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Flat panel sensor

C16401SK-51

Photosensitive area: 140.0 × 122.8 mm

The C16401SK-51 is a highly reliable flat panel sensor for non-destructive inspection and radiography. High quality digital X-ray images can be captured in real time.

Features

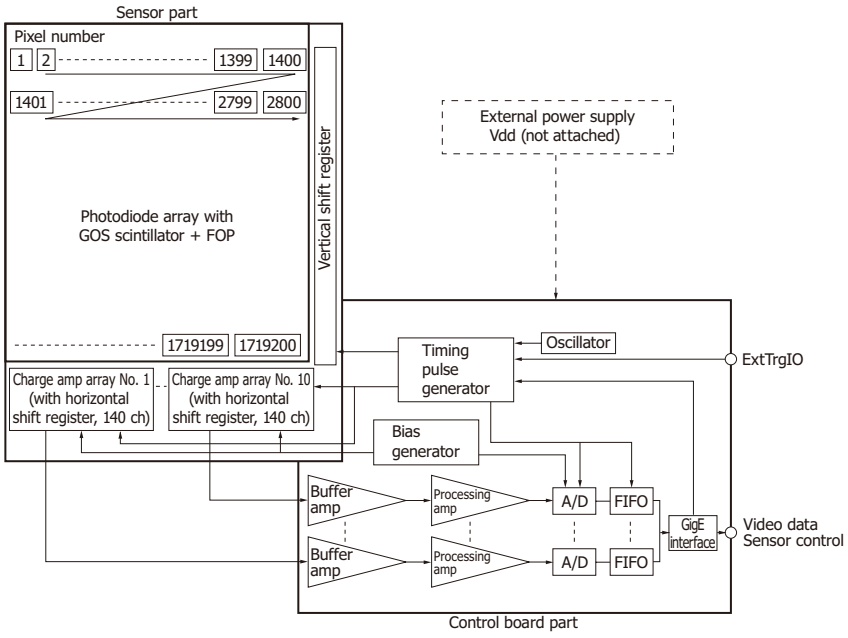
- **Photosensitive area: 140.0 × 122.8 mm**
- **High-speed imaging**
- **Low noise, low defects**
- **16-bit digital output**
- **X-ray tube voltage: 160 kV max.**

Applications

- **Non-destructive inspection**
- **Digital radiography, etc.**

Configuration (1 × 1 Flexible partial mode)

The C16401SK-51 is comprised of a sensor part and a control board part. The sensor part is equipped with a CMOS image sensor chip consisting of a two-dimensional photodiode array, vertical shift registers for row scanning, and a charge amplifier array divided into 10 blocks. Each charge amplifier array has a horizontal shift register and consists of 140 ch charge amplifiers with CDS circuit.
FOP (fiber optic plate) with GOS scintillator is directly installed 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 part converts the analog signal into a 16-bit digital signal, which is sent to a PC through the Gigabit Ethernet interface.



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

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Structure

Parameter		1 × 1 Flexible partial mode	2 × 2 Flexible partial mode	Unit
Photosensitive area		140.0 × 122.8		mm
Pixel size		100 × 100	200 × 200	μm
Effective photosensitive area size (H × V)	Min.	0.8 × 0.1	1.6 × 0.2	mm
	Max.	127.2 × 110.4	127.2 × 110.4	
Number of effective pixels (H × V)*1	Min.	8 × 1	8 × 1	pixels
	Max.	1272 × 1104	636 × 552	
Readout circuit		Charge amplifier array		-
Video output interface		Gigabit Ethernet		-
Digital output		16		bit
ExtTrgIO		TTL (VIH: 2 V, VIL: 0.8 V)		-
Scintillator		GOS		-

*1: Only multiples of 8 can be set.

