ORCA-Flash4.0 V3
Digital CMOS Camera
C13440-20CU / C13440-20CU01
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.1.8
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HAMAMATSU PHOTONICS K.K.

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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. Be careful that the mounting screw does not enter more than 8 mm from the surface of the base plate. Screwing it in further can impair normal operation.

Lenses (C13440-20CU)

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.)

When using F-mount (C13440-20CU01)

A F-mount adapter can be subject to light leaks due to the mating flange mechanism. When used with a high sensitivity, long exposure camera, it may be possible to detect photons originating from the F-mount light leakage. In this case, it is recommended to create a dark condition for the camera such as a dark room, dark box or wrap the F-mount flange area with a dark cloth.

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

Using water cooling

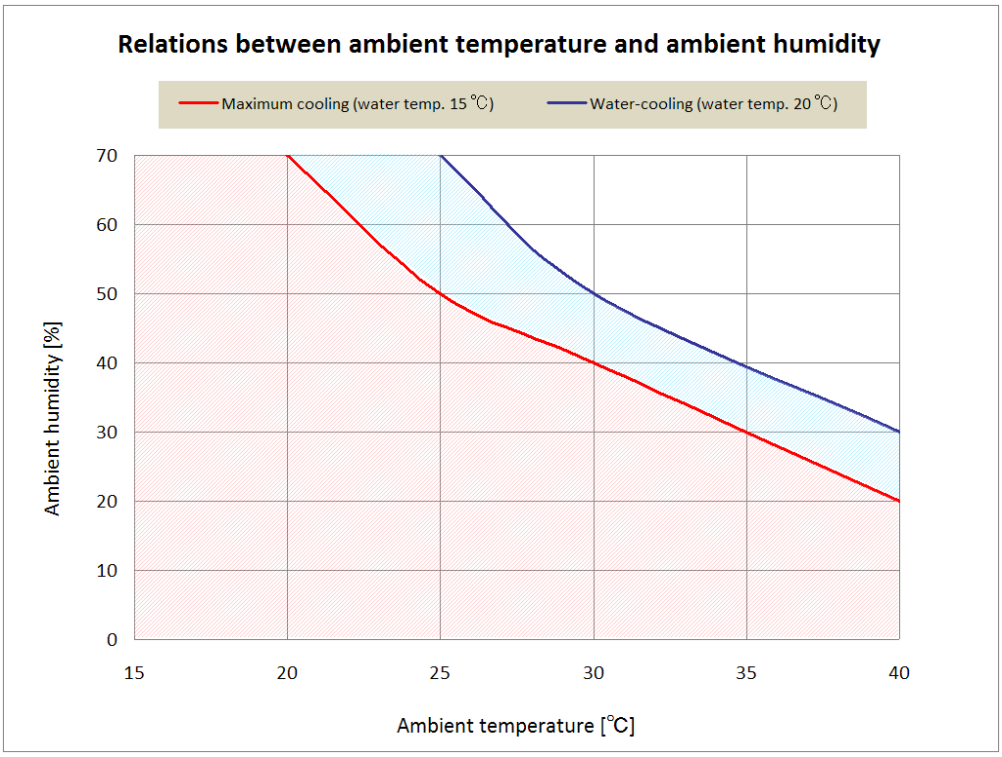
Be careful water does not splash on the camera. Cut off the power supply of the circulating water cooler and the camera when you remove and install the cooling water hoses.

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 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.

Camera: C13440-20CU or C13440-20CU01	1
AC adapter	1
Power supply cord for AC adapter	1
Lens mount cap (attached to the camera)	1
C13440-20CU Before Use (Booklet)	1
C13440-20CU Instruction manual (CD-ROM)	1
QC sheet	1

[Option]

Cooling water hose (2 hoses)	A10788-04
SMA-BNC cable	A12106-05
SMA-SMA cable	A12107-05
Camera Link interface board	M9982-29
Camera Link interface cable	A14038-04
USB 3.0 interface board	M9982-25
USB 3.0 interface cable	A12467-03
Adjustable pole for C11440-22CU	A11185-01
Fixing bracket for C11440-22CU cable	A13261-01

- 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 camera may not confirm to CE marking regulation if other type of cable is used with.

Note

- If you use the above options, Refer to the each installation manual.

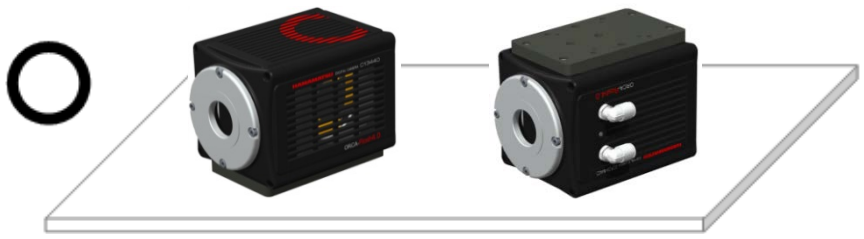
3. INSTALLATION

Avoid using or storing this camera in the following places

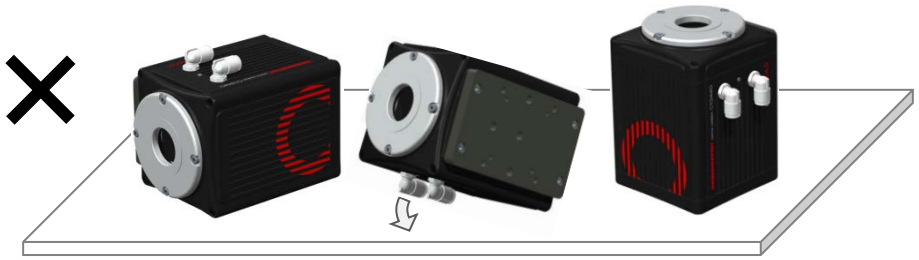
- Places where the temperature is not the operating temperature indicated in the specifications
- Places where the temperature is not the storage temperature indicated in the specifications
- Places where the temperature varies greatly
- In direct sunlight or near a heater
- Places where the humidity 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. 2.2 kg.

Contents

4. OVERVIEW

C13440-20CU / C13440-20CU01 is equipped with the new scientific image sensor, an advanced CMOS device that realizes the multiple benefits of high resolution, high readout speed, and low noise all at once.
The camera provides 4.0 megapixels resolution at 100 fps (frames/s) (and up to 25 655 fps by sub-array readout) while achieving 1.0 electrons (median) 1.6 electrons (r.m.s) readout noise performance. Moreover, the camera delivers high sensitivity through its on-chip micro lens, 37 000:1 high dynamic range that makes the camera suitable for almost any scientific application from bright field imaging to low-light fluorescence imaging across a wide spectral range. Various external trigger functions and timing output functions ensure proper timing control with peripheral equipment to cover a wide range of applications.
The camera is the new scientific digital camera for life science microscopy, semiconductor inspection, x-ray scintillator readout or industrial imaging.

5. FEATURES

(1) Readout noise

In the camera, the pixel amplifier is optimized: it has high gain from optimizing the semiconductor process, and the difference among pixel amplifiers are greatly minimized. In addition, there is on-chip CDS (correlated double sampling) circuit, which plays an important role in achieving low noise. Moreover, the sensor features a split readout scheme in which the top and bottom halves of the sensor are readout independently, and the data of each horizontal line is read by 2 lines of column amplifier and A/D in the top and the bottom in parallel and simultaneously. As a result, it achieves very fast readout speed while keeping very good low-noise performance.
The camera has lower readout noise (1.0 electrons (median), 1.6 electrons (r.m.s)) than the conventional cooled CCD camera. Moreover, high-speed readout (100 fps with 2048 pixels × 2048 pixels) with very low readout noise, which was impossible, can now be achieved.
In addition, the camera can achieve further lower readout noise (0.8 electrons (median), 1.4 electrons (r.m.s) with slow scan mode (30 fps with 2048 pixels × 2048 pixels).

(2) Cooling structure

In the camera, the CMOS image sensor is cooled down by a peltier element to suppress the dark current. If the CMOS image sensor is exposed to the atmosphere, condensation of the moisture from the air might occur. However the camera has a special hermetic chamber structure to isolate the sensor from the atmosphere, and the chamber is filled with nitrogen gas.

(3) Pixel number and pixel size

CMOS image sensor has 6.5 µm x 6.5 µm pixel sizes that is equivalent to conventional CCD image sensor (2/3 inch, 1.3 megapixels). Also, the camera can observe a wider field of view because the pixel number is about 3 times that of the conventional CCD image sensor (2/3 inch, 1.3 megapixels)

(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.

(5) Frame rate

CMOS image sensor which this camera adopts realizes both low noise (1.0 electrons (median) 1.6 electrons (r.m.s)) and high speed readout (100 fps with 2048 pixels x 2048 pixels) simultaneously, by a split readout scheme in which the top and the bottom halves of the sensor are readout independently, and the data of each horizontal line is read by 2 lines of column amplifier and A/D in the top and the bottom in parallel and simultaneously.

(6) Real-time correction functions

There are a few pixels in CMOS image sensor that have brighter or darker intensity, and a few pixels that have slightly higher readout noise performance, when compared to surrounding pixels. The camera has a real-time variant (defective) pixel correction feature to further improve image quality. The correction can be performed in real-time without sacrificing any of the readout speed.

(7) Data reduction functions

The camera provides a maximum 4.0 megapixel resolution at a rate of 100 fps and with 16 bit intensity levels per pixel. With these conditions, the camera outputs 800 MB of data per second, making it necessary to store a large amount of data. With data reduction functions now available in the camera, it is possible to select reduced areas of the image and/or reduced intensity levels to transfer and store only the data of interest.

(8) Interface

This camera has both Camera Link and USB 3.0 interface.

Camera Link Interface:

The camera Link interface is able to transfer large volumes of data. It can transfer a 4 megapixels image with 100 fps.
In order to realize such a large volume data transfer, the camera uses Camera Link "Full Configuration Deca Mode" which is an expanded version of Camera Link "Full Configuration". It enables a transfer maximum 85 MHz x 10 Taps (8 bit) image data to computer as fast as 100 fps.
In order to use this interface, a Camera Link interface board which supports "Full Configuration Deca Mode" is required.

USB 3.0 Interface:

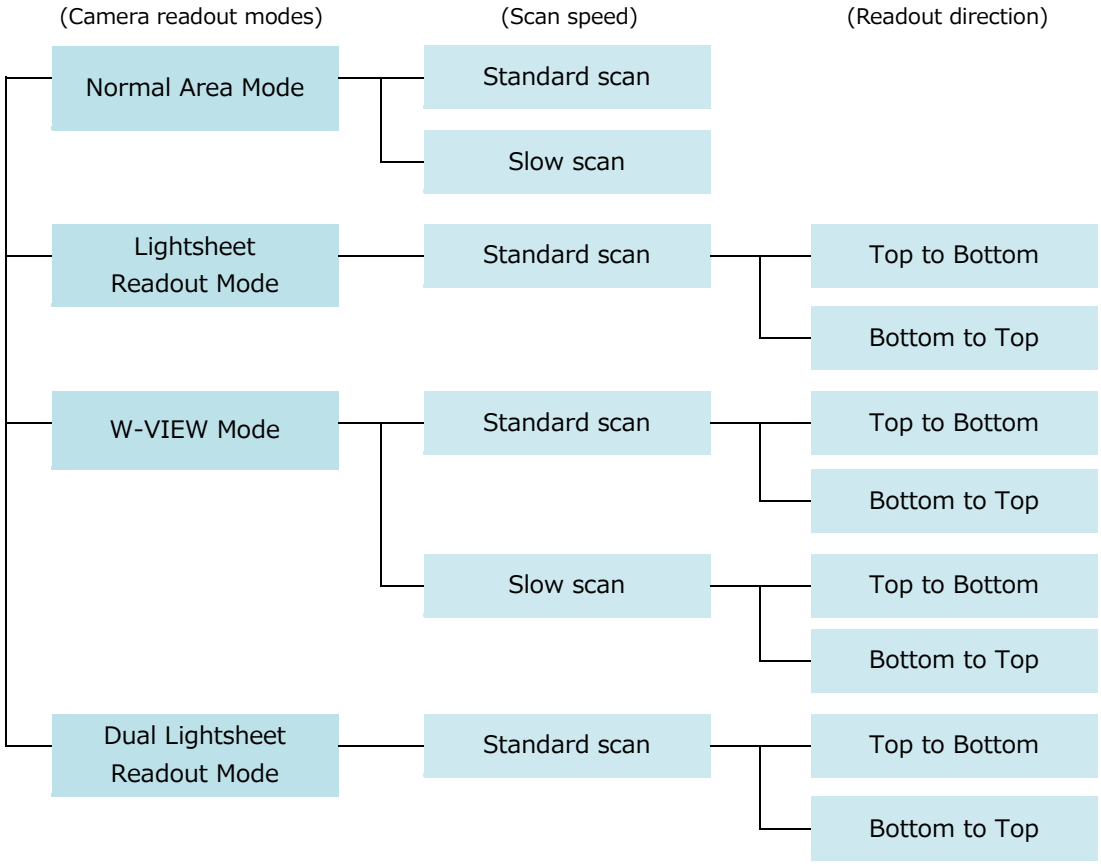
USB 3.0 interface is able to transfer a 4 megapixels image with 40 fps. It is versatile interface which is suitable to use when fast data transfer is not required.
This interface does not require a Camera Link interface board. It transfers image with moderate transfer speed.

- When a connection interface is changed from Camera Link to USB 3.0, and vice versa, the application software must be closed and the camera must be turned off.

- Do not connect Camera Link and USB 3.0 interface simultaneously.

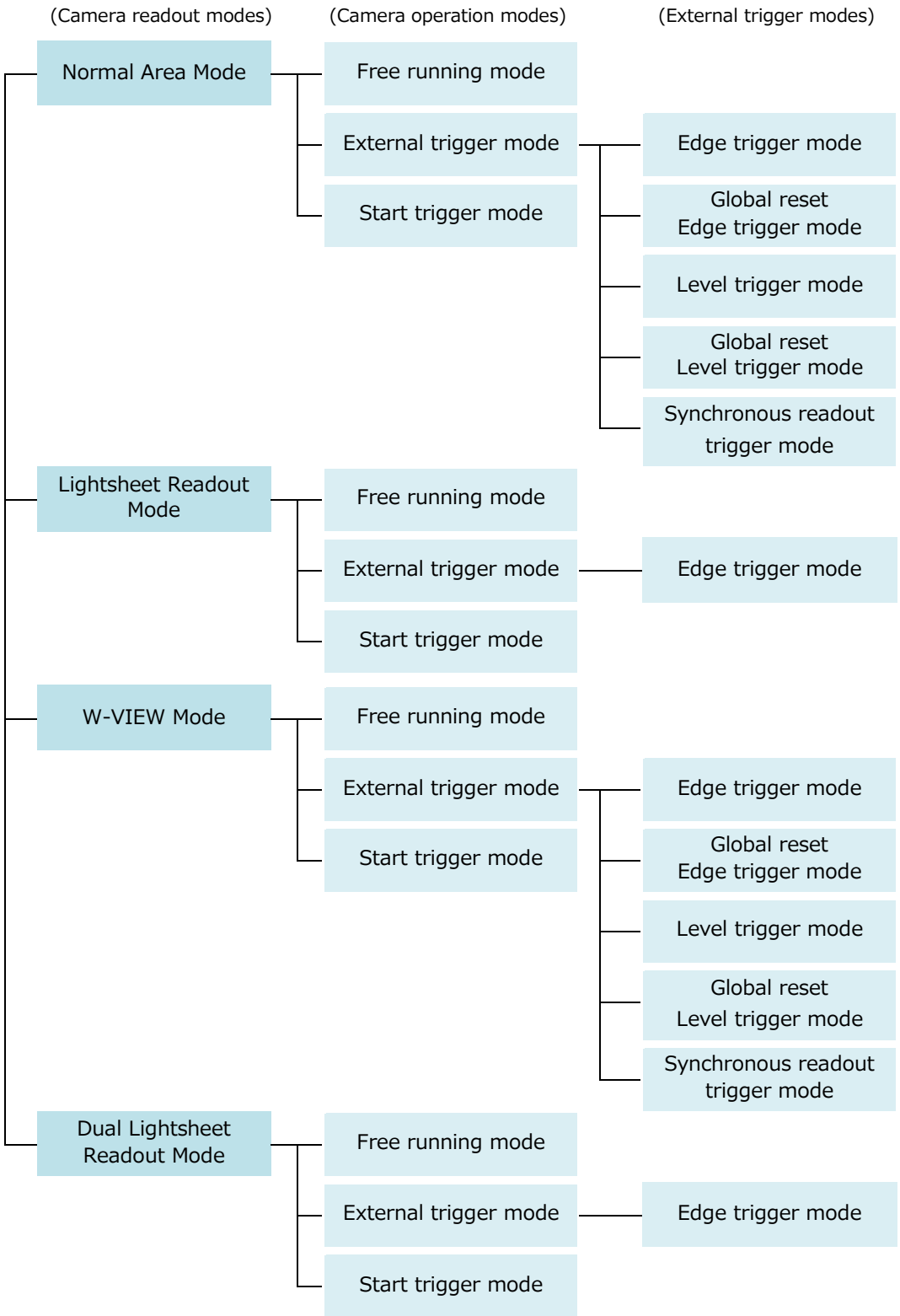
(9) Camera readout modes

The camera has four kinds of readout mode, Normal Area Mode, Lightsheet Readout Mode, W-VIEW Mode and Dual Lightsheet Readout Mode. The camera also has two scan speed in Normal Area Mode and W-VIEW Mode, and two readout direction in Lightsheet Readout Mode, W-VIEW Mode and Dual 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 operating the camera by a trigger input for a continuous imaging.



6. NAME AND FUNCTION OF PARTS

(1) C13440-20CU (C-mount type)

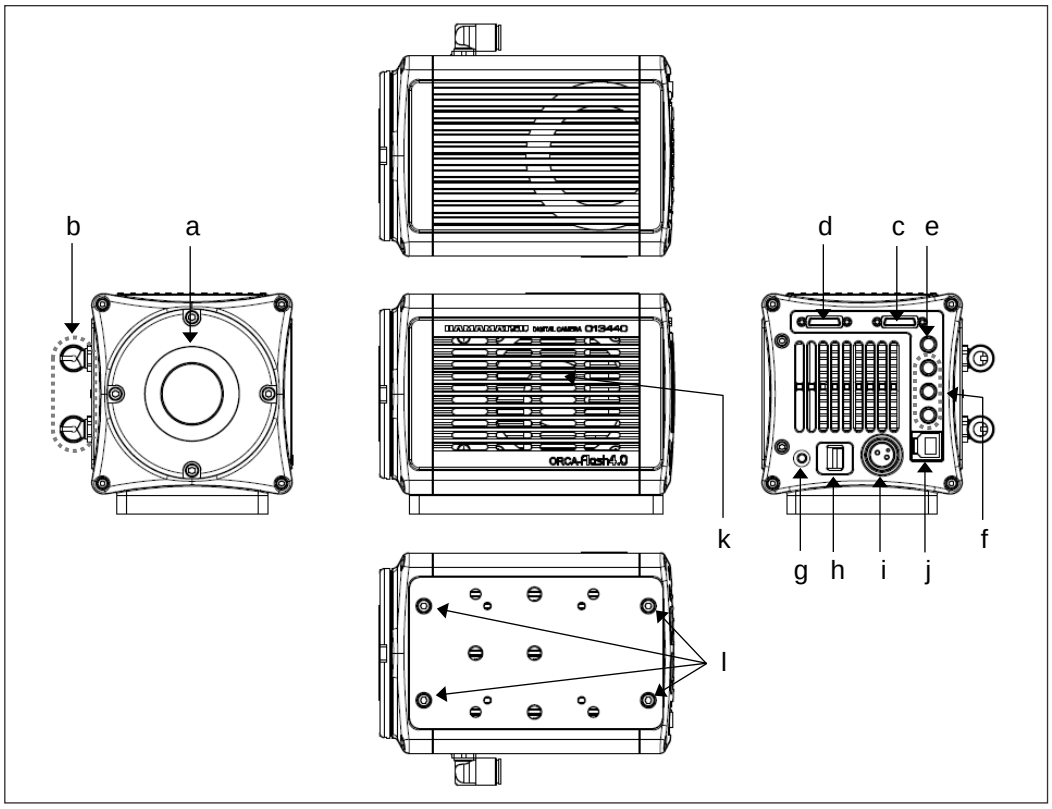


Figure 6-1

(2) C13440-20CU01 (F-mount type)

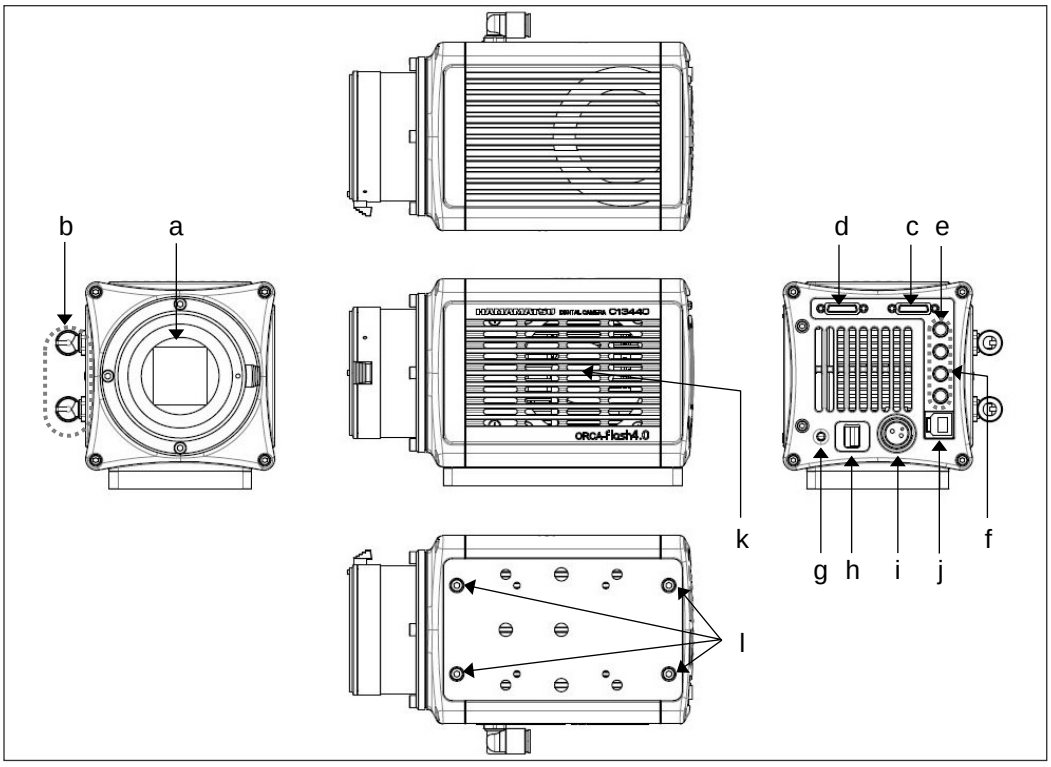


Figure 6-2

CAUTION	• Place the camera the water connectors to be lateral side. Do not place the rear panel of the camera, which connectors are located, to be at the bottom (Do not block ventilation openings.).

a. Lens mount

C13440-20CU can be attached to C-mount lens or an optics system.
C13440-20CU01 can be attached to F-mount lens or an optics system.

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)

It connects the camera and the circulating water cooler with the cooling water hoses. The connector position of WATER IN/OUT is not specified.

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

c. Camera Link interface connector 1 [DIGITAL OUT 1]

d. Camera Link interface connector 2 [DIGITAL OUT 2]

The connector 1 is connected to the Camera Link interface connector 1 on the computer.
The connector 2 is connected to the Camera Link interface connector 2 on the computer.

- When a connection interface is changed from Camera Link to USB 3.0, and vice versa, the application software must be closed and the camera must be turned off.
- Do not connect Camera Link and USB 3.0 interface simultaneously.

e. Trigger input connector [EXT.TRIG]

This is used when the camera is being operated using external synchronization.
Input is 3.3 V LVCMOS level, and input impedance is 10 kΩ.
When an external trigger is input, the trigger is activated at the falling or rising edge of the signal. (You can choose external trigger polarity between Negative and Positive.)

