ORCA-Halo
sCMOS Camera
C17440-20U
Instruction manual

Thank you for your purchase

CAUTION	• Follow the safety precautions in Chapter 1 in order to avoid personal injury and damage to property when using this camera. The manual describes the correct handling method of the camera and provides instructions that should be followed to avoid accidents. **Read this manual carefully** before using this camera. After reading this manual, store it in a location where you can refer to it at any time.

Ver.1.0
March 2025

HAMAMATSU PHOTONICS K.K.

C0680301-00

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1. SAFETY PRECAUTIONS

1-1 SYMBOLS

The symbols shown below are used for this camera.

⎓	Direct current
~	Alternating current

1-2 CLASSIFICATION OF WARNINGS

We have classified the warnings symbols that appear in this instruction manual and on the camera as follows for your convenience. Make sure that you fully understand them and follow the instructions they contain.

⚠ **WARNING**	Improper handling of the camera without observing these warnings could lead to serious injury to the user and even death.
⚠ **CAUTION**	Improper handling of the camera without observing these cautions could lead to personal injury to the user or damage to property.

	This symbol indicates a cautionary item that should be followed when handling the camera. Read the contents carefully to ensure correct and safe use.
	This symbol indicates an action that is forbidden. Read and follow the instructions carefully.
	This symbol indicates a compulsory action or instruction. Read and follow the instructions carefully.
Note	This symbol indicates a note to help you get the best performance from the camera. Read the contents of the note carefully to ensure correct and safe use. Failure to observe one of these notes might impair the performance of the camera.

⚠ WARNING

Power supply

Use the camera with the indicated voltage on the rating sticker. Using a different voltage can damage the camera and lead to fire or electric shock.

Cables

Do not to place heavy objects on cables or bend them excessively. Doing so can damage the cables and lead to fire or electric shock.

Power supply cord

Use the accessory power supply cord when using this camera.

AC adapter

Use the accessory AC adapter when this using this camera.

Do not touch the plug with wet hands. Doing so can lead to electric shock.

Do not attempt to dismantle or modify the camera

Doing so can also lead to damage and even injury, as some internal components become very hot or high voltage. Do not touch parts that are not indicated in this manual.

Do not allow foreign objects

Such as combustible substances, metal objects or water to get inside the camera. These can damage the camera and lead to fire or electric shock.

In the event of an anomaly

such as the image suddenly disappearing or the occurrence of a strange noise, a strange smell or smoke coming from the camera, immediately turn off the power switch and unplug the power supply cord and contact a Hamamatsu subsidiary or your local distributor. Do not attempt to repair the camera yourself.

CAUTION

AC adapter

When unplugging the power supply cord, do not pull on the cord. Remove the plug from the outlet to avoid causing electric shock or fire.

When unplugging the power supply cord, do not pull on the cord, but remove the plug from the camera to avoid breakdown of the AC adapter or the camera.

Connecting and disconnecting cables

Always turn off the power supply of the peripheral device before connecting and disconnecting cables.

Mounting the camera

When mounting the camera to a tripod or other fixture, use the optional base plate. Use the attached screws with the baseplate. Using other screws may destroy the circuit parts inside the camera.
Attachment taps of mount adaptor can also be used.

Lenses

Be careful not to screw the lens more than 7 mm into the C-mount of the camera. Doing so can scratch the protective glass. (Some wide-angle lenses in particular can have a thread of 7 mm or more.)

Shipping precautions

When transporting the camera by truck, ship, airplane, etc., wrap it securely in packaging material or something similar.

Strong impact

Do not subject the camera to strong shocks (such as dropping it). Doing so can damage the camera.

Operating environment

This camera is designed and tested for use in an industrial environment. If this camera is used in residential areas, EMI (electro-magnetic interference) may occur. This camera must not be used in residential areas.

Disposal

When disposing of the camera, take appropriate measures in compliance with applicable regulations regarding waste disposal and correctly dispose of it yourself, or entrust disposal to a licensed industrial waste disposal company. In any case, be sure to comply with the regulations in your country, state, region or province to ensure the camera is disposed of legally and correctly.

CAUTION

FCC Rules

Note **This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.**

Note **This device has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the device is operated in a commercial environment. This device generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this device in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.**

Note **Changes or modifications not expressly approved by the party responsible for compliance could void user's authority to operate the device.**

CAUTION

Using water cooling

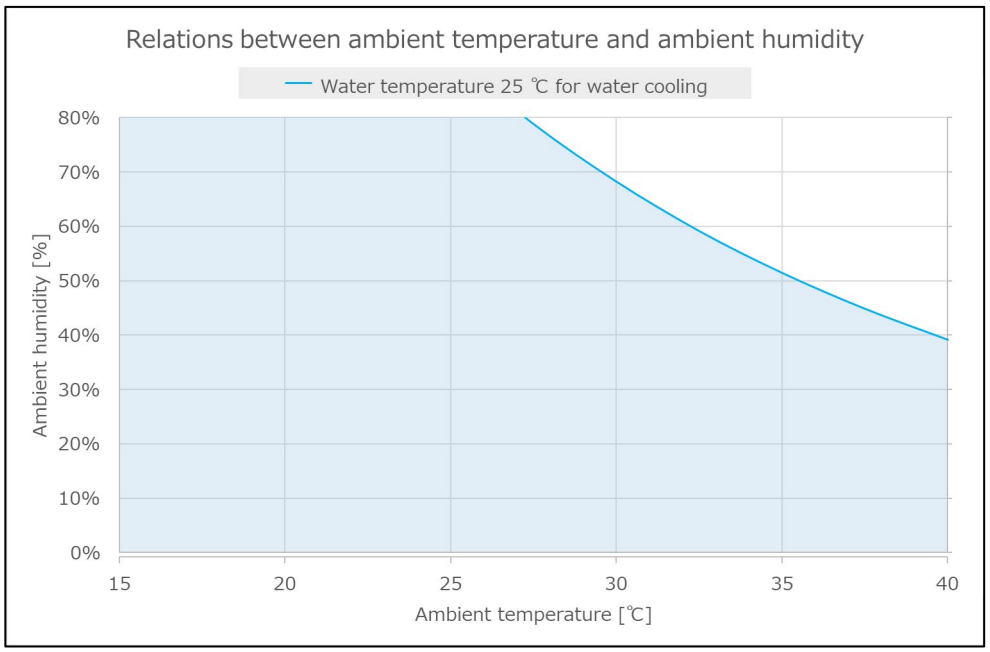
Be careful water does not splash on the camera. Cut off the power supply of the circulating water cooler and the camera when you remove and install the cooling water hoses.

Cooling water

It is recommended to use soft water (except pure water) for cooling water. Follow instruction manual which is attached to your circulating water cooler for an appropriate temperature range of cooling water. If you plan on using water other than soft water as recommended for example antifreeze etc, refer to description of cooling water which is written in 12. "MAINTENANCE" or contact a Hamamatsu subsidiary or your local distributor.

Condensation

At the Water-cooling, if ambient temperature and ambient humidity become high, condensation will take place easily. Use the camera under the environment where condensation will not take place referring to the light blue area of following graph.



2. CHECK THE CONTENTS OF PACKAGE

When opening the package, check that the following items are included before use.
If the contents are incorrect, insufficient or damaged in any way, contact a Hamamatsu subsidiary or your local distributor before attempting to operate the camera.

Description	QTY
sCMOS Camera: C17440-20U	1
AC adapter	1
Power supply cord for AC adapter	1
Lens mount cap (attached to the camera)	1
Water protection cover	1
C17440-20U Before Use (Booklet)	1
C17440-20U Instruction manual (CD-ROM)	1

[Option]

Description	Part no.
Circulating water cooler	C3142-11
Cooling water hose (2 hoses)	A10788-04
SMA-BNC cable	A12106-05
SMA-SMA cable	A12107-05
USB 3.0 interface board with USB 3.0 interface cable	M9982-41
USB 3.0 interface board	M9982-32
USB 3.0 interface cable	A17160-03
Base plate for C17440-20U	A17657-01

- Handle the circulating water cooler and the cooling water according to the instruction manual of the circulating water cooler.

Note

- The cable listed in option is highly recommended for use with the camera. The camera and camera system may not confirm to CE marking and FCC regulations if other type of cable is used with.

Note

- When using options and peripheral devices, see each instruction manual or installation manual.

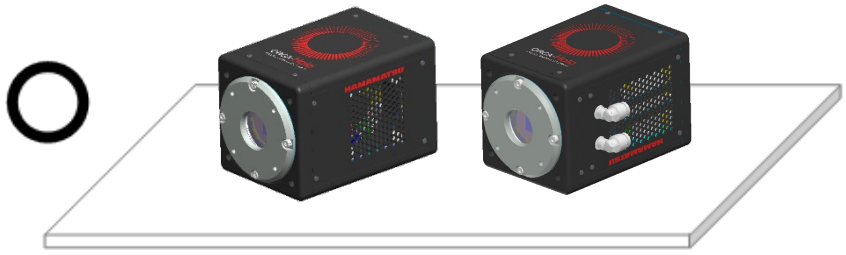
3. INSTALLATION

Avoid using or storing this camera in the following places

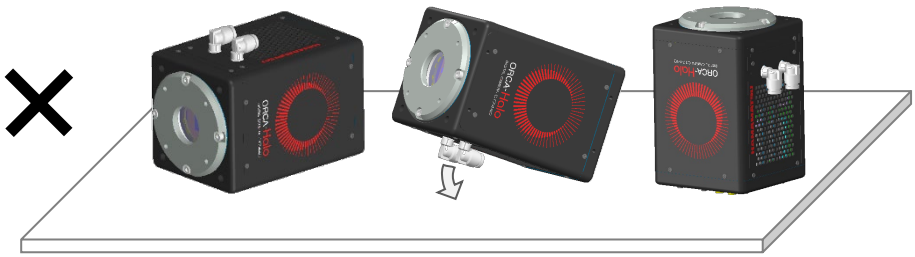
- Places where the temperature is not the operating temperature indicated in the specifications
- Places where the temperature is not the storage temperature indicated in the specifications
- Places where the temperature varies greatly
- In direct sunlight or near a heater
- Places where the humidity levels are not the operating humidity levels indicated in the specifications and where the camera may be exposed to liquid
- Places where the humidity levels are not the storage humidity levels indicated in the specifications and where the camera may be exposed to liquid
- Close to a strong source of magnetism or ratio waves
- Places where there are vibrations
- Places where the camera may come into contact with corrosive gases (such as chlorine or fluorine)
- Places where there is a lot of dust

How to place the camera (when the camera is placed on a table)

Place the camera with the water connectors to sideways.



Ensure that there is sufficient airflow through the camera fan.
(Do not block ventilation openings.)



Do not allow the ventilation ports to become blocked.

To prevent the camera from overheating, do not wrap the camera in cloth or any other material, or in any way allow the camera's ventilation ports to become blocked. If the camera is being operated in a closed environment, ensure clearance of at least 10 cm from both the intake and exhaust vents when setting up when setting up the camera.

Weight of the camera

Be careful not to drop the camera when moving it as it is approx. 1.0 kg.

Contents

4. OVERVIEW

The C17440-20U is a cooled type scientific CMOS (sCMOS) camera equipped with an advanced sCMOS device, realizing high sensitivity, low readout noise, low dark current and high pixel number of 9 mega pixels.

Since the C17440-20U has three modes: The standard mode with a balance of readout noise of 1.6 electrons r.m.s. and full well capacity of 16 000 electrons, the 8x sensor gain mode focusing on low readout noise of 1.3 electrons r.m.s., and the high full well capacity mode focusing on high full well capacity of 49 100 electrons. The users can select the most suitable mode depending on their applications.

The C17440-20U can output high resolution image of 9 megapixels with 18.1 fps (Frame per second) at 16 bit, or 24.2 fps at 12 bit.

The C17440-20U can realize high quantum efficiency of 86% at peek wave length by equipping back side illuminated sensor and it enables the camera to acquire higher quality image in low light level imaging than a conventional front side illuminated sensor.

Since the C17440-20U has two cooling modes of air cooling with fan and water cooling and it can be easily switched, the users can flexibly use it in response to changes in experimental environment.

Moreover, since the C17440-20U has various external trigger functions which can control the acquisition timing with peripheral devices, it enables optimal imaging for a wide range of applications. The camera is suitable not only for life science microscopy imaging but also for semiconductor inspection, X-ray scintillator readout and industrial imaging.

5. FEATURES

(1) Readout noise

This camera achieves the lowest read noise of 1.3 electrons (rms) at 9 megapixels, 16-bit output, standard well capacity, 18.1 fps readout speed, and 8x gain setting.

(2) Pixel number and pixel size

This camera has a pixel size of 3.76 µm x 3.76 µm, which is relatively small among our scientific CMOS cameras and can capture high spatial resolution image. In addition, the large pixel number of 9 megapixels (3000 pixels x 3000 pixels) provides a wide field of view of 11.280 mm x 11.280 mm, which is useful for low-magnification applications in life sciences.

(3) Quantum efficiency

Adopting the back-illuminated senso improves quantum efficiency across a wide wavelength range from blue to near-infrared, achieving a high quantum efficiency of
86 % at the peak wavelength.

(4) Readout methods

The camera has a variety of readout modes. In addition to full resolution readout mode (1×1), sub-array readout and binning readout (2×2, 4×4) are supported. It also has a light sheet readout mode.

(5) Frame rate

Even at 3000 x 3000 pixels, this camera achieves both low noise of 1.3 electrons (rms) and a high frame rate of 18.1 fps. In addition, the bidirectional readout in light sheet readout mode enables a higher frame rate compared to conventional light sheet microscope systems.

(6) Real-time correction functions

This camera is equipped with functions for correcting the offset level, gain, and pixel defects on each pixel to improve image quality. This function is performed in real time according to the output speed of the camera, so the frame rate will not be reduced by performing the correction.

(7) Cooling structure

In this camera, a Peltier element is used to cool the CMOS image sensor and suppress dark current. If the CMOS image sensor is exposed to the air directly, moisture may condense. To prevent this, the CMOS image sensor is isolated from the air and the inside is filled with dry nitrogen.

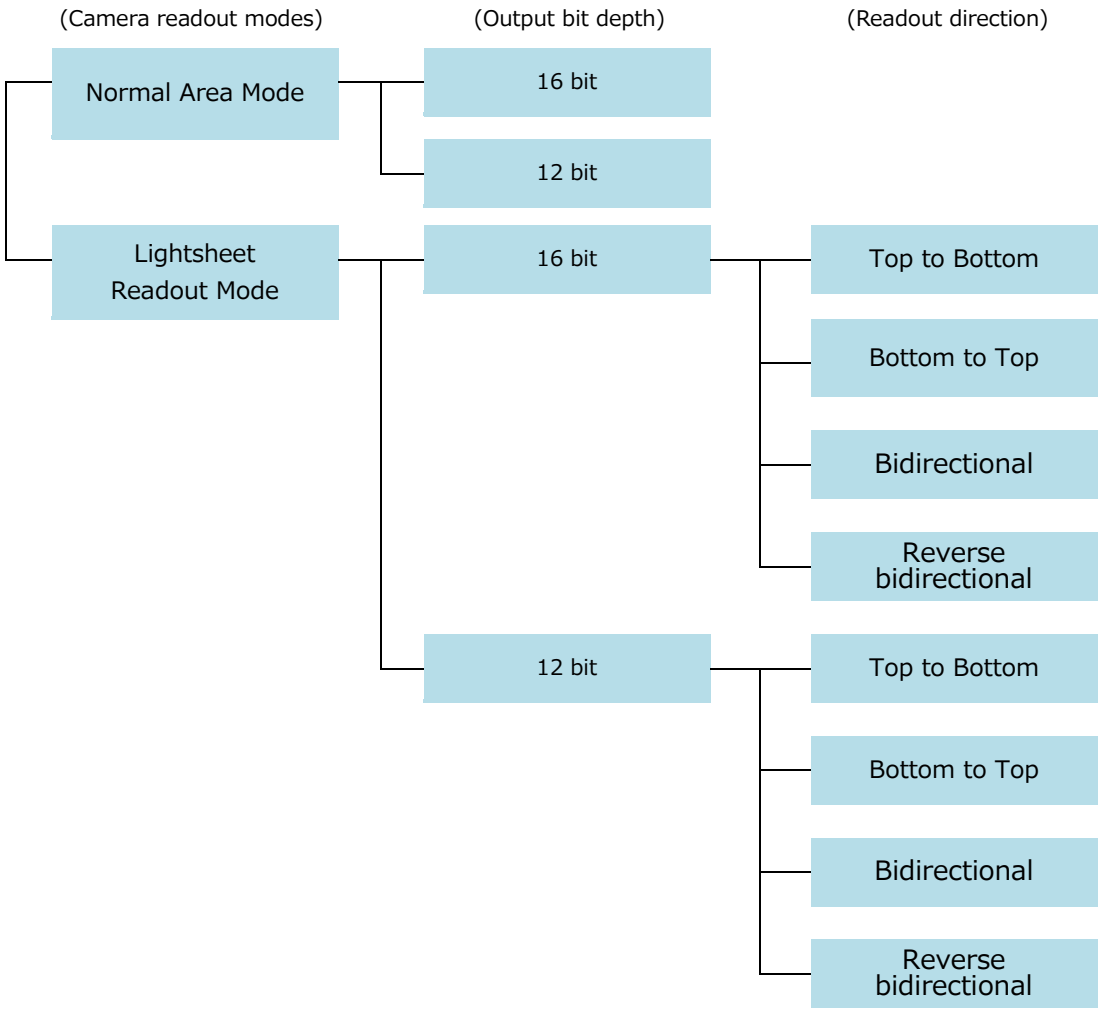
(8) Interface

This camera is equipped with a USB interface. It can transfer 9 mega pixel images at 18.1 fps. To achieve a higher frame rate, the output bit depth can be decreased to 12 bits, allowing it to transfer 9 mega pixel images at 24.2 fps.

- When connecting or disconnecting interface, the application software must be closed, and the camera must be turned off.