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

Parameter	Symbol	Value	Unit
Supply voltage	Vdd	+8.0 to +12.0	V
Input signal voltage (ExtTrgIO)	Vin	0 to +6.0	V
Operating temperature*2	Topr	0 to +40	°C
Storage temperature*2	Tstg	-10 to +50	°C
X-ray tube voltage	-	20 to 160	kV

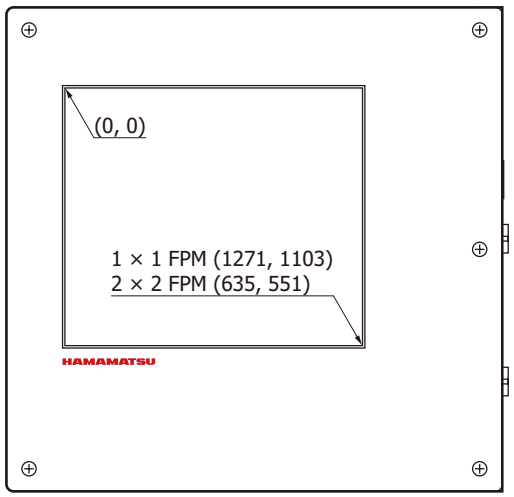
*2: No dew condensation
When there is a temperature difference between a product and the surrounding area in high humidity environments, dew condensation may occur on the product surface. Dew condensation on the product may cause deterioration in characteristics and reliability.

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.

Selectable scan modes

It is possible to switch between two modes with different number of effective pixels and pixel sizes.

Effective pixel area for each scan mode



- 1 × 1 Flexible partial mode
  Number of effective pixels: 1272 × 1104 (100 × 100 μm/pixel)
- 2 × 2 Flexible partial mode
  Number of effective pixels: 636 × 552 (200 × 200 μm/pixel)

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Electrical and optical characteristics (Ta=25 °C, Vdd=+9.0 V, unless otherwise noted)

■ 1 × 1 Flexible partial mode (FPM)

Parameter	Symbol	Min.	Typ.	Max.	Unit
Maximum frame rate*3	Sf(max)	21	-	2783	frames/s
Frame rate	Sf(ext)	0.1	-	Sf(max)	frames/s
Noise (rms)*4	N(rms)	-	1200 (34)	2400 (68)	electrons (LSB)
Saturation charge	Cast	-	2.3	-	M electrons
Sensitivity*5	S	2320 (260)	2900 (330)	-	LSB/mR (LSB/μGy)
Resolution*6	Reso	4.0	4.5	-	line pairs/mm
Dynamic range	-	950	1900	-	-

■ 2 × 2 Flexible partial mode

Parameter	Symbol	Min.	Typ.	Max.	Unit
Maximum frame rate*3	Sf(max)	67	-	3569	frames/s
Frame rate	Sf(ext)	0.1	-	Sf(max)	frames/s
Noise (rms)*4	N(rms)	-	1300 (16)	2600 (32)	electrons (LSB)
Saturation charge	Cast	-	5.4	-	M electrons
Sensitivity*5	S	2480 (288)	3100 (360)	-	LSB/mR (LSB/μGy)
Resolution*6	Reso	2.0	2.5	-	line pairs/mm
Dynamic range	-	2050	4100	-	-

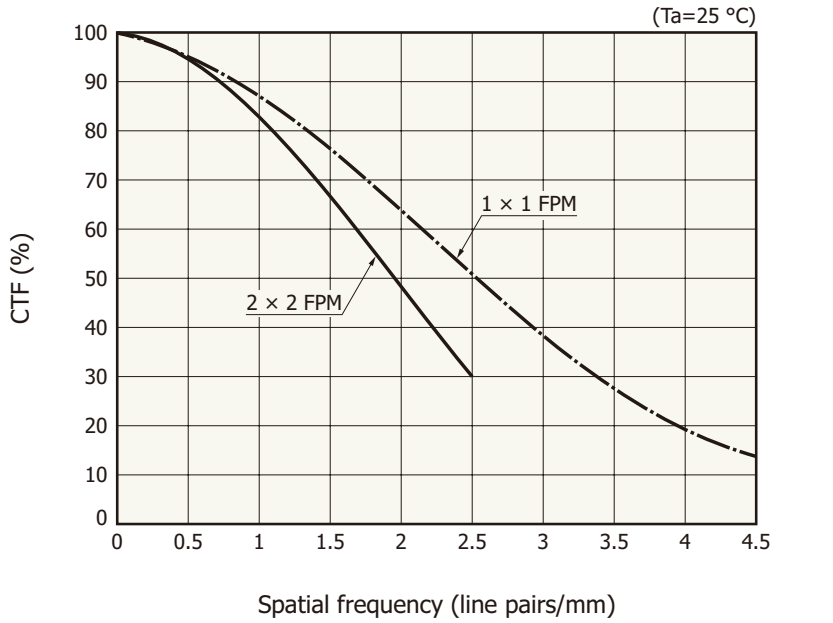
*3: It depends on the number of effective pixels (V).
The maximum frame rate is the minimum when the number of effective pixels (V) is the maximum, and the maximum frame rate is the maximum when the number of effective pixels (V) is the minimum.
The relationship between the number of effective pixels (V) and the maximum frame rate is shown below.
*4: Internal trigger mode at maximum effective photosensitive area, at maximum frame rate
*5: Calculated by subtracting the dark image from the X-ray image. X-ray tube voltage=130 kV
*6: Spatial frequency at CTF=5%