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

This is used when peripheral device(s) require synchronization with the camera.
Output is 3.3 V LVCMOS level, and it is output though BUS TRANSCEIVER IC SN74LVC541. Output impedance is 33 Ω.

Note

- Determine termination according to cable length and so on.

g. STATUS lamp [STATUS]

The LED indicates status of camera.

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

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

h. Power switch [POWER]

The power is turned on/off.

- When the power switch is set to "ON", the camera turns on and starts initialization and the lamp blinks in green.
- When the initialization is completed, the lamp color stays in green.
- When the camera transfers data, and the lamp color turns orange.
- When the power switch is set to "OFF", the camera returns to the power off state and the lamp turns off.

i. DC power input connector [DC IN]

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

j. USB 3.0 interface connector [USB 3.0]

This is connected to the USB 3.0 interface connector on the computer.

- When a connection interface is changed from Camera Link to USB 3.0, and vice versa, the application software must be closed and the camera must be turned off.

- Do not connect Camera Link and USB 3.0 interface simultaneously.

k. 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.

l. Base plate

This base plate is for attaching to a lab jack or a tripod.
When you use an adjustable pole (A11185-01) or a fixing bracket (A13261-01), detach the base plate, and then attach the options.

Note

- Refer to the installation manual of options about the detaching method of base plate and the attaching method of the option.

7. CONNECTION

Refer to the figure when connecting the various cables.

(1) Camera Link interface

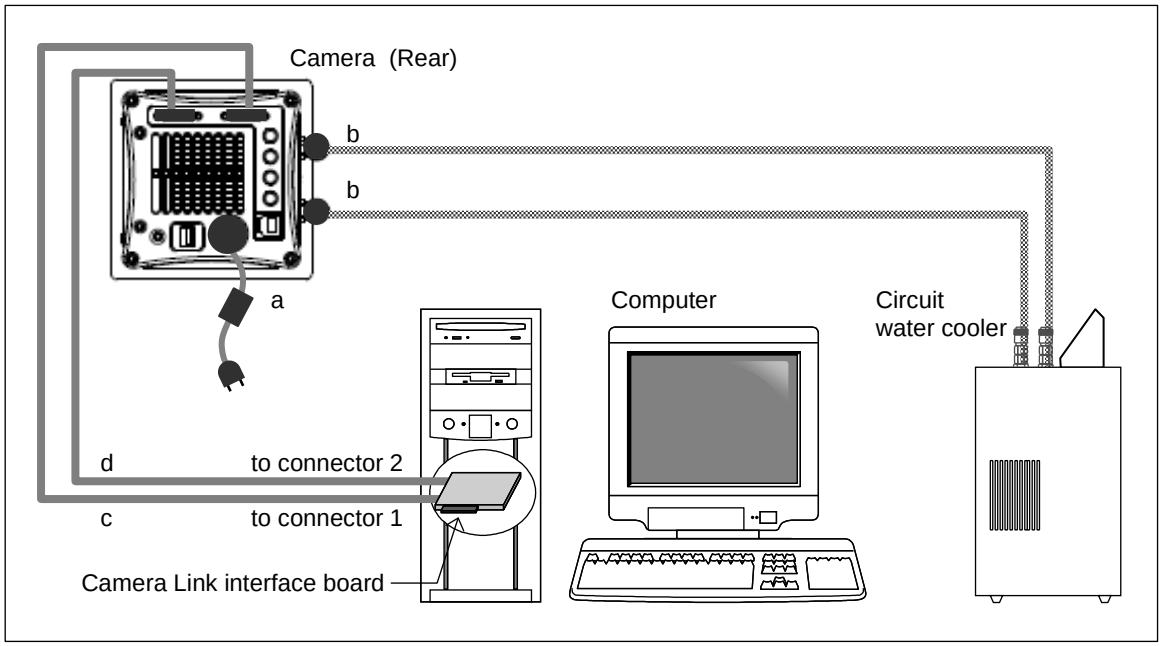


Figure 7-1

(2) USB 3.0 interface

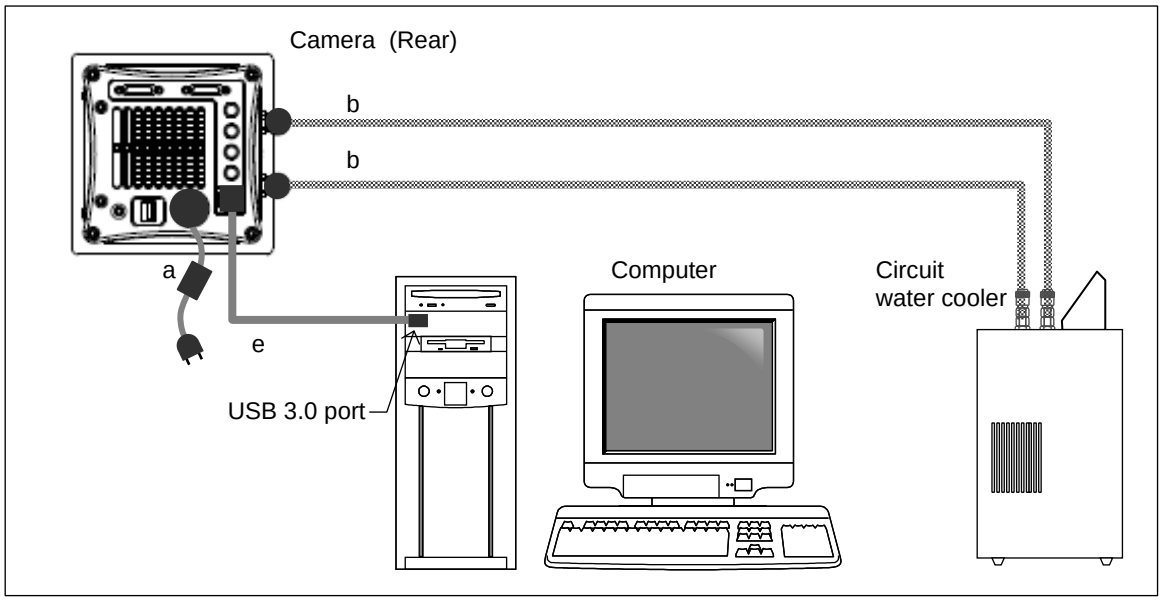


Figure 7-2

⚠CAUTION	• Place the camera the water connectors to be lateral side. Do not place the rear panel of the camera, which connectors are located, to be at the bottom (Do not block ventilation openings.).

Note	• When you connect cables, turn off the power supply of the camera and the peripheral devices.
	• If you use the above options, see each installation manual.

a. AC adapter

This is the cord to supply a power supply. Use the accessory AC adapter.

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

It connects the camera and circulating water cooler. The insert position of WATER IN/OUT on the camera WATER connector is not specified.

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

c. Camera Link interface cable 1 (Option)

This is the cable to connect the Camera Link interface connector 1 of the camera and the Camera Link interface connector 1 on the computer.

d. Camera Link interface cable 2 (Option)

This is the cable to connect the Camera Link interface connector 2 of the camera and the Camera Link interface connector 2 on the computer.

- When a connection interface is changed from Camera Link to USB 3.0, and vice versa, the application software must be closed and the camera must be turned off.
- Do not connect Camera Link and USB 3.0 interface simultaneously.

Note

- Hamamatsu recommends A14038-04 optional Camera Link interface cable for this camera. The camera complies with EMC direction with using A14038-04 Camera Link interface cable. Be careful that the camera with other interface cable may not fulfill the EMC directive requirements.

e. USB 3.0 interface cable (Option)

This is the cable to connect the USB 3.0 interface connector of the camera and the USB 3.0 interface connector on the computer.

- When a connection interface is changed from Camera Link to USB 3.0, and vice versa, the application software must be closed and the camera must be turned off.
- Do not connect Camera Link and USB 3.0 interface simultaneously.

Note

- Hamamatsu recommends A12467-03 optional USB 3.0 interface cable for this camera. The camera complies with EMC direction with using A12467-03 Camera Link interface cable. Be careful that the camera with other interface cable may not fulfill the EMC directive requirements.

8. WATER COOLING

⚠CAUTION	• Improper handling of the camera without observing these cautions could lead to personal injury to the user or damage to property.

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

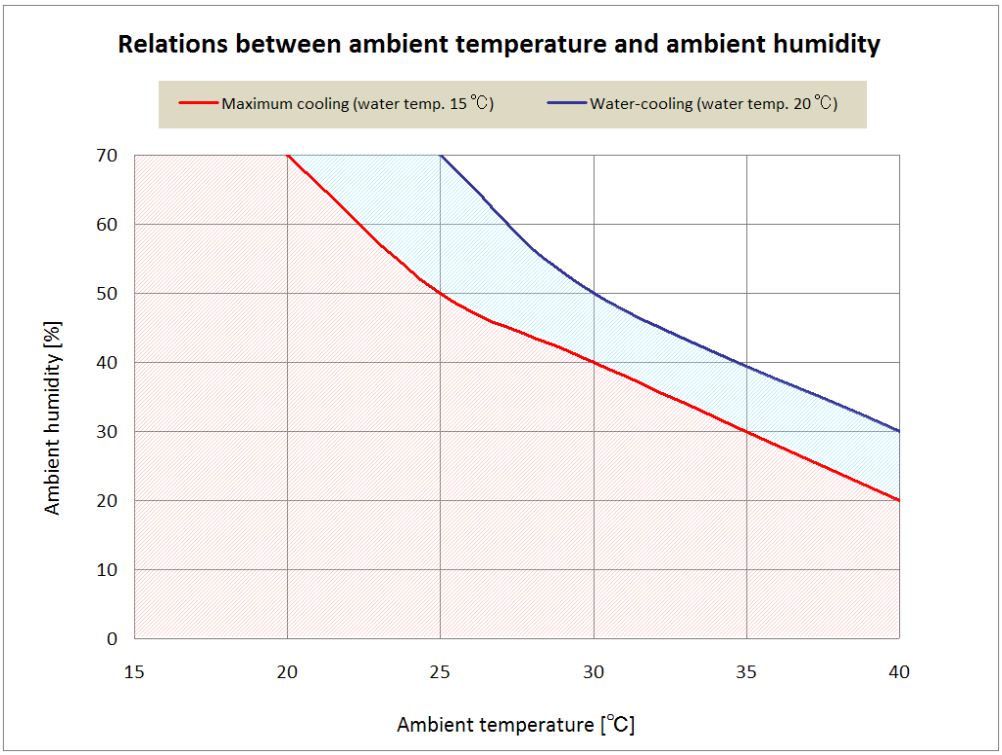
It is recommended to use soft water (except pure water) for cooling water.
If you plan on using water other than soft water as recommended for example antifreeze etc, Refer to description of cooling water which is written in 12. “MAINTENANCE” or contact a Hamamatsu subsidiary or your local distributor.

(3) Recommendation temperature

Hamamatsu recommends 20 °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 under the environment where condensation will not take place referring to the following graph.



(5) 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.

(6) Start water cooling and water cooling in operation

- Confirm the water is flowing before starting the camera cooling and that the camera does cool.
- Keep 0.45 L/min flow rate for water circulation.
- Do not stop the circulating water cooler while the camera is working.

(7) Cooling water hose

The 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 8-1)
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 8-2)

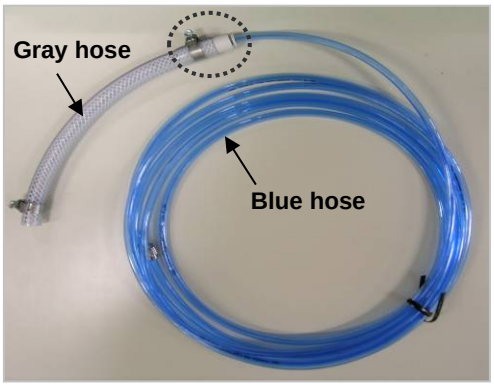


Figure 8-1

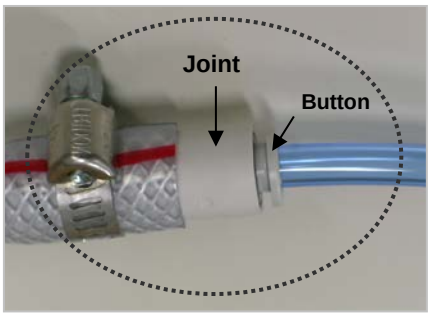


Figure 8-2

(8) Connection of the cooling water hose

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

- Stop water circulation when connecting / disconnecting the hose, and turn off the power of the camera and the circulating water cooler.
- Confirm that cooling water stops.
- Prepare water absorption sheet (such as Waste, Towel or so) and catch pan in order to avoid water drop or water splash.

(9) 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 WATER COOLING HOSES

Figure 8-3

1. Place the camera on the stable table.
2. Connect water cooling hose into the WATER connector on the camera.
   - Insert the hose fully into the WATER connector on the camera. (as shown in Figure 8-3)
   - 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 water drop or splash is found.

8-3 DISCONNECTION OF WATER COOLING HOSES

⚠CAUTION	• Remove the water cooling 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 water inside by blowing air from 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 the 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 8-4

9. OPERATIONS

9-1 OPERATING PRECAUTIONS

Be careful of the following when you operate the camera.

(1) Cooling method

Cooling of this equipment is done using a Peltier element.
With a Peltier element, when current is supplied, one surface is cooled, and the other surface is heated. CMOS image sensor is positioned on the cooled side, and cooling is done by discharging the heat from the heated surface.
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 20 °C.
Both water-cooling or air-cooling are available as cooling method, CMOS image sensor cooling temperature is more stable under water cooling operation.

(3) Protection circuit

This camera’s thermoelectric cooling device is protected by a thermal protection circuit.
If the internal temperature of the camera becomes abnormally hot, the protection circuit operates to inform the user by a buzzer alarm (beep tone) and lighting the camera red LED light while simultaneously cutting the current supply to the Peltier element. As soon as this protection is implemented, turn off the power switch, unplug the AC supply. Then 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 present cooling mode set-up of this camera can be checked using “DCAM Configurator”. (refer to 9-5 “STARTUP DCAM CONFIGURATOR”)

Note

- When using F-mount(C13440-20CU01), a F-mount adapter can be subject to light leaks due to the mating flange mechanism. When used with a high sensitivity, long exposure camera, it may be possible to detect photons originating from the F-mount light leakage. In this case, it is recommended to create a dark condition for the camera such as a dark room, dark box or wrap the F-mount flange area with a dark cloth.

9-2-1 WHEN USING AIR-COOLING

1. Connect the equipment as shown in Figure 7-1 before operating of the camera.
2. Turn on the camera.
3. Check cooling fan is operating properly and air is circulating.

- When cooling method of the camera is set by water-cooling method, the fan does not start rotating.

9-2-2 WHEN USING WATER-COOLING

1. Connect the equipment as shown in Figure 7-1 before operating of the camera.
2. Turn on the circulating water cooler.
3. Check cooling water is circulating properly.
4. Turn on the camera.
5. Turn on the cooling switch of the camera from 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.

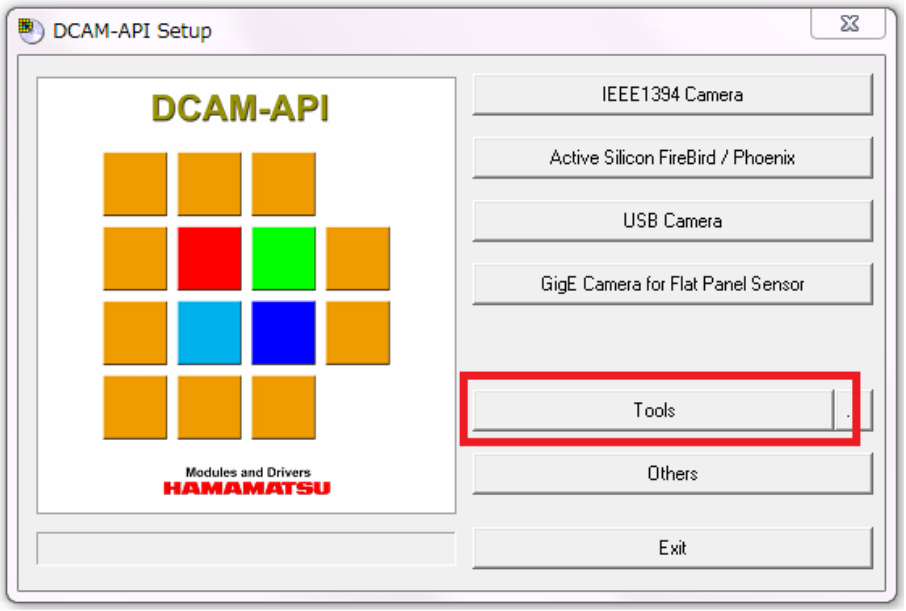
1. End the imaging or transmission of image data with the application software.
2. Turn off the camera and peripheral devices.
3. Turn off the circulating water cooler. (at water-cooling)

9-5 STARTUP DCAM CONFIGURATOR

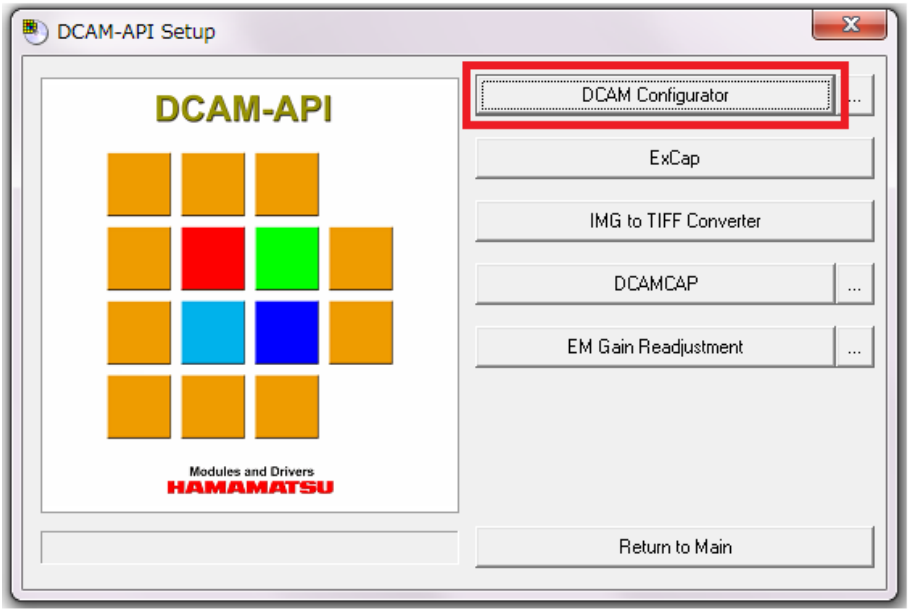
The following is a procedure to startup “DCAM Configurator”.

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.

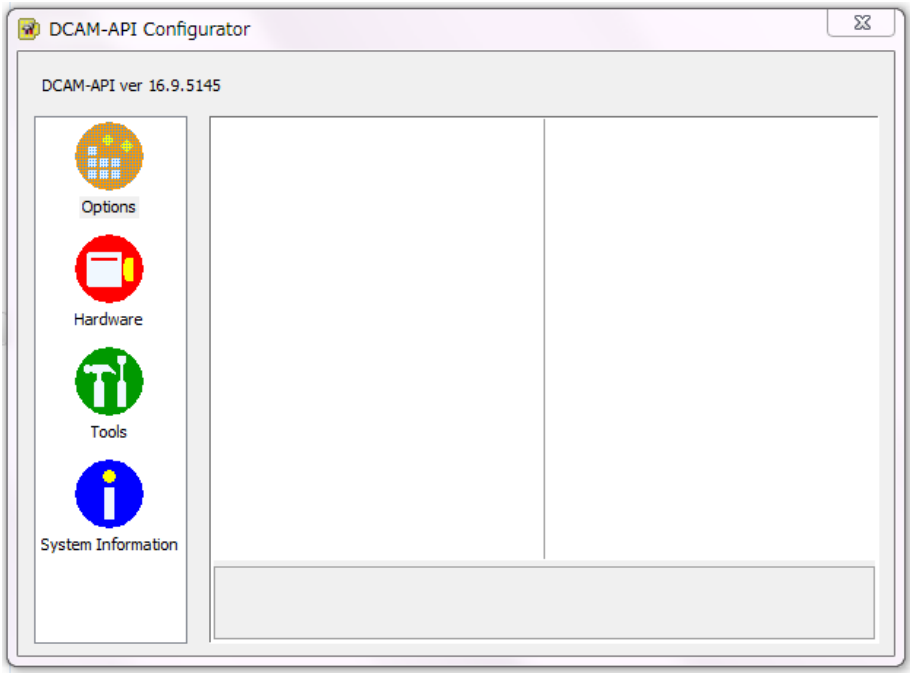
2. Click on “Tools”.



3. Click on “DCAM Configurator”.

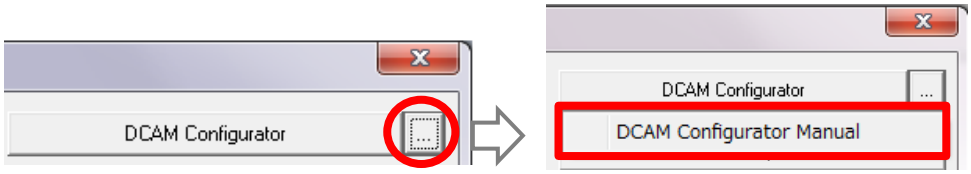


4. “DCAM Configurator” window is displayed. The startup is completed with this.



- Even if the camera's power supply is turned off, the state of setting is kept.
- The state of setting can confirm according to “Hardware” icon on DCAM Configurator window.

- After the startup, operate DCAM Configurator according to "DCAM Configurator Instruction manual". The manual is displayed when the following buttons on DCAM Setup window are clicked.



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 switching the switch one by one. (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. In addition, CMOS image sensor realizes both low noise and high speed readout simultaneously, by a split readout scheme in which the top and the bottom halves of the sensor are readout independently, and the data of each horizontal line is read by 2 lines of column amplifier and A/D in the top and the bottom in parallel and simultaneously.

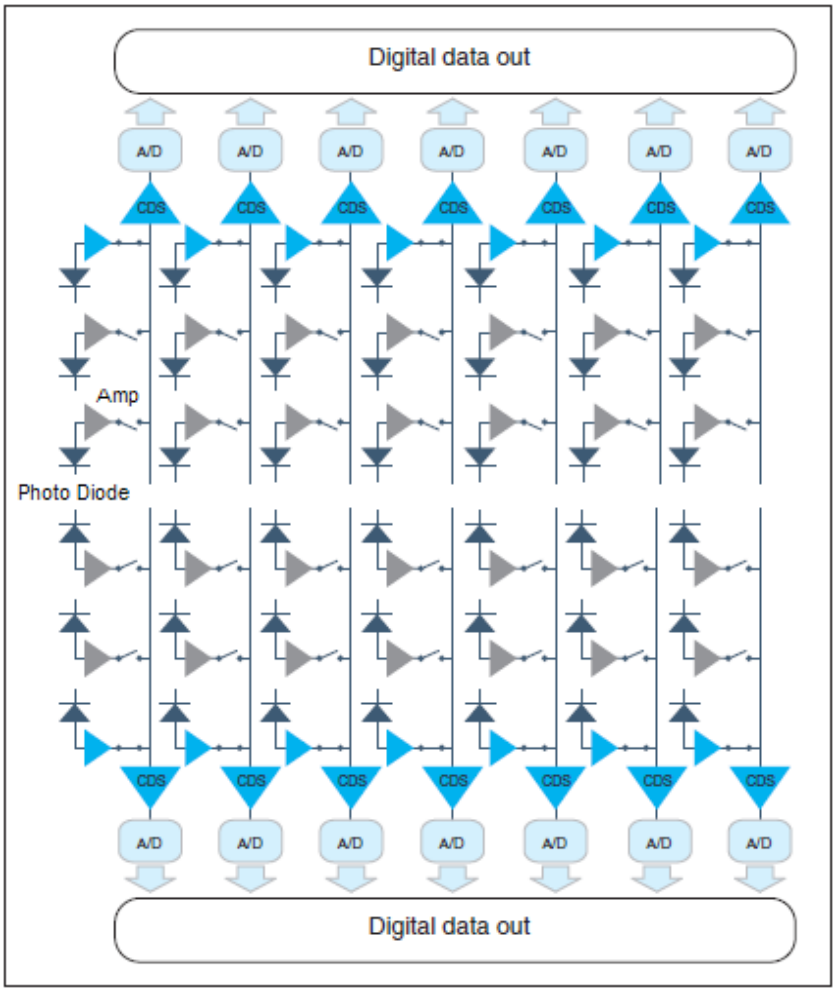


Figure 10-1 Structure of CMOS image sensor

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 line by line. Therefore, the exposure timing is different on one screen. (Figure 10-2) But even if the object moves during the exposure, the affect of rolling shutter is very small.