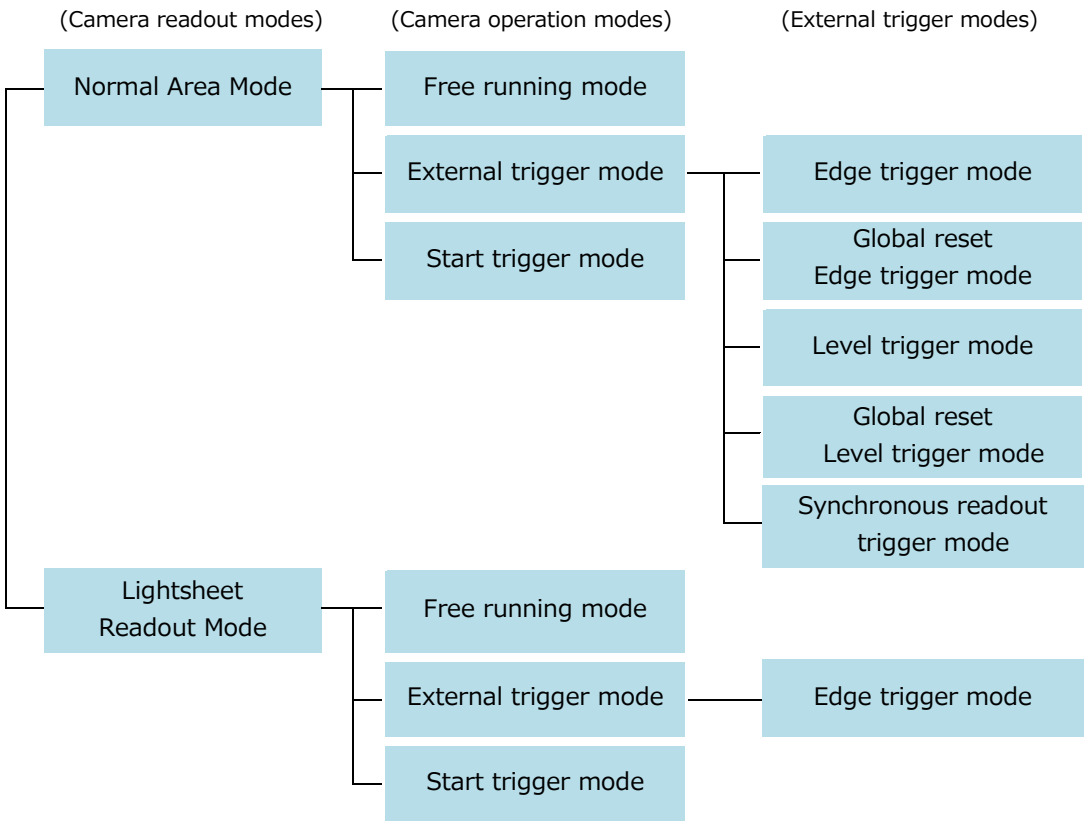
(9) Camera readout modes

The camera has two readout modes, Normal Area Mode and Lightsheet Readout Mode. The camera also has 16 bit output and 12 bit output in each readout mode. Readout direction can be switched in Lightsheet Readout Mode.



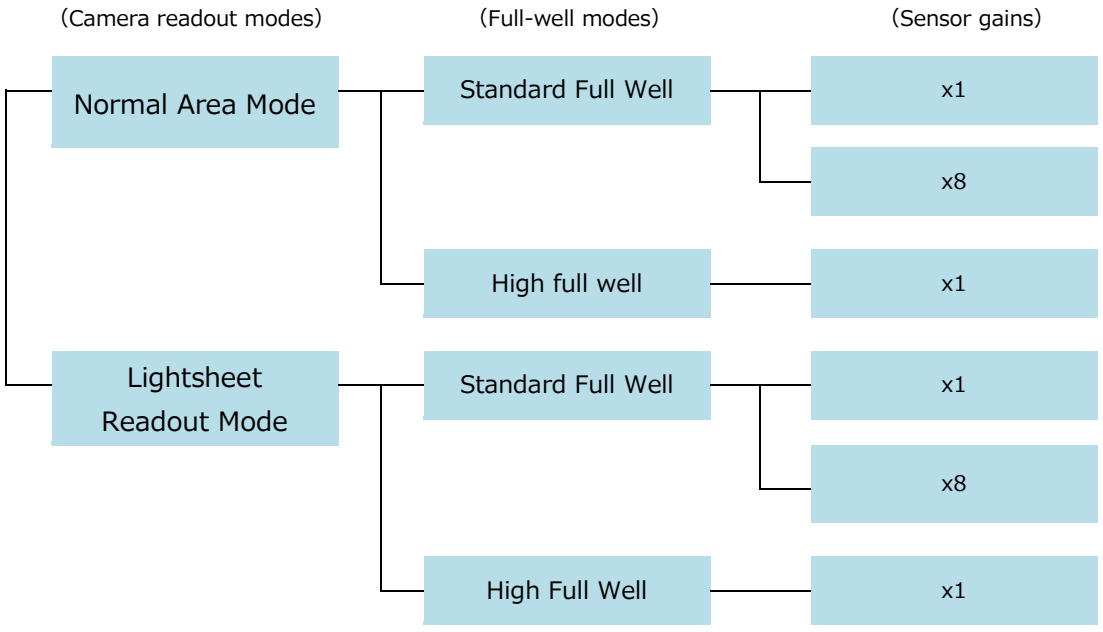
(10) Camera operation modes

The camera has three operation modes: 1) Free running mode, in which the exposure and readout timing are controlled by the internal microprocessor, and 2) External trigger mode, in which the exposure and readout timing are decided by an external trigger. 3) Start trigger mode is used to start a continuous imaging by a trigger input.



(11) Full-well modes and Sensor gains

By arranging full well mode and sensor gain mode, the users can select the mode from the standard mode with a balance of readout noise and full well capacity, the 8x sensor gain mode with focusing on low readout noise and the high full well capacity mode focusing on high full well capacity.



6. NAME AND FUNCTION OF PARTS

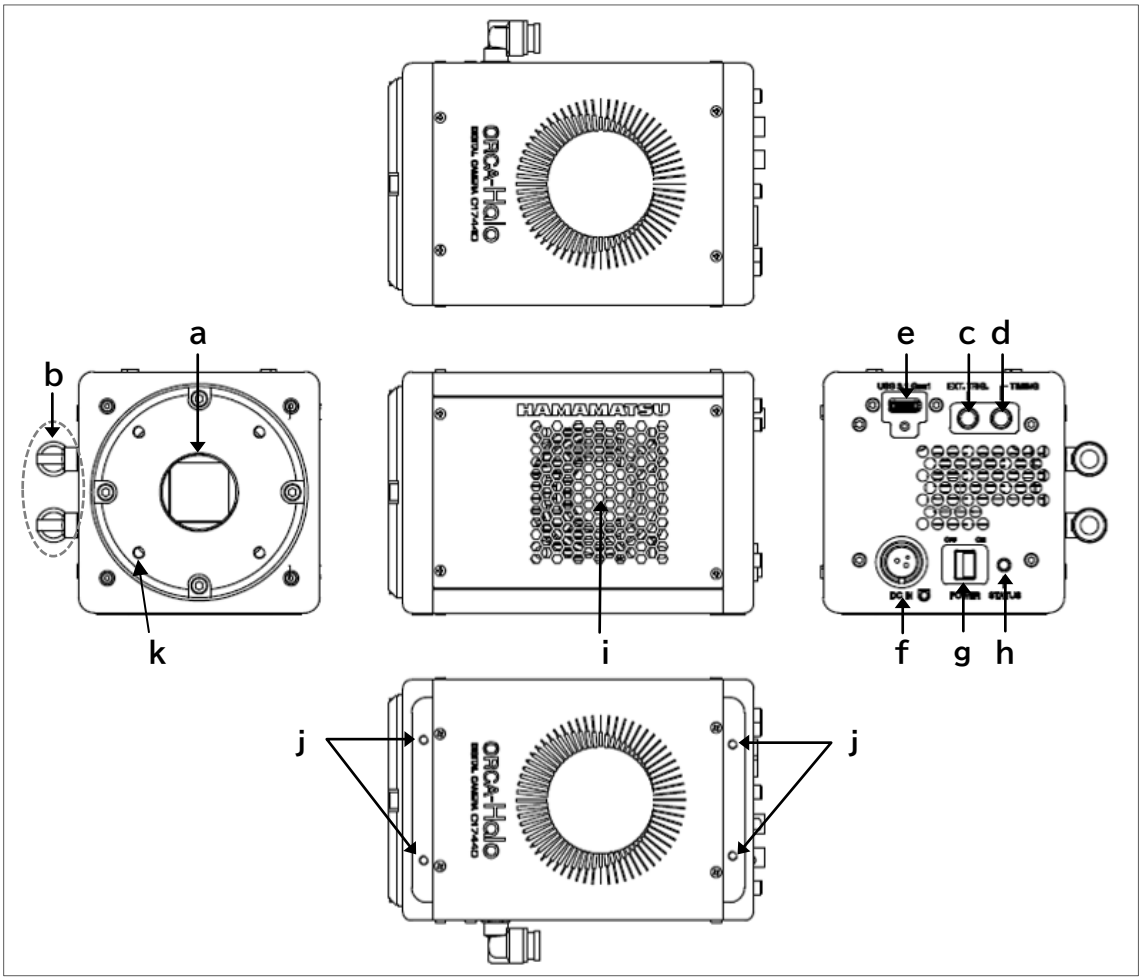


Figure 6-1

CAUTION	• Place the camera so that lateral side with the water connectors is facing outward. Do not place the camera with the rear panel facing downward. (Do not block ventilation openings.).

a. Lens mount

This camera can be attached to C-mount lens or an optics system with C-mount.

Note	• The depth of the C-mount is 7 mm. Screwing in the C-mount too deeply might scratch the glass surface.

b. WATER connector [WATER] (when using Water-cooling)

These connectors are used for connecting the camera and circulating water cooler with the cooling water hoses. The connector position of WATER IN/OUT is not specified. We recommend you use the camera with water cooling when you want to avoid the vibration of the fan.

CAUTION	• See 8 “WATER COOLING” for instruction of water-cooling.

c. Trigger input connector [EXT.TRIG]

This connector is used when the camera is operated in the external mode. The input level is TTL or 3.3 V LVCMOS level, and the input impedance is 10 kΩ. The camera exposure starts synchronizing with the falling or rising edge of it. (You can choose external trigger signal polarity between Negative and Positive.)

d. Timing out connector 1,2,3 [TIMING 1,2,3]

From these connectors, the timing signals are output for synchronizing with peripheral device(s). The output level is 3.3 V LVCMOS level and output impedance is 33 Ω.

Note

- Determine termination according to cable length and so on.

e. USB interface connector [USB 3.1 Gen 1]

This is connected to the USB interface connector on the computer.

- When connecting or disconnecting interface, the application software must be closed, and the camera must be turned off.

f. DC power input connector [DC IN]

This is the power supply terminal. Use the accessory AC adapter.

g. Power switch [POWER]

The switch is used to turn the power on and off.

- When the power is turned on, the camera initialization starts, and the STATUS lamp begins to blink in orange.
- When the initialization is completed, the STATUS lamp is turned on in green, the camera begins to work.
- When the camera is capturing images, the STATUS lamp turns orange.
- When the power is turned off, the camera becomes the power off status and the STATUS lamp is turned off.

h. STATUS lamp [STATUS]

The LED indicates the status of the camera. The following color indicates each status.

Lighting color	Status of power distribution
Turn off (no color)	Power off
Orange (Blinking)	Initialization
Green (lighting)	Power on
Orange (lighting)	Capturing images
Red (lighting)	Heat up

CAUTION

- When the camera heats up, stop operation and unplug the AC adapter immediately.

i. Air inlet

This is the inlet for the heat ventilation.

- If the camera is being operated in an enclosed environment, ensure to keep clearance at least 10 cm from both intake and exhaust vents when setting up.

- To prevent overheating inside the camera, do not wrap the camera in cloth or other material, or block the camera's ventilation.

j. Screw holes for attaching the option

They are used for attaching a base plate (A17657-01) which is the option of C17440-20U.

- Use the attached screws with the baseplate, never use other screws otherwise they may destroy the circuit parts inside the camera.

Note

- Refer to the installation manual of option about the attaching method of the option.

k. Screw holes of mount adaptor

By using these four screw holes (4-M4-4), the camera can be attached to other instruments.

7. CONNECTION

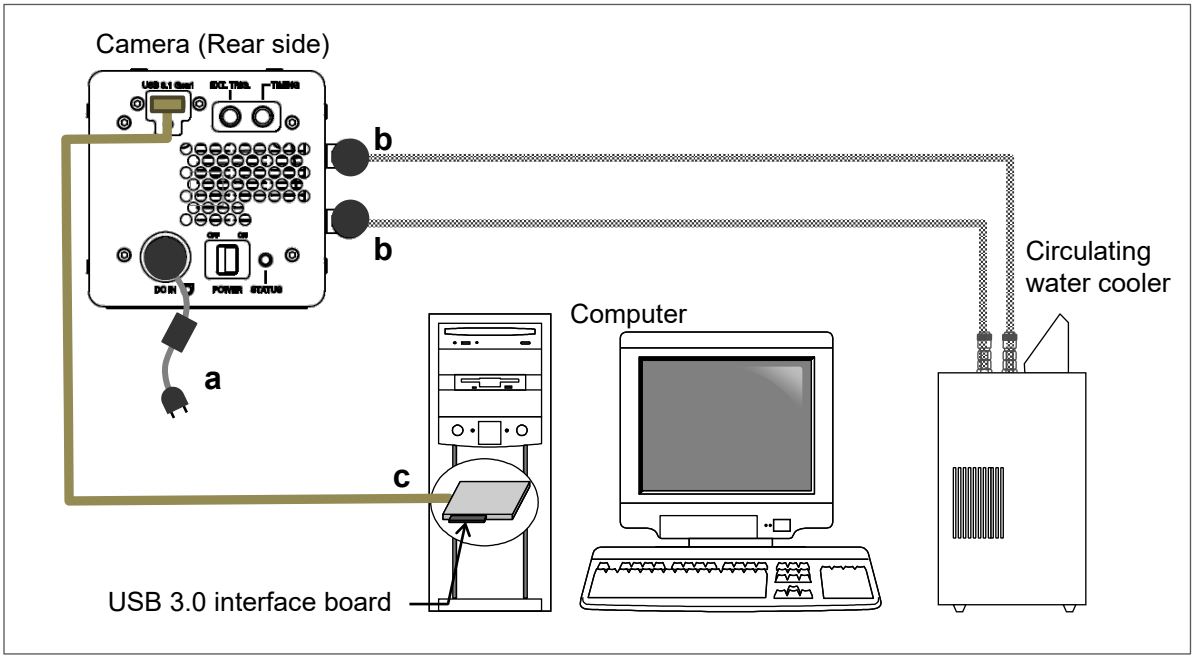


Figure 7-1

CAUTION	• When placing the camera directly on the desk or etc., make sure ventilation openings on the side with water connectors and rear panel are not blocked.

	• When connect cables, turn off the power supply of the camera and the peripheral devices.
Note	• When using options and peripheral devices, see each instruction manual or installation manual.

a. AC adapter and power supply cord.

Supplies the power to the camera. Use the accessory AC adapter.

b. Cooling water hoses (at Water-cooling: Option)

Connect the WATER connectors of the camera and circulating water cooler so that the cooled water can circulate in them. The WATER connectors of the camera can be used for either IN or OUT.

CAUTION	• See 8 “WATER COOLING” for instruction of water-cooling.

c. USB interface cable (Option)

Connects the USB interface connector of the camera to the USB interface connector of interface board of the computer.

	• When connecting or disconnecting interface, they must be done after closing application software and turn off the camera.
Note	• Hamamatsu recommends A17160-03 optional USB 3.0 interface cable for this camera. The camera complies with EMC and FCC regulations with using A17160-03 USB 3.0 interface cable. Be careful that the camera with other interface cable may not fulfill the EMC and FCC directive requirements.

8. WATER COOLING

CAUTION	• Make sure to observe the following cautions and procedures to avoid damaging the camera and peripheral devices.

8-1 CAUTIONS

(1) Change the cooling method

The default setting of cooling method is Air-cooling. Cooling mode can be changed by software which is called, “DCAM Configurator”. (refer to 9-5 “STARTUP DCAM CONFIGURATOR”).

(2) Cooling water

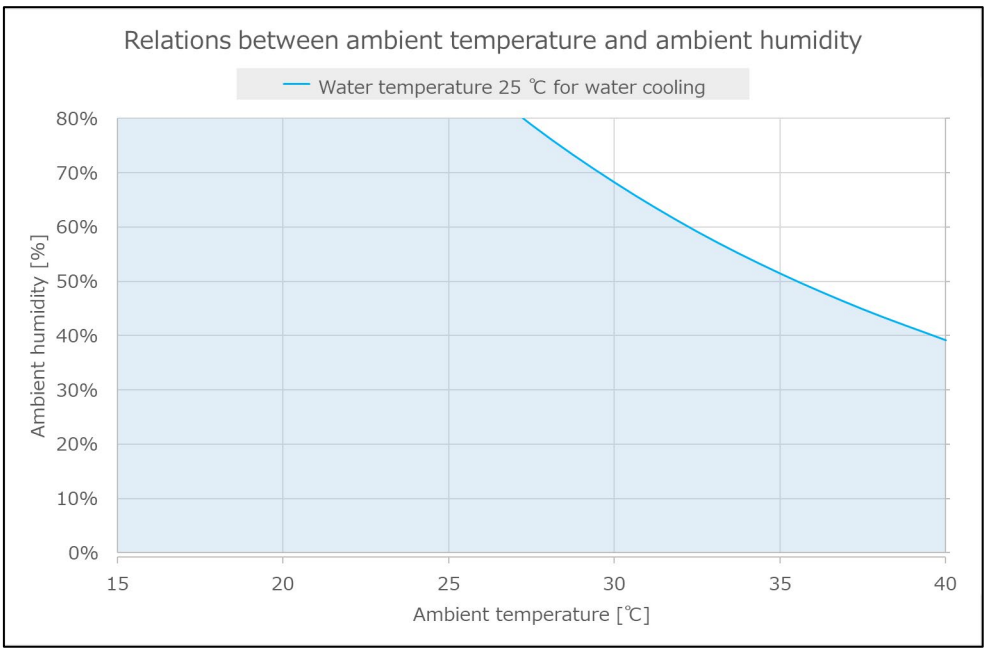
It is recommended to use soft water (except pure water) for cooling water.
If you plan on using water other than soft water as recommended for example antifreeze etc., refer to description of cooling water which is written in 12. “MAINTENANCE” or contact a Hamamatsu subsidiary or your local distributor.

(3) Recommendation temperature

Hamamatsu recommends 25 °C for Circulating water temperature.
For the appropriate temperature range of the cooling water, confirm with the instruction manual of your circulating water cooler.

(4) Condensation

Use the camera in the environment where condensation does not occur inside the camera and on the cooling water hoses. To avoid condensation, set water temperature at 25 °C and control ambient temperature and humidity come to be within the light blue area on the graph.