$$1 \times 1 \text{ FPM: } Sf(max) = \frac{1.0}{\{42.5 \times (\text{Image Vsize} + 4) + 0.12 \times [1228 - (\text{Image Vsize} + 4)]\} \times 10^{-6}}$$

$$2 \times 2 \text{ FPM: } Sf(max) = \frac{1.0}{\{26.7 \times (\text{Image Vsize} + 4) + 0.12 \times [1228 - (\text{Image Vsize} \times 2 + 4)]\} \times 10^{-6}}$$

Note: Image Vsize: number of effective pixels (V)

Resolution



Other specifications [1 × 1 Flexible partial mode (Ta=25 °C, Vdd=+9.0 V, unless otherwise noted)]

Parameter	Min.	Typ.	Max.	Unit
Defect line*7	-	-	12	lines
Adjacent defect line*7	-	-	1	line pairs
Bright line output adjacent to defect line*8	-	-	120	%
Defect cluster*8	-	-	None	-
Output offset*9	-	1000	3000	LSB

*7: A vertical or horizontal line consisting of four or more consecutive pixels with 1/8 or less of the average sensitivity of the surrounding pixels.
There shall be no adjacent defects both vertically and horizontally.
*8: See P.5 "Description of terms (1 × 1 Flexible partial mode)."
*9: Average of all effective pixels at maximum frame rate

Description of terms (1 × 1 Flexible partial mode)

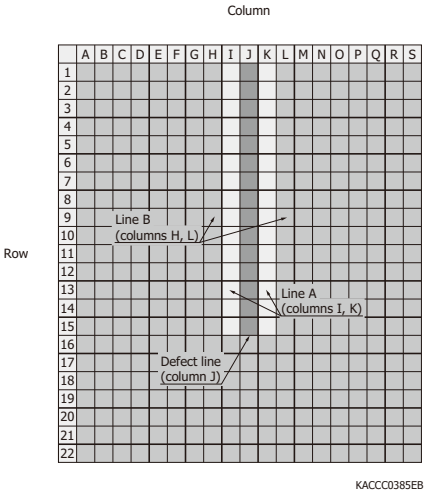
⊳ Bright line output adjacent to defect line

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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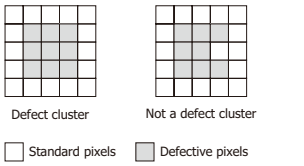
⊳ Defect cluster

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



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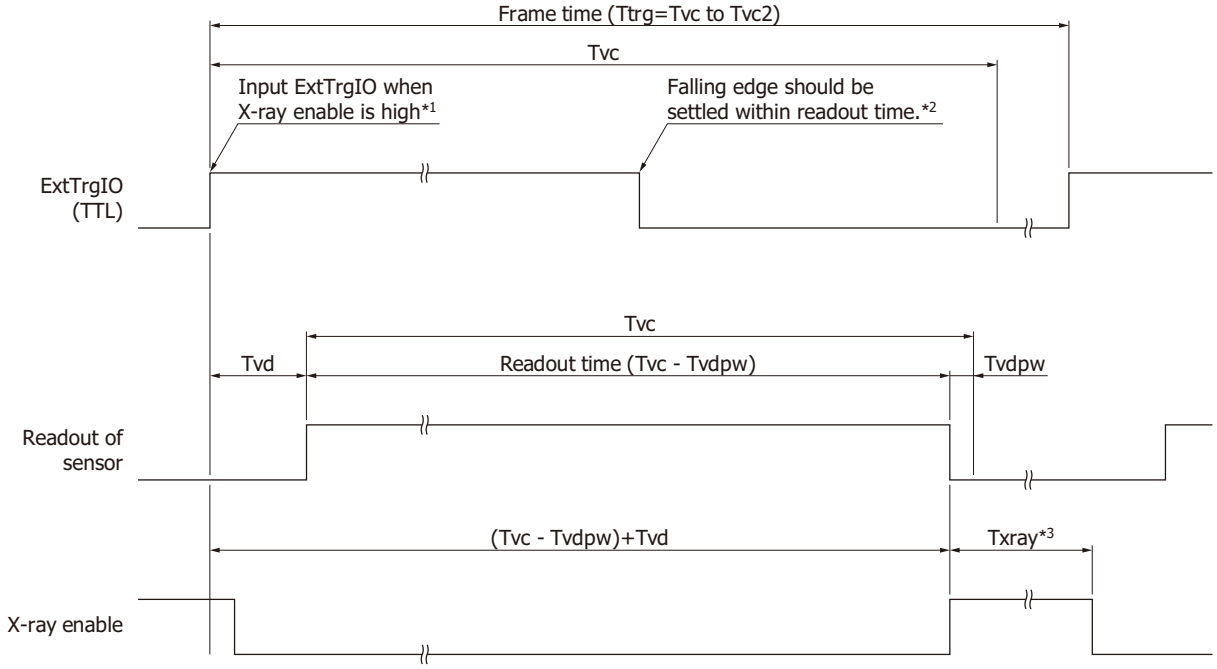
Timing chart