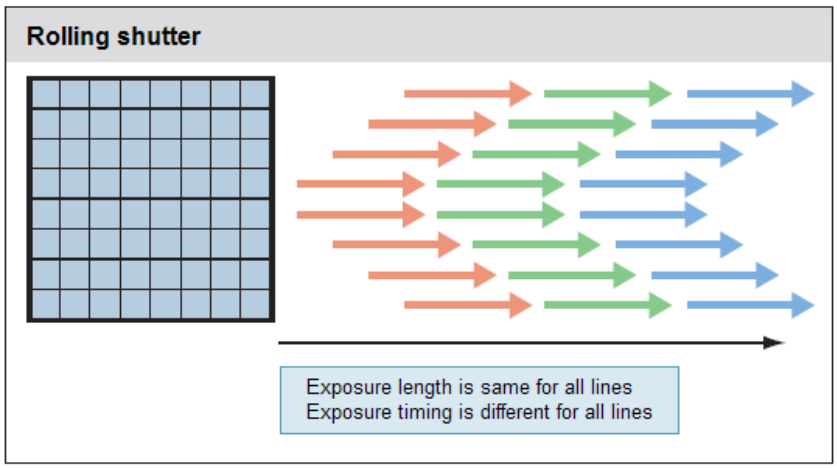


Figure 10-2 Readout timing of Rolling shutter

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 center line to the top and from the center line to the bottom simultaneously (center line is depicted in red line in the diagram).

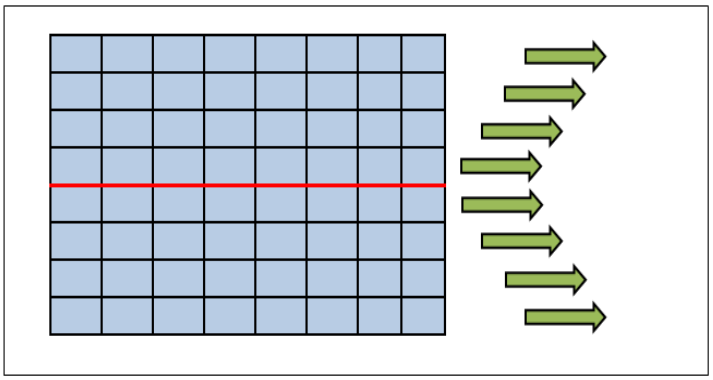


Figure 11-1 Normal area mode readout direction

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. When a target area is placed in the center of the screen, sub-array readout can perform the fastest readout. 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.

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 standard scan readout speed can achieve a frame rate of 100 fps for full resolution with low noise (1.0 electrons (median), 1.6 electrons (r.m.s.)), and the slow scan readout speed can achieve even lower noise (0.8 electrons (median), 1.4 electrons (r.m.s.)) with a frame rate of 30 fps for full resolution.
Camera Link interface is necessary to transfer the image data with 100 fps of fast frame rate for full resolution.
When you use USB 3.0 interface, the frame rate is up to 40 fps (16 bit of digital output) for full resolution.
The frame rate with USB 3.0 interface will be faster when you use 12 bit or 8 bit of digital output.

Scan speed	Digital output	Frame rate for full resolution	
		Camera Link	USB 3.0
Standard scan	16 bit	100 fps	40 fps
	12 bit		53 fps
	8 bit		80 fps
Slow scan	16 bit	30 fps	30 fps
	12 bit		
	8 bit		

Note

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

11-1-4 FRAME RATE CALCULATION

(1) Standard scan: Camera Link

Vn = Number of vertical line (at the center area of the image sensor)
Exp1 = 1.004 ms to 10 s (input in units of seconds)
1H = 9.744 36 µs

Operation modes	Calculation formula	Horizontal	Vertical	Frame rate
Free running mode	1/(Vn/2×1H)	2048	2048	100
			1024	200
			512	400
			256	801
			128	1603
			64	3206
			8	25 655
External trigger mode (Edge trigger / Level trigger)	1/(Vn/2×1H+Exp1+10×1H)	2048	2048	90
			1024	164
			512	278
			256	425
			128	579
			64	707
			8	877
External trigger mode (Synchronous readout trigger)	1/(Vn/2×1H+5×1H)	2048	2048	99
			1024	198
			512	393
			256	771
			128	1487
			64	2773
			8	11 402

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”.

Note

- The calculation formula and the frame rate value do not depend on the bit depth of digital output.

(2) Standard scan: USB 3.0

Hn = Number of horizontal pixel
Vn = Number of vertical line (at the center area of the image sensor)
Exp1 = 1.004 ms to 10 s (input in units of seconds)
1H = 9.744 36 µs
round () = Round down to integer
roundup() = Round up to integer

1. 16 bit Digital output

Operation modes	Binning	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Hn>512 V≥16	1/(round(Vn/2048/40/1H) ×1H)	2048 × 2048	40
				2048 × 512	160
				2048 × 64	1282
		Hn>512 Vn≤8	1/(roundup(Vn/2048/40/1H) ×1H)	2048 × 8	9329
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H)	512 × 2048	100
				512 × 512	400
				512 × 8	25 655
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H)	1024 × 1024	100
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H)	512 × 512	100
External trigger mode (Edge trigger / Level trigger)	1×1	Hn>512 V≥152	1/(round(Vn/2048/40/1H) ×1H)	2048 ×2048	40
				2048 × 512	160
		Hn>512 Vn≤144	1/(Vn/2×1H+Exp1+10×1H)	2048 × 64	707
				2048 × 8	877
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H+Exp1+10×1H)	512 × 2048	90
				512 × 512	278
				512 × 8	877
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H+Exp1+10×1H)	1024 × 1024	90
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H+Exp1+10×1H)	512 × 512	90
External trigger mode (Synchronous readout trigger)	1×1	Hn>512 8≤Vn≤2048	1/(round(Vn/2048/40/1H) ×1H)	2048 × 2048	40
				2048 × 512	160
				2048 × 64	1282
				2048 × 8	10 262
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H+5×1H)	512 × 2048	99
				512 × 512	393
				512 × 8	11 402
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H+5×1H)	1024 × 1024	99
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H+5×1H)	512 × 512	99

2. 12 bit Digital output

Operation modes	Binning	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Hn>512 Vn≥16	1/(round(Vn/2048/53/1H) ×1H)	2048 × 2048	53
				2048 × 512	212
				2048 × 64	1710
		Hn>512 Vn≤8	1/(roundup(Vn/2048/53/1H) ×1H)	2048 × 8	12 827
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H)	512 × 2048	100
				512 × 512	400
				512 × 8	25 655
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H)	1024 × 1024	100
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H)	512 × 512	100
External trigger mode (Edge trigger / Level trigger)	1×1	Hn>512 Vn≥256	1/(round(Vn/2048/53/1H) ×1H)	2048 × 2048	53
				2048 × 512	212
		Hn>512 Vn≤248	1/(Vn/2×1H+Exp1+10×1H)	2048 × 64	707
				2048 × 8	877
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H+Exp1+10×1H)	512 × 2048	90
				512 × 512	278
				512 × 8	877
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H+Exp1+10×1H)	1024 × 1024	90
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H+Exp1+10×1H)	512 × 512	90
External trigger mode (Synchronous readout trigger)	1×1	Hn>512 Vn≥16	1/(round(Vn/2048/53/1H) ×1H)	2048 × 2048	53
				2048 × 512	212
				2048 × 64	1710
		Hn>512 Vn≤8	1/(Vn/2×1H+5×1H)	2048 × 8	11 402
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H+5×1H)	512 × 2048	99
				512 × 512	393
				512 × 8	11 402
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H+5×1H)	1024 × 1024	99
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H+5×1H)	512 × 512	99

3. 8 bit Digital output

Operation modes	Binning	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Hn>512 Vn≥16	1/(round(Vn/2048/80/1H) ×1H)	2048 × 2048	80
				2048 × 512	320
				2048 × 64	2565
		Hn>512 Vn≤8	1/(roundup(Vn/2048/80/1H) ×1H)	2048 × 8	17 103
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H)	512 × 2048	100
				512 × 512	400
				512 × 8	25 655
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H)	1024 × 1024	100
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H)	512 × 512	100
External trigger mode (Edge trigger / Level trigger)	1×1	Hn>512 Vn≥912	1/(round(Vn/2048/80/1H) ×1H)	2048 × 2048	80
		Hn>512 Vn≤904	1/(Vn/2×1H+Exp1+10×1H)	2048 × 512	278
				2048 × 64	707
				2048 × 8	877
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H+Exp1+10×1H)	512 × 2048	90
				512 × 512	278
				512 × 8	877
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H+Exp1+10×1H)	1024 × 1024	90
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H+Exp1+10×1H)	512 × 512	90
External trigger mode (Synchronous readout trigger)	1×1	Hn>512 Vn≥48	1/(round(Vn/2048/80/1H) ×1H)	2048 × 2048	80
				2048 × 512	320
				2048 × 64	2565
		Hn>512 Vn≤40	1/(Vn/2×1H+5×1H)	2048 × 8	11 402
		Hn≤512 8≤Vn≤2048	1/(Vn/2×1H+5×1H)	512 × 2048	99
				512 × 512	393
				512 × 8	11 402
	2×2	64≤Hn≤1024 4≤Vn≤1024	1/(Vn×1H+5×1H)	1024 × 1024	99
	4×4	32≤Hn≤512 2≤Vn≤512	1/(Vn×2×1H+5×1H)	512 × 512	99

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”.

(3) Slow scan: Camera Link, USB 3.0 (Common to the two interfaces)

Vn = Number of vertical line (at the center area of the image sensor)
Exp1 = 3.021 ms to 10 s (input in units of seconds)
1H = 32.4812 µs

Operation modes	Calculation formula	Horizontal	Vertical	Frame rate (fps)
Free running mode	1/(Vn/2×1H)	2048	2048	30
			1024	60
			512	120
			256	240
			128	481
			64	962
			8	7696
External trigger mode (Edge trigger / Level trigger)	1/(Vn/2×1H+Exp1+10×1H)	2048	2048	27
			1024	50
			512	85
			256	133
			128	184
			64	228
			8	287
External trigger mode (Synchronous readout trigger)	1/(Vn/2×1H+5×1H)	2048	2048	29
			1024	59
			512	117
			256	231
			128	446
			64	832
			8	3420

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”.

Note

- The calculation formula and the frame rate value do not depend on the bit depth of digital output.

11-1-5 CONFIGURING EXPOSURE TIME

The exposure time setting can be done by the units of 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) Standard scan

Exp1 = 1 ms to 10 s (38.96 µs to 10 s with sub-array setting) (input in units of seconds)
Exp2 = Exp1 ÷ 9.744 36 µs (round up to integer)

Calculation formula	9.744 36 µs × Exp2

(2) Slow scan

Exp1 = 3 ms to 10 s (129.99 µs to 10 s with sub-array setting) (input in units of seconds)
Exp2 = Exp1 ÷ 32.4812 µs (round up to integer)

Calculation formula	32.4812 µs × Exp2

Available setting range of the exposure time is the following.

Operation modes	Setting range	
	Standard scan	Slow scan
Free running mode	1 ms to 10 s	3 ms to 10 s
Free running mode (at Sub-array)	38.96 µs* to 10 s	129.99 µs* to 10 s
External trigger mode	1 ms to 10 s	3 ms to 10 s

* 38.96 µs (Standard scan) and 129.99 µs (Slow scan) is the minimum exposure time when sub-array is set to 8 lines vertically symmetric (4 lines in top half and 4 lines in bottom half) with respect to the horizontally center axis. The minimum exposure time vary depend on vertical line number of sub-array setting.

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, which is faster than the video rate*. (* 100 fps with standard scan with Camera Link, 40 fps with USB 3.0 (16 bit digital output) and 30 fps with slow scan)
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.

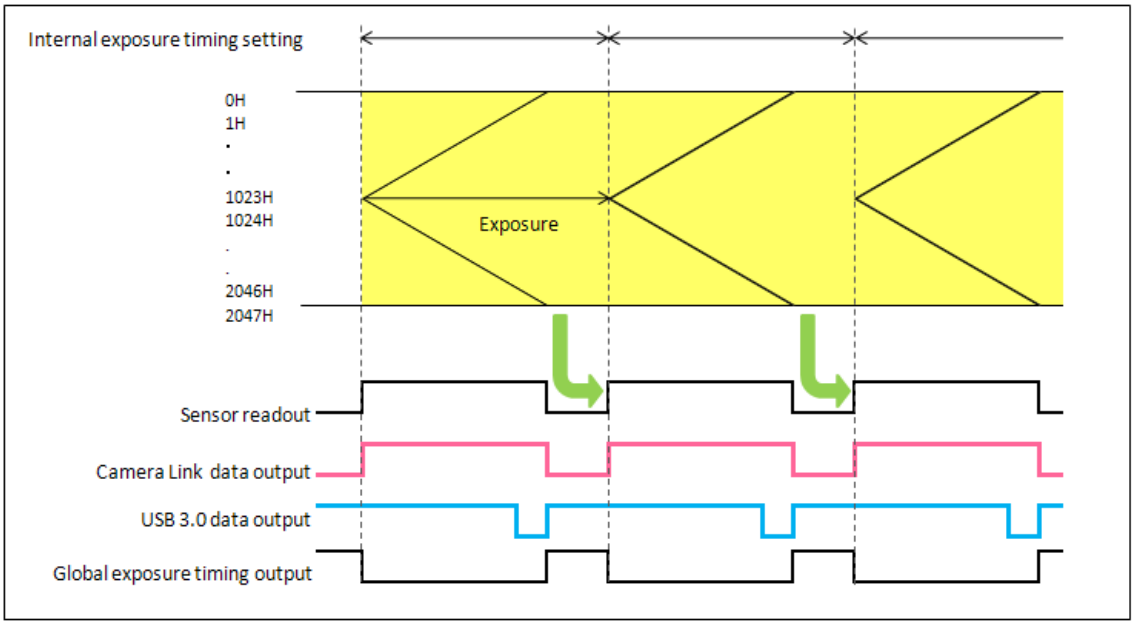


Figure 11-2

(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 100 fps (standard scan via Camera Link), 40 fps (standard scan via USB 3.0) or 30 fps (slow scan) at full resolution even when the exposure time is short.

Camera Link:

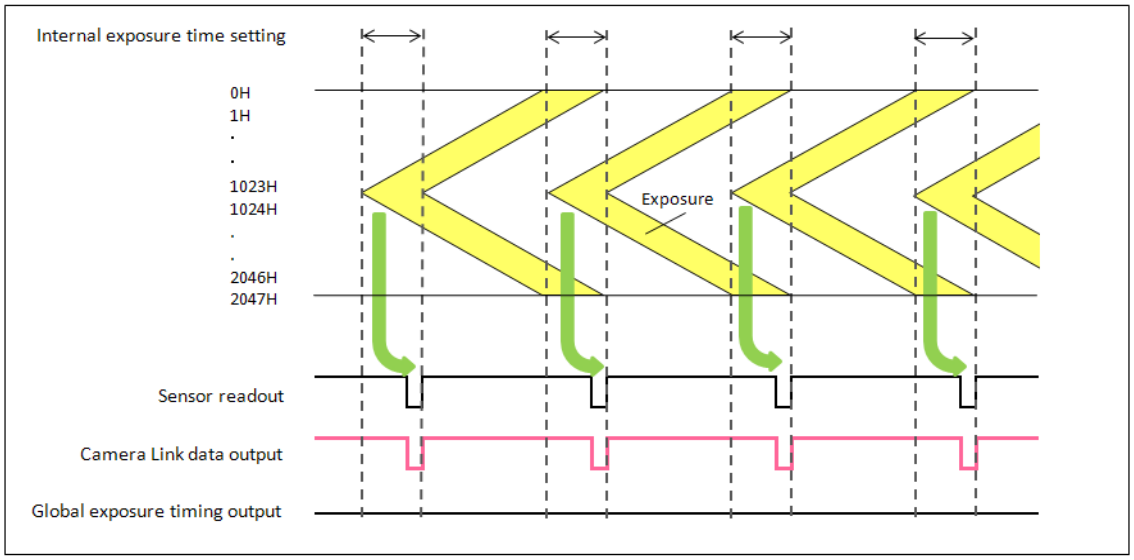


Figure 11-3

USB 3.0:

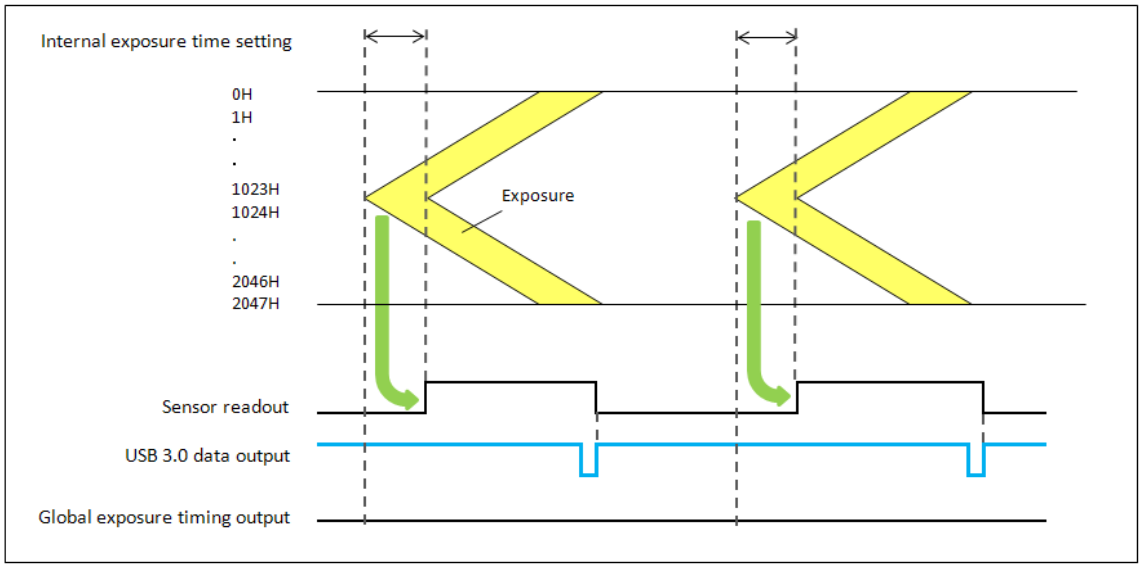


Figure 11-4

11-1-6-2 External trigger mode

The camera has various external trigger functions to synchronize the camera with the external equipment. In External trigger mode, the external equipment 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. (1023H and 1024H in the following figure) The exposure of the second line is begun after the readout time of one line passes (1022H and 1025H in the following figure), and the exposure is begun one by one for each line.

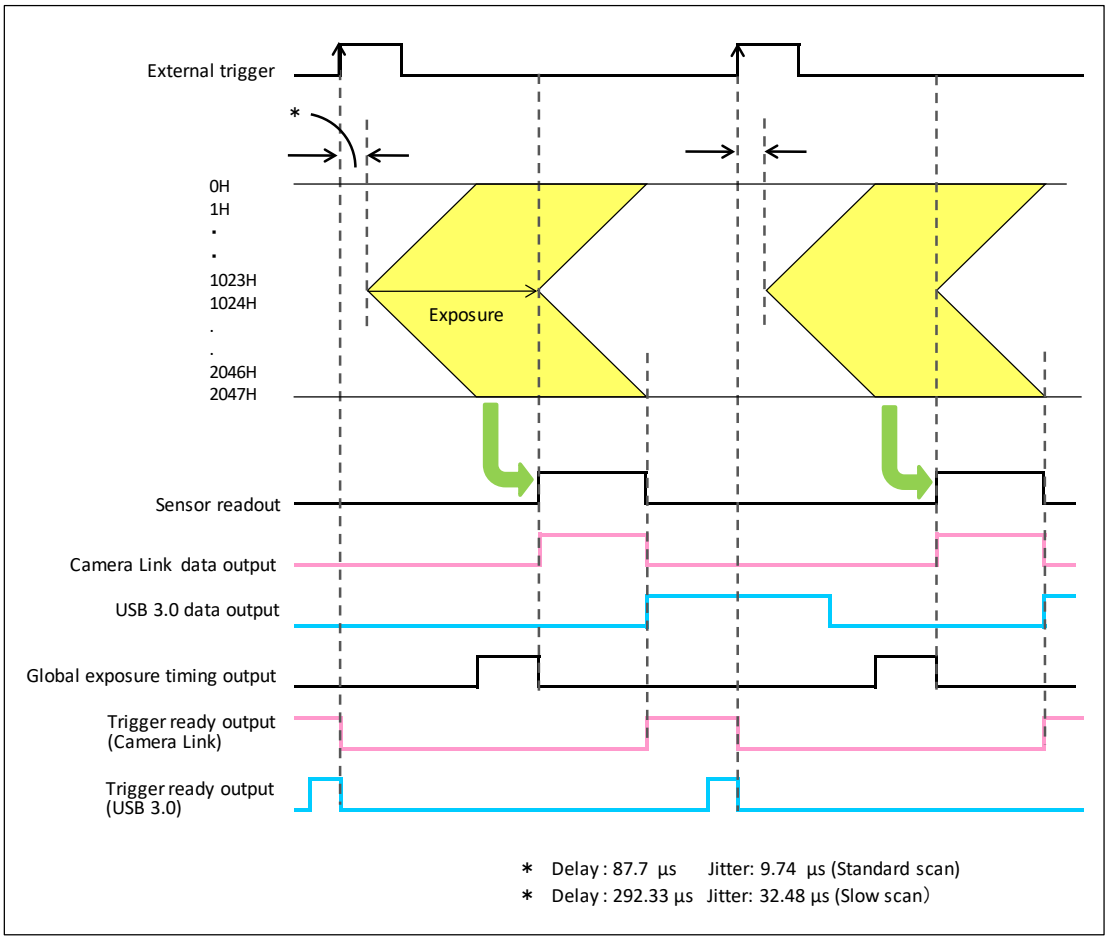


Figure 11-5 (Ex. rising edge)

(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.