Graph 8-1

(5) Water Protection Cover

- When the side with the water connectors is on the top, the cooling water may come into the camera through holes of the camera panel during the insertion and removal of the cooling water hoses. To avoid it, make sure to attach the WATER PROTECTION COVER (Figure 8-1) on the panel with water connectors, and use the camera with the condition (Figure 8-2).
- Since the WATAR PROTECTION COVER is made from magnet sheet, it is not easy to move it, however please fit it to the recess of the panel properly.
- When using in air cooling, remove the WATAR PROTECTION COVER because it stops the air flow.

Figure 8-1

Figure 8-2

(6) Handling of the circulating water cooler

Handle the circulating water cooler and the cooling water according to an instruction manual of the circulating water cooler. Proper performance may not be achievable if a non-recommended circulating water cooler is used.

(7) Start water cooling and water cooling in operation

- Turn on the camera after confirming the cooling water is flowing correctly.
- Confirm the camera is cooling.
- Keep 0.45 L/min flow rate for water circulation.
- Do not stop the circulating water cooler while the camera is working.

(8) Cooling water hose

The cooling water hose has a blue hose (Internal diameter: 4 mm / External diameter: 6 mm) and a gray hose (Internal diameter: 8 mm / External diameter: 13.5 mm). (Figure 8-3)
If the hose size on circulating water cooler is the same as blue hose, remove gray hose from the joint part. The gray hose can be removed when blue hose is pulled with pushing the button of the joint on gray hose. (Figure 8-4)

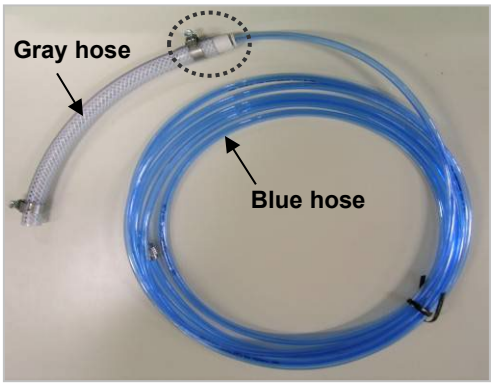


Figure 8-3

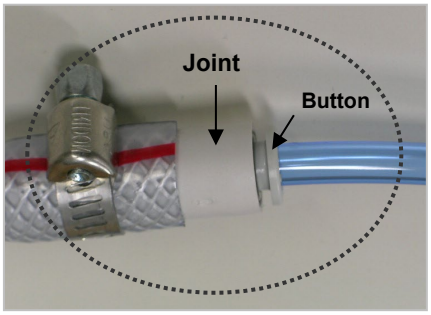


Figure 8-4

(9) Connecting or disconnecting the cooling water hose

CAUTION	• Follow the instruction in Section 8-2 “CONNECTION OF COOLING WATER HOSES” and Section 8-3 “DISCONNECTION OF COOLING WATER HOSES” to connect / disconnect the hose.

- When connecting or disconnecting the cooling water hose, turn off the camera and circulating water cooler.
- Confirm the cooling water circulation is stopping.
- Prepare water absorption sheet (such as Waste, Towel or so) and catch pan in order to avoid water drop or water splash.

(10) Deterioration of the cooling water hose

Replace the water hose with a new one whenever it cannot keep 0.45 L/min flow rate for water circulation due to the hose deterioration.

8-2 CONNECTION OF COOLING WATER HOSES

Figure 8-5

1. Place the camera on the stable table.
2. Insert cooling water hoses into the WATER connector on the camera.
   - Insert the hose fully into the WATER connector on the camera. (as shown in Figure 8-5)
   - Confirm the hose stops at it.
3. Set the camera onto a microscope (If the camera is used on the microscope).
   If it is easy to connect the hose onto the camera after the camera is set onto the microscope then it is OK to connect the hose after the camera is set on the microscope.
4. Connect the hose onto the circulating water cooler.
   Follow the instruction on the circulating water cooler when you connect the hose onto the circulating water cooler.
5. Turn on the circulating water cooler and confirm the cooling water is flowing normally.

CAUTION	• Stop the circulating water cooler when the water flow is abnormal, or when water leak from the WATER connector is found.

8-3 DISCONNECTION OF COOLING WATER HOSES

CAUTION	• Remove the cooling water hoses only when it is necessary to remove.
CAUTION	• Cooling water may be left inside the camera even after hoses are removed. In such case, remove the left water inside the camera by blowing air from Water connectors. Be careful not to splash water onto the camera.

1. Turn off the camera power and all peripheral devices including circulating water cooler.

2. Remove the hose on circulating water cooler side.
   Follow the instruction on the circulating water cooler when you disconnect the hose from the circulating water cooler.

3. Remove water or water drop inside the hose and camera by air.
   - Blow air from one side of hose. Prepare water absorption sheet (such as Waste, Towel or so) and catch pan on another side of hose in order to avoid water drop or water splash.
   - Blow Air until no water drop come out.

4. Remove the camera from the microscope (if the camera is used on the microscope).
   It is not necessary to remove the camera from the microscope if it is possible to remove the hoses from the camera as it is.

5. Place the camera on the stable table.
   Put the lens cap on to protect the sensor.

6. Change the WATER connector direction to be downward.
   Prepare water absorption sheet (such as Waste, Towel or so) and catch pan.

7. Remove hoses one by one, and wipe water.
   Disconnect hoses with pushing button while being careful not to splash water.

Figure 8-6

9. OPERATIONS

9-1 OPERATING PRECAUTIONS

Be careful of the following when you operate the camera.

(1) Cooling method

Cooling of this device is done using a Peltier element.
When an electric current is supplied to the Peltier element, one side of the element is cooled while the other side is heated. CMOS image sensor is positioned on the cooled side, and heated side is cooled by dissipating the heat through the heat sink.
The camera has two cooling methods, Air-cooling method and Water-cooling method.
The default of cooling method is Air-cooling. Cooling mode can be changed by software which is called, “DCAM Configurator”. (refer to 9-5 “STARTUP DCAM CONFIGURATOR”).

Cooling method	Detail
Air-cooling method (Forced air-cooled) (Default)	The heated side of a peltier element is cooled by a fan inside the camera. When the camera is turned on, the fan starts rotating and cooling is started.
Water-cooling method	Circulating water cooler (Optional) is used for cooling the heated side of a peltier element. Cooling does not start just turning on the camera. Cooling water circulation must be started before start operating the camera in water-cooling. A fan inside the camera does not rotate.

CAUTION	• See 8 “WATER COOLING” for instruction of water-cooling.

- Do not switch to water-cooling method when water-cooling is unnecessary.

(2) Ambient temperature

The recommended ambient temperature for camera operation is 25 °C. The recommended water temperature is 25 °C, too. When the ambient temperature is higher than 25 °C in the air-cooling, the CMOS image sensor temperature doesn’t go down enough or doesn’t become stable in some cases. In this case by switching to water-cooling, the CMOS image sensor temperature can go down more and become more stable than in air-cooling.

(3) Protection circuit

The CMOS image sensor and Peltier element are protected from their abnormal temperature increase by a thermal protection circuit. If the internal temperature of the camera becomes abnormally hot, the protection circuit start operating and inform the users by alarming buzzer (beep tone) and lighting red LED, and simultaneously shuts down the supply current to the Peltier element.

As soon as this protection circuit is worked, turn off the power switch and unplug the AC supply. After that, remove the cause of the overheating.

9-2 PREPARATING FOR IMAGING

Use the following procedure when start operating the camera.

- When you connect cables, turn off the power supply of the camera and the peripheral devices.

Note

- After cooling mode was changed, the camera memorizes the last setting as the default setting for cooling. The current cooling mode can be checked using “DCAM Configurator”. (refer to 9-5 “STARTUP DCAM CONFIGURATOR”)

9-2-1 WHEN USING AIR-COOLING

1. Connect the devices using cables as shown in Figure 7-1 before turning on the devices.
2. Turn on the power switch on the back panel of the camera.
3. Check the fan inside the camera is rotating properly and air is circulating.

- When cooling method of the camera is set by water-cooling method, the fan does not start rotating.
- Do not use the water protection cover when using air-cooling.

9-2-2 WHEN USING WATER-COOLING

1. Connect the devices using cables as shown in Figure 7-1 before turning on the devices.
2. Turn on the circulating water cooler.
3. Check cooling water is circulating properly.
4. Turn on the power switch on the back panel of the camera.
5. Turn on the cooling switch of the camera from the application software.

Note

- Refer to the manual of application software for ON/OFF of the cooling switch of a camera.

9-3 IMAGING

Operate the camera from application software.

9-4 END OF IMAGING

Follow the procedure below when imaging is finished.

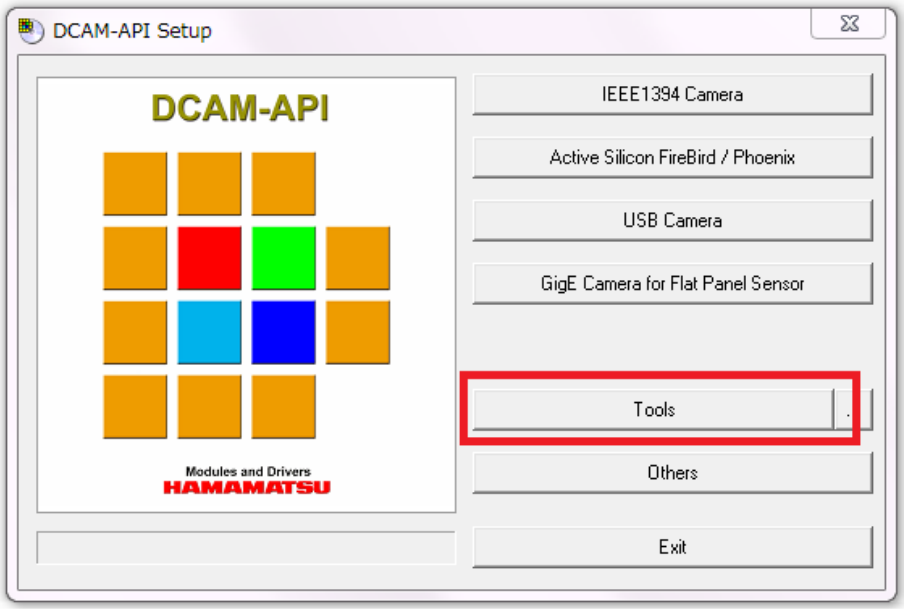
1. End the imaging or transmission of image data with the application software.
2. Turn off the camera and peripheral devices.
3. Turn off the circulating water cooler. (at water-cooling)

9-5 STARTUP DCAM CONFIGURATOR

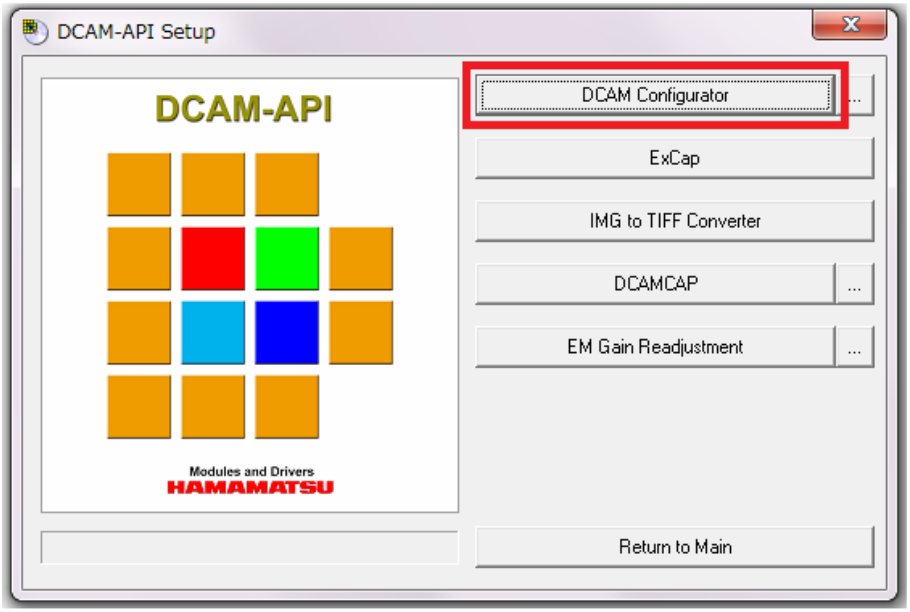
The following is a procedure to startup of “DCAM Configurator”.

1. Open “Setup.exe” in the DCAM-API software’s folder.
   If the DCAM-API software is not installed on your computer, insert the media of DCAM-API software in the slot of your computer. When it is inserted, “DCAM-API Setup” window is displayed automatically.

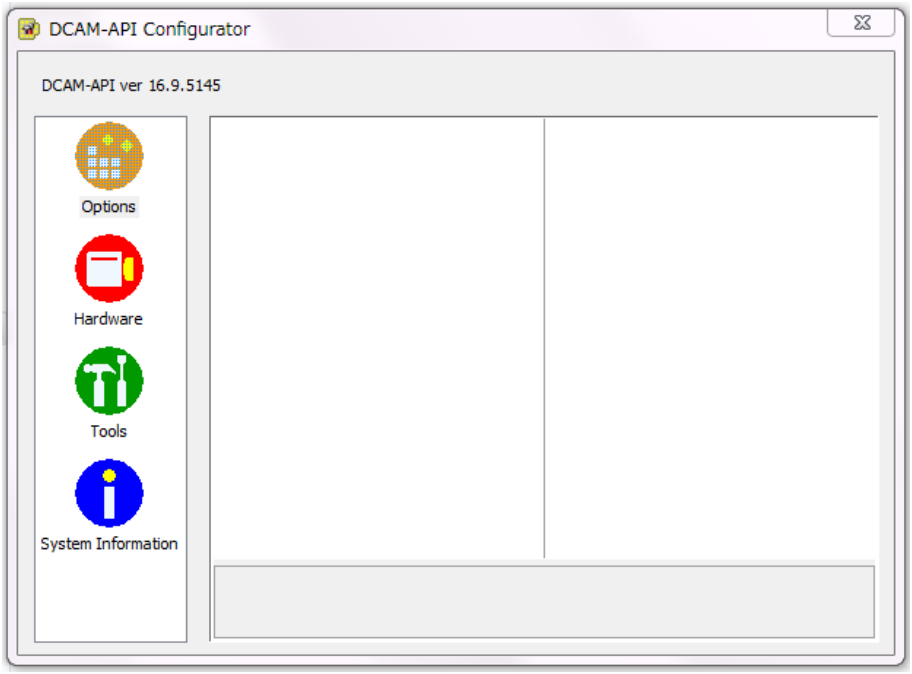
2. Click on “Tools” after “DCAM-API Setup” window is displayed.



3. Click on “DCAM Configurator” after the window is changed to below.

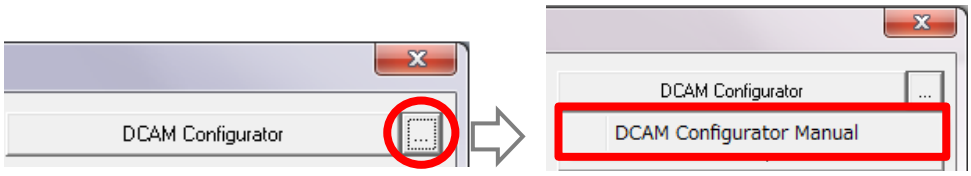


4. “DCAM Configurator” window is displayed. The startup of “DCAM Configurator” is completed with this.



5. By clicking on “Hardware” icon on DCAM Configurator window, you can check a state of cooling mode and set the cooling mode.

- On the operation after the startup, follow to "DCAM Configurator Instruction manual".
- The instruction manual is displayed according to the step shown in the following texts and figures.
- Click on the button of " ... " where the right side of "DCAM Configurator" on DCAM Setup window, then "DCAM Configurator Manual " will be appeared.
- Click on "DCAM configurator Manual", then the instruction manual will be displayed as a PDF.



- Even if the camera's power supply was turned off, the state of setting is kept.

10. DESCRIPTION OF CMOS IMAGE SENSOR

10-1 THEORY OF CMOS IMAGE SENSOR

The pixel of a CMOS image sensor is composed of the photodiode and the amplifier that converts the charge into voltage. Entered light is converted to charge and converted to voltage in the pixel. The voltage of each pixel is output by changing each pixel switch one by one sequentially. (Figure 10-1)
The scientific CMOS image sensor used in this camera has an on-chip CDS (correlated double sampling) circuit, which plays an important role in achieving low noise.

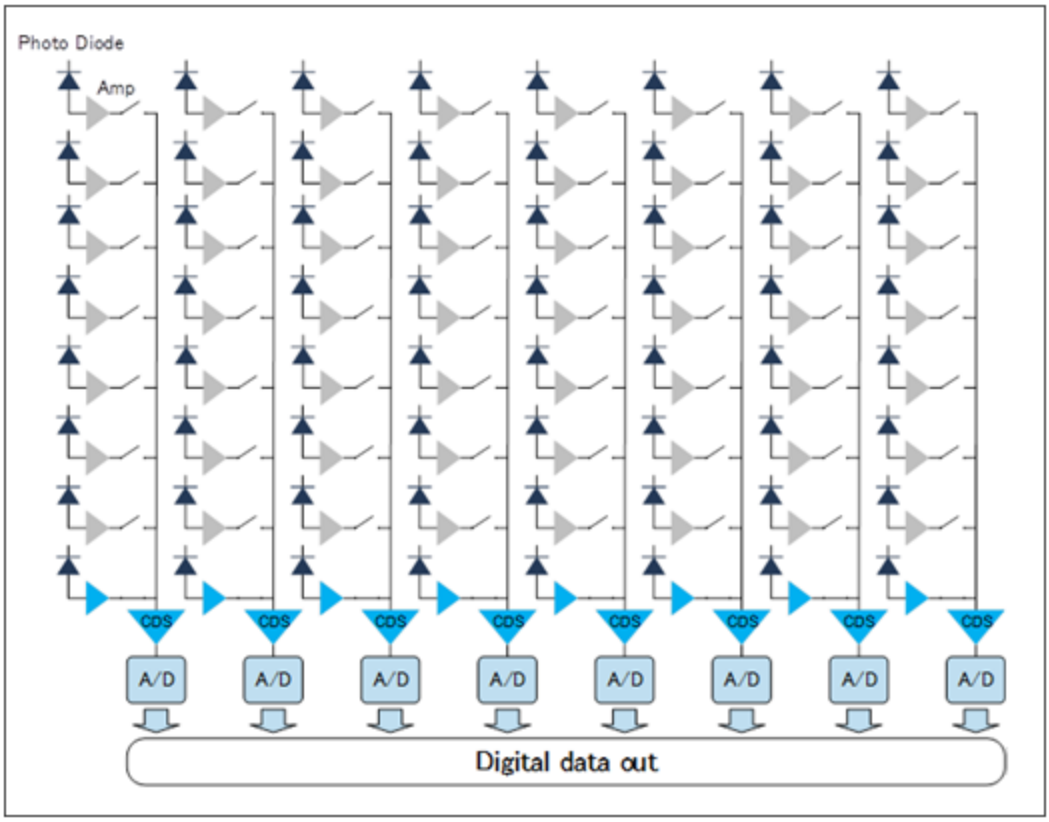


Figure 10-1 Structure of CMOS image sensor

10-2 READOUT METHOD OF CMOS IMAGE SENSOR

The exposure and the readout method of CMOS image sensor which this camera adopts is rolling shutter. In the rolling shutter, the exposure and readout are done row by row sequentially. Therefore, the exposure timing of each row is different even on the same frame. But even if the object moved during the exposure, the effect may be small in almost cases of actual imaging.