To acquire images in external trigger mode, input an external trigger pulse as shown below.
When used in synchronization with a pulsed X-ray source, X-rays should be irradiated during the Txray period.



*1: Input trigger signal into ExtTrgIO when X-ray enable is High. Trigger signal is ignored and images cannot be acquired when X-ray enable is Low.
*2: Set the fall within the readout time (Tvc-Tvdpw). If this is not possible, make sure there is no noise in the trigger signal. Noisy trigger signals can cause the flat panel sensor to malfunction. Check the waveform quality of the trigger signal before applying the trigger signal into the flat panel sensor. Using shielded or twisted pair cables is recommended.
*3: Txray = Ttrg - (Tvc - Tvdpw + Tvd)

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Parameter	Symbol	1 × 1 FPM	2 × 2 FPM	Unit
Delay time from ExtTrgIO input to readout start	Tvd	94.2	61.6	µs
Minimum cycle of one frame	Tvc	1/Sf(max)*10		s
Maximum cycle of one frame	Tvc2	10		s
Standby time until start of reading next frame*11	Tvdpw	102.4	69.3	µs

*10: This changes according to the number of effective pixels (V). See "Electrical and optical characteristics (P.3)."
*11: ExtTrgIO entered during this period is ignored. Enter ExtTrgIO after Tvdpw has elapsed after X-ray enable rises.

System requirements

● PC (operation verification environment)
- PC: Precision T5600 standard model (Dell)
- OS: See "Compatibility Note.pdf" in "https://dcam-api.com/".
- CPU: Intel® Xeon® Processor E5-2620 (15 M Cache, 2.00 GHz, 7.20 GT/s Intel® QPI)
- Memory: 4 GB (2 GB × 2) for 32-bit OS
  8 GB (2 GB × 4) for 64-bit OS
  DDR RDIMM memory (1600 MHz, ECC)
- Microsoft.net Framework: Version 2.0 and later

● Power source: Vdd=+9.0 V [11 W (1.3 A), Voltage range: Vdd=+8.0 to +12.0 V]
- The voltages described above are specified at the flat panel sensor side.
- Please use a low noise series power supply. (Avoid using a switching power supply.)
- Install a noise filter on the AC power line to prevent surges on the AC line.

● DCAM-API (digital camera application programming interface): produced by Hamamatsu
- The driver software and DLL are included in DCAM-API. DCAM-SDK which includes function manuals and sample software can be provided to OEM users.
- DCAM-API can be downloaded from "https://dcam-api.com/".

● Ethernet protocol : UDP (user datagram protocol)

● Network interface card (NIC)
- Use an NIC that meets the following specifications.
  1. Equivalent products of major manufacturers capable of 1 Gbps or more (Intel*12, Marvel, Realtek, etc.)
  2. Support OS, PCI-Express, Jumbo Frame.
  3. Transfer all images without dropping frames.
- The flat panel sensor is designed subject to point-to-point connection. Make one-to-one connection from the flat panel sensor to the NIC on the PC.
- Please adjust the settings of the NIC to which the flat panel sensor is connected. For more information, see the GigE chapter of "Compatibility Note.pdf" in "https://dcam-api.com/."
- Set the BIOS to the recommended setting. Otherwise, images transferred to the PC may be sporadically corrupted. For more information, see the note *23 of "Compatibility Note.pdf" in "https://dcam-api.com."
- Applications that involve data communication (e.g. Microsoft Teams) must be closed during image acquisition as they will affect image capture performance.
- If a Gig-E switch must be used due to equipment specifications, use a Gig-E switch that supports Layer 2, Jumbo Frame and do verification to make sure all images can be transferred without dropping frames.
- If the recommended NIC is not available, use an NIC that supports PCI-Express, Jumbo Frame and do verification to make sure all images can be transferred without dropping frames.

