pin assignment and cable color

Pin No.	Color	Signal
1	Red	ExtTrgLemo (TTL)
2	Black	Signal GND
Shield	-	Analog GND

2-pin receptacle: ECP.0S.302.CLL made by LEMO S.A.  
Mating plug: FFA.0S.302.CLAC37 made by LEMO S.A.

## ■ Binning mode

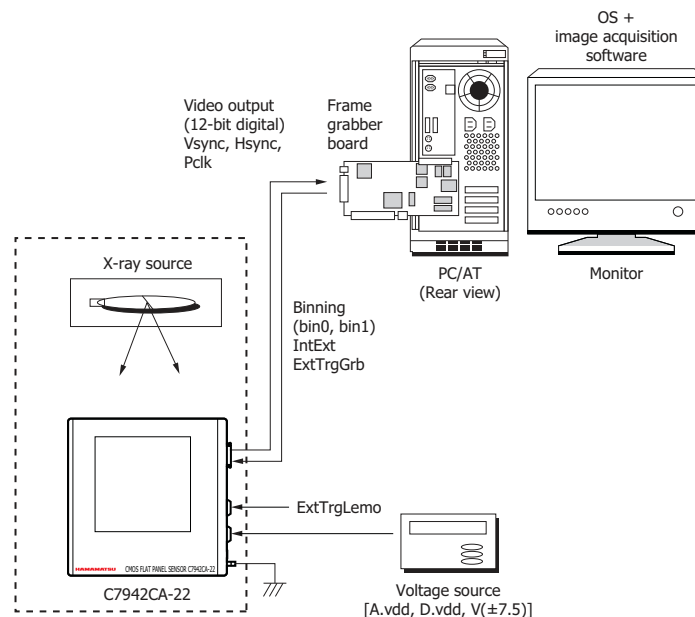
The C7942CA-22 has binning mode for reading out signals from multiple pixels at a time. The binning mode setting can be changed by using I/O port.

[Table 4] Binning mode setting (Grabber interface: 40-pin receptacle)

Operating mode	Pin No.	
	No. 15 (bin0)	No. 16 (bin1)
Single operation (1 × 1)	Low	Low
2 × 2 binning	High	Low
4 × 4 binning	High	High

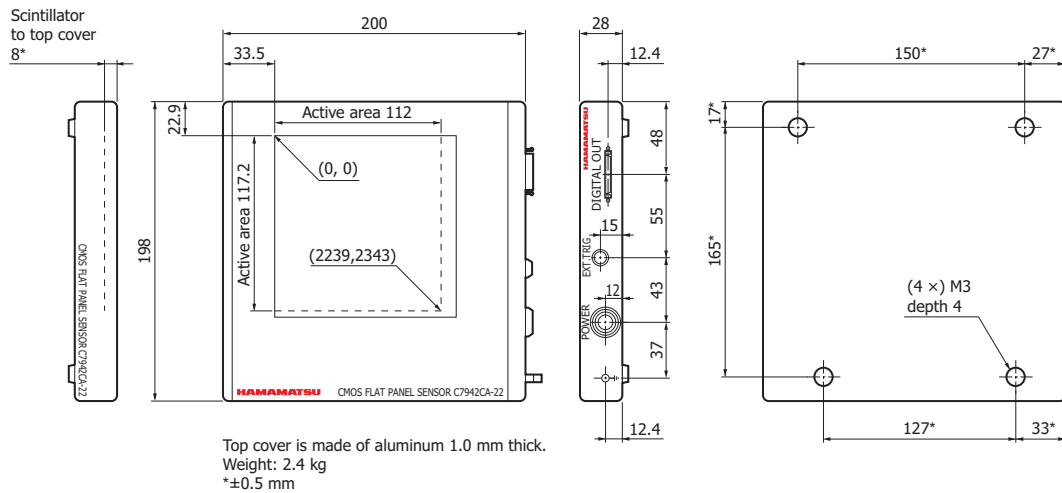
## ■ Connection example

Install the frame grabber board into the PC by the manufacturer's instructions. When a general-purpose frame grabber board with I/O control is used, the binning mode or trigger mode can be set by controlling bin0, bin1, IntExt, and ExtTrgGrb through the I/O line.



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**Dimensional outline (unit: mm, tolerance: ±1 mm unless otherwise noted)**



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**Notice**

- Do not subject the flat panel sensors to strong vibration or shock (Strong shock such as drop impacts may cause permanent damage to these sensors).
- Users must take responsibility for implementing X-ray shielding safety measures to avoid the risk of X-ray exposure.
- Data listed in this datasheet is defined at the time of shipment. Characteristics may vary somewhat due to exposure to X-rays so take proper countermeasures such as making periodic image correction.
- This product is warranted for a period of 12 months after the date of the shipment.  
The warranty is limited to make a replacement or repair of any defective product due to defects in workmanship or materials used in manufacture. The warranty does not cover loss or damage caused by natural disaster, misuse (including modifications and any use not complying with the environment, application, usage and storage conditions described in this datasheet), or total radiation dose over 1 MR (incident X-ray energy: less than 100 kVp) even within the warranty period.
- As described above, flat panel sensors have limited resistance to radiation. This must be taken into account when using a flat panel sensor under continuous irradiation (This sensor cannot be used for in-line application).
- When using flat panel sensors in non-destructive inspection equipment, please contact us and provide information such as irradiation conditions.