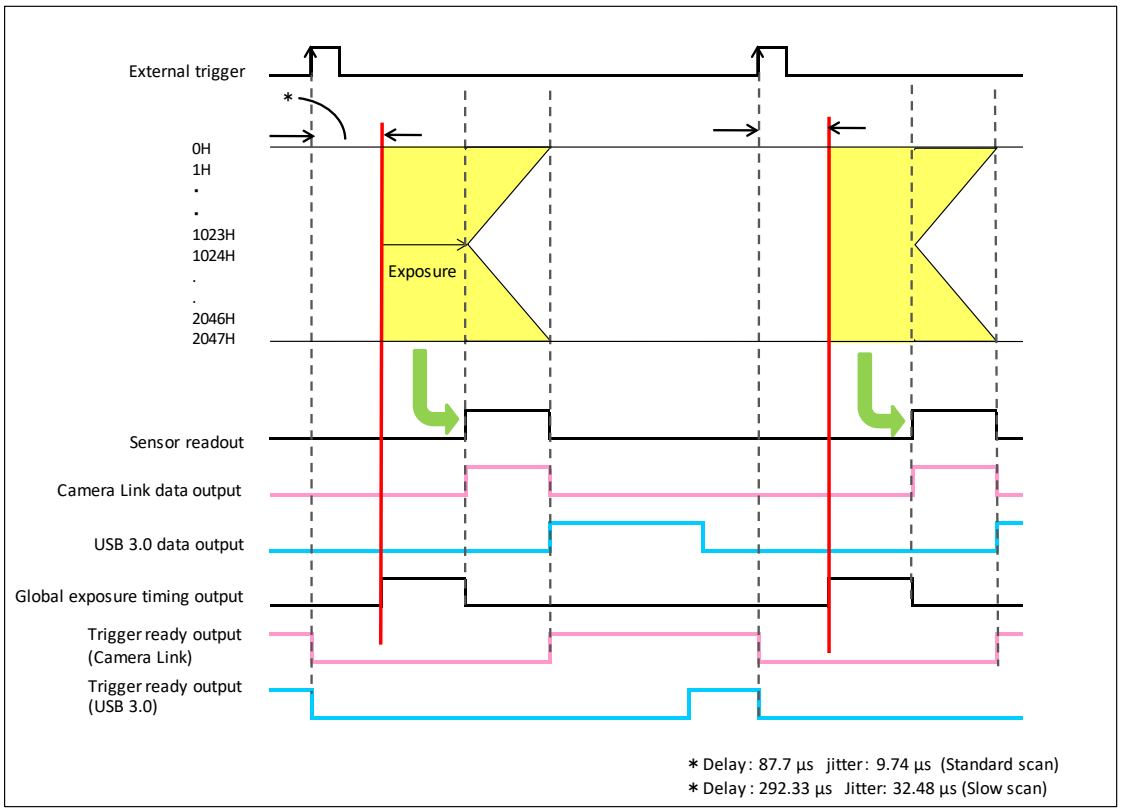


Figure 11-6 (Ex. rising edge)

(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. The minimum trigger pulse width is 1.05 ms (standard scan) or 3.18 ms (slow scan).

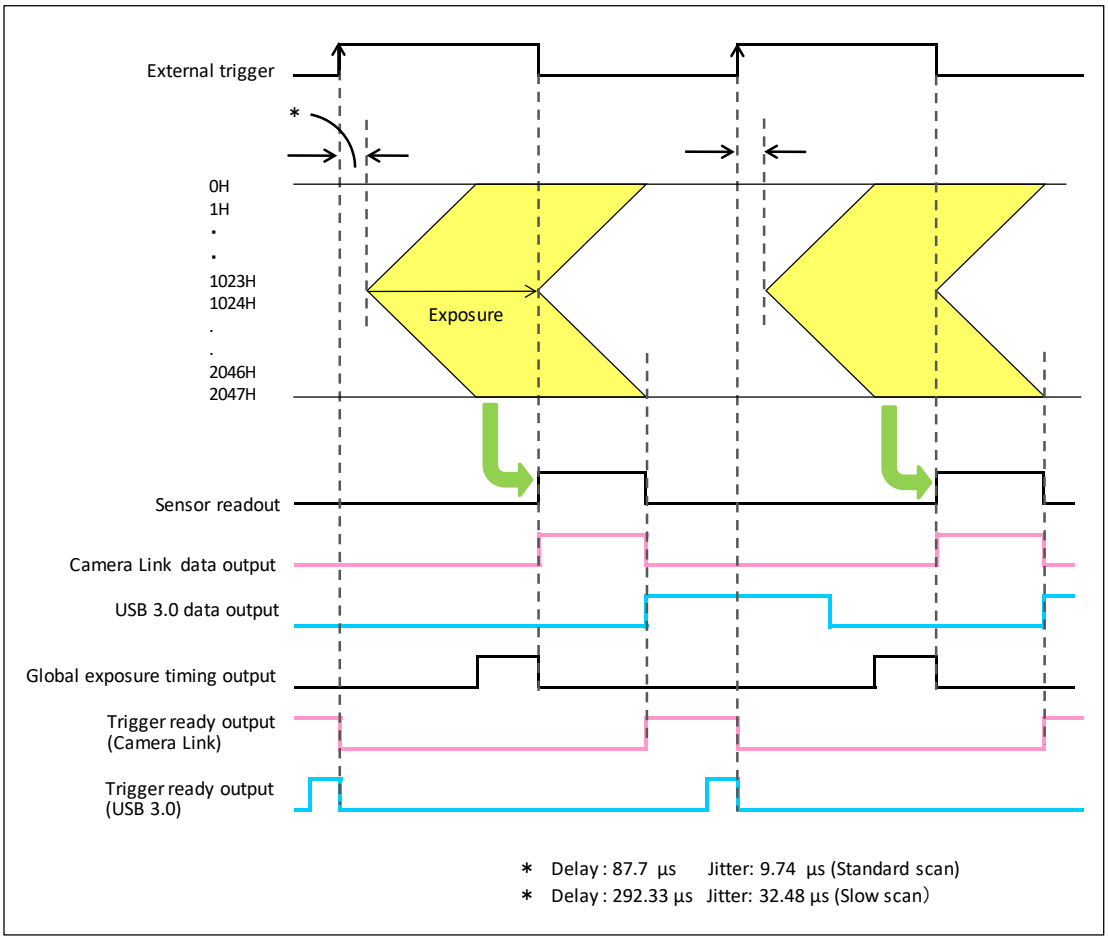


Figure 11-7 (Ex. level High)

(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.

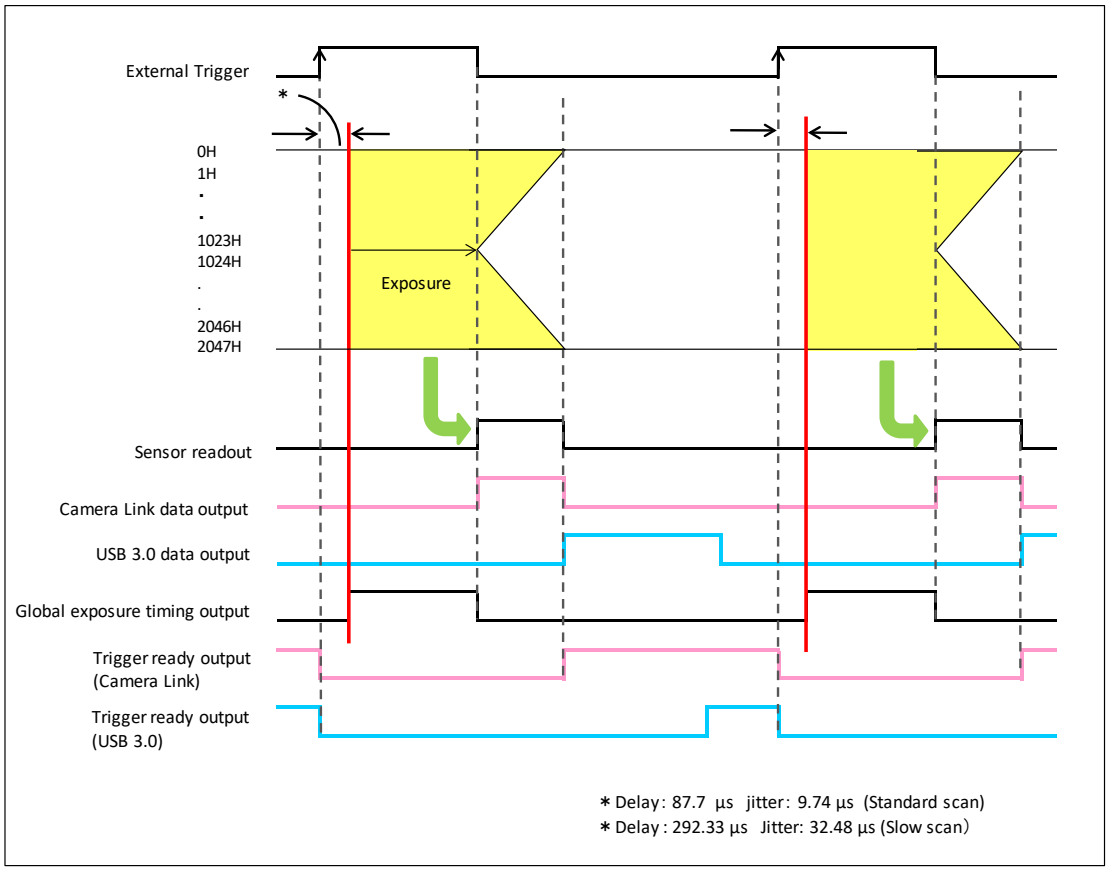


Figure 11-8 (Ex. level High)

(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.

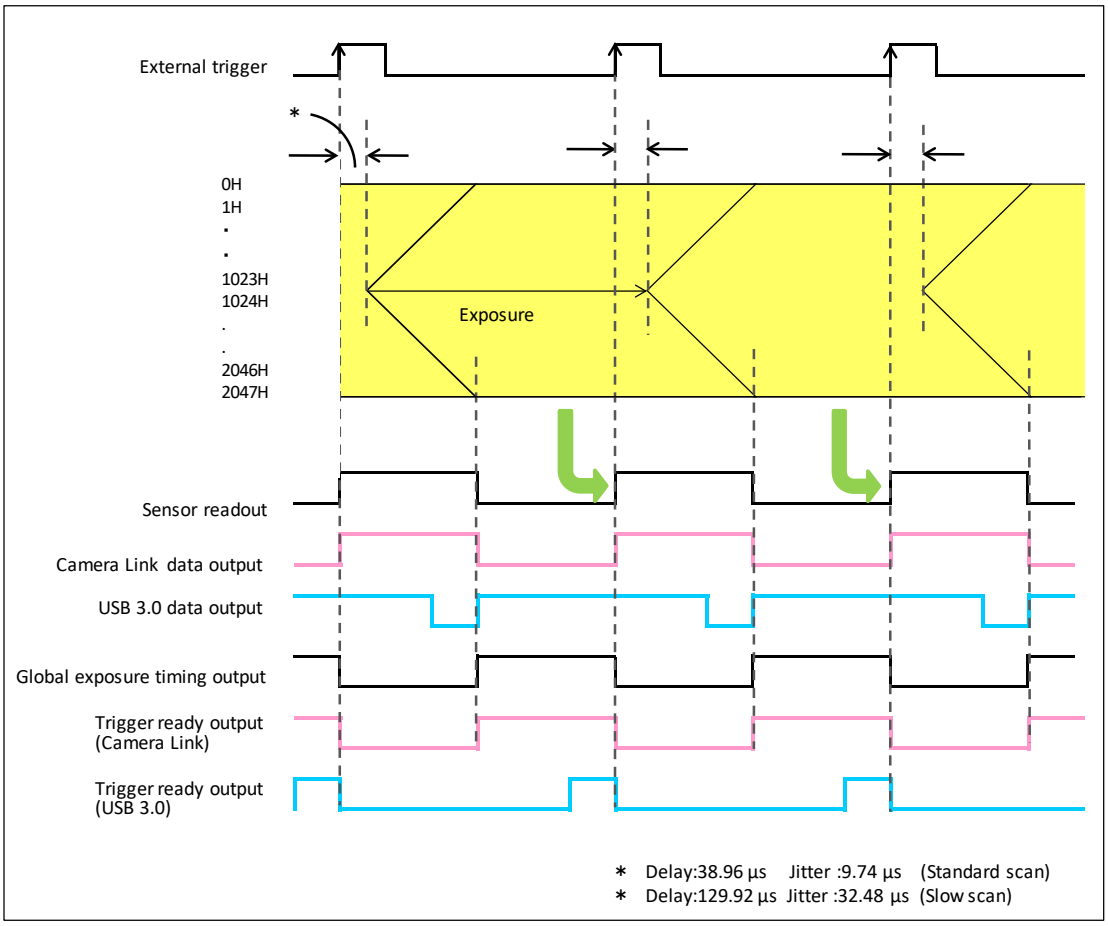


Figure 11-9 (Ex. rising edge)

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 3.

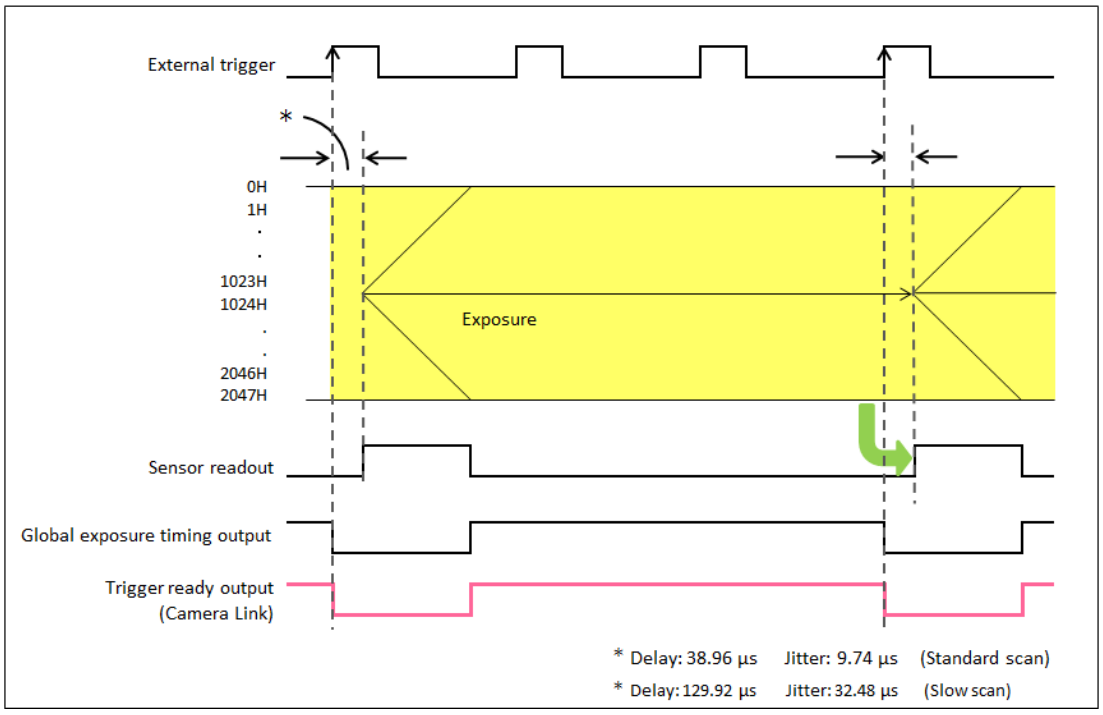


Figure 11-10 (Trigger Times)

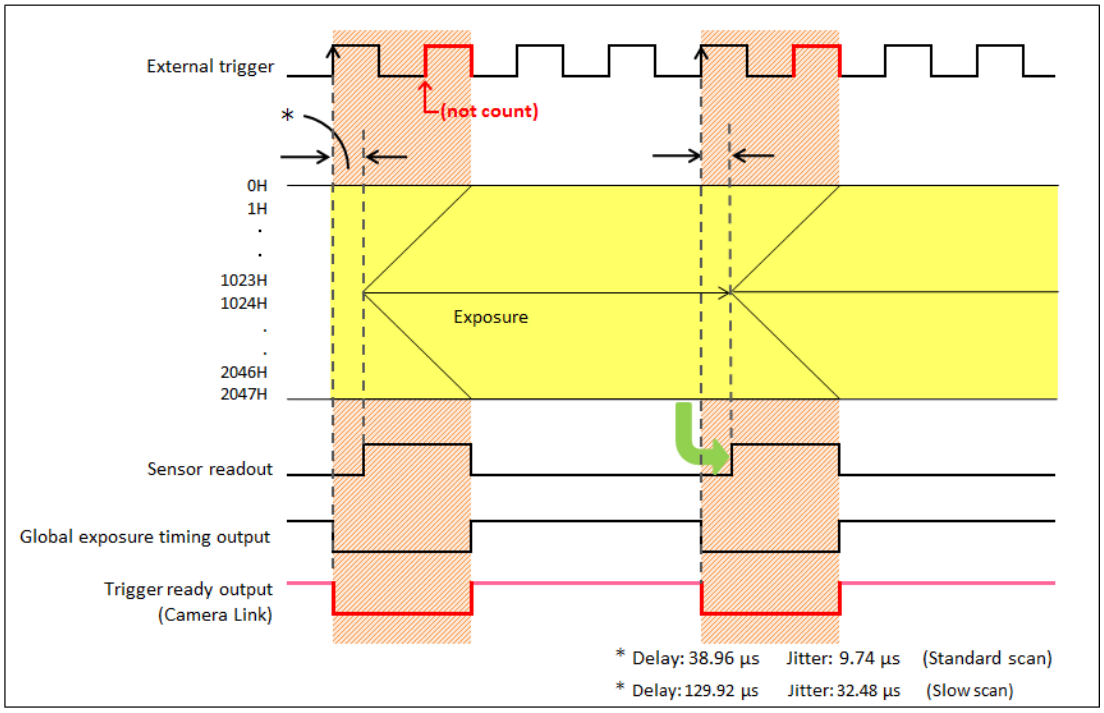


Figure 11-11 (Examples where triggers are not counted)

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).

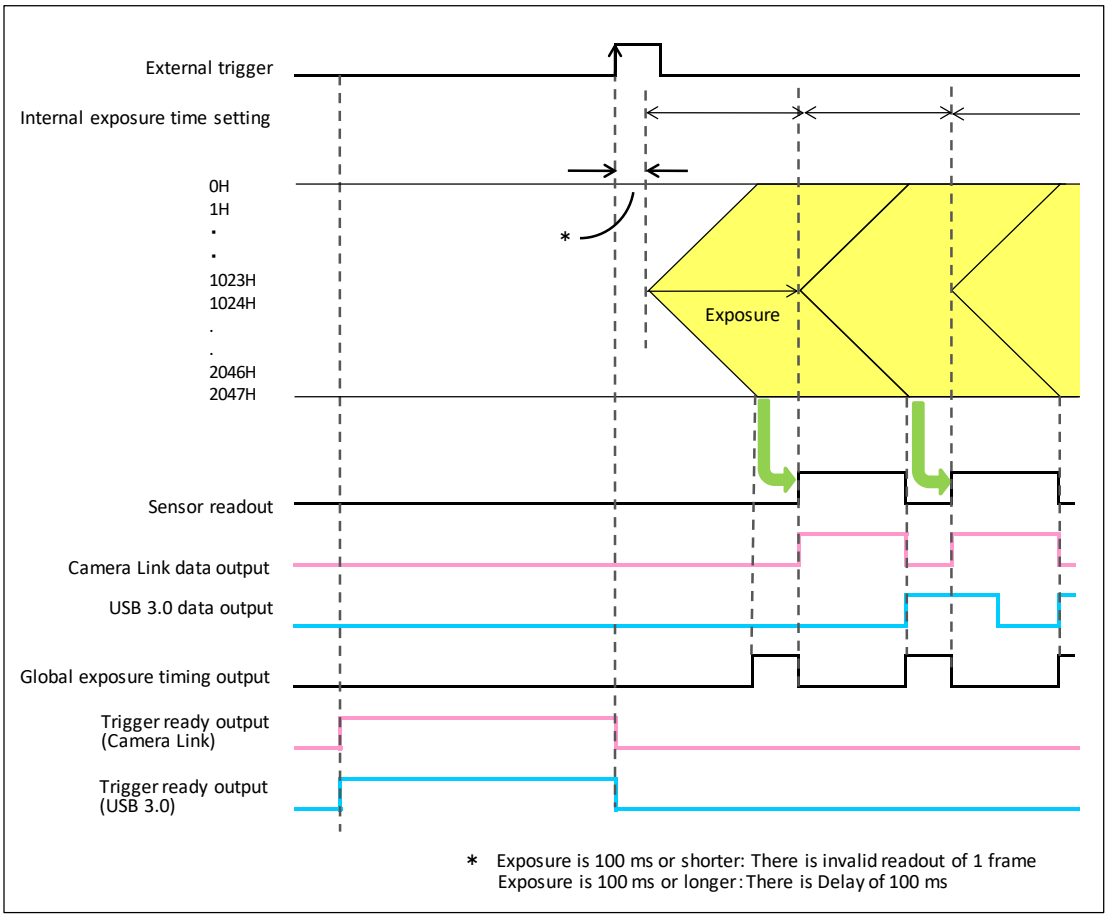


Figure 11-12 (Ex. rising edge)

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) 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 pulsewidth is output after the preset delay from the end of the sensor readout.
Vsync	The signal with the preset pulsewidth is output after the preset delay from the start of the sensor readout.
Input trigger signal	The signal with the preset pulsewidth is output after the preset delay from the input trigger signal.

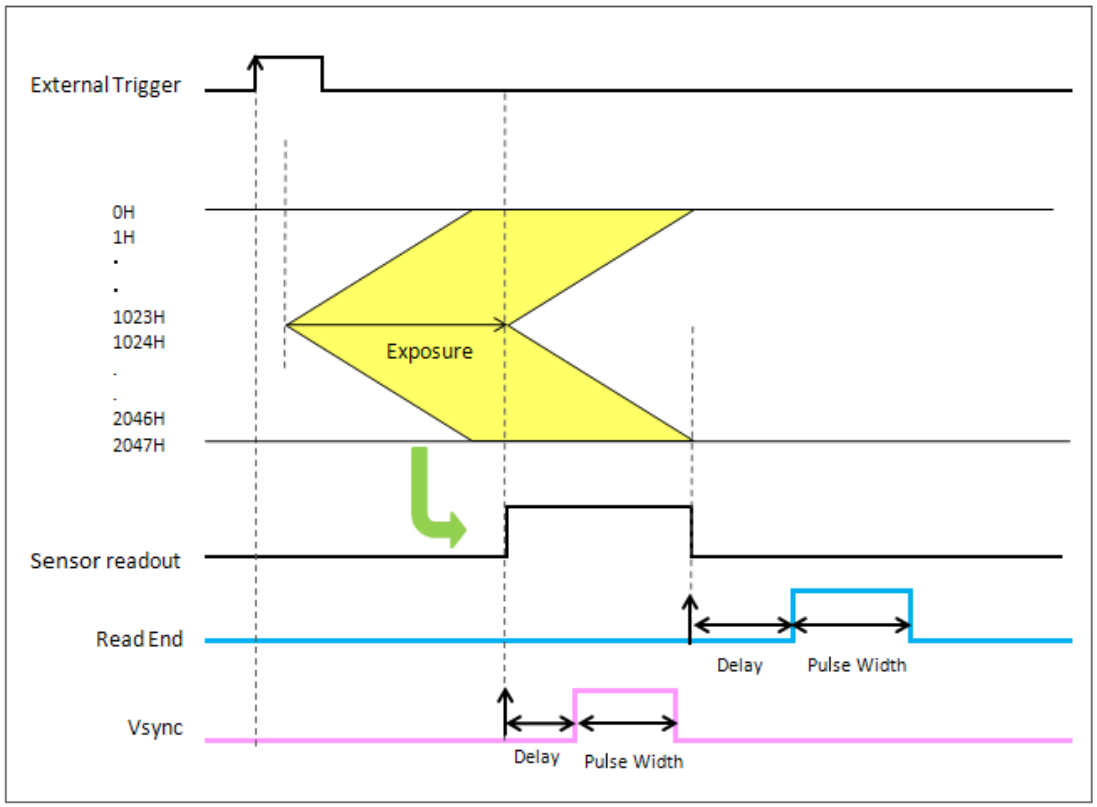


Figure 11-13 Programmable timing output

(3) 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

The camera reads out from the center line to the top line and to the bottom line simultaneously in normal area mode. (Figure 11-14)
The camera reads out from the top to the bottom line or from the bottom to the top line in Lightsheet Readout Mode. (Figure 11-15)

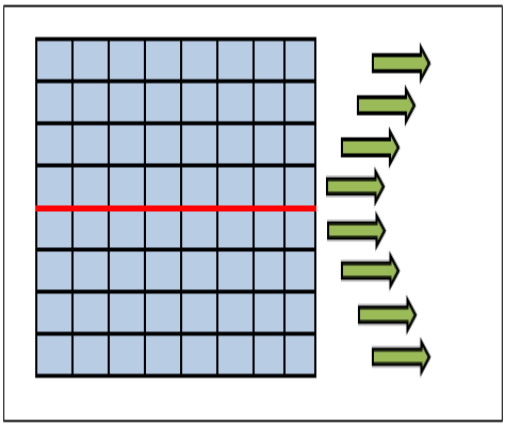


Figure 11-14 Normal area mode

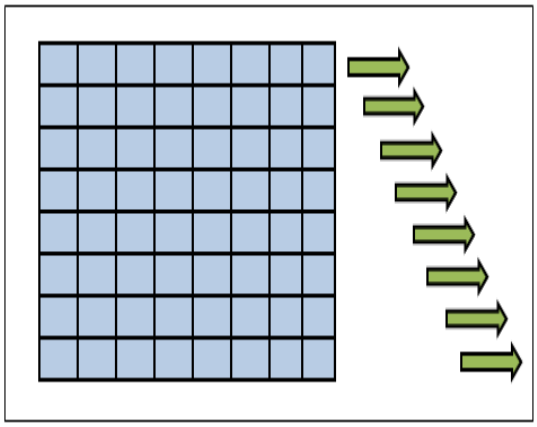


Figure 11-15 Lightsheet Readout Mode

- Top to bottom readout (Figure 11-16): The data is readout from the top to the bottom line.
- Bottom to top readout (Figure 11-17): The data is readout from the bottom to the top line.