The power cable, LAN cable, image acquisition software, and image processing libraries are excluded from the flat panel sensor.

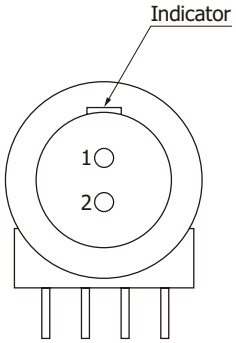
*12: Excluding Intel 82577LM Gigabit network connection

Note: Microsoft and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

Pin connections

Power connector

Power plug (flat panel sensor side): ZXG.0B.302.HLN (Quanma)



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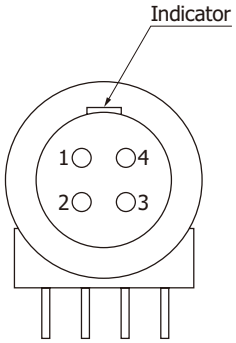
Pin no.	Signal
1	Vdd
2	GND

Note: Power cable should be prepared by the user.
Applicable receptacle: TGG.0B.302 (Quanma), FGG.0B.302 (LEMO)

External I/O connector

4-pin receptacle (flat panel sensor side): ZXG.0B.304.HLN (Quanma)



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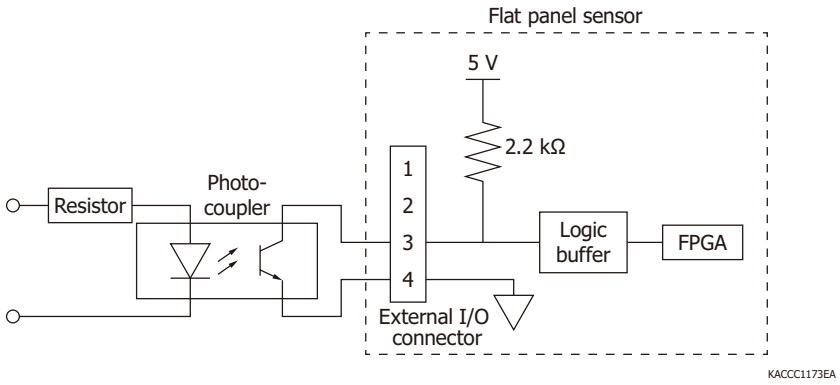
Socket no.	Signal	Note
1	X-ray enable (TTL)	Confirmation signal of pulse X-ray irradiation timing. CMOS 5 V output. Irradiate X-rays when the output is high.
2	Digital GND	GND
3	ExtTrgIO (TTL)*13	Trigger signal input in external trigger mode
4	Digital GND	GND

*13: For the absolute maximum rating of ExtTrgIO, refer to "Absolute maximum ratings (P.2)."
Note: Cable for external trigger signal input should be prepared by the user.
Applicable plug: TGG.0B.304 (Quanma), FGG.0B.304 (LEMO)
We recommend using shielded or twisted pair cable to reduce noise. If overshoot or undershoot is unavoidable, consider installing the photocoupler. See "Photocoupler connection (P.9)."

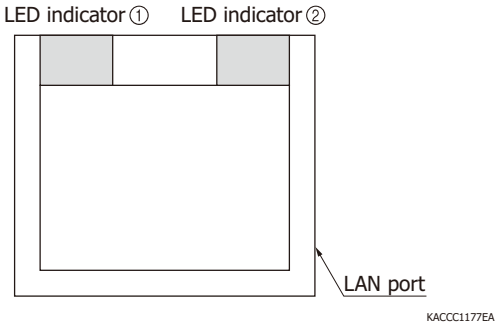
Photocoupler connection



[Table 1] Trigger mode

Trigger mode	ExtTrgIO	Remark
External trigger mode	Rectangular signal	Control the integration time at the rising edge of the ExtTrgIO signal.
Internal trigger mode	High or open	Control the integration time by DCAM command.