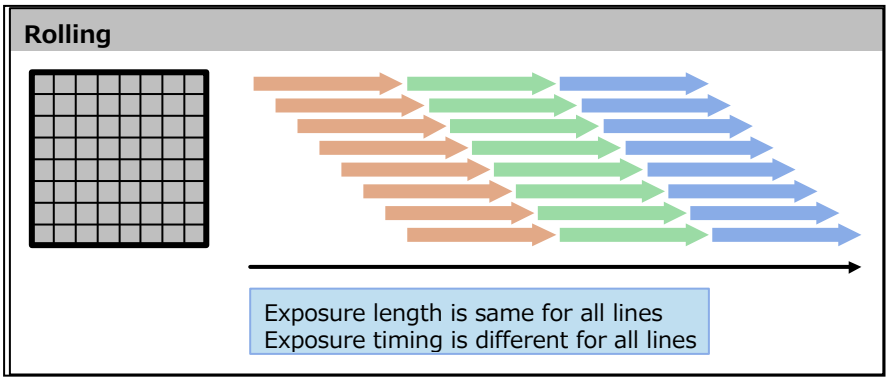


Figure 10-2 Readout timing of Rolling shutter

10-3 PRECAUTION WHEN USING CMOS IMAGE SENSOR

This camera uses scientific CMOS image sensor. Careful attention must be paid to the following points when using CMOS image sensor.

(1) White spot

CMOS image sensor has some high dark current pixels caused by the defect of silicon wafer. Those high dark current pixels appear as higher intensity and brighter pixels than around pixels when the exposure time is set long. Those pixels are called as “White spot” (“hot pixel”).
This camera has real time defect pixel correction function which can replace the defect pixels registered in advance with the data of surrounding pixels.
Hitting of cosmic ray or radiation ray (X-ray, gamma ray, UV light, etc.) on the sensor generates many electrons and they may appear as a white spot, but this white spot is temporary and disappear in the next frame.
In addition, although the probability is very low, the impact of cosmic rays and radiation (X-rays, gamma rays, ultraviolet rays, etc.) is large, and it may cause permanent defects in silicon wafers and defective pixels with large dark current. In current technology, there is no way to avoid generating high dark current defect pixels. It means there is a possibility to generate new white spots after the factory shipment.
Even if the white spot occurs, dark offset subtraction* with software can reduce the effect of white spots because intensities of white spots are proportional to the exposure time and have reproducibility with a constant sensor temperature.

* Dark subtraction: After acquiring an image using a certain exposure time is loaded, CMOS image sensor is exposed to darkness for the same amount of time, and another image is obtained. After this, the difference between the images is determined, and the data for the dark portion of the original image is nullified.

(2) Folding distortion

A rough-edged flicker may be visible when imaging striped patterns, lines, and similar subject matter.

(3) Over light

⚠ CAUTION	• Be careful not to input too strong light such as high-energy laser into CMOS image sensor because CMOS image sensor may be damaged by over light.

11. DESCRIPTION OF VARIOUS FUNCTIONS

11-1 NORMAL AREA MODE

11-1-1 CAMERA READOUT MODES (READOUT DIRECTION)

The camera reads out the image sensor from the top to the bottom line.

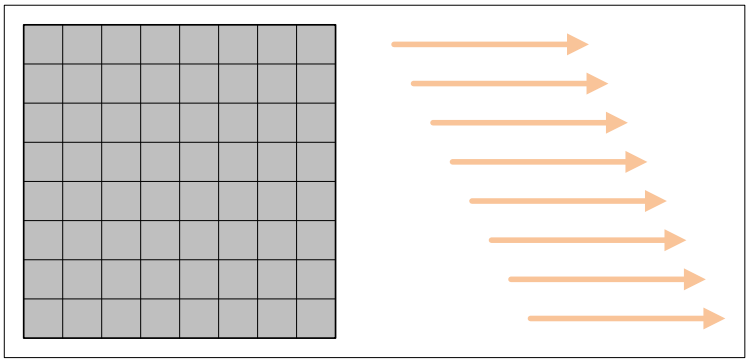


Figure 11-1 Normal area mode readout direction

11-1-2 READOUT METHODS

(1) Normal readout (Full resolution readout mode; 1×1 readout)

Perform charge readout from camera individually for all pixels.

(2) Binning readout (2×2 / 4×4 readout)

With this camera, 2×2 binning readout and 4×4 binning are available by adding the signal of adjacent pixels in the digital domain. Binning readout is a method for achieving high sensitivity in exchange for losing resolution.

(3) Sub-array readout

Sub-array readout is a procedure only a region of interest is scanned. It is possible to increase the frame rate by reducing the number of vertical lines scanned. In sub-array readout, binning configuration is enabled.
Size and a position of the readout area can be configured according to the table below.

Size		Position	
Horizontal	Vertical	Horizontal	Vertical
4 pixels	4 lines	4 pixels	4 lines

Note

- Minimum settable step of the size and position on the table is in only the case that the camera is used with DCAM-API.

Note

- Refer to 11-1-4 “FRAME RATE CALCULATION” about the frame rate of each readout mode.

11-1-3 READOUT SPEED (SCAN SPEED)

The readout speed of this camera depends on the bit depth of digital output. It can readout full resolution images with the speed of 18.1 fps at 16 bit and 24.2 fps at 12 bit.

Digital output	Frame rate for full resolution
16 bit	18.1 fps
12 bit	24.2 fps

Note

- Refer to 11-1-4 “FRAME RATE CALCULATION” about the frame rate of each readout mode.

11-1-4 FRAME RATE CALCULATION

(1) 16 bit digital output

Hn = Number of horizontal pixel
Vn = Number of vertical line
Exp1 = 170 µs to 10 s (input in units of seconds)
24 µs to 10 s (when the global reset mode)
1H = 12.19 µs
Exp2 = roundup_even(Exp1/1H)
roundup_even() = Round up to even number
roundup() = Round up to integer

Operation modes	Binning	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Smaller value of the following formula ・1/((Vn+38)×1H) ・1/((roundup(Hnx(Vn+1) /(167787110.4x1H)))x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 x 3000	18.1
			2048 x 2048	39.3
			1024 x 1024	77.2
			512 x 512	149
			256 x 256	278
			256 x 8	1780
			256 x 4	1950
	2×2	1/((Vnx2+38)×1H)	1500 ×1500	26.9
	4×4	1/((Vnx4+38)×1H)	750 ×750	26.9
External trigger mode (Edge trigger / Level trigger)	1×1	Smaller value of the following formula ・1/((Vn+EXP2+43)×1H) ・1/((roundup(Hnx(Vn+1) /(167787110.4x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 x 3000	18.1
			2048 x 2048	38.9
			1024 x 1024	75.8
			512 x 512	144
			256 x 256	261
			256 x 8	1260
			256 x 4	1340
	2×2	1/((Vnx2+EXP2+43)×1H)	1500 ×1500	26.8
	4×4	1/((Vnx4+EXP2+43)×1H)	750 ×750	26.8
External trigger mode (Global reset edge trigger / Global reset level trigger)	1×1	Smaller value of the following formula ・1/((Vn+EXP2+45)×1H) ・1/((roundup(Hnx(Vn+1) /(167787110.4x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 x 3000	18.1
			2048 x 2048	39.1
			1024 x 1024	76.5
			512 x 512	146
			256 x 256	270
			256 x 8	1490
			256 x 4	1600
	2×2	1/((Vnx2+EXP2+45)×1H)	1500 ×1500	26.9
	4×4	1/((Vnx4+EXP2+45)×1H)	750 ×750	26.9

Operation modes	Binning	Calculation formula	Hn × Vn	Frame rate (fps)
External trigger mode (Synchronous readout trigger)	1×1	Smaller value of the following formula ・1/((Vn+39)×1H) ・1/((roundup(Hnx(Vn+1) /(167787110.4x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 x 3000	18.1
			2048 x 2048	39.2
			1024 x 1024	77.1
			512 x 512	148
			256 x 256	277
			256 x 8	1600
			256 x 4	1900
	2×2	1/((Vnx2+39)×1H)	1500 ×1500	26.9
	4×4	1/((Vnx4+39)×1H)	750 ×750	26.9

Note

- The frame rate value is valid 3 digits and rounded down to 4th digit.

Note

- The calculation formula and the frame rate value of Start trigger mode (External trigger mode) are same as Free running mode. About this mode, refer to 11-1-6-3 “Start trigger mode”.

(2) 12 bit digital output

Hn = Number of horizontal pixel
Vn = Number of vertical line
Exp1 = 41 μs to 10 s (input in units of seconds)
1H = 5.167 μs
Exp2 = roundup_even(Exp1/1H)
roundup_even() = Round up to even number
roundup() = Round up to integer

Operation modes	Binning	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Smaller value of the following formula ・1/((Vn+32)×1H) ・1/((roundup(Hnx(Vn+1) /(223746877.44×1H)))x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(223746877.4x1H)))x1H)	3000 x 3000	24.2
			2048 x 2048	53.3
			1024 x 1024	183
			512 x 512	355
			256 x 256	672
			256 x 8	4830
			256 x 4	5370
	2×2	1/((Vnx2+32)×1H)	1500 ×1500	63.8
	4×4	1/((Vnx4+32)×1H)	750 ×750	63.8
External trigger mode (Edge trigger / Level trigger)	1×1	Smaller value of the following formula ・1/((Vn+EXP2+37)×1H) ・1/((roundup(Hnx(Vn+1) /(223746877.44x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(223746877.4x1H)))x1H)	3000 x 3000	24.2
			2048 x 2048	53.3
			1024 x 1024	181
			512 x 512	347
			256 x 256	643
			256 x 8	3650
			256 x 4	3950
	2×2	1/((Vnx2+EXP2+37)×1H)	1500 ×1500	63.5
	4×4	1/((Vnx4+EXP2+37)×1H)	750 ×750	63.5

Operation modes	Binning	Calculation formula	Hn × Vn	Frame rate (fps)
External trigger mode (Global reset edge trigger / Global reset level trigger)	1×1	Smaller value of the following formula ・1/((Vn+EXP2+39)×1H) ・1/((roundup(Hnx(Vn+1) /(223746877.4x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(223746877.4x1H)))x1H)	3000 x 3000	24.2
			2048 x 2048	53.3
			1024 x 1024	181
			512 x 512	349
			256 x 256	651
			256 x 8	3950
			256 x 4	4300
	2×2	1/((Vnx2+EXP2+39)×1H)	1500 ×1500	63.6
	4×4	1/((Vnx4+EXP2+39)×1H)	750 ×750	63.6
External trigger mode (Synchronous readout trigger)	1×1	Smaller value of the following formula ・1/((Vn+33)×1H) ・1/((roundup(Hnx(Vn+1) /(223746877.4x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(223746877.4x1H)))x1H)	3000 x 3000	24.2
			2048 x 2048	53.3
			1024 x 1024	183
			512 x 512	355
			256 x 256	669
			256 x 8	4720
			256 x 4	5230
	2×2	1/((Vnx2+33)×1H)	1500 ×1500	63.6
	4×4	1/((Vnx4+33)×1H)	750 ×750	63.6

Note

- The frame rate value is valid 3 digits and rounded down to 4th digit.

Note

- The calculation formula and the frame rate value of Start trigger mode (External trigger mode) are same as Free running mode. About this mode, refer to 11-1-6-3 “Start trigger mode”.

11-1-5 CONFIGURING EXPOSURE TIME

The exposure time can be set in seconds.
The actual exposure time setting is defined by the following formula, and the camera automatically calculates a longer and closest value from the specified exposure time setting.

(1) 16 bit digital output

Exp1 = 170 µs to 10 s (input in units of seconds)
Exp2 = Exp1 ÷ 12.19 µs (round up to even number)

Calculation formula	Exp2 × 12.19 µs

In the case of the global reset mode
Exp1 = 24 µs to 10 s (input in units of seconds)
Exp2 = Exp1 ÷ 12.19 µs (round up to even number)

Calculation formula	(Exp2 × 12.19 µs) + 19.97 µs

(2) 12 bit digital output

Exp1 = 41 µs to 10 s (input in units of seconds)
Exp2 = Exp1 ÷ 5.167 µs (round up to even number)

Calculation formula	Exp2 × 5.167 µs

In the case of the global reset mode
Exp1 = 10 µs to 10 s (input in units of seconds)
Exp2 = Exp1 ÷ 5.167 µs (round up to even number)

Calculation formula	(Exp2 × 5.167 µs) + 5.917 µs

Available setting range of the exposure time is the following.

Digital output	Setting range
16 bit	170 µs (24 µs when the global reset mode) to 10 s
12 bit	41 µs (10 µs when the global reset mode) to 10 s

11-1-6 CAMERA OPERATION MODES

11-1-6-1 Free running mode

The camera has Free running mode which the exposure and readout timing can be set and controlled by an internal microprocessor. Free running mode has normal readout mode (in which the exposure time is longer than the 1 frame readout time) and electrical shutter mode (in which the exposure time is shorter than the 1 frame readout time). These readout modes are automatically switched depending on the exposure time setting.

Note

- Contact a Hamamatsu subsidiary or your local distributor for the detail of the timing information.

(1) Normal readout

The normal readout mode is suitable for observation, monitoring, field of view and focus adjustment, and animation because it can operate with full resolution and first frame rate (18.1 fps with 16 bit digital output, 24.2 fps with 12 bit digital output).
In addition, the exposure time can be extended to collect more signals and increase the signal to noise ratio if the object is dark. In the normal readout mode, the exposure time is the same or longer than the 1 frame readout time. In this mode, the frame rate depends on the exposure time, and it becomes frame rate = 1/exposure time. The maximum exposure time is 10 s.

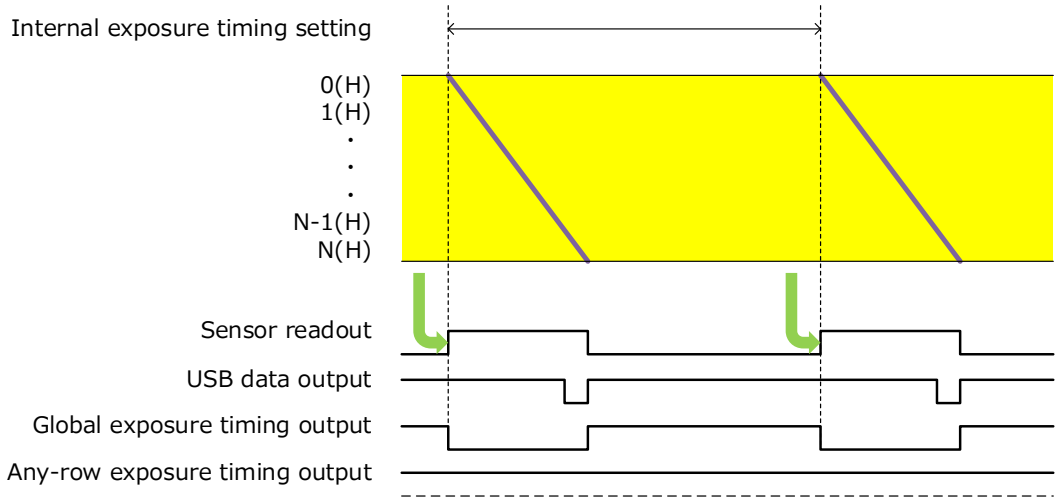


Figure 11-2

(2) Electrical shutter

The electrical shutter mode is used to get a proper signal level when signal overflow happens due to too much input photons in normal readout mode. In this mode, the fastest frame rate is 18.1 fps (16 bit digital output), 24.2 fps (12 bit digital output) at full resolution even when the exposure time is short.

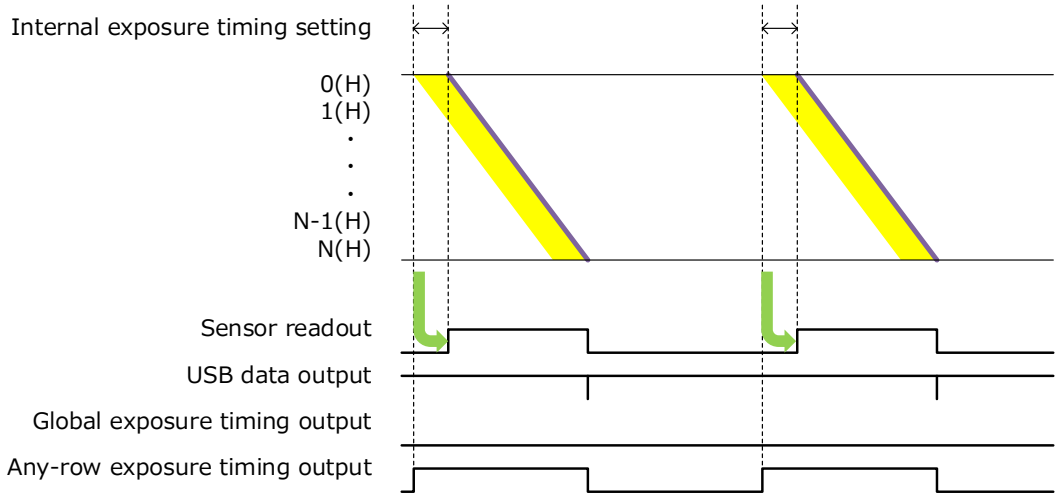


Figure 11-3

11-1-6-2 External trigger mode

The camera has various external trigger functions to synchronize the camera with the external devices. In External trigger mode, the external device becomes a master, and the camera becomes a slave.

Note

- Contact a Hamamatsu subsidiary or your local distributor for the detail of the timing information.

(1) Edge trigger mode

The Edge trigger mode is used so that the exposure starts according to an external signal. Exposure time is set. In this mode, the exposure of the first line begins on the edge (rising / falling) timing of the input trigger signal into the camera. (0(H) in the following figure) The exposure of the second line is begun after the readout time of one line passes (1(H) in the following figure), and the exposure is begun one by one for each line.