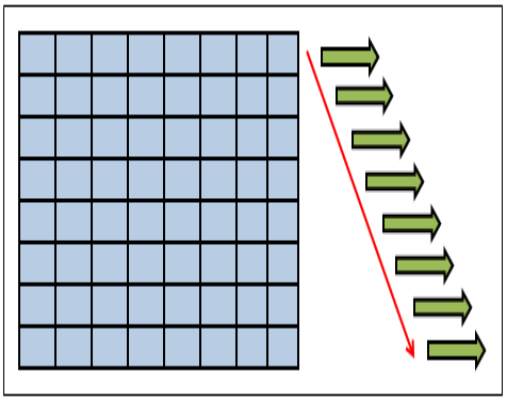


Figure 11-16 Top to bottom readout

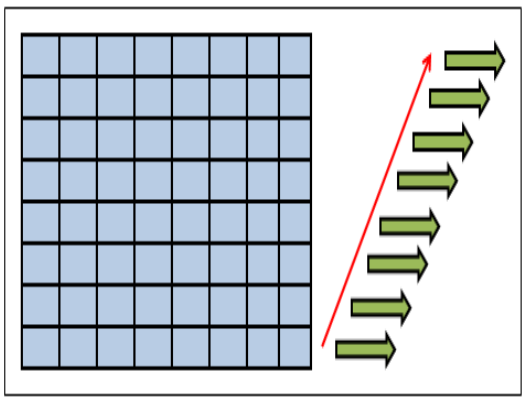


Figure 11-17 Bottom to top readout

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
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.

(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

The frame rate calculation and the value of frame rate are common to all camera operation modes (Free running mode / External trigger mode (Edge trigger) / Start trigger mode).

(1) Camera Link

Vn = Number of vertical line
Exp1= 9.744 36 µs to 10 s (input in units of seconds to the calculation formula)
1H = 9.744 36 µs to 100 ms

Operation modes	Calculation formula	Horizontal	Vertical	Frame rate (fps)
Common to all modes (Free running mode / External trigger mode (Edge trigger) / Start trigger mode)	1/(Exp1+(Vn+10)×1H)	2048	2048	49
			1024	99
			512	196
			256	384
			128	738
			64	1368
			8	5401
			4	6841

(2) USB 3.0

Hn = Number of horizontal pixel
Vn = Number of vertical line
Exp1 = 9.744 36 µs to 10 s (input in units of seconds to the calculation formula)
1H = 9.744 36 µs to 100 ms
round () = Round down to integer
roundup() = Round up to integer

1. 16 bit Digital output

Readout	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
1×1	Hn>512 Vn≥48	1/(round(Vn/2048/40/1H) ×1H)	2048 × 2048	40
			2048 × 512	160
			2048 × 64	1282
	Hn>512 Vn≤44	1/(Exp1+(Vn+10)×1H)	2048 × 8	6841
	Hn≤512 4≤Vn≤2048		512 × 2048	49
			512 × 512	196

2. 12 bit / 8 bit Digital output

Readout	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
1×1	128≤Hn≤2048 4≤Vn≤2048	1/(Exp1+(Vn+10)×1H)	2048 × 2048	49
			2048 × 512	196
			2048 × 64	1368
			2048 × 8	6841

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.

Vn = Number of vertical line
1H = 9.744 36 µs to 100 ms

Readout time = Vn × 1H

The range of exposure time with Lightsheet Readout Mode is as shown below.
The maximum exposure time can be decided according to the readout time of a frame, which is longer than 10 s or not.

1H to (Vn × 1H) : when (Vn × 1H) < 10 s
1H to 10 s : when (Vn × 1H) ≥ 10 s

11-2-5 TIMING DIAGRAM

(1) Free running mode

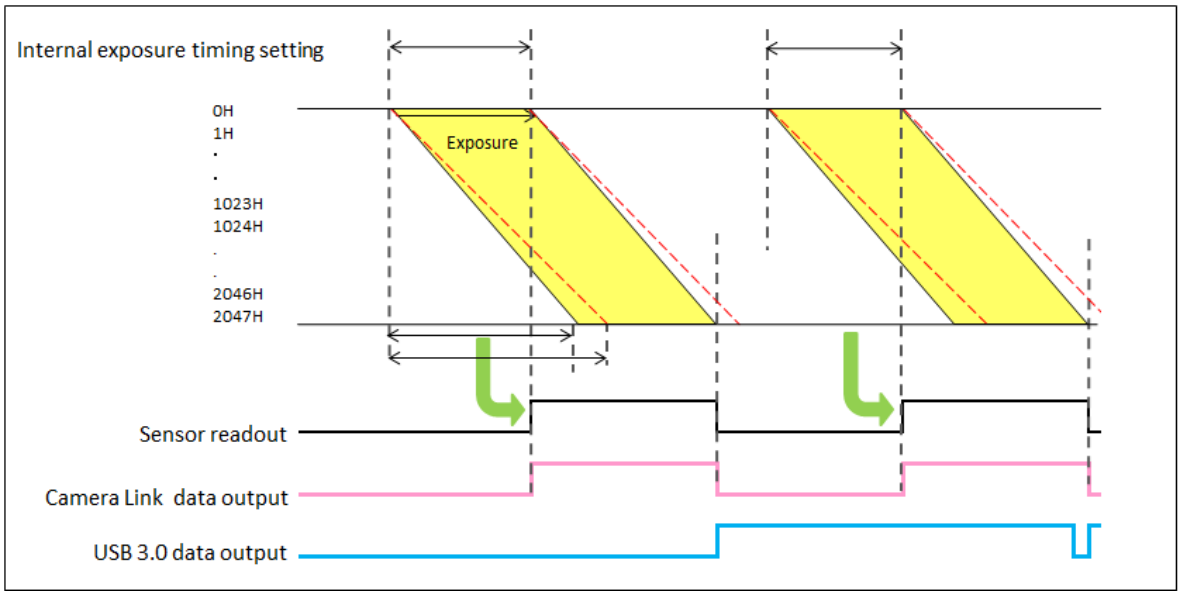


Figure 11-18 (Ex. Top to bottom readout)

(2) Edge trigger mode (External trigger mode)

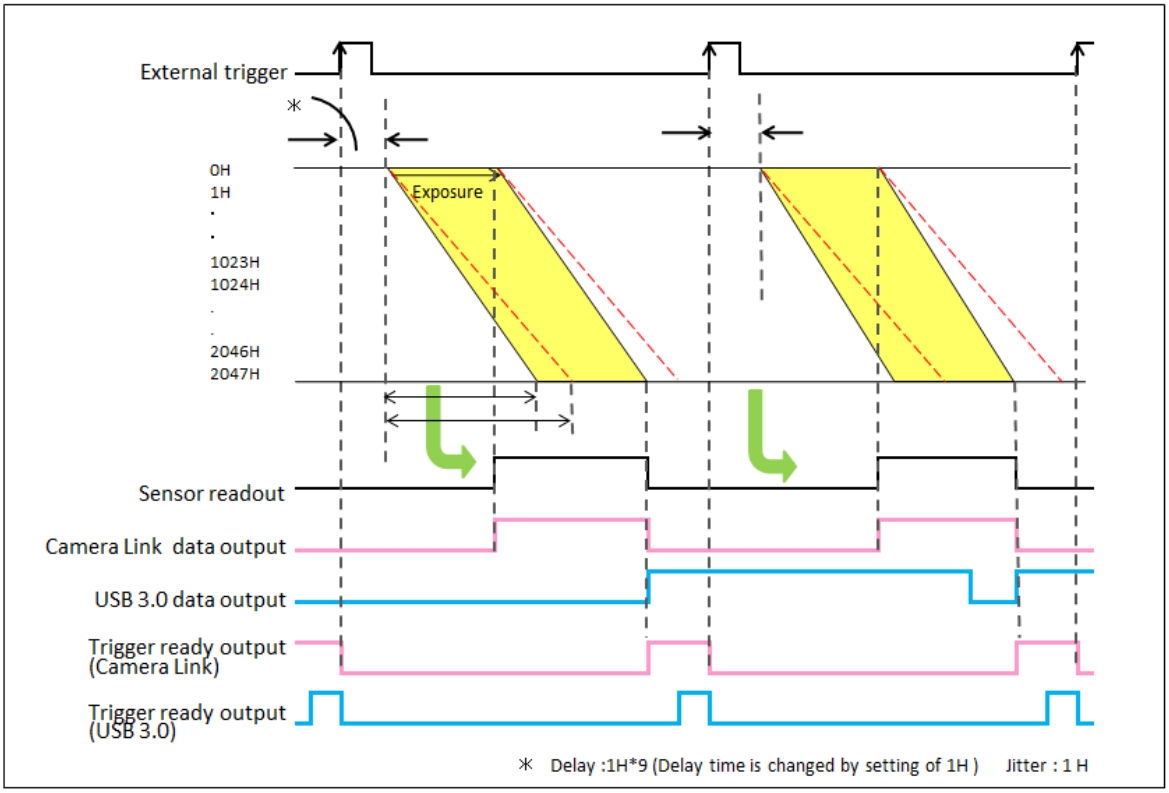


Figure 11-19 (Ex. rising edge, Top to bottom readout)

(3) Start trigger mode

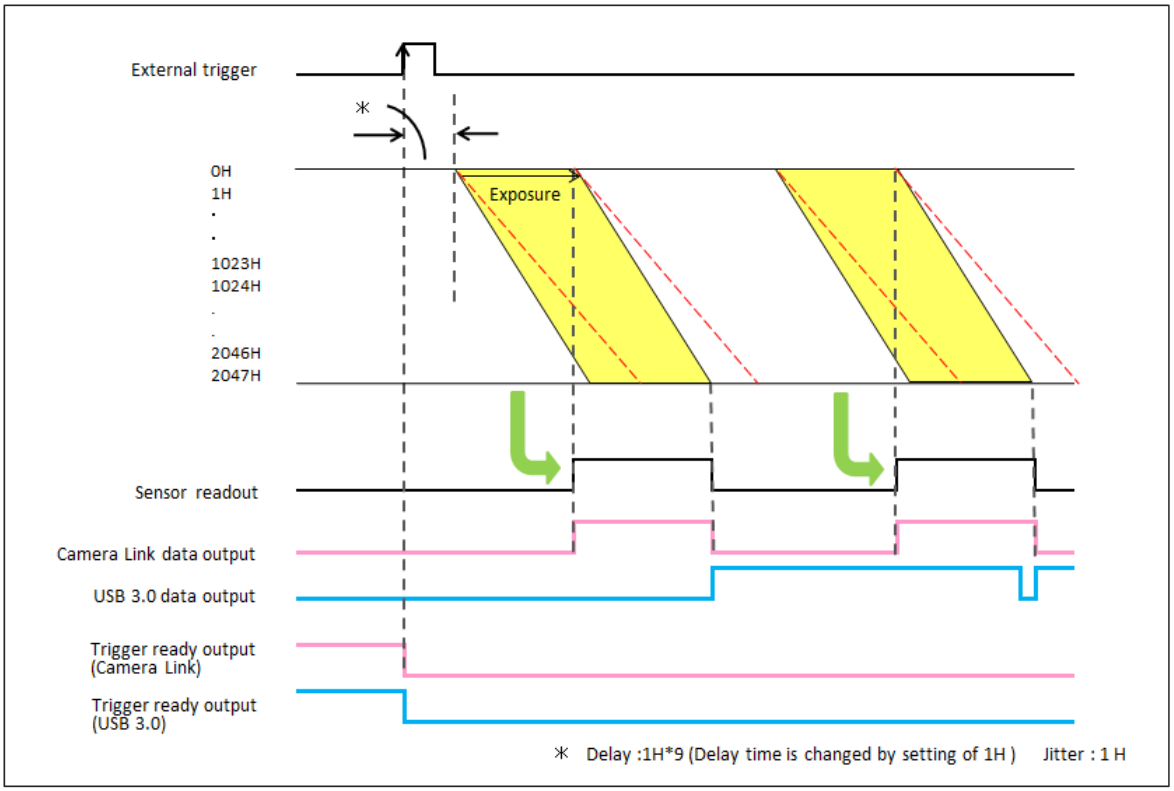


Figure 11-20 (Ex. rising edge, Top to bottom readout)

11-2-6 TRIGGER OUTPUT

The camera provides a range of trigger output signals with Lightsheet Readout Mode. The global exposure timing output is not provided, however, because there is no timing where all lines expose at the same time with Lightsheet Readout Mode.
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) and Vsync for programmable timing output. In addition that, it is also possible to program an optional pulse width and an optional delay time to Hsync for programmable timing output with Lightsheet Readout Mode.

(1) 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 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 pulsewidth is output after the preset delay from the end of the sensor readout.
Vsync	The signal with the preset pulsewidth is output after the preset delay from the start of the sensor readout.
Hsync	The signal with the preset pulsewidth is output after the preset delay from the horizontal synchronized signal in the camera.

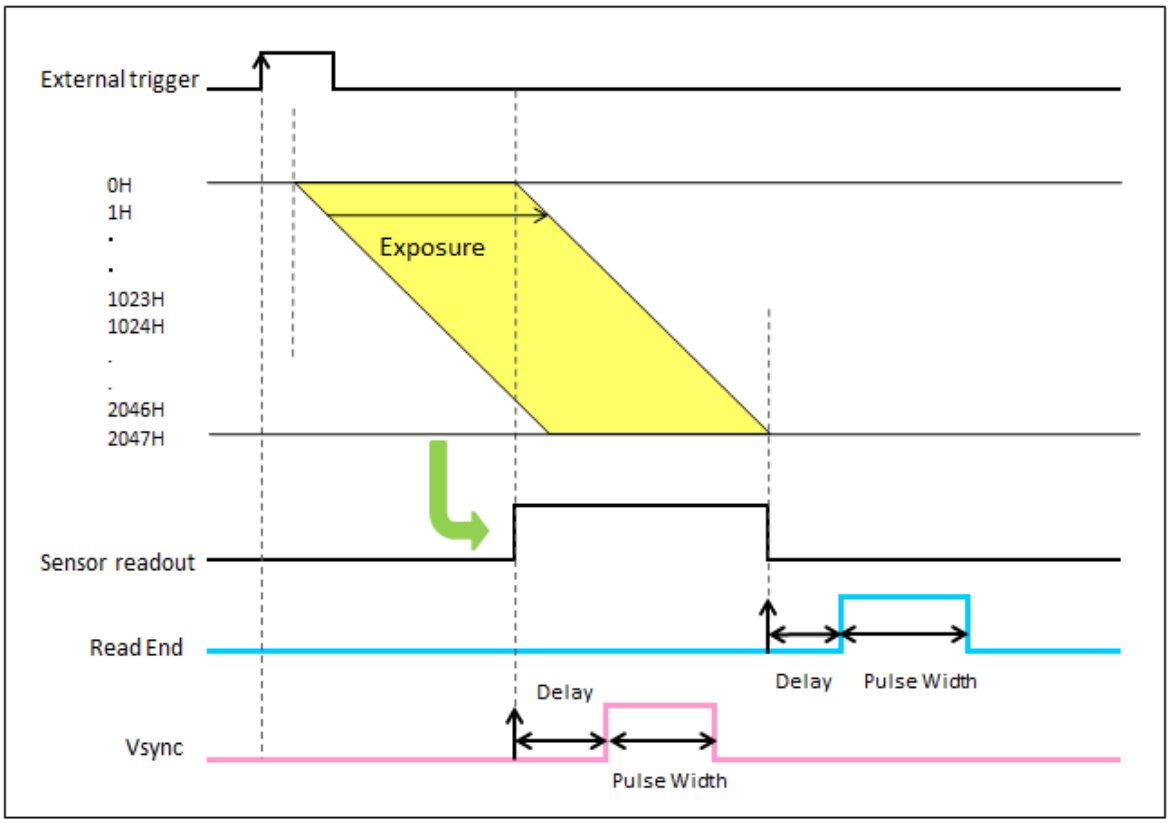


Figure 11-21 Programmable timing output (Top to bottom readout)

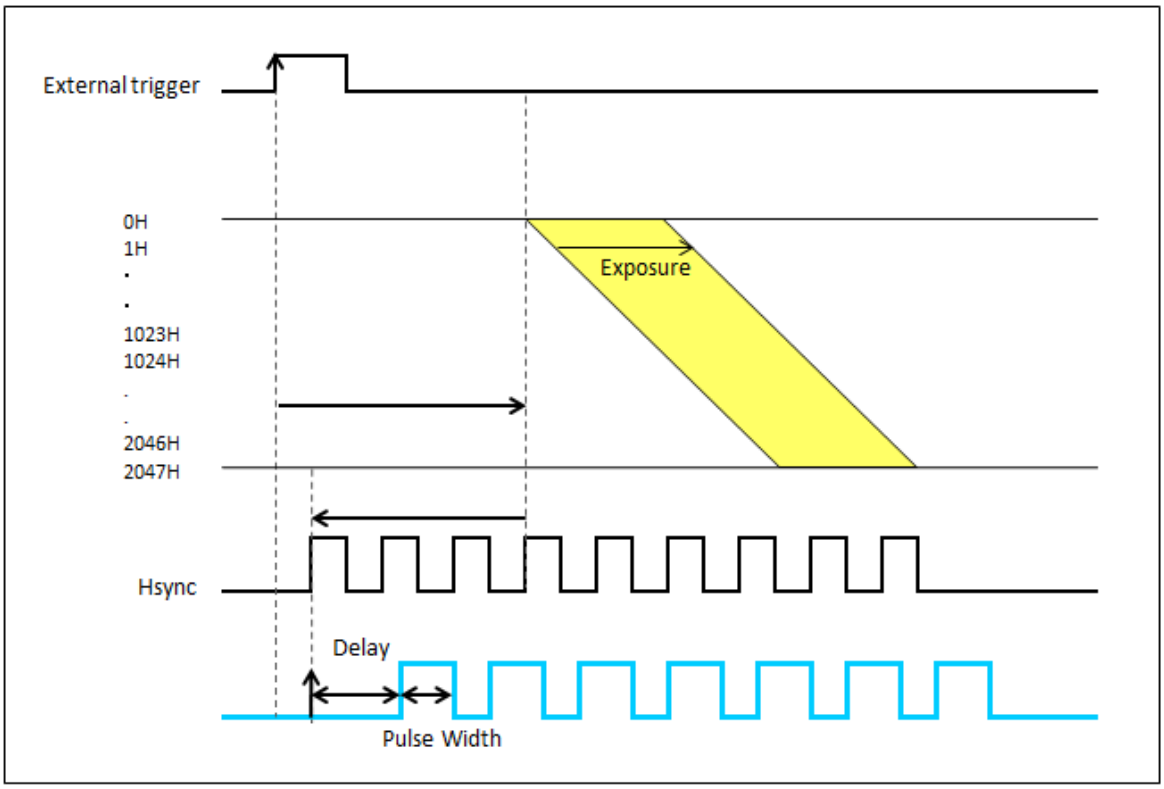


Figure 11-22 Programmable timing output referenced with Hsync (Top to bottom readout)

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.

11-3 W-VIEW MODE

The exposure time and the position of sub-array readout can be set for the top half area and the bottom half area independently in W-VIEW Mode. This function is optimized for simultaneous image acquisition of dual wavelength images.

11-3-1 READOUT DIRECTION

The readout direction can be set for the top half area and the bottom half area independently in W-VIEW Mode. (Figure 11-23, 24, 25, 26)

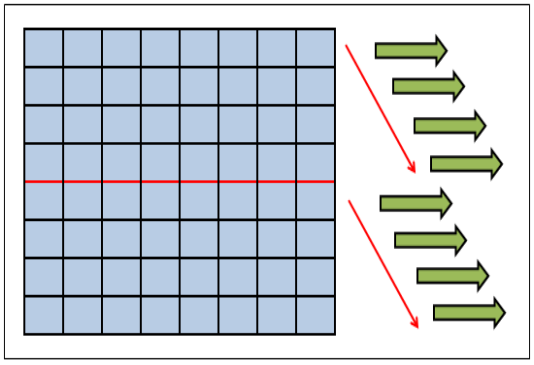


Figure 11-23 Top: top to center / Bottom: center to bottom

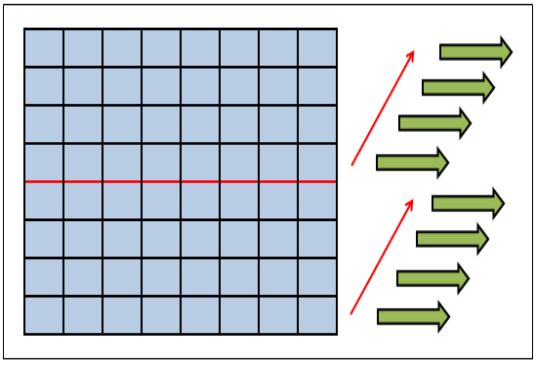


Figure 11-24 Top: center to top / Bottom: bottom to center

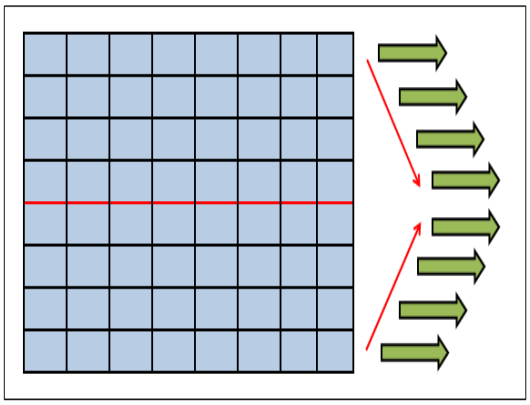


Figure 11-25 Top: top to center / Bottom: bottom to center

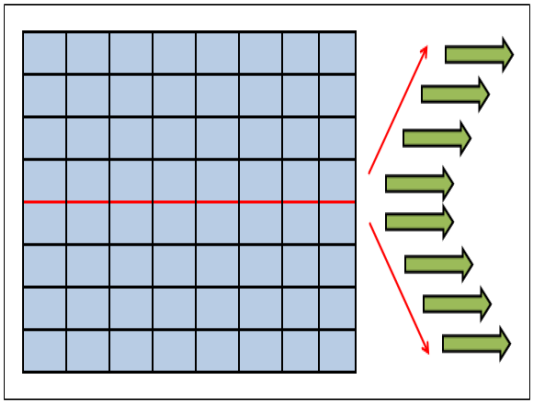


Figure 11-26 Top: center to top / Bottom: center to bottom

11-3-2 ABOUT READOUT AT LIGHTSHEET READOUT MODE

(1) Readout methods

This mode can set Normal readout, Binning readout, and Sub-array readout.
In sub-array mode, the position of sub-array readout can be set independently in the top and bottom half areas.
The size and the position of the sub-array readout area can be configured according to the table below.