LED indicators



[Table 2] LED indicator information for LED connectors

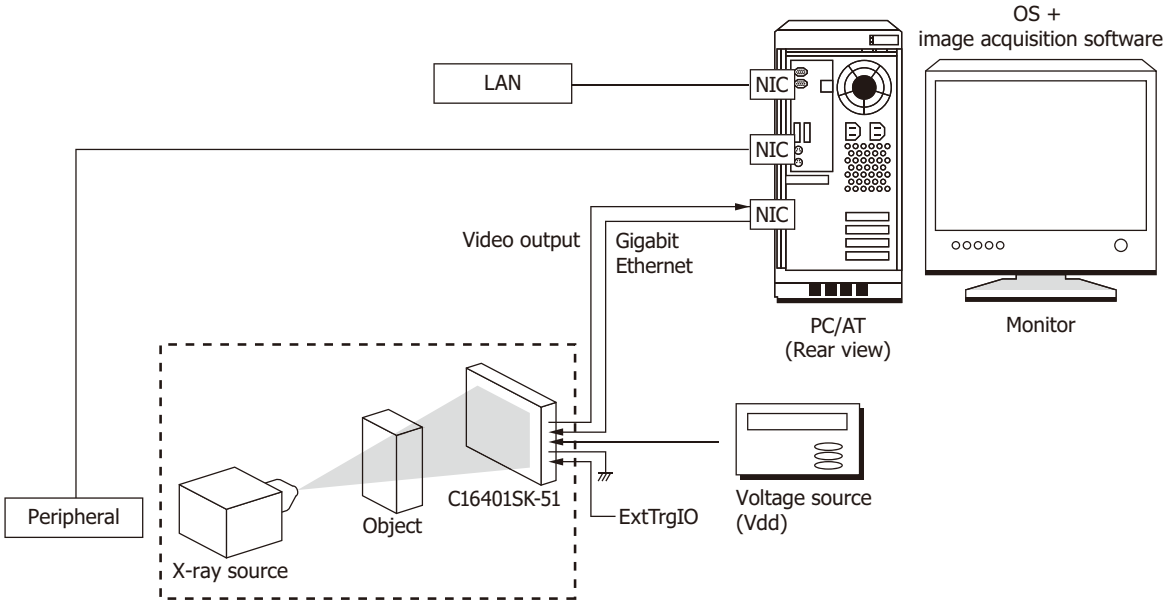
LED indicator ①	LED indicator ②	Status
OFF	OFF	No connection
OFF	Lighting	Connecting (1 Gbps)
OFF	Blinking	Sending/receiving data (1 Gbps)
Lighting	Lighting	Connecting (100 Mbps)
Blinking	Blinking	Sending/receiving data (100 Mbps)

Connection example

After installing DCAM-API in a PC that supports Gigabit Ethernet, connect the C16401SK-51 to that PC.

· Make connection using a LAN cable that meets CAT5e or higher standard.

· The specification herein mentioned may not be obtained when the flat panel sensor is controlled through network of in-house LAN, etc.