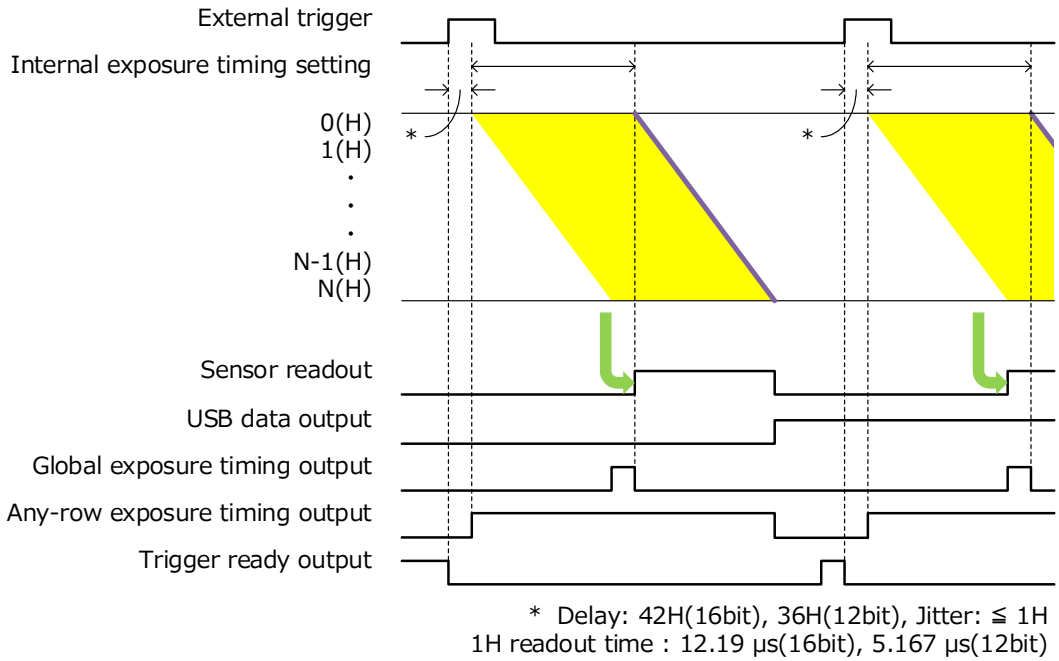


Figure 11-4 (Ex. rising edge)

(2) Global reset Edge trigger mode

Global reset function enables to reset the electric charge of all pixels at the same time. Then all pixels can start exposure at the same time.
With this Global reset Edge trigger mode, the exposure of all pixels begins on the edge (rising / falling) timing of the input trigger signal into the camera.

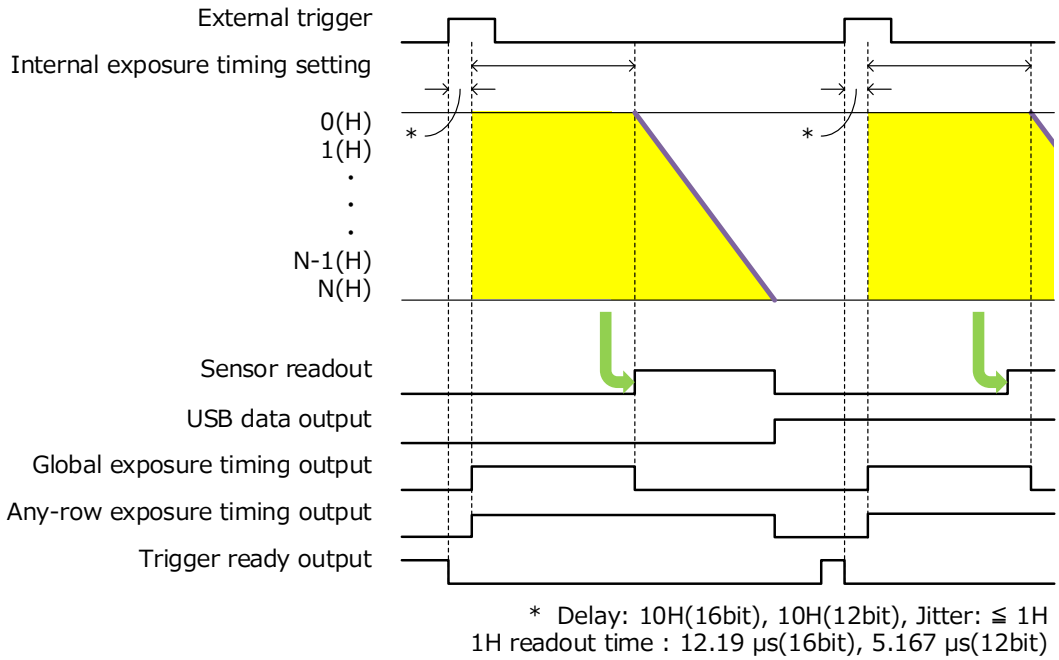


Figure 11-5 (Ex. rising edge)

(3) Level trigger mode

The Level trigger mode is used to control both exposure start timing and exposure time length by inputting external trigger pulses. In this mode, the camera starts exposure at the start of high or low period of the input trigger pulse and stops exposure at the end of high or low period of the input trigger pulse. The example below is for the trigger level High. The exposure of the first line begins when the trigger signal becomes High, and the exposure of the second line begins after the readout time of line one passes. Each exposure begins one by one for each line. The exposure of the first line is finished when the trigger signal becomes low, and signal readout is begun. The exposure time of each line is defined by the time that the input trigger is high.

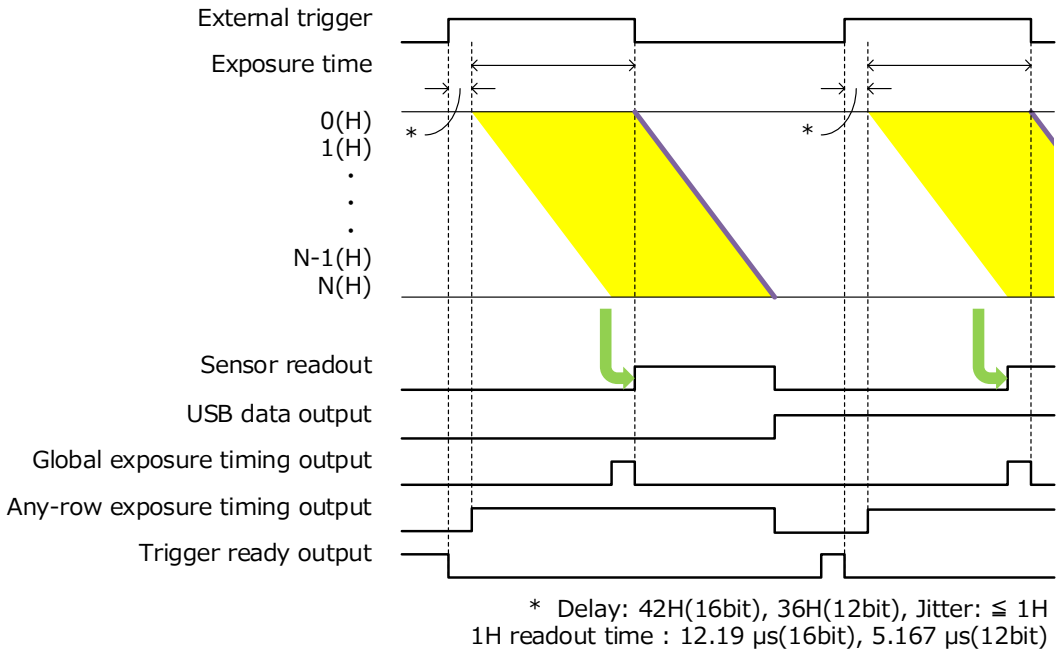


Figure 11-6 (Ex. level High)

(4) Global reset Level trigger mode

Global reset function enables to reset the electric charge of all pixels at the same time. Then all pixels can start exposure at the same time.
The example below is for the trigger level High. With this Global reset Level trigger mode, the exposure of all pixels begins when the trigger signal becomes High.

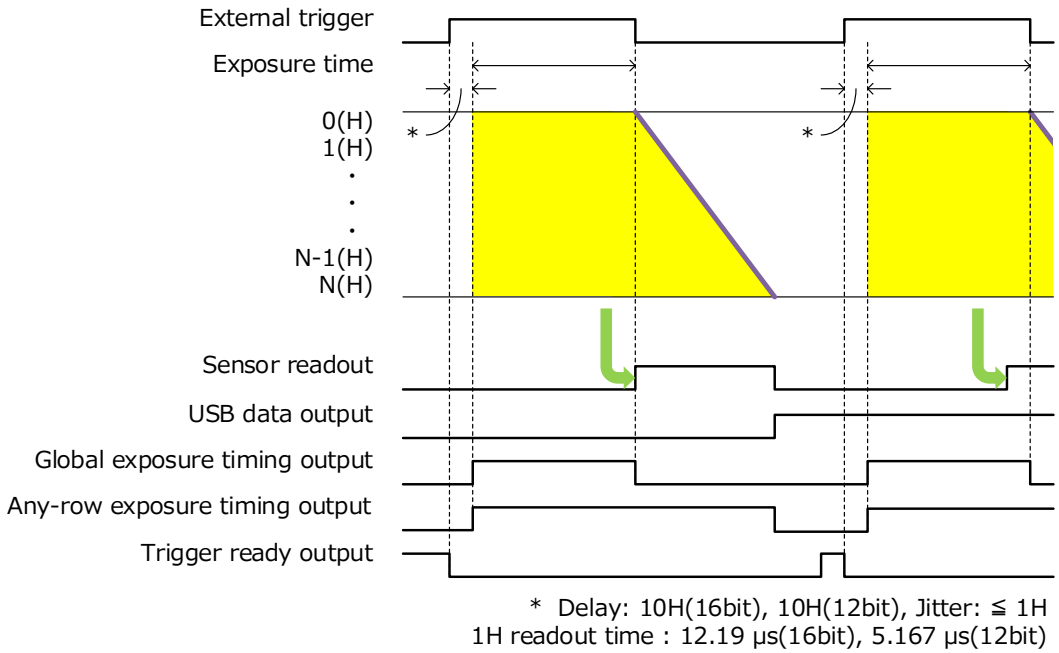


Figure 11-7 (Ex. level High)

(5) Synchronous readout trigger mode

The Synchronous readout trigger mode is used for continuous imaging when it is necessary to control the exposure start timing of each frame from an external source. It is useful for confocal microscopy. For example, when the camera is used with a spinning disk confocal microscope and the camera exposure time is synchronized to the spinning disk's rotation speed, it is possible to eliminate uneven illumination (called banding noise) caused by variation of the spinning disk rotation speed. Also, it is useful for securing as long exposure time as possible while controlling the exposure start timings by external trigger signals.

Normal operation (when the Trigger Time is set as 1.);
The Synchronous readout trigger mode is used for continuous imaging when it is necessary to control the exposure start timing of each frame from an outside source and also when it is necessary to secure as long exposure time as possible. In the Synchronous readout trigger mode, the camera ends each exposure, starts the readout and also, at the same time, starts the next exposure at the edge of the input trigger signal (rising / falling edge). That is, the interval between the same edges of the input trigger becomes the exposure time.

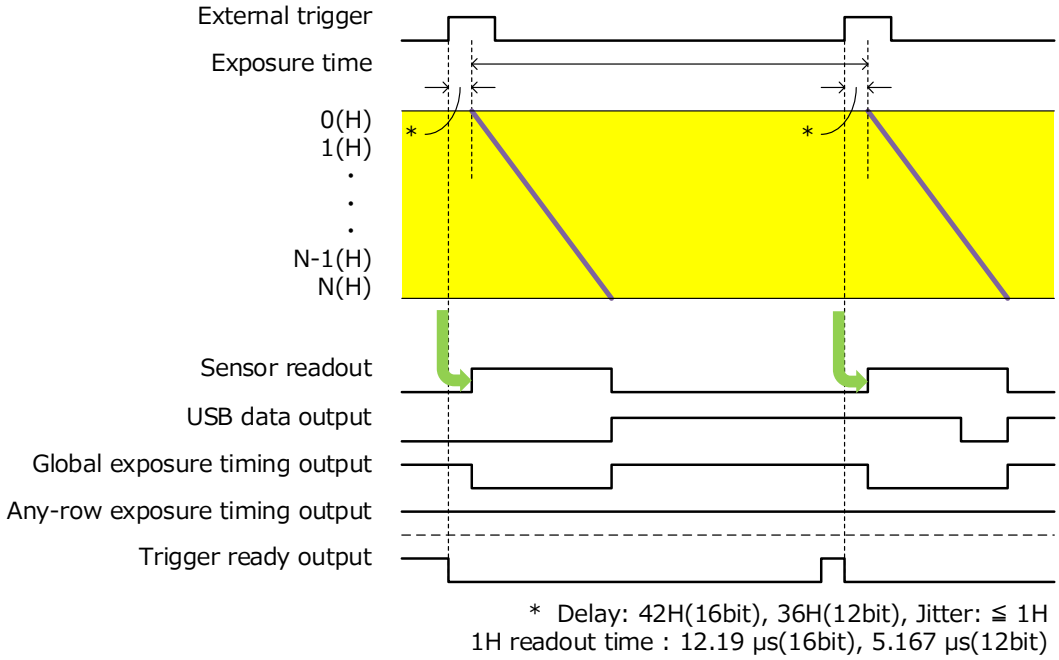


Figure 11-8 (Ex. rising edge)

Trigger Times;
Also in the Synchronous readout trigger mode, synchronous readout can be controlled by specifying, the number of timing pulses to determine the exposure time. The input trigger is valid only during the trigger ready is enabled.

The following figure shows the exposure timing when the Trigger Times is set as 4.

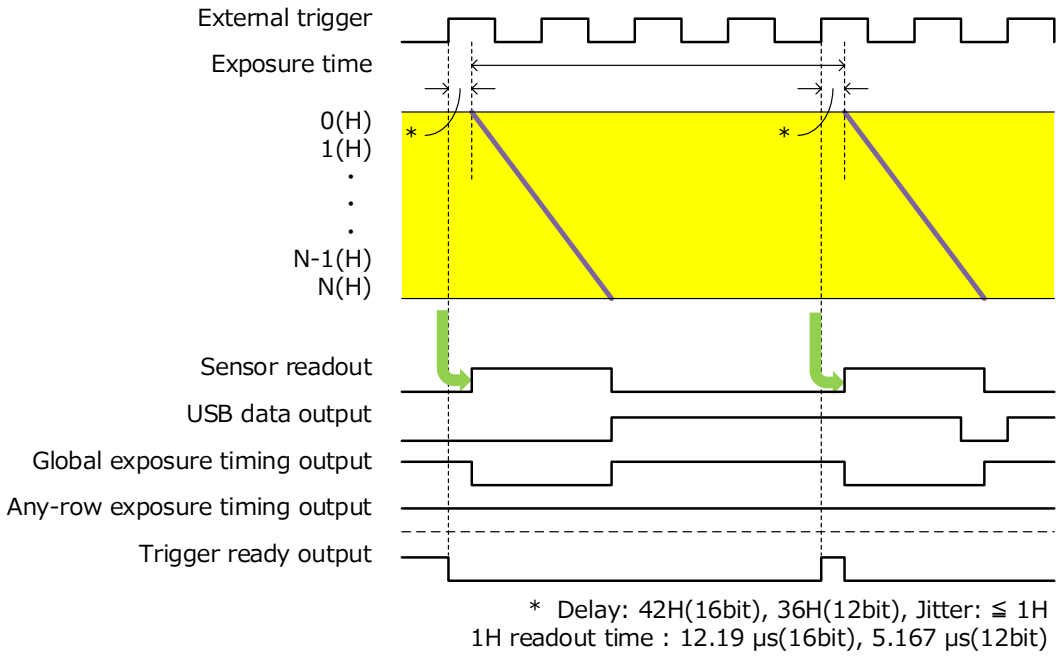


Figure 11-9 (Trigger Times)

11-1-6-3 Start trigger mode

Start trigger mode is to start operating the camera by a trigger input for a continuous imaging. It is useful to secure the frame rate as fast as possible when continuous image acquisition and not to sacrifice the exposure time. For example, when it is necessary to measure the phenomenon after stimulation, it is possible to start continuous image acquisition at the stimulation timing.

Start trigger mode is to start operating the camera by a trigger input for continuous imaging, and it works at the highest frame rate because it is operated in internal trigger mode. In Start trigger mode, the camera starts exposure and switches to internal trigger mode by the edge of an external trigger signal (rising / falling edge).

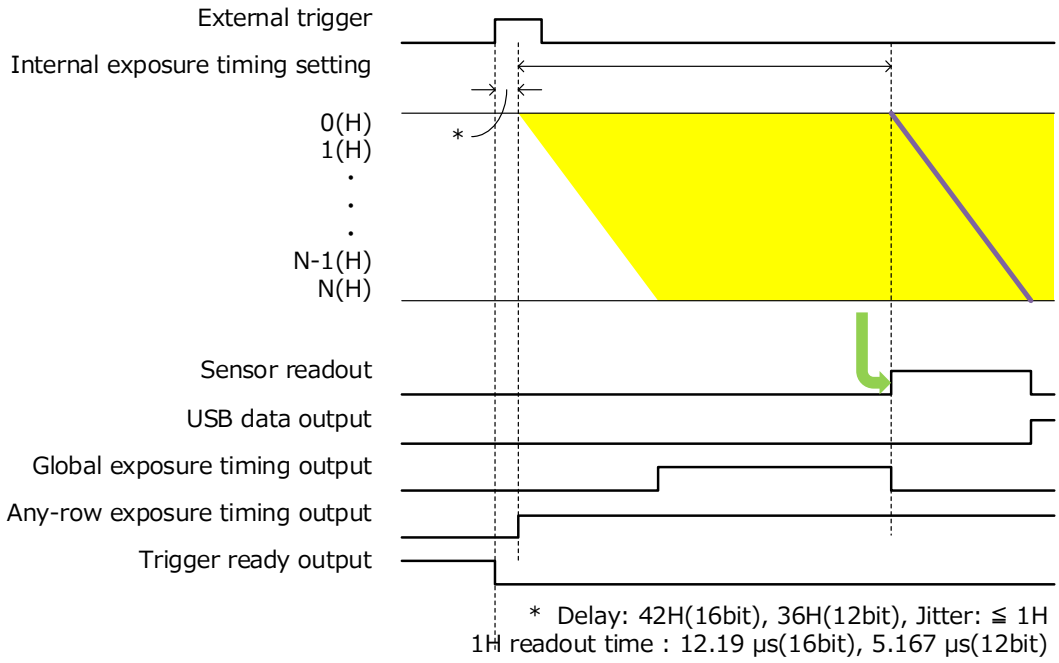


Figure 11-10 (Ex. rising edge)

11-1-6-4 External trigger delay function

In most cases when a delay between the laser pulse emission and the exposure start is needed, a delay unit is set between the laser and camera to control trigger timing. In each external trigger mode of the camera, the delay can be set to the trigger signal input to the camera by command. With this setting, a range of trigger can be arranged without a delay unit. The range for delay time is 0 μs to 10 s (1 μs steps).