Size		Position	
Horizontal	Vertical	Horizontal	Vertical
128 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.

Note

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

(2) Readout speed (Scan speed)

This mode can set Standard scan and Slow scan.

(3) Camera operation modes

This mode can use; Free running mode, External trigger mode (Edge trigger mode, Global reset Edge trigger mode , Level trigger mode, Global reset Level trigger mode, Synchronous readout mode), and Start trigger mode.

11-3-3 FRAME RATE CALCULATION

(1) Standard scan: Camera Link

Vn = Number of vertical line
Exp1 = 1.004 ms to 2 s (input in units of seconds to the calculation formula)
1H = 9.744 36 µs

Operation modes	Calculation formula	Horizontal	Vertical	Frame rate (fps)
Free running mode	1/(Vn×1H)	2048	1024	100
			512	200
			256	400
			128	801
			64	1603
			32	3206
			4	25 655
External trigger mode (Edge trigger / Level trigger)	1/(Vn×1H+Exp1+10×1H)	2048	1024	90
			512	164
			256	278
			128	425
			64	579
			32	707
			4	877
External trigger mode (Synchronous readout trigger)	1/(Vn×1H+5×1H)	2048	1024	99
			512	198
			256	393
			128	771
			64	1487
			32	2773
			4	11 402

Note

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

Note

- The calculation formula and the frame rate value do not depend on the bit depth of digital output.

(2) Standard scan: USB 3.0

Hn = Number of horizontal pixel
Vn = Number of vertical line
Exp1= 1.004 ms to 2 s (input in units of seconds to the calculation formula)
1H = 9.744 36 µs
round () = Round down to integer
roundup() = Round up to integer

1. 16 bit Digital output

Operation modes	Binning	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Hn>512 Vn≥8	1/(round(Vn/1024/40/1H) ×1H)	2048 × 1024	40
				2048 × 256	160
				2048 × 32	1282
		Hn>512 Vn≤4	1/(roundup(Vn/1024/40/1H) ×1H)	2048 × 4	9329
		Hn≤512 4≤Vn≤1024	1/(Vn×1H)	512 × 1024	100
				512 × 256	400
				512 × 4	25 655
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H)	1024 × 512	100
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H)	512 × 256	100
External trigger mode (Edge trigger / Level trigger)	1×1	Hn>512 Vn≥76	1/(round(Vn/1024/40/1H) ×1H)	2048 × 1024	40
				2048 × 256	160
		Hn>512 Vn≤72	1/(Vn×1H+Exp1+10×1H)	2048 × 32	707
				2048 × 4	877
		Hn≤512 4≤Vn≤1024	1/(Vn×1H+Exp1+10×1H)	512 × 1024	90
				512 × 256	278
				512 × 4	877
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H+Exp1+10×1H)	1024 × 512	90
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H+Exp1+10×1H)	512 × 256	90
External trigger mode (Synchronous readout trigger)	1×1	Hn>512 Vn≥8	1/(round(Vn/1024/40/1H) ×1H)	2048 × 1024	40
				2048 × 256	160
				2048 × 32	1282
		Hn>512 Vn≤4	1/(roundup(Vn/1024/40/1H) ×1H)	2048 × 4	9329
		Hn≤512 4≤Vn≤1024	1/(Vn×1H+5×1H)	512 × 1024	99
				512 × 256	393
				512 × 4	11 402
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H+5×1H)	1024 × 512	99
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H+5×1H)	512 × 256	99

2. 12 bit Digital output

Operation modes	Binning	Horizontal Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Hn>512 Vn≥8	1/(round(Vn/1024/53/1H) ×1H)	2048 × 1024	53
				2048 × 256	212
				2048 × 32	1710
		Hn>512 Vn≤4	1/(roundup(Vn/1024/53/1H) ×1H)	2048 × 4	12 827
		Hn≤512 4≤Vn≤1024	1/(Vn×1H)	512 × 1024	100
				512 × 256	400
				512 × 4	25 655
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H)	1024 × 512	100
	4×4	32≤Hn≤512 1≤Vn≤ 256	1/(Vn×4×1H)	512 × 256	100
External trigger mode (Edge trigger / Level trigger)	1×1	Hn>512 Vn≥128	1/(round(Vn/1024/53/1H) ×1H)	2048 × 1024	53
				2048 × 256	212
		Hn>512 Vn≤124	1/(Vn×1H+Exp1+10×1H)	2048 × 32	707
				2048 × 4	877
		Hn≤512 4≤Vn≤1024		512 × 1024	90
				512 × 256	278
				512 × 4	877
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H+Exp1+10×1H)	1024 × 512	90
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H+Exp1+10×1H)	512 × 256	90
External trigger mode (Synchronous readout trigger)	1×1	Hn>512 Vn≥8	1/(round(Vn/1024/53/1H) ×1H)	2048 × 1024	53
				2048 × 256	212
				2048 × 32	1710
		Hn>512 Vn≤4	1/(Vn×1H+5×1H)	2048 × 4	11 402
		Hn≤512 4≤Vn≤1024		512 × 1024	99
				512 × 256	393
				512 × 4	11 402
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H+5×1H)	1024 × 512	99
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H+5×1H)	512 × 256	99

3. 8 bit Digital output

Operation modes	Binning	Horizontal Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
Free running mode	1×1	Hn>512 Vn≥8	1/(round(Vn/1024/80/1H) ×1H)	2048 × 1024	80
				2048 × 256	320
				2048 × 32	2565
		Hn>512 Vn≤4	1/(roundup(Vn/1024/80/1H) ×1H)	2048 × 4	17 103
		Hn≤512 4≤Vn≤1024	1/(Vn×1H)	512 × 1024	100
				512 × 256	400
				512 × 4	25 655
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H)	1024 × 512	100
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H)	512 × 256	100
External trigger mode (Edge trigger / Level trigger)	1×1	Hn>512 Vn≥456	1/(round(Vn/1024/80/1H) ×1H)	2048 × 1024	80
		Hn>512 Vn≤452	1/(Vn×1H+Exp1+10×1H)	2048 × 256	278
				2048 × 32	707
				2048 × 4	877
		Hn≤512 4≤Vn≤1024		512 × 1024	90
				512 × 256	278
				512 × 4	877
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H+Exp1+10×1H)	1024 × 512	90
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H+Exp1+10×1H)	512 × 256	90
External trigger mode (Synchronous readout trigger)	1×1	Hn>512 Vn≥24	1/(round(Vn/1024/80/1H) ×1H)	2048 × 1024	80
				2048 × 256	320
				2048 × 32	2565
		Hn>512 Vn≤20	1/(Vn×1H+5×1H)	2048 × 4	11 402
		Hn≤512 4≤Vn≤1024		512 × 1024	99
				512 × 256	393
				512 × 4	11 402
	2×2	64≤Hn≤1024 2≤Vn≤512	1/(Vn×2×1H+5×1H)	1024 × 512	99
	4×4	32≤Hn≤512 1≤Vn≤256	1/(Vn×4×1H+5×1H)	512 × 256	99

Note

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

(3) Slow scan: Camera Link, USB 3.0 (Common to two interfaces)

Vn = Number of vertical line
Exp1 = 3.021 ms to 6 s (input in units of seconds to the calculation formula)
1H = 32.4812 µs

Operation modes	Calculation formula	Horizontal	Vertical	Frame rate (fps)
Free running mode	1/(Vn×1H)	2048	1024	30
			512	60
			256	120
			128	240
			64	481
			32	962
			4	7696
External trigger mode (Edge trigger / Level trigger)	1/(Vn×1H+Exp1+10×1H)	2048	1024	27
			512	50
			256	85
			128	133
			64	184
			32	228
			4	287
External trigger mode (Synchronous readout trigger)	1/(Vn×1H+5×1H)	2048	1024	29
			512	59
			256	117
			128	231
			64	446
			32	832
			4	3420

Note

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

Note

- The calculation formula and the frame rate value do not depend on the bit depth of digital output.

11-3-4 CONFIGURING EXPOSURE TIME

The exposure time can be set independently for the top and bottom half areas. The exposure time setting can be done by the units of 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) Standard scan

Exp1 = 1 ms to 2 s (38.96 µs to 2 s with sub-array setting) (input in units of seconds to the calculation formula)
Exp2 = Exp1÷9.744 36 µs (round up to integer) (input in units of seconds to the calculation formula)

Calculation formula	9.744 36 µs × Exp2

(2) Slow scan

Exp1 = 3 ms to 6 s (129.99 µs to 6 s with sub-array setting) (input in units of seconds to the calculation formula)
Exp2 = Exp1÷32.4812 µs (round up to integer) (input in units of seconds to the calculation formula)

Calculation formula	32.4812 µs × Exp2

Available setting range of the exposure time is the following.

Operation modes	Setting range	
	Standard scan	Slow scan
Free running mode	1 ms to 2 s	3 ms to 6 s
Free running mode (at Sub-array)	38.96 µs* to 2 s --- The same exposure time is set for the top and bottom half areas when the exposure time is 1 ms or shorter.	129.99 µs* to 6 s --- The same exposure time is set for the top and bottom half areas when the exposure time is 3 ms or shorter.
External trigger mode (The exposure time can be set independently for the top and bottom half areas with Edge trigger mode or start trigger mode.)	1 ms to 2 s	3 ms to 6 s

* 38.96 µs (Standard scan) and 129.99 µs (Slow scan) is the minimum exposure time when sub-array is set to vertical 4 lines. The minimum exposure time vary depend on vertical line number of sub-array setting.

11-3-5 TIMING DIAGRAM

The timing diagram in W-VIEW Mode is shown below.
When different exposure time is set for the top and bottom half areas, the end of exposure timing becomes the same.

(1) Free running mode

Electrical shutter mode works for the half area whose exposure time is shorter than the other half area exposure in W-VIEW Mode. When the exposure time for the both half areas are shorter than the frame readout time, electrical shutter mode works for the both half areas.

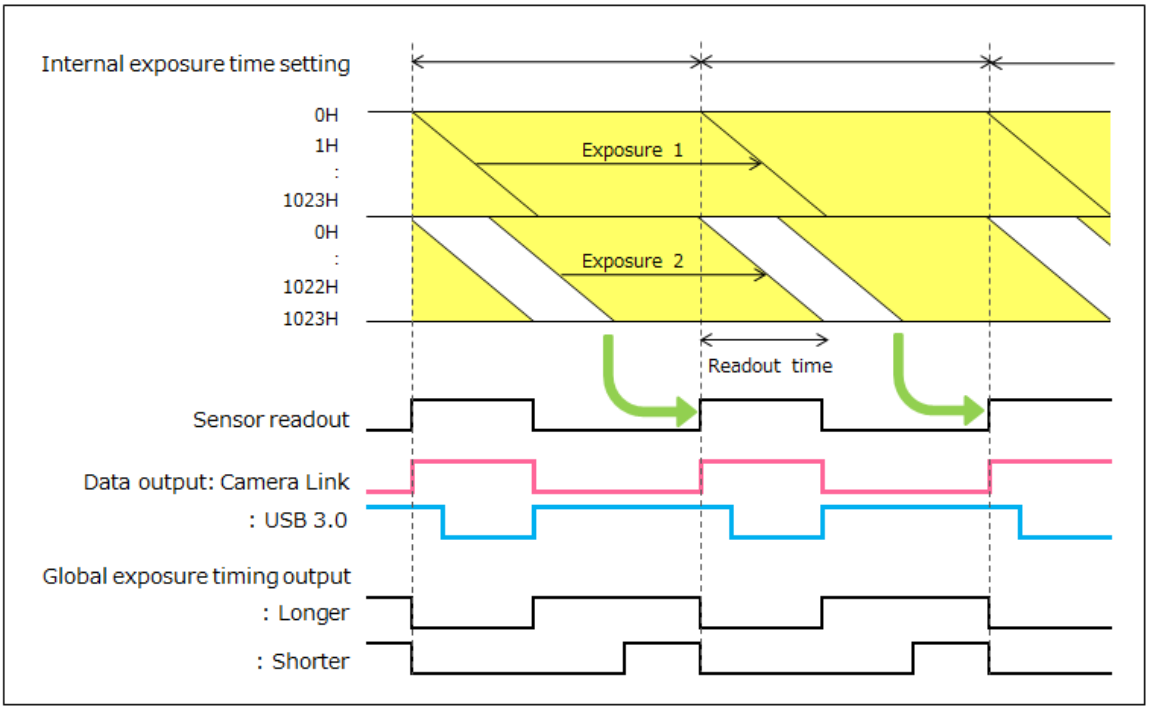


Figure 11-27 (Ex. Top: top to center / Bottom: center to bottom)

Note

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

(2) External trigger mode, Start trigger mode

The exposure time can be set independently for the top and bottom half areas with Edge trigger mode, Global reset Edge trigger mode and start trigger mode in W-VIEW Mode. The exposure time for both half areas is the same with Level trigger mode, Global reset Level trigger mode and Synchronous readout trigger mode.

Note

- The each timing diagram of Level trigger mode, Global reset Level trigger mode and Synchronous readout trigger mode is as same as with the each timing diagram of Normal Area Mode. Refer to 11-1-6-2 “External trigger mode” and 11-1-6-3 “Start trigger mode”.

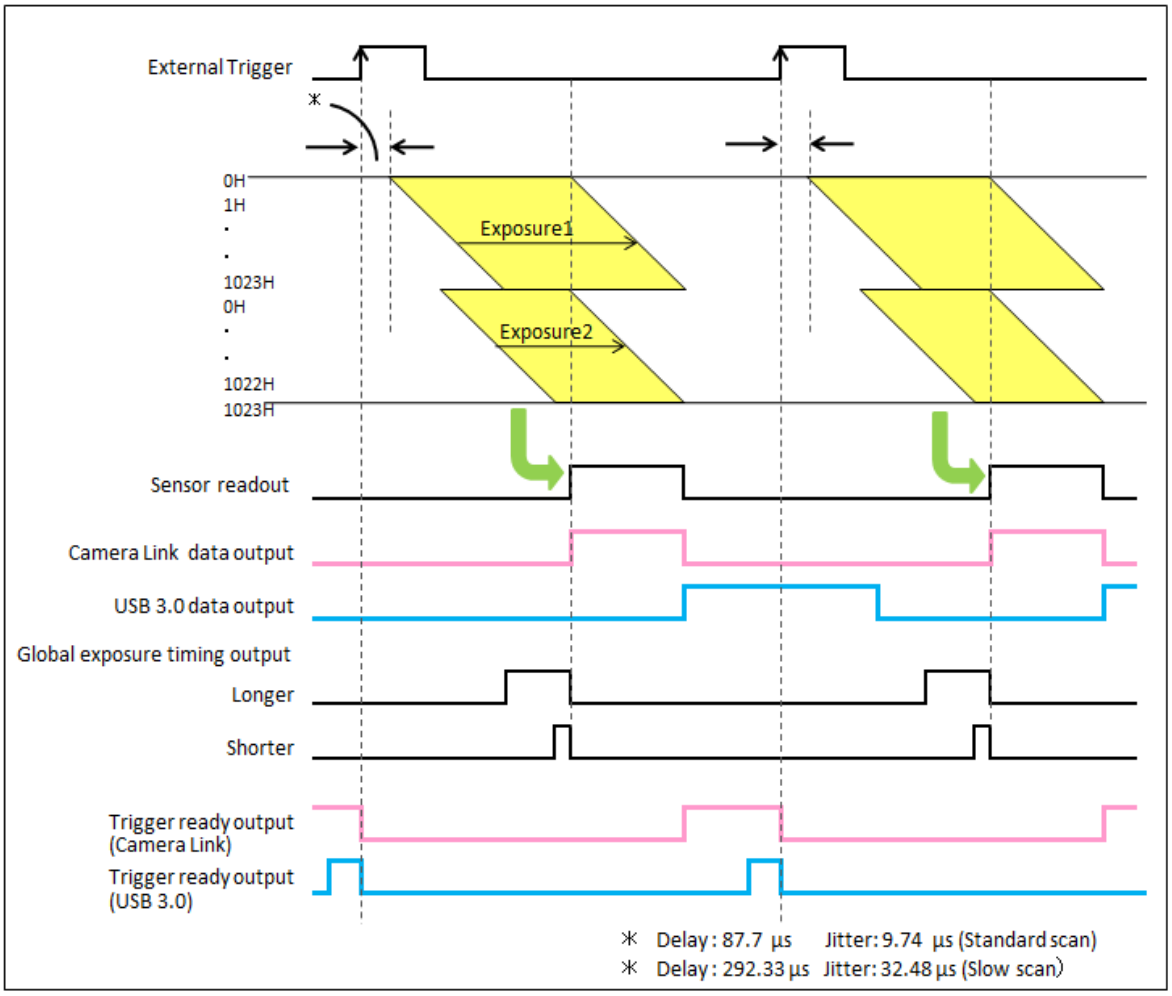


Figure 11-28 Edge trigger mode (Ex. Top: top to center / Bottom: center to bottom)

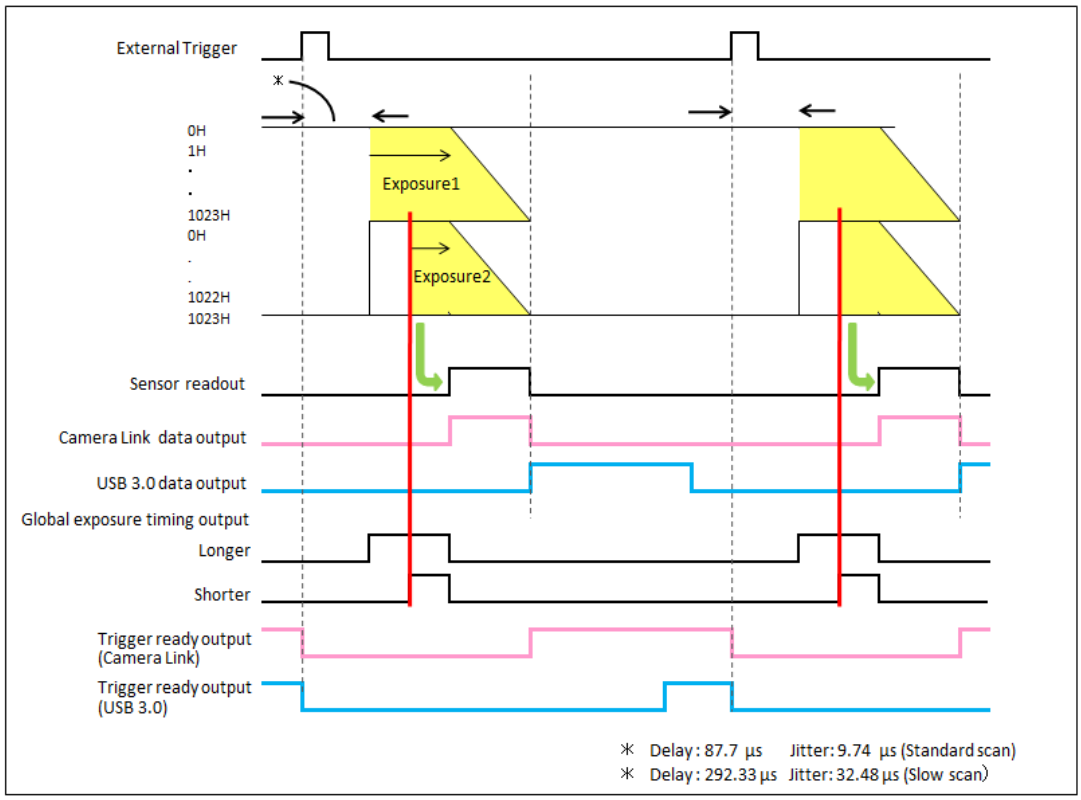


Figure 11-29 Global reset Edge trigger mode (Ex. Top: top to center / Bottom: center to bottom)

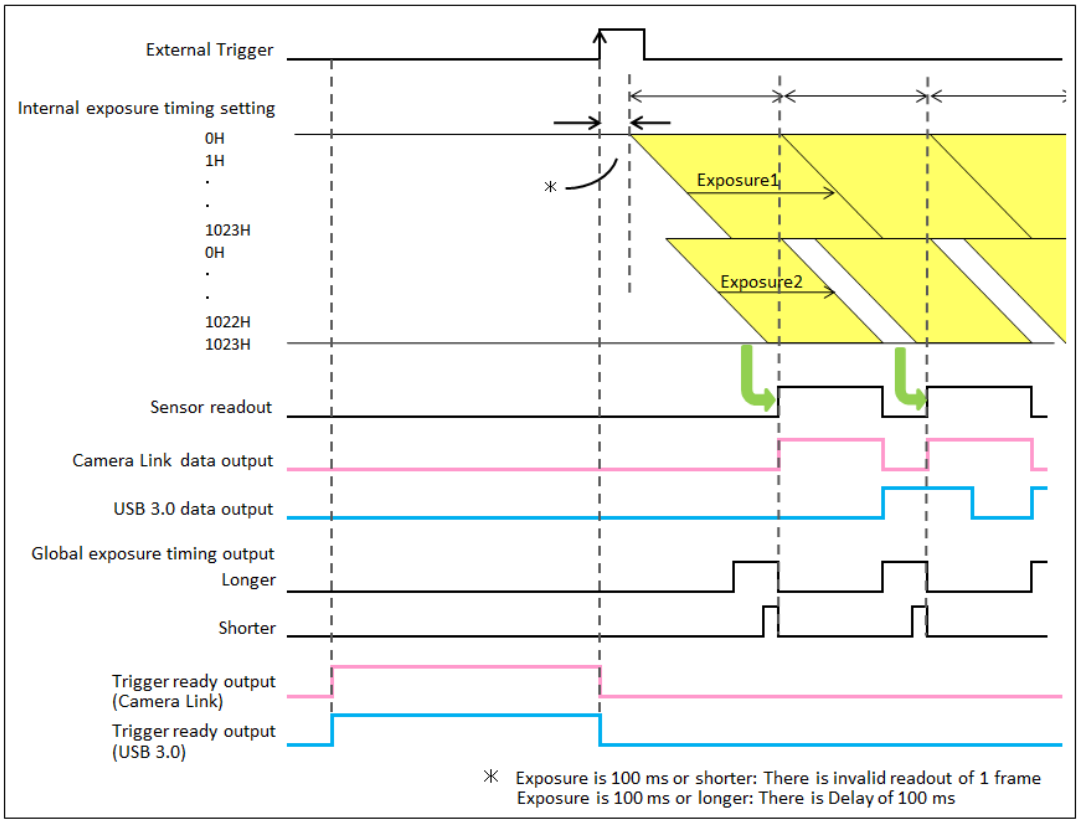


Figure 11-30 Start trigger mode (Ex. Top: top to center / Bottom: center to bottom)

Note

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

11-3-6 TRIGGER OUTPUT

The camera provides a range of trigger output signals with W-VIEW Mode. It is possible to output a pulse that shows the period where all lines in the top or bottom half area expose at the same time.

(1) Global exposure timing output

It shows the global exposure timing where all lines in the top or bottom half area expose at the same time. In W-VIEW Mode, there are two kinds of global exposure timing output for the longer and the shorter exposure time. This output can set either global exposure timing output for the longer or shorter exposure time.

Note

- There is no output signal when the exposure time for the both top and bottom half area is shorter than the frame readout time.

(2) 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 pulsewidth is output after the preset delay from the end of the sensor readout.
Vsync	The signal with the preset pulsewidth is output after the preset delay from the start of the sensor readout.
Input trigger signal	The signal with the preset pulsewidth is output after the preset delay from the input trigger signal.