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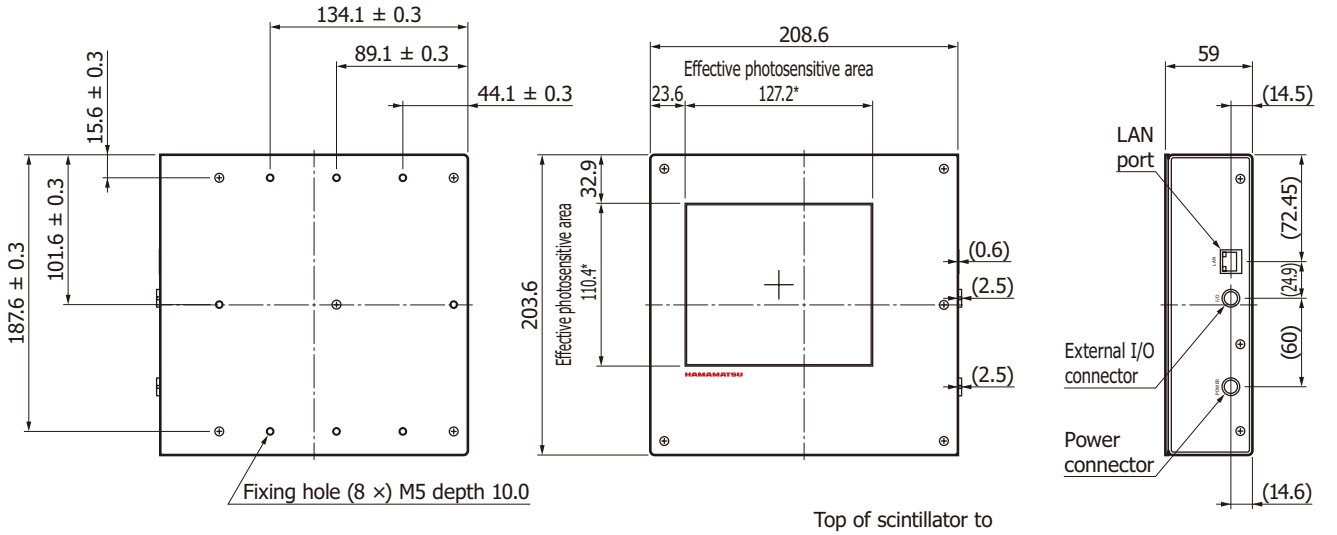
Dimensional outline (unit: mm)



* Keep the X-ray irradiation range within the effective photosensitive area.
Tolerance unless otherwise noted: ±1.0
Value in parentheses indicate refarence values
Top cover: CFRP (thickness: 2.0)
Weight: 5.1 kg

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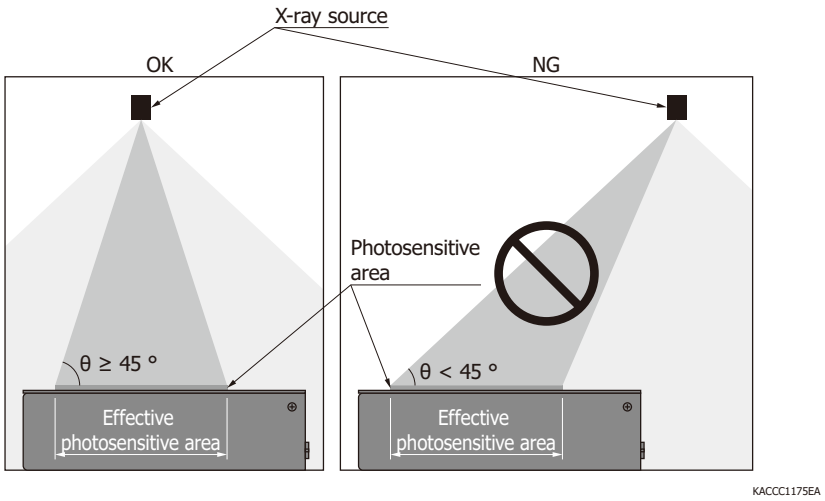
Notice

· Do not subject the flat panel sensor to strong vibration or shock. (Strong shock such as drop impacts may cause permanent damage to the product.)
· User must take responsibility for implementing X-ray shielding safety measures to avoid the risk of X-ray exposure.
· The surface of the sensor module is vulnerable to damage, so do not place sharp or hard objects on the sensor.
· Do not remove the top cover. Exposing the sensor will end the warranty period.
· Do not pour liquid on the product.
· The flat panel sensor consists of two circuits. Do not separate the boards.
· The data values shown in this datasheet are the factory values. Since the characteristics may change due to X-ray irradiation, take appropriate measures such as periodic correction.
· The warranty of the product is limited to repair of the product or delivery of a replacement if a defect is found within one year after delivery and our company is notified. However, even within the warranty period, our company shall not be liable for damages resulting from natural disasters or improper use (modification, disassembly, and violation of the environment, application, usage and storage conditions described in this document), or cumulative radiation dose exceeding 11.25 MR (100 kGy) (X-ray tube voltage: 160 kV or less).
· When this product is used in the equipment, take appropriate measures such as shielding this product and its connecting cable.
· The cables to be connected to the product should be fixed to the equipment.

X-ray irradiation angle

The angle of X-ray irradiation should be at least 45 degrees to the light receiving surface. If it is below 45 degrees, the electronic components around the photosensitive area will not be shielded from X-rays, which may give the product irreparable damage and is not covered by the warranty.



Related information

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

Precautions

· Disclaimer