11-1-7 TRIGGER OUTPUT

The camera provides a range of trigger output signals to synchronize with an external instrument and the camera becomes the master and the external instrument becomes the slave.

There are three different trigger output functions as follows.

- Global exposure timing output
- Programmable timing output
- Trigger ready output

Also, it can output continuous High output (High output fixed) or continuous Low output (Low output fixed). They are output from Timing out connector.

(1) Global exposure timing output

It shows the global exposure timing where all lines expose at the same time. There is a case that one event is divided into two frames because the timing of the exposure in each line is different for the rolling shutter. However, by using the Global exposure timing output the global exposure becomes possible for the phenomenon that happens for this period. Global exposure timing output shows the period where all lines expose at the same time.

Note

- There is no output signal when the exposure time is less than the frame rate.

(2) Any row exposure timing output

Global exposure timing output shows the limited exposure period when all rows expose at the same time while the any row exposure timing output shows total exposure period when any of the rows expose.

(3) Programmable timing output

By using the programmable timing output, synchronizing external devices is simple. A system that needs simple timing signal does not require a delay unit or pulse generator. It is possible to program and output a pulse that has an optional pulse width and an optional delay time to Read End (the end of readout timing), Vsync or Input trigger signal. The setting range for delay time is 0 μs to 10 s, and the setting range for pulse width is 1 μs to 10 s.

The relation between the parameter which can be set with each reference signal, and an output signal becomes below.

Reference signal	Output signal
Read End	The signal with the preset pulse width is output after the preset delay from the end of the sensor readout.
Vsync	The signal with the preset pulse width is output after the preset delay from the start of the sensor readout.
Input trigger signal	The signal with the preset pulse width is output after the preset delay from the input signal.

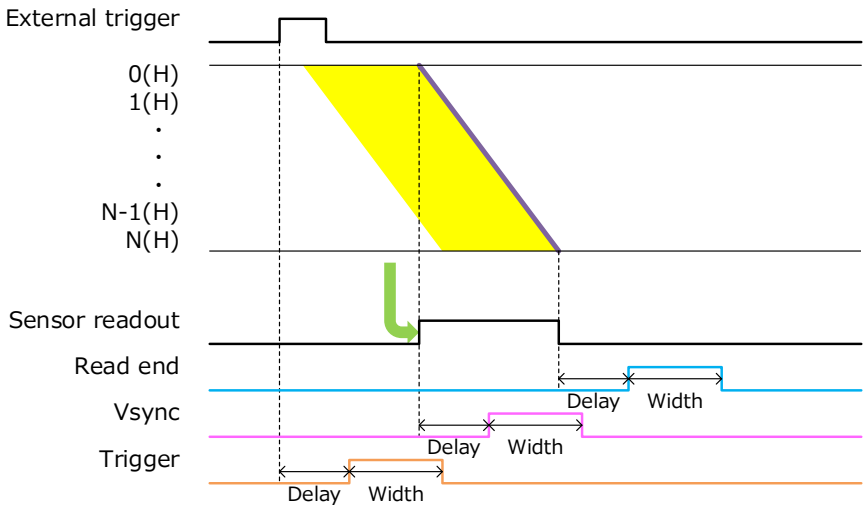


Figure 11-11 Programmable timing output

(4) Trigger ready output

The trigger ready output is useful to make the frame intervals as short as possible in external trigger mode. For example, when the camera is working in the Edge trigger mode, the next frame can start after the previous frame exposure is done. Thus, the camera cannot accept a trigger for the next frame during the exposure period. To reduce useless time to be as short as possible, it is necessary to know the period when the camera can accept a trigger for the next frame. The trigger ready output shows the trigger ready period when the camera can accept an external trigger in External trigger mode.

11-2 LIGHTSHEET READOUT MODE

Lightsheet Readout Mode is a unique feature of CMOS image sensor which provides improved control over the rolling shutter mechanism.
By finely synchronizing the camera readout with the illumination scan, scattered light is rejected allowing images of higher signal to noise ratios to be acquired.

The detail information of Lightsheet Readout Mode is published on our website.

Website https://www.hamamatsu.com/jp/en/product/cameras/cmos-cameras/lightsheet-readout-mode.html

11-2-1 READOUT DIRECTION

Lightsheet Readout Mode has 4 readout directions of Forward, Backward, Bidirectional and Reverse bidirectional. Forward mode readouts lines from top to bottom (Figure 11-12). Backward mode readouts lines from bottom to top (Figure 11-13). Bidirectional mode readouts lines from top to bottom at the first frame and switches the readout direction in frame by frame (Figure 11-14). Reverse bidirectional mode readouts lines from bottom to top at the first frame and switches the readout direction in frame by frame (Figure 11-15).

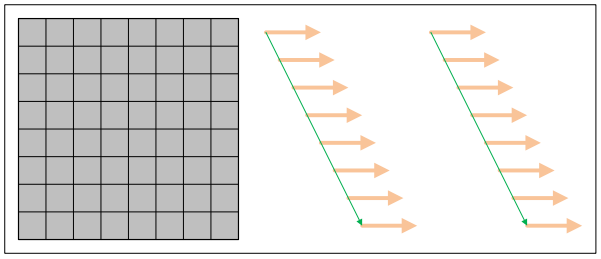


Figure 11-12 Top to Bottom readout

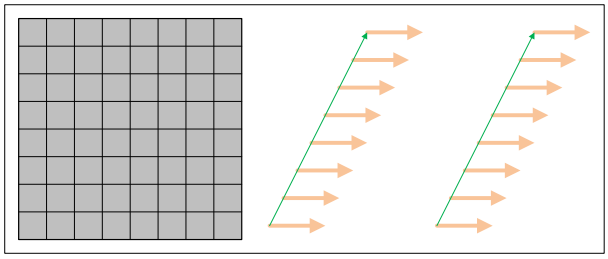


Figure 11-13 Bottom to Top readout

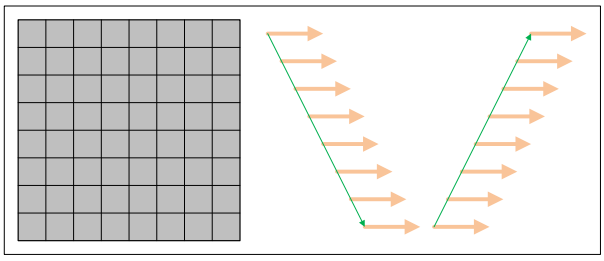


Figure 11-14 Bidirectional readout

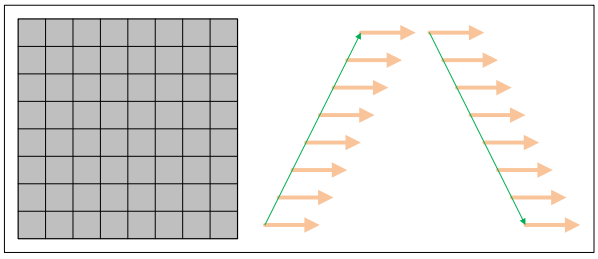


Figure 11-15 Reverse bidirectional readout

11-2-2 ABOUT READOUT AT LIGHTSHEET READOUT MODE

(1) Readout methods

This mode can set Normal readout and Sub-array readout.
Binning readout mode is not supported at Lightsheet Readout Mode.
The size and the position of the sub-array readout can be configured according to the table below.

Size		Position	
Horizontal	Vertical	Horizontal	Vertical
1 pixels	4 lines	1 pixels	4 lines

Note

- Minimum settable step of the size and position on the table is in only the case that the camera is used with DCAM-API.

(2) Camera operation modes

This mode can use; Free running mode, Edge trigger mode (External trigger mode), and Start trigger mode.

11-2-3 FRAME RATE CALCULATION

(1) 16 bit digital output

Hn = Number of horizontal pixel
Vn = Number of vertical line
Exp1 = 170 µs to 960 ms (input in units of seconds to the calculation formula)
1H = 12.19 µs to 320 µs
Exp2 = roundup_even(Exp1/1H)
roundup_even() = Round up to even number
roundup() = Round up to integer

Operation modes	Readout direction	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	Top to Bottom / Bottom to Top	Smaller value of the following formula ・1/((Vn+EXP2+42)×1H) ・1/(roundup(Hnx(Vn+1) /(167787110.4x1H))x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 × 3000	18.1
			2048 × 2048	38.9
			1024 × 1024	75.9
			512 × 512	144
			256 × 256	262
			256 × 8	1280
			256 × 4	1360
	Bidirectional / Reverse bidirectional	Smaller value of the following formula ・1/((Vn+EXP2+78)×1H) ・1/(roundup(Hnx(Vn+1) /(167787110.4x1H))x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 × 3000	18.1
			2048 × 2048	38.3
			1024 × 1024	73.4
			512 × 512	135
			256 × 256	235
			256 × 8	820
			256 × 4	854
External trigger mode (Edge trigger)	Top to Bottom / Bottom to Top	Smaller value of the following formula ・1/((Vn+EXP2+43)×1H) ・1/((roundup(Hnx(Vn+1) /(167787110.4x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 × 3000	18.1
			2048 × 2048	38.9
			1024 × 1024	75.8
			512 × 512	144
			256 × 256	261
			256 × 8	1260
			256 × 4	1340
	Bidirectional / Reverse bidirectional	Smaller value of the following formula ・1/((Vn+EXP2+79)×1H) ・1/((roundup(Hnx(Vn+1) /(167787110.4x1H))+1)x1H) When Hn is 3000, 1/((roundup((Hn+72)x(Vn+1) /(167787110.4x1H)))x1H)	3000 × 3000	18.1
			2048 × 2048	38.3
			1024 × 1024	73.4
			512 × 512	135
			256 × 256	234
			256 × 8	811
			256 × 4	845

(2) 12 bit digital output

Hn = Number of horizontal pixel
Vn = Number of vertical line
Exp1 = 41 µs to 2.731 s (input in units of seconds to the calculation formula)
1H = 5.167 µs to 910.2 µs
Exp2 = roundup_even(Exp1/1H)
roundup_even() = Round up to even number
roundup() = Round up to integer

Operation modes	Readout direction	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	Top to Bottom / Bottom to Top	Smaller value of the following formula ・1/((Vn+EXP2+36)×1H) ・1/(roundup(Hnx(Vn+1) /(223746877.4x1H))x1H) When Hn is 3000, 1/(roundup((Hn+72)x(Vn+1) /(223746877.4x1H))x1H)	3000 × 3000	24.2
			2048 × 2048	53.3
			1024 × 1024	181
			512 × 512	348
			256 × 256	645
			256 × 8	3720
			256 × 4	4030
	Bidirectional / Reverse bidirectional	Smaller value of the following formula ・1/((Vn+EXP2+72)×1H) ・1/(roundup(Hnx(Vn+1) /(223746877.4x1H))x1H) When Hn is 3000, 1/(roundup((Hn+72)x(Vn+1) /(223746877.4x1H))x1H)	3000 × 3000	24.2
			2048 × 2048	53.3
			1024 × 1024	175
			512 × 512	326
			256 × 256	576
			256 × 8	2190
			256 × 4	2300
External trigger mode (Edge trigger)	Top to Bottom / Bottom to Top	Smaller value of the following formula ・1/((Vn+EXP2+37)×1H) ・1/((roundup(Hnx(Vn+1) /(223746877.4x1H))+1)x1H) When Hn is 3000, 1/(roundup((Hn+72)x(Vn+1) /(223746877.4x1H))x1H)	3000 × 3000	24.2
			2048 × 2048	53.3
			1024 × 1024	181
			512 × 512	347
			256 × 256	643
			256 × 8	3650
			256 × 4	3950
	Bidirectional / Reverse bidirectional	Smaller value of the following formula ・1/((Vn+EXP2+73)×1H) ・1/((roundup(Hnx(Vn+1) /(223746877.4x1H))+1)x1H) When Hn is 3000, 1/(roundup((Hn+72)x(Vn+1) /(223746877.4x1H))x1H)	3000 × 3000	24.2
			2048 × 2048	53.3
			1024 × 1024	175
			512 × 512	326
			256 × 256	574
			256 × 8	2170
			256 × 4	2270

Note

- The frame rate value is valid 3 digits and rounded down to 4th digit.

Note

- The calculation formula and the frame rate value of Start trigger mode (External trigger mode) are same as Free running mode.

11-2-4 READOUT TIME OF THE HORIZONTAL LINE

Readout time and exposure time can be varied with Lightsheet Readout Mode for synchronizing the camera readout with the illumination scan.

(1) 16 bit digital output

Vn = Number of vertical line
1H = 12.19 µs to 320 µs

Readout time = Vn × 1H

Exposure time setting range	14H to (Vn × 1H) :2H step

(2) 12 bit digital output

Vn = Number of vertical line
1H = 5.167 µs to 320 µs

Readout time = Vn × 1H

Exposure time setting range	8H to (Vn × 1H) :2H step

11-2-5 TIMING DIAGRAM

(1) Free running mode

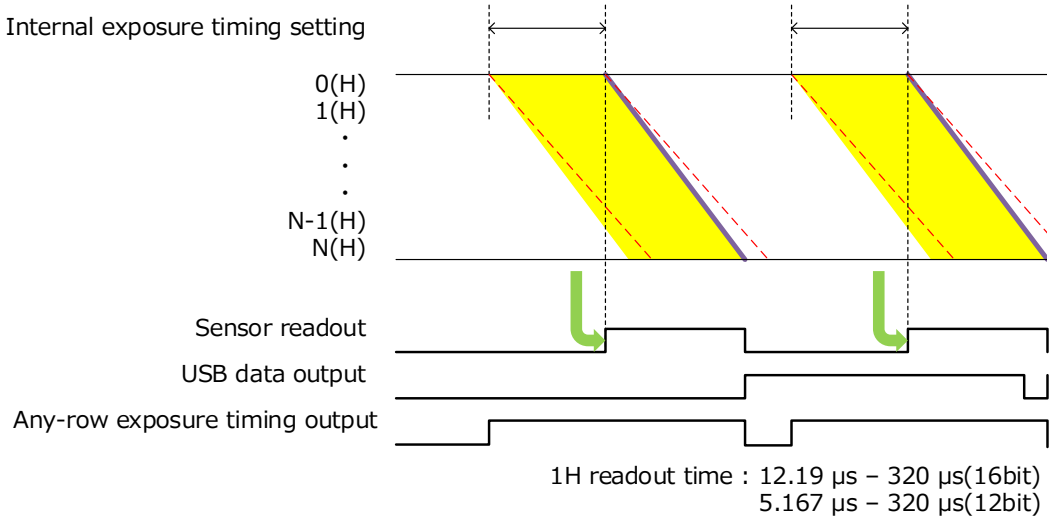


Figure 11-16 (Ex. Top to bottom readout)

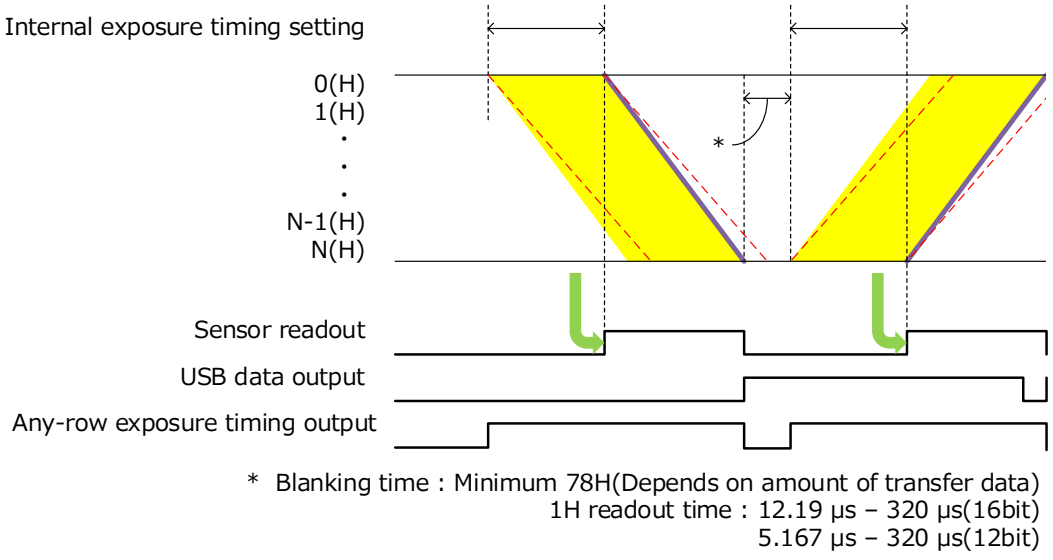
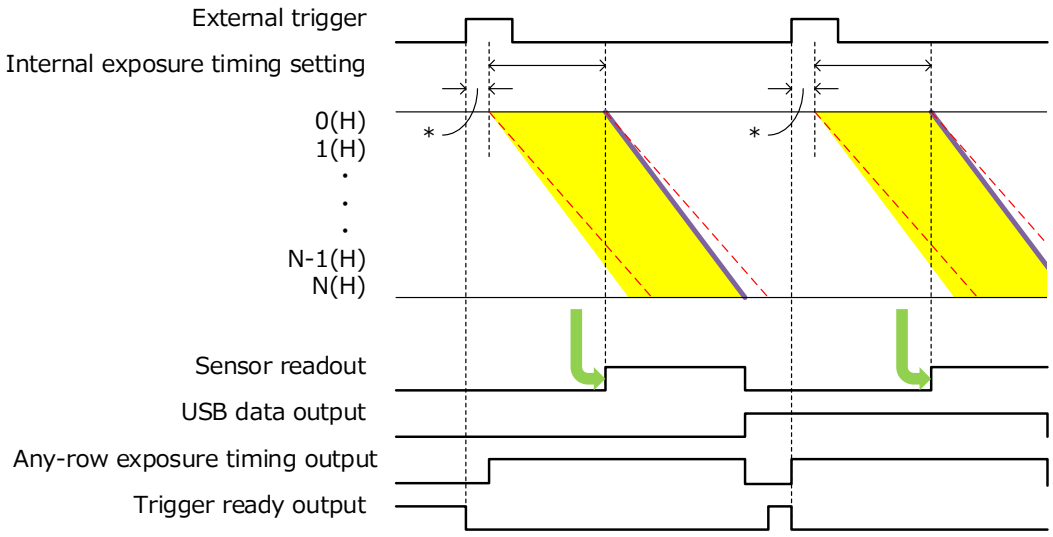