**Guideline on the regular replacement period of consumables**

The characteristics of the flat panel sensor degrade when it is subject to X-ray irradiation. The scintillator undergoes discoloration causing the flat panel sensor's sensitivity to be reduced, and dark output increases as the photodiodes are damaged. The photodiodes' dark output may also increase locally. In addition to regularly acquiring images for correction, consider regularly replacing the flat panel sensor as a consumable product.

As a guideline on the regular replacement period of the flat panel sensor, the period until the total warranty dose is reached can be used. The period until the total warranty dose is reached can be calculated simply using the following formula.

$$\text{Period until the total warranty dose is reached [day]} = \frac{\text{Total warranty dose [MR]} \times \text{Minimum sensitivity [LSB/mR]} \times 0.7^*}{\text{Saturation output [LSB/frame]} \times \text{Maximum frame rate [frames/s]} \times 3600 \text{ [s/hour]} \times \text{X-ray irradiation time [hours/day]}}$$

\* Sensitivity attenuation of the flat panel sensor due to X-ray irradiation

As an example, if the following values are substituted in the above formula, the number of operating days is 237.

- Total warranty dose: 1 MR
- Minimum sensitivity: 20 LSB/mR (80 kVp)
- Saturation output: 4096 LSB/frame
- Maximum frame rate: 2 frames/s
- X-ray irradiation time: 2 hours/day

Typical examples of variations in the sensitivity and dark output due to X-ray irradiation are provided in the flat panel sensor application manual. If you would like to obtain the application manual, contact your local Hamamatsu office.

**Description of terms**

☒ **Blemish**

Length of pixel cluster which has less than 90 % of the average sensitivity of the surrounding pixels.

☒ **Bright line output adjacent to a defect line**

The relative sensitivity ratio "a/b" should be 120 % or less for both vertical and horizontal lines, where "a" and "b" are defined as follows:

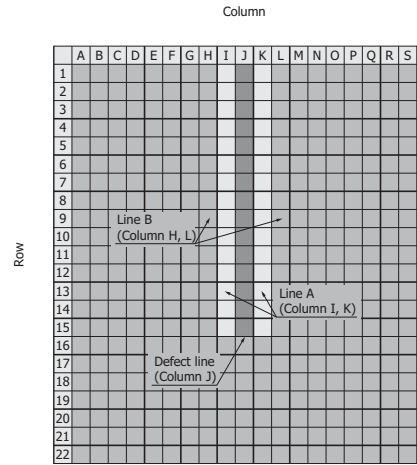
- a: Average sensitivity of bright line (Line A) adjacent to defect line
- b: Average sensitivity of standard line (Line B) adjacent to Line A

Note that the average sensitivity of the bright line is calculated from the region adjacent to the defect region in the defect line.

Example: See the right figure.

Defect region in defect line: From pixel (J, 1) to pixel (J, 15)

- a: Average sensitivity from pixel (I, 1) to pixel (I, 15) or from pixel (K, 1) to pixel (K, 15)
- b: Average sensitivity from pixel (H, 1) to pixel (H, 15) or from pixel (L, 1) to pixel (L, 15)



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☒ **Defect cluster**

Formed with more than 3 × 3 pixels which have less than 1/8 of the average sensitivity of the surrounding pixels.



This is defined as defect cluster. This is not defined as defect cluster.

□ Normal pixel    ■ Defective pixel

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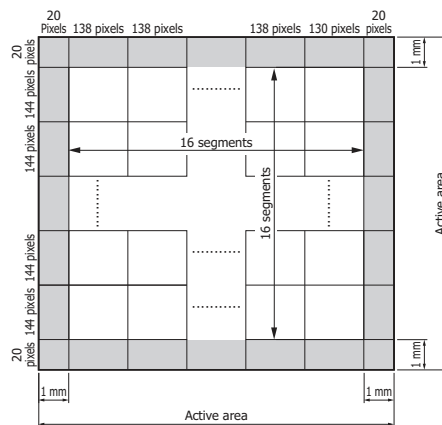
☒ **Nonuniformity of sensitivity**

16 × 16 segments are 16 × 16-divided active area excluded 1 mm from the whole edge. Xij is defined as the average sensitivity of each segment.

Uniformity of sensitivity is calculated as following equation.

$$\text{Nonuniformity of sensitivity} = \frac{\sigma}{\bar{x}}$$

- σ: standard deviation of 16 × 16 "Xij"
- $\bar{x}$ : average value of 16 × 16 "Xij"



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## ▣ Frame grabber cables (A8406 series)

Hamamatsu provides the A8406 series as frame grabber board cables. The A8406 series is available in several types with different cable lengths and terminations. Check the cable specifications that meet your needs. For detailed information, refer to the A8406 series data sheet.

## ▣ Related information

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

- Precautions
- Disclaimer

Information described in this material is current as of January, 2016.

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.

The product warranty is valid for one year after delivery and is limited to product repair or replacement for defects discovered and reported to us within that one year period. However, even if within the warranty period we accept absolutely no liability for any loss caused by natural disasters or improper product use. Copying or reprinting the contents described in this material in whole or in part is prohibited without our prior permission.

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