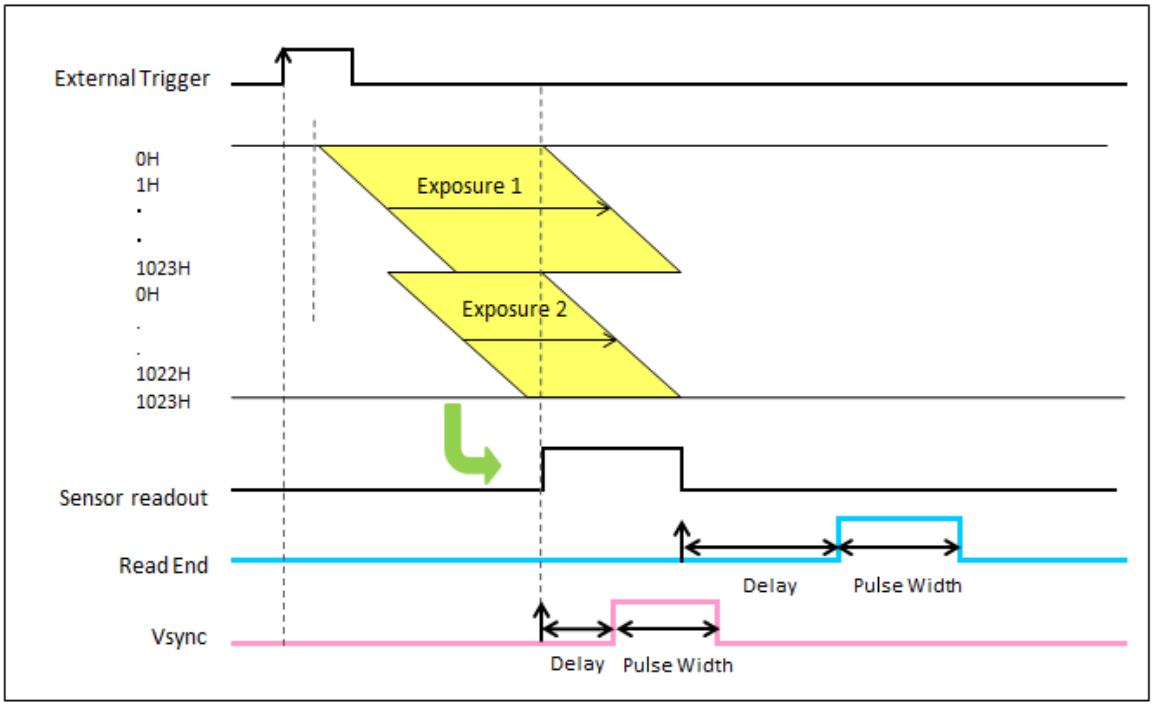


Figure 11-31 Programmable timing output

11-4 DUAL LIGHTSHEET READOUT MODE

Dual 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.
Dual Lightsheet Readout Mode can achieve 2 time faster frame rate than that of Lightsheet Readout Mode. The position of sub-array readout can be set for the top half area and the bottom half area independently in Dual Lightsheet Readout Mode.

11-4-1 READOUT DIRECTION

The readout direction can be set for the top half area and the bottom half area independently in Dual Lightsheet Readout Mode. (Figure 11-32, 33, 34, 35)

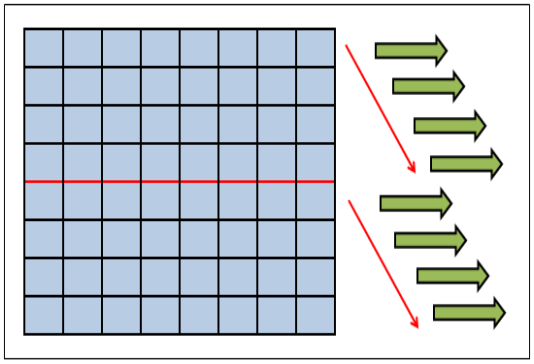


Figure 11-32 Top: top to center
/ Bottom: center to bottom

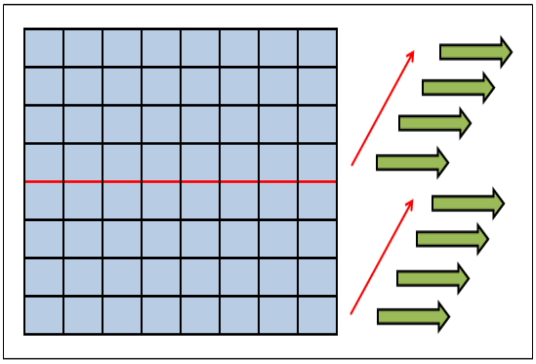


Figure 11-33 Top: center to top
/ Bottom: bottom to center

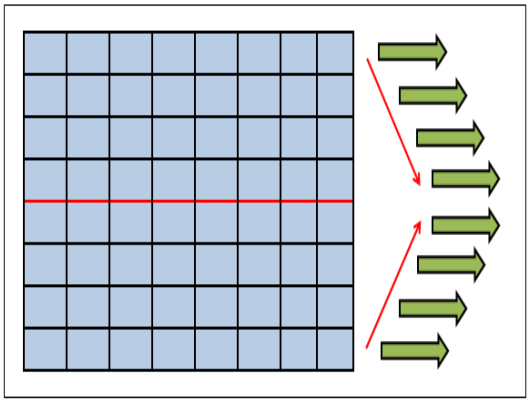


Figure 11-34 Top: top to center
/ Bottom: bottom to center

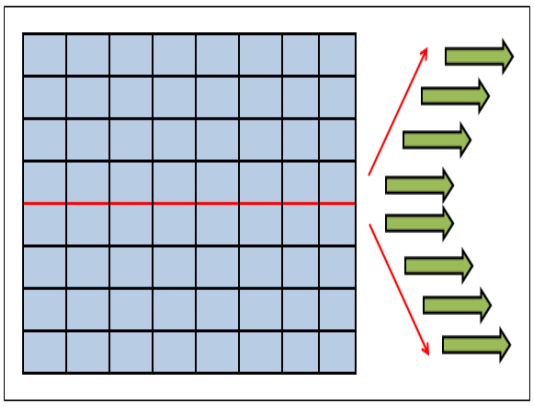


Figure 11-35 Top: center to top
/ Bottom: center to bottom

11-4-2 ABOUT READOUT AT DUAL LIGHTSHEET READOUT MODE

(1) Readout methods

This mode can set Normal readout and Sub-array readout.
Binning readout mode is not supported at Dual 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
128 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.

(2) Camera operation modes

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

11-4-3 FRAME RATE CALCULATION

The frame rate calculation and the value of frame rate are common to all camera operation modes (Free running mode / External trigger mode (Edge trigger) / Start trigger mode).

(1) Camera Link

Vn = Number of vertical line
Exp1 = 9.744 36 µs to 10 s (input in units of seconds to the calculation formula)
1H = 9.744 36 µs to 100 ms

Operation modes	Calculation formula	Horizontal	Vertical	Frame rate (fps)
Common to all modes (Free running mode / External trigger mode (Edge trigger) / Start trigger mode)	1/(Exp1+(Vn+10)×1H)	2048	1024	99
			512	196
			256	384
			128	738
			64	1368
			32	2368
			4	6841

(2) USB 3.0

Hn = Number of horizontal pixel
Vn = Number of vertical line
Exp1= 9.744 36 µs to 10 s (input in units of seconds to the calculation formula)
1H = 9.744 36 µs to 100 ms
round () = Round down to integer
roundup() = Round up to integer

1. 16 bit Digital output

Readout	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
1×1	Hn>512 Vn≥8	1/(round(Vn/1024/40/1H) ×1H)	2048 × 1024	40
			2048 × 256	160
			2048 × 32	1282
	Hn>512 Vn≤4	1/(Exp1+(Vn+10)×1H)	2048 × 4	6841
	Hn≤512 4≤Vn≤1024	1/(Exp1+(Vn+10)×1H)	512 × 1024	99
			512 × 256	384

2. 12 bit Digital output

Readout	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
1×1	Hn>512 Vn≥16	1/(round(Vn/1024/53/1H)×1H)	2048 × 1024	53
			2048 × 256	212
			2048 × 32	1710
	Hn>512 Vn≤12	1/(Exp1+(Vn+10)×1H)	2048 × 4	6841
	Hn≤512 4≤Vn≤1024	1/(Exp1+(Vn+10)×1H)	512 × 1024	99
			512 × 256	384

3. 8 bit Digital output

Readout	Horizontal / Vertical	Calculation formula	Hn × Vn	Frame rate (fps)
1×1	Hn>512 Vn≥48	1/(round(Vn/1024/80/1H)×1H)	2048 × 1024	80
			2048 × 256	320
			2048 × 32	2386
	Hn>512 Vn≤44	1/(Exp1+(Vn+10)×1H)	2048 × 4	6841
	Hn≤512 4≤Vn≤1024	1/(Exp1+(Vn+10)×1H)	512 × 1024	99
			512 × 256	384

11-4-4 READOUT TIME OF THE HORIZONTAL LINE

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

Vn = Number of vertical line
1H = 9.744 36 µs to 100 ms

Readout time = Vn × 1H

The range of exposure time with Lightsheet Readout Mode is as shown below.
The maximum exposure time can be decided according to the readout time of a frame, which is longer than 10 s or not.

1H to (Vn × 1H) : when (Vn × 1H) < 10 s
1H to 10 s : when (Vn × 1H) ≥ 10 s

11-4-5 TIMING DIAGRAM

(1) Free running mode

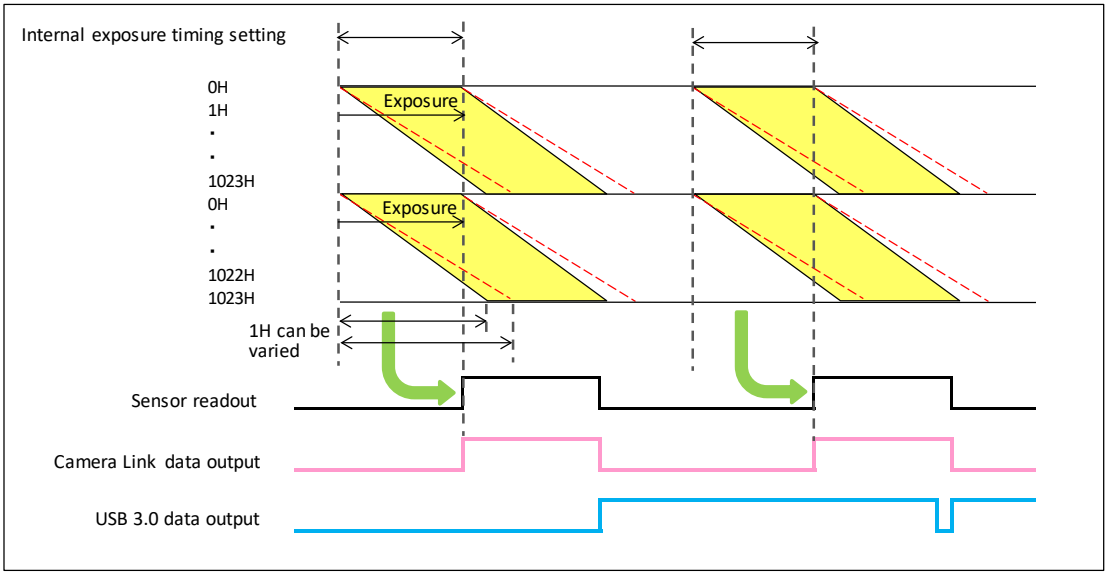


Figure 11-36 (Ex. Top: top to center / Bottom: center to bottom)

(2) Edge trigger mode

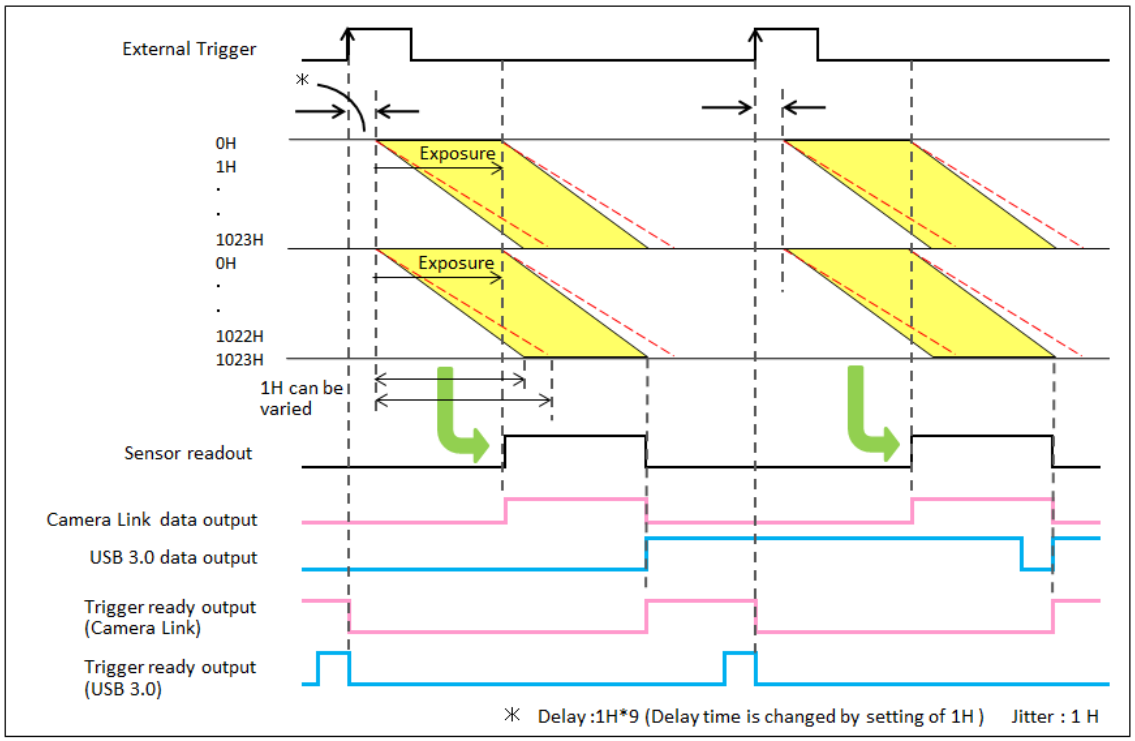


Figure 11-37 (Ex. rising edge, Top: top to center / Bottom: center to bottom)

(3) Start trigger mode

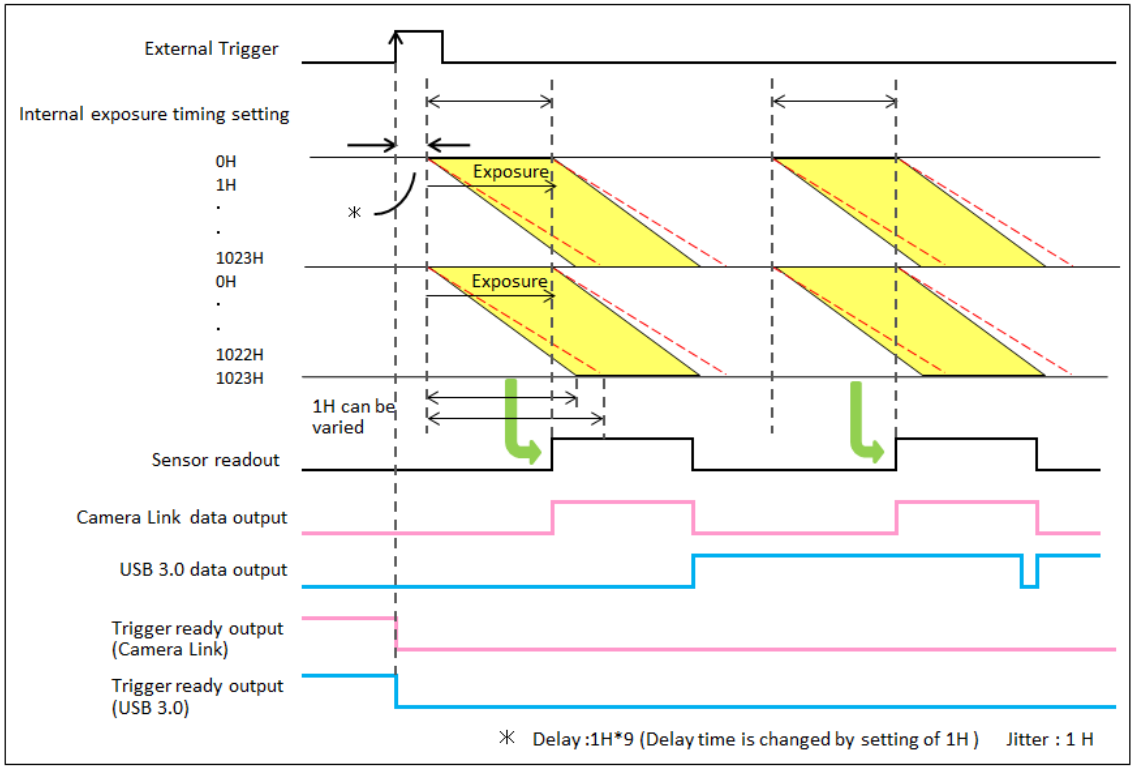


Figure 11-38 (Ex. rising edge, Top: top to center / Bottom: center to bottom)

11-4-6 TRIGGER OUTPUT

The camera provides a range of trigger output signals with Dual Lightsheet Readout Mode. The global exposure timing output is not provided, because there is no timing where all lines expose at the same time with Dual Lightsheet Readout Mode.
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) and Vsync for programmable timing output. In addition that, it is also possible to program an optional pulse width and an optional delay time to Hsync for programmable timing output with Dual Lightsheet Readout Mode.

(1) 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 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 pulsewidth is output after the preset delay from the end of the sensor readout.
Vsync	The signal with the preset pulsewidth is output after the preset delay from the start of the sensor readout.
Hsync	The signal with the preset pulsewidth is output after the preset delay from the horizontal synchronized signal in the camera.

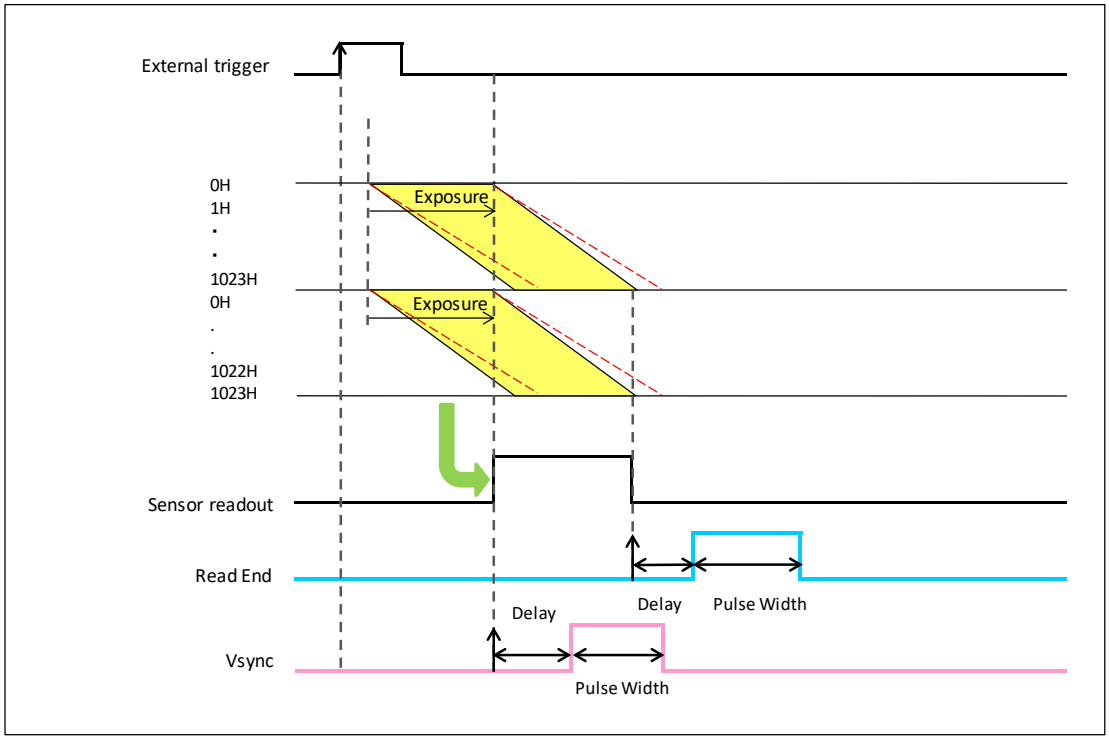


Figure 11-39 Programmable timing output (Top: top to center / Bottom: center to bottom)

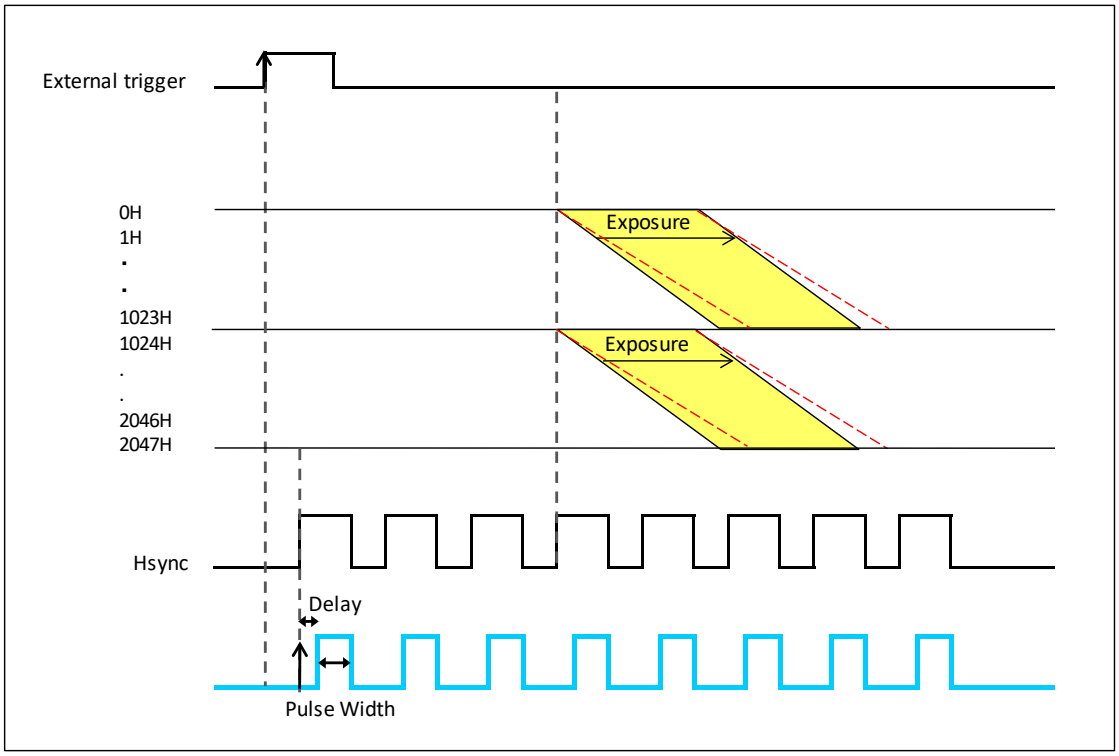


Figure 11-40 Programmable timing output referenced with Hsync (Top: top to center / Bottom: center to bottom)

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.

11-5 REAL-TIME DEFECT PIXEL CORRECTION

There are a few pixels in CMOS image sensor that have slightly higher readout noise performance compared to surrounding pixels. And the extended exposures may cause a few white spots which is caused by failure in part of the silicon wafer in CMOS image sensor. The camera has real-time variant 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 the exposure time.

Correction Level for white spots	Exposure time	Ratio of the number of pixels to be corrected to the number of all pixels
High	In case of 1 second or longer exposure time	Approximately 0.1 %
Medium (Default)	In case of 1 second or shorter exposure time	Approximately 0.05 %
Low	In case of 10 ms (default) or shorter exposure time	Less than 0.001 %

11-6 DATA REDUCTION FUNCTIONS

The camera provides 4.0 megapixels resolution at 100 fps and 16 bit of gradation.
Then the camera outputs 800 MB of data per second, and large capacity of storage device would be necessary to store such a large amount of data.
The camera has data reduction functions that required data only outputs.

11-6-1 DATA EXTRACTION

Data extraction is a function to reduce the amount of data by compressing data of unrequired area. User can specify the required area in units of 4 x4 pixels using camera driver software “DCAM-API”. The “DCAM-API” reconstructs the original image from the output data.
The data extraction process is performed in real-time without sacrificing the readout speed at all.
The extracted area size should be less than 3/4 of original image size.
In the case of sub-array readout mode, the vertical sub-array size should be more than 128 lines for Normal Area Mode and Lightsheet Readout Mode, the vertical sub-array size should be more than 64 lines for W-VIEW Mode and Dual Lightsheet Readout Mode.