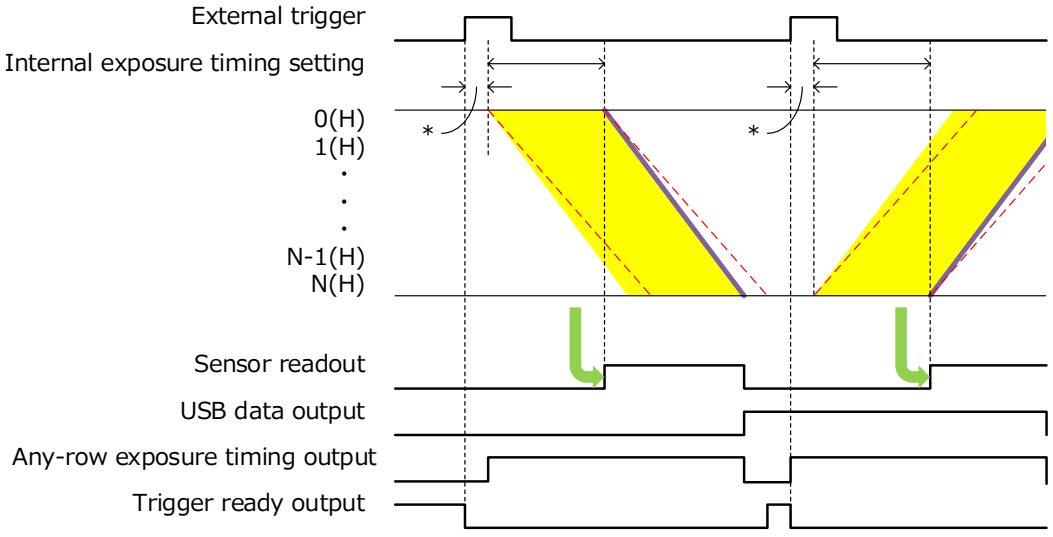
Figure 11-17 (Ex. Bidirectional readout)

(2) Edge trigger mode (External trigger mode)



* Delay: 42H(16bit), 36H(12bit), Jitter: ≦ 1H
1H readout time : 12.19 µs – 320 µs(16bit)
5.167 µs – 320 µs(12bit)

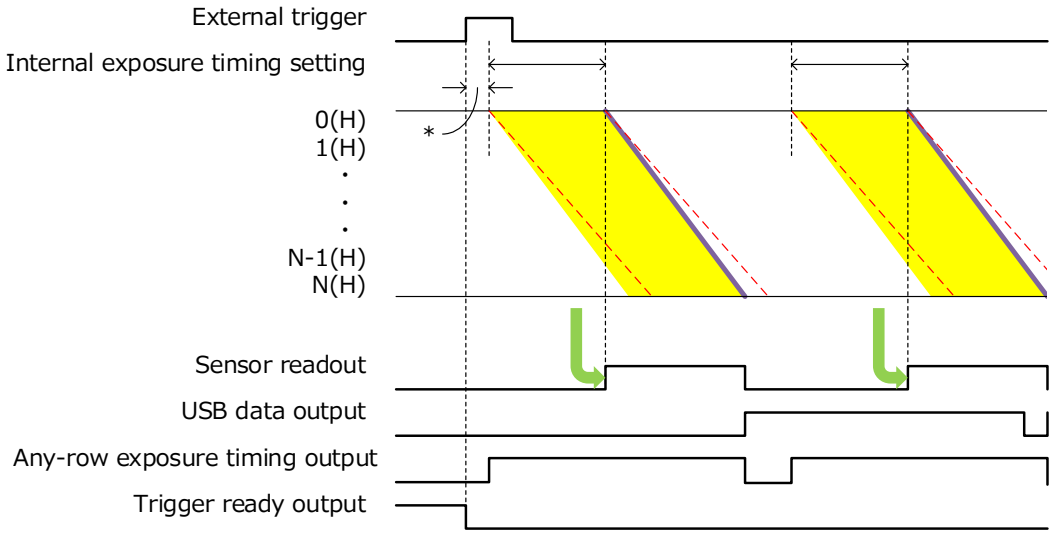
Figure 11-18 (Ex. rising edge, Top to bottom readout)



* Delay: 42H(16bit), 36H(12bit), Jitter: ≦ 1H
1H readout time : 12.19 µs – 320 µs(16bit)
5.167 µs – 320 µs(12bit)

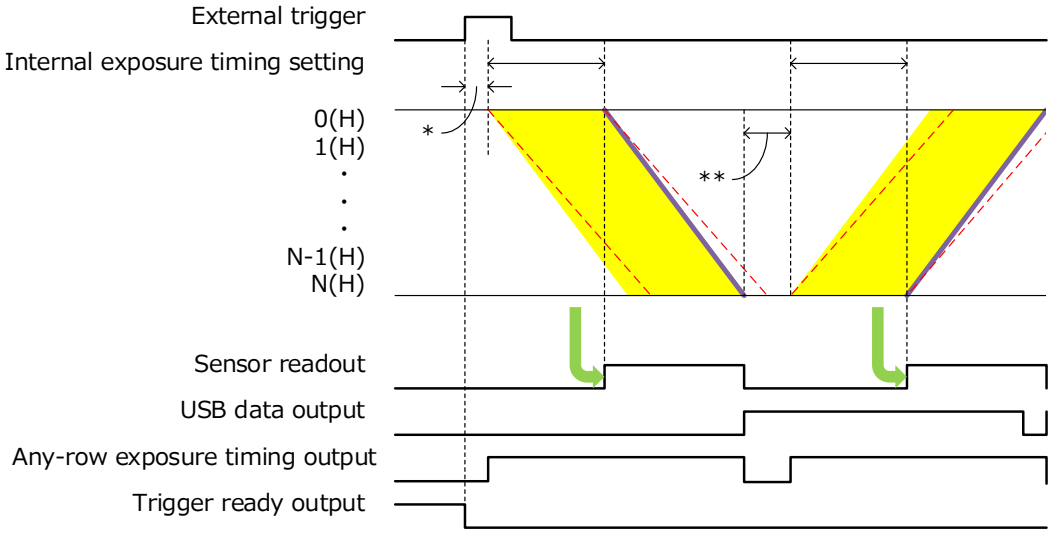
Figure 11-19 (Ex. rising edge, Bidirectional readout)

(3) Start trigger mode



* Delay: 42H(16bit), 36H(12bit), Jitter: ≦ 1H
1H readout time : 12.19 µs – 320 µs(16bit)
5.167 µs – 320 µs(12bit)

Figure 11-20 (Ex. rising edge, Top to bottom readout)



* Delay: 42H(16bit), 36H(12bit), Jitter: ≦ 1H
** Blanking time : Minimum 78H(Depends on amount of transfer data)
1H readout time : 12.19 µs – 320 µs(16bit)
5.167 µs – 320 µs(12bit)

Figure 11-21 (Ex. rising edge, Bidirectional readout)

11-2-6 TRIGGER OUTPUT

The camera provides various trigger output signals to synchronize with an external instrument and the camera becomes the master and the external instrument becomes the slave.

There are three different trigger output functions as follows.

- Any row exposure timing output
- Programmable timing output
- Trigger ready output

Also, it can output continuous High output (High output fixed) or continuous Low output (Low output fixed). They are output from Timing out connector.

Note

- The Lightsheet Readout Mode does not have the period where all lines expose at the same time. The Global exposure timing output is not output.

(1) Any row exposure timing output

Global exposure timing output shows the limited exposure period when all rows expose at the same time while the any row exposure timing output shows total exposure period when any of the rows expose.

(2) Programmable timing output

By using the programmable timing output, synchronizing with external devices is simple. A system which needs simple timing signal does not require a delay unit or pulse generator. It is possible to program and output a pulse that has an optional pulse width and an optional delay time to Read End (the end of readout timing), Vsync, Input trigger signal or Hsync. The range of delay is 0 µs to 10 s, and the range of pulse width is 1 µs to 10 s.
The relation between the parameter which can be set with each reference signal, and an output signal becomes as shown below.

Reference signal	Output signal
Read End	The signal with the preset pulse width is output after the preset delay from the end of the sensor readout.
Vsync	The signal with the preset pulse width is output after the preset delay from the start of the sensor readout
Input trigger signal	The signal with the preset pulse width is output after the preset delay from the input signal.
Hsync	The signal with the preset pulse width is output after the preset delay from the horizontal synchronized signal in the camera.

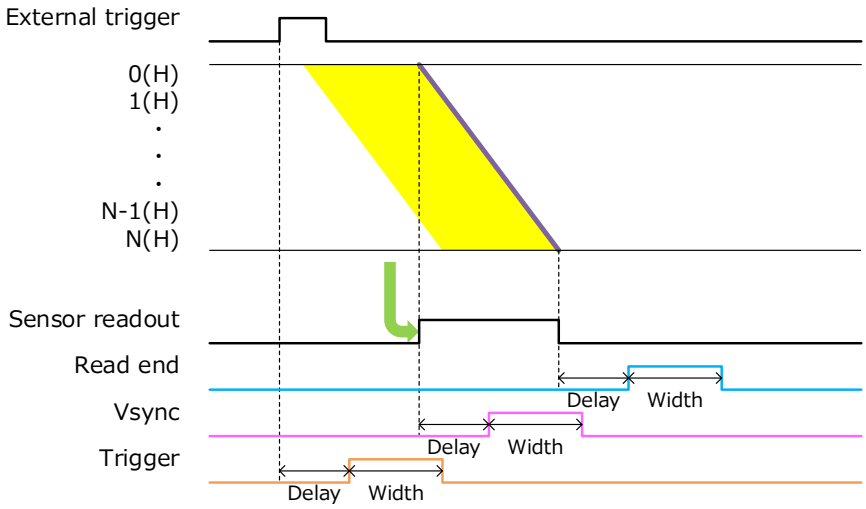


Figure 11-22 Programmable timing output (Top to bottom readout)

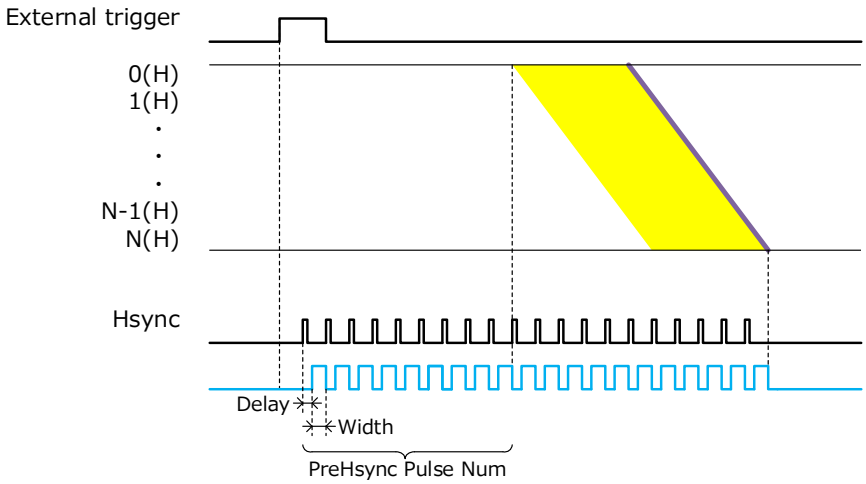


Figure 11-23 Programmable timing output referenced with Hsync (Top to bottom readout)

When you choose Hsync for the reference of programmable timing output, camera can output some pulses before start the exposure. It is called as Pre-Hsync. You can set the number of Pre-Hsync.

(3) Trigger ready output

This output behaves the same operation as Normal Area Mode and Lightsheet Readout Mode. Refer to 11-1-7(4) "Trigger ready output" for the details.

11-3 REAL-TIME DEFECT PIXEL CORRECTION

There are a few white spots which is caused by failure in part of the silicon wafer in CMOS image sensor. The camera has real-time pixel correction features to improve image quality.
The correction is performed in real-time without sacrificing the readout speed at all. This function can be turned ON and OFF. (Default is ON)
User can choose the correction level for white spots depend on required image quality.

Correction Level for white spots	Number of pixels to be corrected (ratio to the number of all pixels)
High	Approximately 10 000 pixels (approximately 0.1 %)
Medium (Default)	Approximately 3000 pixels (approximately 0.05 %)
Low	Approximately 50 pixels (less than 0.0005 %)

11-4 MASTER PULSE

The camera has master pulse function which can generate pulses that is independent of the exposure or readout timing of image sensor. External trigger mode can work synchronized with the timing pulses that the master pulse generates, except for External trigger mode in Lightsheet Readout Mode and Dual Lightsheet Readout Mode. The master pulse can be set as a reference signal of the programmable timing output, so it is possible to set up a synchronous system with peripheral devices without external pulse generator.
This function can be turned ON and OFF. (Default is OFF)
The master pulse supports free running mode, start trigger mode and burst mode. The range of interval time is 5 μs to 10 s, and the step is 1 μs for the master pulse.

(1) Free running mode

The camera generates pulses inside of the camera during the master pulse is ON.

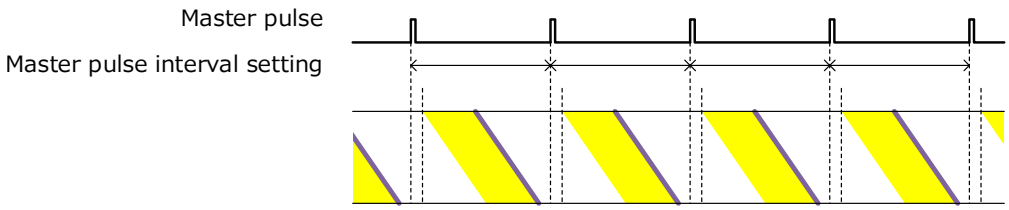


Figure 11-24 (Camera: Normal area, Edge trigger mode)

(2) Start trigger mode

The camera starts generating pulses inside of the camera by input trigger signal.

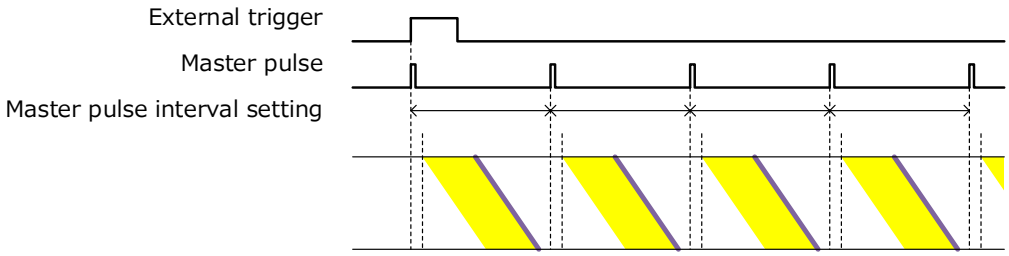


Figure 11-25 (Camera: Normal area, Edge trigger mode)

(3) Burst mode

The camera starts generating pulses inside of the camera by input trigger signal, and the camera stops generating pulses after the specified number of pulses are generated. And then, the camera will be ready for the next input trigger signal.

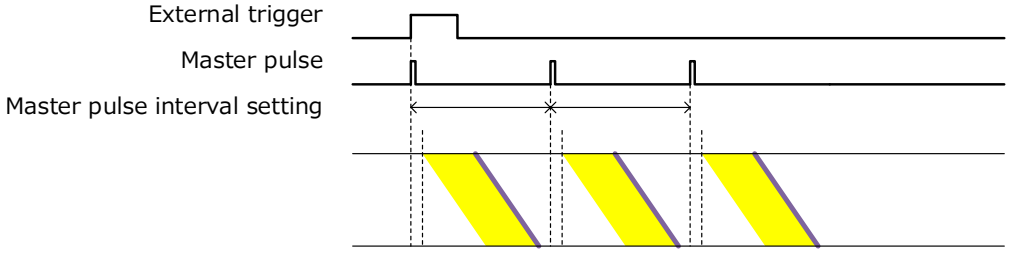


Figure 11-26 (Camera: Normal area, Edge trigger mode) (The number of pulses is specified as 3)

12. MAINTENANCE

12-1 CARE

Perform cleaning of this device with the dry soft cloth.

- Do not wipe with a damp cloth or unclean cloth.

Then, the glass window on the image sensor should be cleaned according to the following.

1. Blow the dust from the glass window with an air duster.
2. Moisten a lens cleaning paper with a little ethanol, and wipe over center area of the window, gently.
3. Confirm whether dust is not left.
   Attach the camera to an optics, and check if there is dust or not under the uniform light condition. If there is dust on the image, clean the glass window again.

- Use Lens Cleaning Paper for cleaning of glass window in front of the image sensor.

- Use a plastic tweezers and take extra care not to scratch the glass window with the tweezers. Even with plastic tweezers, there is possibility to make scratch on the glass window in case tweezers touch it.

- Avoid touching the surrounding parts of image area when wiping the glass window.

12-2 INFORMATION ON COOLING WATER FOR THE CIRCULATING WATER COOLER

- Regarding handling cooling water and circulating water cooler, refer to instruction manual attached to the circulating water cooler.

- It is recommended to use soft water (except pure water) for cooling water.

- Do not use hard water for cooling. It causes inside of cooling water circulating path to be calcified or corroded and it result lower flow rate or water flow stop. When using hard water, conduct a process to soften water before use it.

Note

When using cooling water other than recommended

[Pure water]

- Pure water is not appropriate for cooling water. There is possibility that pure water absorbs component of cooling water path and it may cause corrosion. In addition, pure water is easy to be polluted and cause impurity, sliminess or forming foreign substances. It cause lower flow rate or water flow stop.

[Distilled water / Deionized water]

- When using the camera inside clean room, it is possible to use distilled water or deionized water by conducting periodical check. However, notice it increases possibility of corrosion inside cooling water path, lowering flow rate or water flow stop.
- Monthly check: Check water impurity, non-existence of sliminess, foreign particle is not mixed with water or not adhered inside water path and no unusual odor. If you find any of the issues, exchange cooling water and clean cooling water path.

[Soft water from tap]

- It is possible to use soft water from tap with conducting periodical change of cooling water and checkup. However, notice it increases possibility of corrosion inside cooling water path, lowering flow rate or water flow stop.
- Monthly check: Check water impurity, non-existence of sliminess, foreign particle is not mixed with water or not adhered inside water path and no unusual odor. If you find any of the issues, exchange cooling water and clean cooling water path.
- Exchange cooling water every 3 months.
- Clean cooling water path every 6 months.

[Bottled water]

- One example of soft water which is commonly available is mineral water (Hardness less than 70). Check hardness of water by referring product information of bottled water manufacturer.

13. TROUBLESHOOTING

If an abnormality occurs, look up the possible causes in the following tables and, if necessary, report the details to Hamamatsu subsidiary or your local distributor.

13-1 IMAGE IS NOT TRANSFERRED

Cause	Measures	Chapter
AC adapter or other cable is loose	Reconnect the cable	7
AC adapter or other cable is broken	Replace the cable	-

13-2 ALTHOUGH IMAGES ARE TRANSFFERED

Conditions	Cause	Measures	Chapter
Scratches or discoloration visible on the screen	Lens is dirty	Wipe the lens	12
Image is blurred	Lens is not focused	Contact a Hamamatsu subsidiary or your local distributor	17
	Condensation appears	Confirm the operating environmental conditions	8
Only shadowed images are output	Lens mount cap has been left on	Remove the cap	
	Amount of light is too much or too low	Adjust amount of light	
All screens overflow	Too much amount of light	Reduce amount of light	
Noise appears on the screen	Exogenous noise	Find and remove cause	
	Poor connection of internal connector	Contact a Hamamatsu subsidiary or your local distributor	17
	Defective circuit system		

14. SPECIFICATIONS

14-1 CAMERA SPECIFICATIONS

(1) Electric specifications

Imaging device				Scientific CMOS image sensor
Effective number of pixels				3000 (H) × 3000 (V)
Pixel size				3.76 µm × 3.76 µm
Effective area				11.280 mm × 11.280 mm
	Bit	Full well	Sensor gain	
Readout noise (rms) *1 *10	16	Standard	X1	1.2 electrons(median) 1.6 electrons(rms)
	16	Standard	X8	0.9 electrons(median) 1.3 electrons(rms)
	16	High	X1	3.4 electrons(median) 4.1 electrons(rms)
	12	Standard	X1	2.4 electrons(median) 2.6 electrons(rms)
	12	Standard	X8	1.2 electrons(median) 1.6 electrons(rms)
	12	High	X1	7.2 electrons(median) 7.4 electrons(rms)
Full well capacity *1	16	Standard	X1	16 000 electrons
	16	Standard	X8	1950 electrons
	16	High	X1	49 100 electrons
	12	Standard	X1	16 200 electrons
	12	Standard	X8	2040 electrons
	12	High	X1	49 900 electrons
Conversion factor *1	16	Standard	X1	0.24 electrons / count
	16	Standard	X8	0.030 electrons / count
	16	High	X1	0.75 electrons / count
	12	Standard	X1	4.18 electrons / count
	12	Standard	X8	0.52 electrons / count
	12	High	X1	12.86 electrons / count
Dynamic range *1 *2	16	Standard	X1	13 300 : 1(median) 10 000 : 1(rms)
	16	Standard	X8	2160 : 1(median) 1490 : 1(rms)
	16	High	X1	14 500 : 1(median) 12 000 : 1(rms)
	12	Standard	X1	6700 : 1(median) 6190 : 1(rms)
	12	Standard	X8	1680 : 1(median) 1260 : 1(rms)
	12	High	X1	6880 : 1(median) 6690 : 1(rms)

Quantum efficiency *1	at 400 nm	68 %
	at 470 nm	86 %
	at 600 nm	61 %
	at 800 nm	20 %
Cooling method		Forced-air cooled Water cooled
Cooling temperature	Forced-air cooled	+10 °C (Ambient temperature: +25 °C)
	Water cooled	+10 °C (Water temperature: +25 °C)
Dark current *1	cooling temperature:+10 °C	0.03 electrons/pixel/s
Dark offset		200 counts (1600 counts when 16 bit, standard full well and sensor gain x8.)
Dark signal non-uniformity (DSNU) *1*4*10		0.1 electrons r.m.s.
Photo response non-uniformity (PRNU) *1 (7500 electrons)		0.15 % (50% of the full well capacity)
Linearity error *1 (EMVA 1288 standard)		0.2 %

Readout mode			Full resolution readout / Binning readout (2x2, 4x4) *5 / Sub-array readout *6
Readout time (at full resolution) *7	16 bit		36.99 ms
	12 bit		15.64 ms
Framerate			Refer to “Framerate” below this table.
Lightsheet Readout Mode	Row interval time	16 bit	12.19 µs to 320 µs *7
		12 bit	5.167 µs to 320 µs *7
	Readout time (at Full resolution)	16 bit	36.99 ms to 960 ms *7
		12 bit	15.64 ms to 960 ms *7
	Readout mode		Full resolution readout / Sub-array readout *6
	Readout direction		Top to bottom readout Bottom to top readout Bidirectional Reverse bidirectional
Exposure time	16 bit		170 µs to 10 s (12.19 µs step)
	12 bitt		41.3 µs to 10 s (5.167 µs step)
External trigger input mode	Normal Area Mode		Edge trigger / Global reset edge trigger / Level trigger / Global reset level trigger / Synchronous readout trigger / Start trigger
	Lightsheet Readout Mode		Edge trigger / Start trigger
Software trigger mode	Normal Area Mode		Edge trigger / Global reset edge trigger / Start trigger
	Lightsheet Readout Mode		Edge trigger / Start trigger
External trigger input	Connector		External input (SMA connector)
	Level		TTL / 3.3 V LVCMOS
	Polarity		Negative / Positive
	Delay		0 µs to 10 s (1 µs step)
	Trigger times (Synchronous readout trigger)		1 to 10 000

Trigger output	Function	Any row exposure timing output / Global exposure timing output / Trigger ready output / programmable timing outputs / High output / Low output
	level	3.3 V LVCMOS
	polarity	Negative / Positive
Programmable timing output	References signal	Read End / Hsync *8 / Vsync / Trigger
	Delay	0 µs to 10 s (1 µs step)
	Pulse width	1 µs to 10 s (1 µs step)
Master pulse mode	Pulse mode	Free running / start trigger / burst
	Pulse interval time	5 µs to 10 s (1 µs step)
	Pulse burst number	1 to 65 535
Digital output		16 bit / 12 bit
Image processing function		Dark offset correction (Always on)
		Pixel gain correction (Always on)
		Defect pixel correction (ON or OFF, hot pixel correction 3 steps)
Interface		USB 3.0 Super Speed *9
Lens Mount		C-mount

* 1 Typical value
* 2 Calculated from the ratio of the full well capacity and the readout noise at ultra quiet scan
* 3 16 bit, Standard full well, x1
* 4 Digital binning, 2x2,4x4
* 5 Minimum settable step of the size and position are as follows: It is in only the case that the camera is used with DCAM-API.

	Horizontal size	Vertical size	Horizontal position	Vertical position
Normal Area Mode	4 pixel steps	4 line steps	4 pixel steps	4 line steps
Lightsheet Readout Mode	1 pixel step	4 line steps	1 pixel step	4 line steps
Camera only	256 pixel steps	-	4 pixel steps	-

* 6 In the Lightsheet Readout Mode.
* 7 Equivalent to USB 3.2 Gen 1 (SuperSpeed USB 5Gbps).

[Frame rate]

Full resolution	(16 bit) 18.1 fps (12 bit) 24.2 fps
Vertical 2048 lines	2048 x 2048: (16 bit) 39.3 fps (12 bit) 53.3 fps
Vertical 256 lines	256 x 256: (16 bit) 278 fps (12 bit) 672 fps
Vertical 4 lines	256 x 4: (16 bit) 1950 fps (12 bit) 5370 fps

* 8 Valid 3 digits and rounded down to 4th digit.
* 9 When using frame bundle function on DCAM-API.

(2) Power supply specifications

Camera	Input power supply	DC 12 V
	Typical output	---
	Power consumption	25 W
AC adapter	Input power supply	AC 100 V to AC 240 V 50 Hz / 60 Hz 2.5 A
	Typical output	DC 12 V 8.34 A
	Power consumption	74 VA

Note

- Fluctuations of input power supply voltages are not to exceed ±10 % of the nominal voltage.

(3) Operating environment

Ambient operating temperature	0 ºC to + 40 ºC
Ambient storage temperature	-10 ºC to + 50 ºC
Ambient operating humidity	30 % to 80 %, no condensation
Ambient storage humidity	Less than 90 %, no condensation
Place of operating	Indoor, altitude up to 2000 m

(4) Dimensional outline and weight

C17440-20U	Dimensional outline	80 mm (W) × 80.5 mm (H) × 121.5 mm (D)
	Weight	Approx. 1.0 kg (Camera only)

- Be careful not to drop off the camera or not drop underfoot when making it move because it is approx. 1.0 kg.

Note

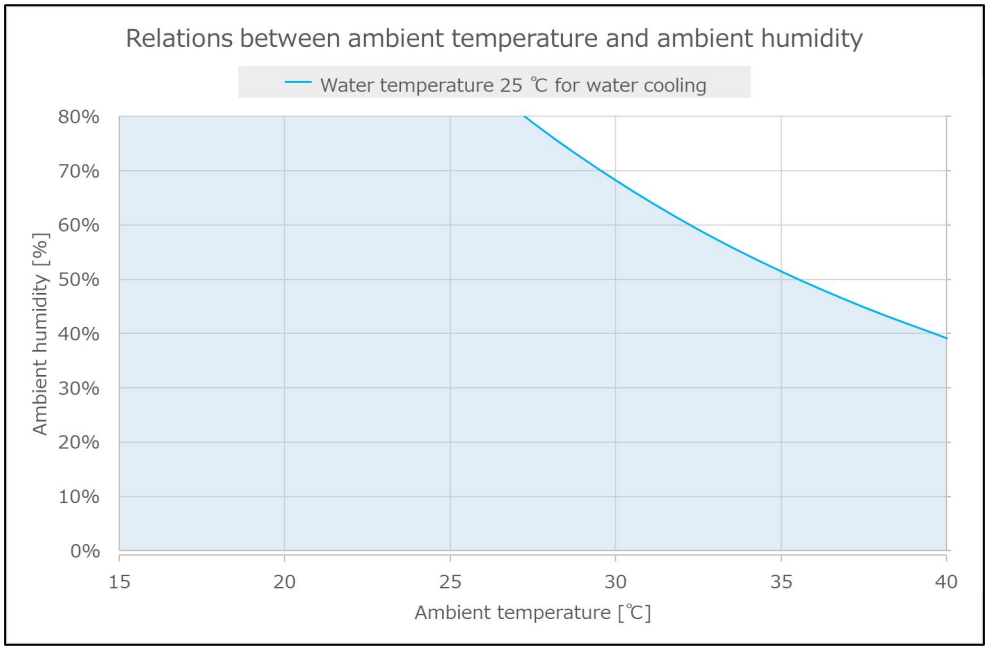
- Refer to 15 “DIMENSIONAL OUTLINES” for detail of dimensions.

(5) Applicable standards

EMC	EN61326-1: 2013 Class A Emission limits: CISPR 11 Group1 Class A Immunity requirements: Table2		
	Function performance and operation mode in immunity tests	Judgment criteria A	Intensity fluctuation of image is within ±5 %.
		Judgment criteria B	Though the operation function is temporarily impaired, it automatically returns to normal operation during EMC test.
		Judgment criteria C	It returns to normal operation reboot the device.
	Restoration procedure in immunity tests	Restart the device after exiting the software and turning off the power to the device.	
RoHS	EN IEC 63000:2018		
FCC	47 CFR FCC Part15 Subpart B Class A		

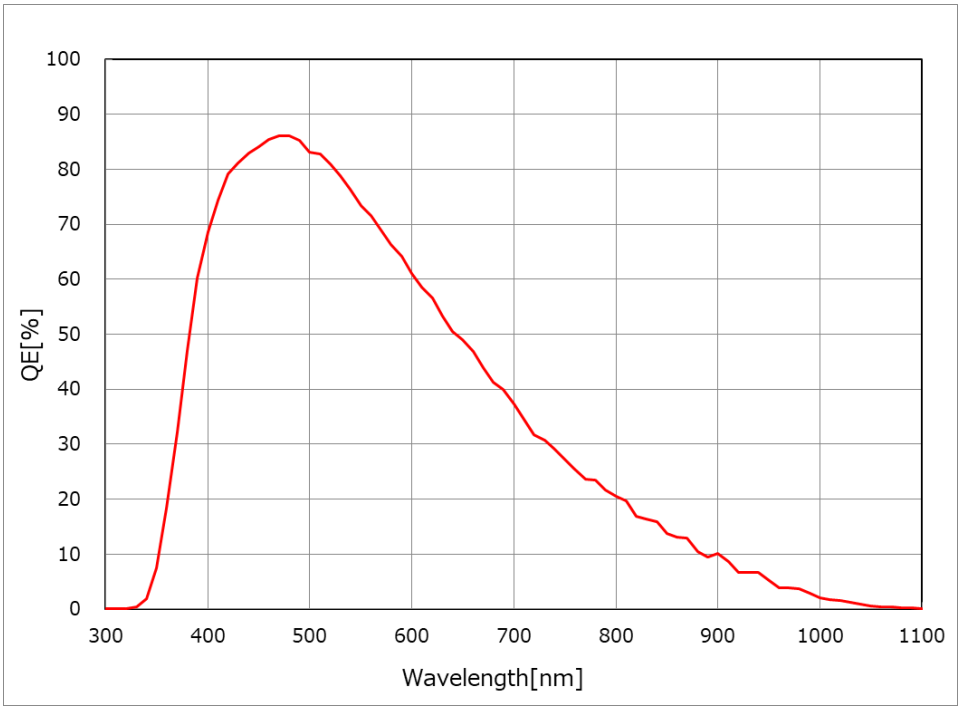
14-2 CONDENSATION

At the Water-cooling, if ambient temperature and ambient humidity become high, condensation will take place easily. Use the camera under the environment where condensation will not take place referring to the following graph.



Graph 14-1

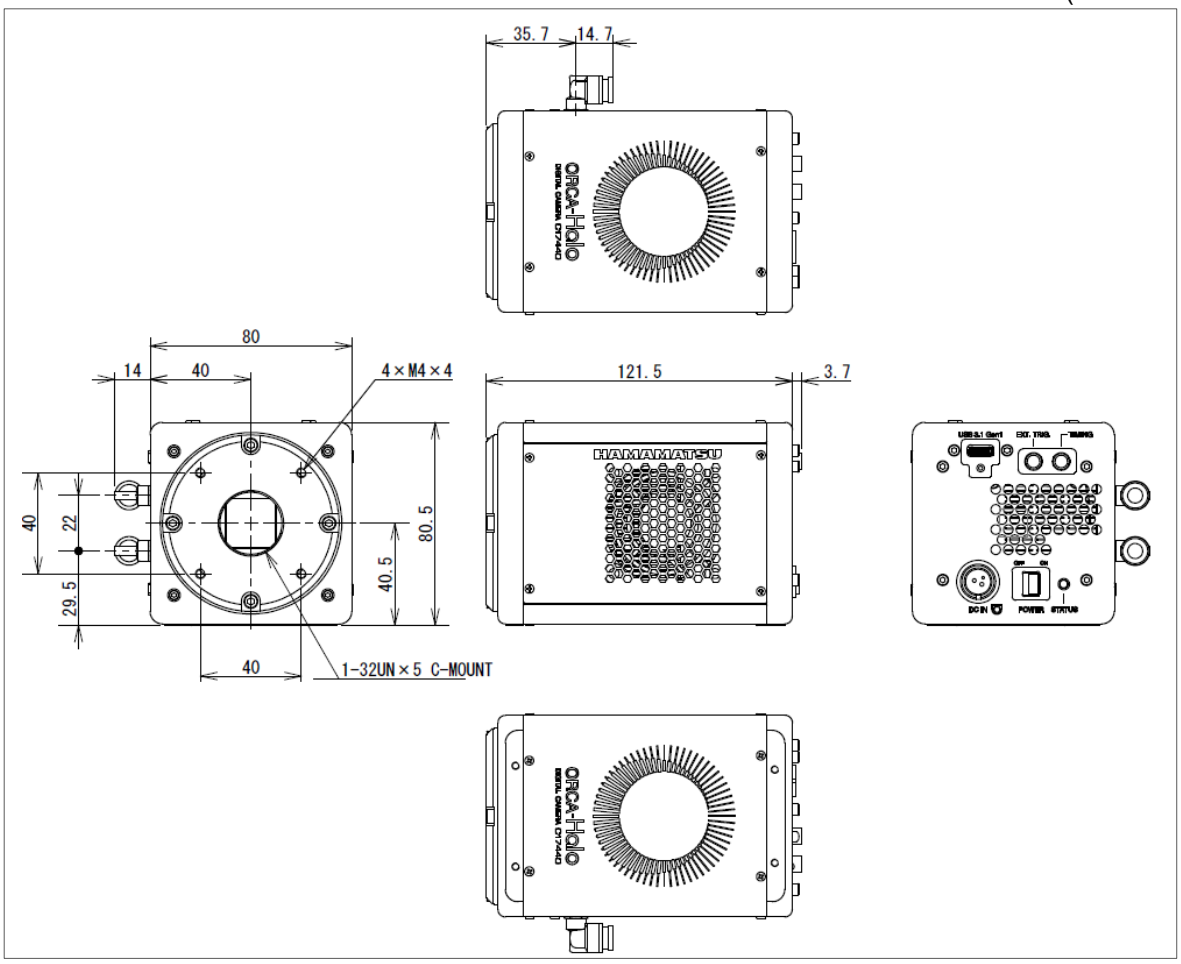
14-3 SPECTRAL RESPONSE CHARACTERISTICS (TYP.)



Graph 14-2

15. DIMENSIONAL OUTLINES

(Unit: mm)



16. WARRANTY

Hamamatsu Photonics have fully inspected this camera and checked that its performance conforms to specifications. In the unlikely event of a breakdown or other malfunction, contact a Hamamatsu subsidiary or your local distributor.

16-1 BASIC WARRANTY

1. Unless otherwise stated by Hamamatsu subsidiary or your local distributor, this camera is under warranty for 24 months from the delivery date.
   - Degradation with cosmic rays and the radiation (X-rays, gamma rays, UV light, etc.) of CMOS image sensor is excepted.

2. The warranty only covers defects in the materials and manufacturing of the camera. You may be liable for repairs during the warranty period in the event of a natural disaster or if you handle the camera contrary to the instructions in this manual, use it without due caution, or try to modify it.

3. We will repair the camera or replace it, subject to availability, free of charge within the terms of the warranty.

16-2 REPAIRS

1. If you notice anything wrong with the camera, confirm whether or not it is malfunctioning by referring to the TROUBLESHOOTING in this instruction manual. You must first clarify the symptoms in order to avoid any misunderstanding or error.

2. If you have any trouble or are unclear about anything, contact a Hamamatsu subsidiary or your local distributor giving the product name, serial number and details of the problem. If Hamamatsu Photonics consider the problem to be a malfunction, we will decide whether dispatch an engineer or have the camera returned to us for repairs.

17. CONTACT INFORMATION

Manufacturer

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