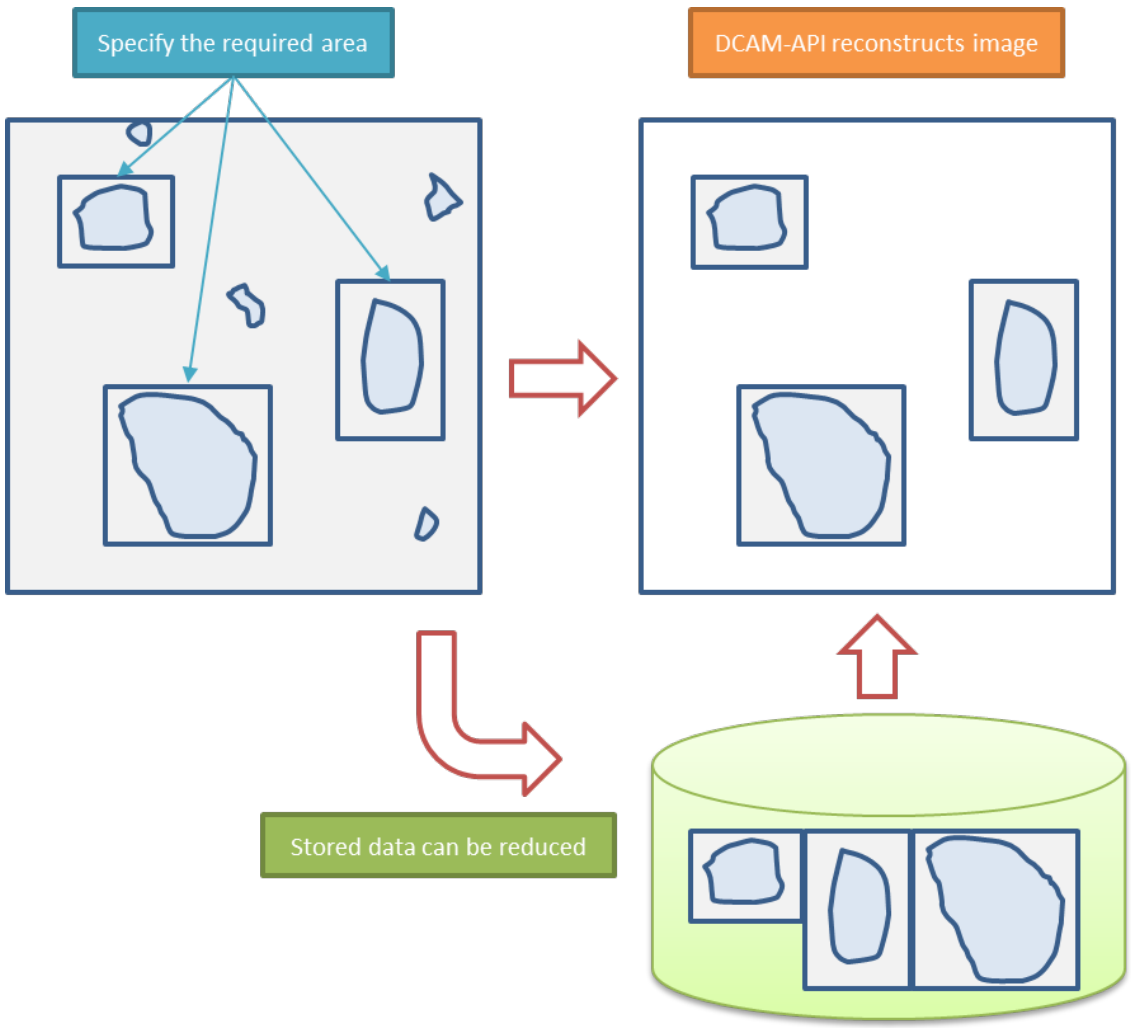


Figure 11-41

11-6-2 12 BIT / 8 BIT DIGITAL OUTPUT

The amount of data can be reduced by 12 bit or 8 bit digital output. The amount of data can be three quarters of original 16 bit data and each pixel have 4096 steps of gradation with 12 bit digital output. And, with 8 bit digital output, the amount of data can be the half of original 16 bit data and each pixel have 256 steps of gradation. When you use USB 3.0 interface, the frame rate can be faster with 12 bit and 8 bit digital output.
The steps of gradation for each pixel would be reduced with 12 bit and 8 bit digital output. However, the look up table function can minimize the lack of gradation by choosing required range of intensity level. User can specify the range of intensity level for the look up table by 16 bit value.
Data extraction can work when the digital output is 16 bit.

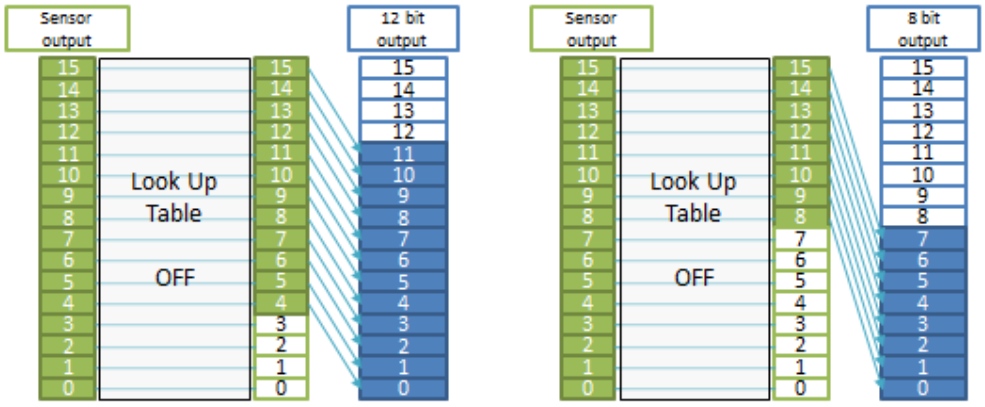


Figure 11-42 LUT OFF

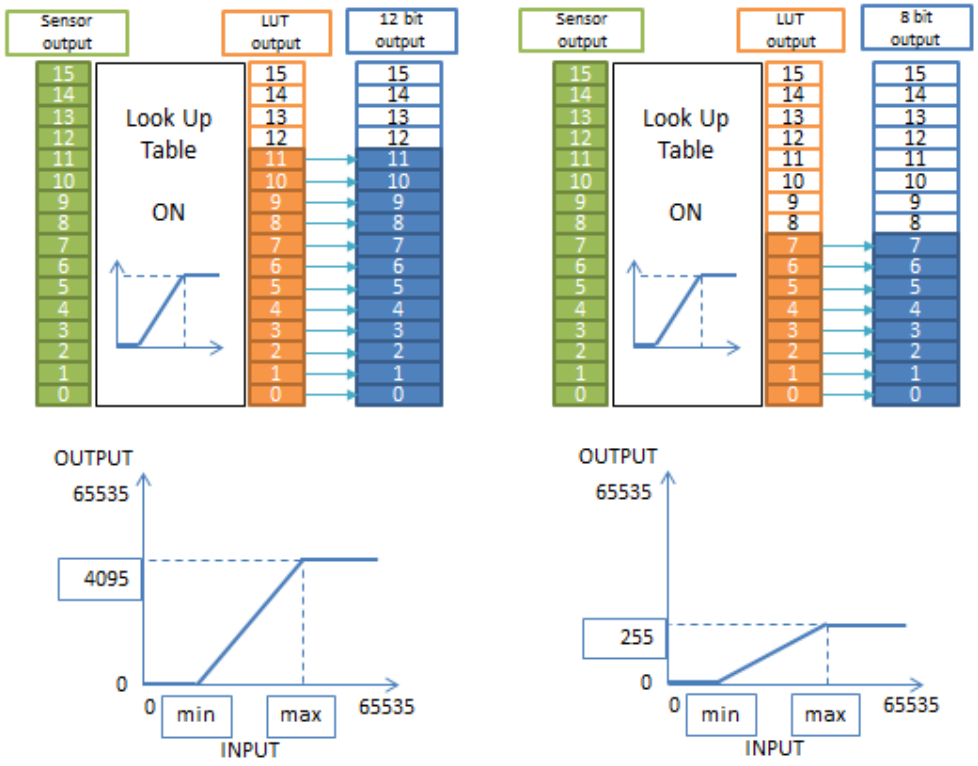


Figure 11-43 LUT ON

Note

- Refer to 11-1-4 Normal Area Mode “FRAME RATE CALCULATION”, 11-2-3 Lightsheet Readout Mode “FRAME RATE CALCULATION”, 11-3-3 W-VIEW Mode “FRAME RATE CALCULATION” or 11-4-3 Dual Lightsheet Readout Mode “FRAME RATE CALCULATION” about the frame rate when you use USB 3.0 interface.

11-7 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 10 µs to 10 s, and the step is 1 µs for the master pulse.

11-7-1 OPERATION MODE

(1) Free running mode

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

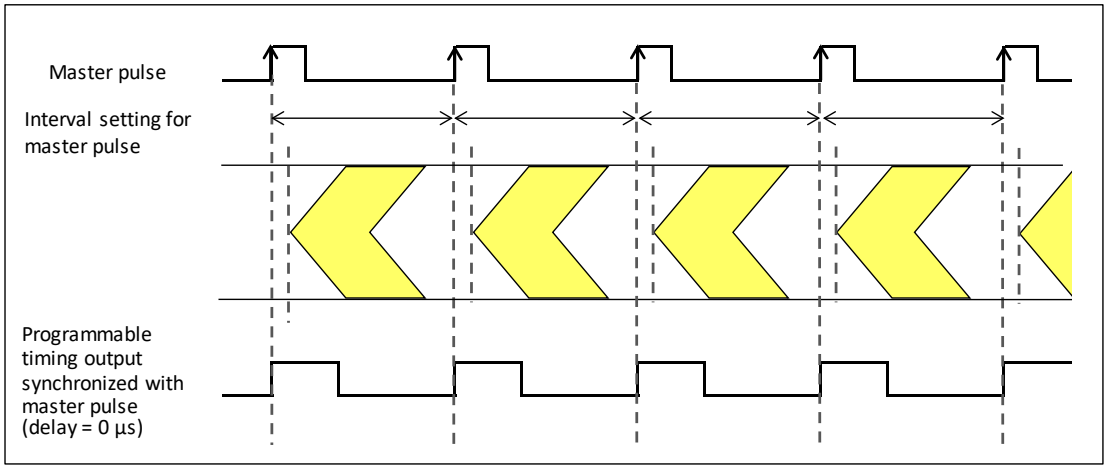


Figure 11-44 (Camera: Normal area, Edge trigger mode)

(2) Start trigger mode

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

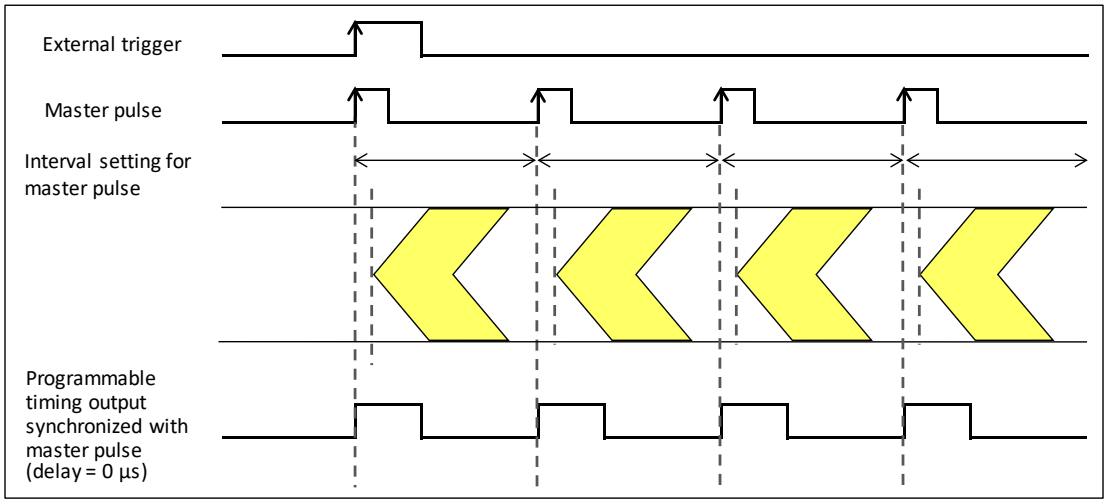


Figure 11-45 (Camera: Normal area, Edge trigger mode)

(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.

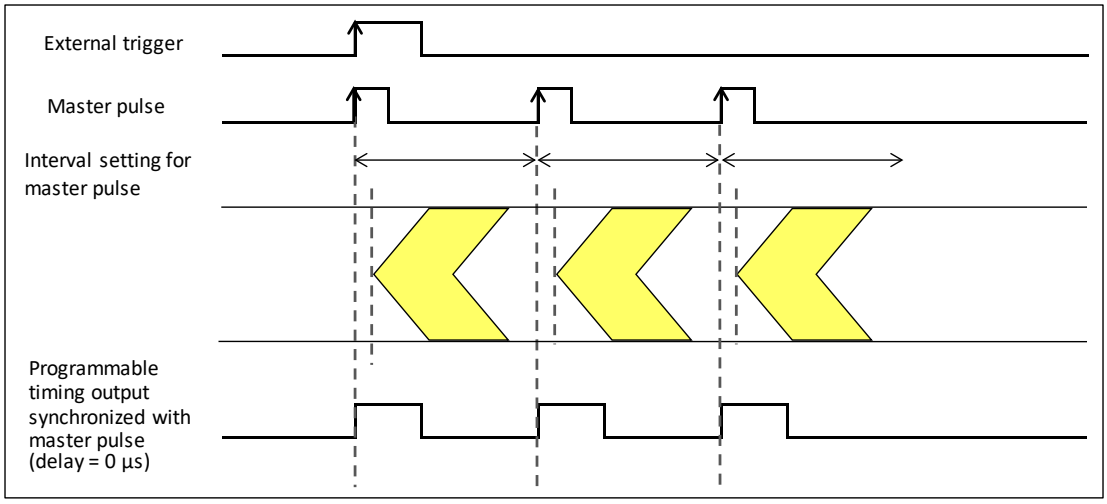


Figure 11-46 (Camera: Normal area, Edge trigger mode) (The number of pulses is specified as 3)

12. MAINTENANCE

12-1 CARE

Perform cleaning of this equipment 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 cause 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.

12-2-1 WHEN USING COOLING WATER OTHER THAN RECOMMENDED

Note

[Pure water]

- Pure water is not appropriate for cooling water. There is possibility that pure water absorb 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	7

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 appear	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

		Camera Link interface	USB 3.0 interface
Imaging device		Scientific CMOS image sensor	
Effective number of pixels		2048 (H) × 2048 (V)	
Cell size		6.5 µm (H) × 6.5 µm (V)	
Effective area		13.312 mm (H) × 13.312 mm (V)	
Full well capacity*1		30 000 electrons	
Cooling method		Peltier device + Forced air-cooled, Water-cooled	
Cooling temperature	at Forced air-cooled	- 10 °C (Ambient temperature: + 20 ºC)	
	at Water-cooled	- 10 °C (Water temperature: + 20 ºC)	
	at Maximum cooling	- 30 °C *1 (at Water-cooled; Water temp. 15 °C, Ambient temp. 20 °C)	
Readout time (at Full resolution)	Standard scan	10 ms	
	Slow scan	33 ms	
Readout noise*1	Standard scan	1.0 electrons (median), 1.6 electrons (r.m.s.)	
	Slow scan	0.8 electrons (median), 1.4 electrons (r.m.s.)	
Dark current *1	at - 10 °C	0.06 electrons/pixel/s	
	at - 30 °C	0.006 electrons/pixel/s	
Dynamic range *2		37 000 : 1	
Dark Signal Non-Uniformity (DSNU) *1		0.3 electrons r.m.s.	
Photo Response Non-Uniformity *1	15000 electrons	0.06 % r.m.s.	
	700 electrons	0.3 % r.m.s.	
Linearity error, low light range *1	EMVA 1288 standard	0.5 %	
	< 500 electrons signal	0.2 % / Less than approx. 1 electron absolute error	
Conversion factor *1		0.46 electrons / count	
Dark offset		100 counts (at Normal readout)	
Frame rate			
at Full resolution	Standard scan	100 fps	40 fps (16 bit) 53 fps (12 bit) 80 fps (8 bit)
	Slow scan	30 fps	30 fps
at 1024 lines at center position	Standard scan	200 fps	80 fps (16 bit) 106 fps (12 bit) 160 fps (8 bit)
	Slow scan	60 fps	60 fps
at 8 lines at center position	Standard scan	25 655 fps	9329 fps (16 bit) 12 827 fps (12 bit) 17 103 fps (8 bit)
	Slow scan	7696 fps	7696 fps
at Horizontal 512 pixels at 8 lines at center position	Standard scan	—	25 655 fps
	Slow scan	—	7696 fps

<table>
<tr><td colspan="3"></td><td>Camera Link interface</td><td>USB 3.0 interface</td></tr>
<tr><td colspan="3" rowspan="2">Readout mode</td><td colspan="2">Binning readout mode 2×2,4×4 (Digital binning) *3</td></tr>
<tr><td>Sub-array readout mode
(Configurable for each vertical 4 pixels and horizontal 128 pixels.)</td><td>Sub-array readout mode
(Configurable for each vertical 4 pixels and horizontal 128 pixels.)</td></tr>
<tr><td rowspan="3">Lightsheet Readout Mode</td><td>Readout time</td><td colspan="2">20 ms to 204.8 s</td></tr>
<tr><td>Readout mode</td><td colspan="2">Full/Sub-array
(Configurable for each vertical 4 pixels and horizontal 128 pixels.)</td></tr>
<tr><td>Readout direction</td><td colspan="2">Top to bottom readout / Bottom to top readout</td></tr>
<tr><td rowspan="3">W-VIEW mode</td><td rowspan="2">Readout mode</td><td colspan="2">Binning readout mode 2×2,4×4 (Digital binning) *3</td></tr>
<tr><td colspan="2">Sub-array readout mode
(Configurable for each vertical 4 pixels and horizontal 128 pixels, the position can be set independently for top and bottom area.)</td></tr>
<tr><td>Readout direction</td><td colspan="2">Top to bottom readout / Bottom to top readout
(The direction can be set independently for top and bottom area.)</td></tr>
<tr><td rowspan="3">Dual Lightsheet Readout Mode</td><td>Readout time</td><td colspan="2">10 ms to 102.4 s</td></tr>
<tr><td>Readout mode</td><td colspan="2">Full/Sub-array
(Configurable for each vertical 4 pixels and horizontal 128 pixels, and the position can be set independently for top and bottom area.)</td></tr>
<tr><td>Readout direction</td><td colspan="2">Top to bottom readout / Bottom to top readout
(The direction can be set independently for top and bottom area.)</td></tr>
<tr><td colspan="4">Exposure time</td></tr>
<tr><td colspan="2" rowspan="2">Free running mode</td><td>Standard scan</td><td colspan="2">1 ms to 10 s</td></tr>
<tr><td>Slow scan</td><td colspan="2">3 ms to 10 s</td></tr>
<tr><td colspan="2" rowspan="2">Free running mode / Sub-array mode</td><td>Standard scan</td><td colspan="2">38.96 µs to 10 s</td></tr>
<tr><td>Slow scan</td><td colspan="2">129.99 µs to 10 s</td></tr>
<tr><td colspan="2" rowspan="2">External trigger mode</td><td>Standard scan</td><td colspan="2">1 ms to 10 s</td></tr>
<tr><td>Slow scan</td><td colspan="2">3 ms to 10 s</td></tr>
<tr><td colspan="2" rowspan="2">Free running mode / W-VIEW mode *5</td><td>Standard scan</td><td colspan="2">1 ms to 2 s</td></tr>
<tr><td>Slow scan</td><td colspan="2">3 ms to 6 s</td></tr>
<tr><td colspan="2" rowspan="2">Free running mode / Sub-array mode / W-VIEW mode *5</td><td>Standard scan</td><td colspan="2">38.96 µs to 2 s
(The same exposure time is set for top and bottom areas when the exposure time is 1ms or shorter.)</td></tr>
<tr><td>Slow scan</td><td colspan="2">129.99 µs to 6 s
(The same exposure time is set for top and bottom areas when the exposure time is 3ms or shorter.)</td></tr>
<tr><td colspan="2" rowspan="2">External trigger mode / W-VIEW mode *5</td><td>Standard scan</td><td colspan="2">1 ms to 2 s</td></tr>
<tr><td>Slow scan</td><td colspan="2">3 ms to 6 s</td></tr>
<tr><td colspan="3">Lightsheet Readout Mode</td><td colspan="2" rowspan="2">9.7 µs to 10 s
(The exposure time is the same for top and bottom area.)</td></tr>
<tr><td colspan="3">Dual Lightsheet Readout Mode</td></tr>
<tr><td rowspan="6">External trigger Function</td><td colspan="2">Normal area mode</td><td colspan="2">Edge trigger mode / Global reset Edge trigger mode / Level trigger mode / Global reset Level trigger mode / Synchronous readout trigger mode / Start trigger mode</td></tr>
<tr><td colspan="2">Lightsheet Readout Mode</td><td colspan="2">Edge trigger mode / Start trigger mode</td></tr>
<tr><td rowspan="4">W-VIEW mode</td><td colspan="2">Edge trigger mode / Global reset Edge trigger mode
(The exposure time can be set independently for top and bottom area.)</td></tr>
<tr><td colspan="2">Level trigger mode / Global reset Level trigger mode
(The exposure time is the same for top and bottom area.)</td></tr>
<tr><td colspan="2">Synchronous readout trigger mode
(The exposure time is the same for top and bottom area.)</td></tr>
<tr><td colspan="2">Start trigger mode
(The exposure time can be set independently for top and bottom area.)</td></tr>
<tr><td colspan="2">Dual Lightsheet Readout Mode</td><td colspan="2">Edge trigger mode / Start trigger mode</td></tr>
</table>

		Camera Link interface	USB 3.0 interface
External signal input		External input (SMA connector, Camera Link)	External input (SMA connector)
External trigger input level		3.3 V LVCMOS level	
External trigger delay function		0 µs to 10 s (1 µs step)	
External signal output		Global exposure timing output / Trigger ready output / Programmable timing output 1 / Programmable timing output 2 / Programmable timing output 3 (Continuous High or Low output)	
External trigger output level		3.3 V LVCMOS level	
Master pulse	Pulse mode	Free running / start trigger / burst	
	Pulse interval	10 µs to 10 s (1 µs step)	
Digital output		16 bit / 12 bit / 8 bit	
Image processing function		Real-time offset correction	
		Real-time gain correction	
		Real-time defect pixel correction (Off / Low / Medium / High)	
		Data extraction	
Interface		Camera Link Full configuration*4	USB 3.0 Super Speed*6
Lens mount		C-mount (C13440-20CU) / F-mount (C13440-20CU01)	

* 1 Typical value
* 2 Calculated from the ratio of the full well capacity and the readout noise.
* 3 Digital binning processing in the camera.
* 4 Original mode based on 80 bit mode.
* 5 The exposure time can be set independently for top and bottom area.
* 6 Equivalent to USB 3.2 Gen 1 (SuperSpeed USB 5 Gbps)

(2) Power supply specifications

a. Camera

Input power supply	DC 12 V
Typical output	---
Power consumption	55 W

b. 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	120 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

C13440-20CU	Dimensional outline	85 mm (W) × 93.5 mm (H) × 125 mm (D)
	Weight	Approx. 2.2 kg (Camera only)
C13440-20CU01	Dimensional outline	85 mm (W) × 93.5 mm (H) × 154.5 mm (D)
	Weight	Approx. 2.2 kg (Camera only)

- Be careful not to drop off the camera or not drop underfoot when making it move because it is approx. 2.2 kg.

Note

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

(5) Applicable standards

EMC	EN61326-1: 2013 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.

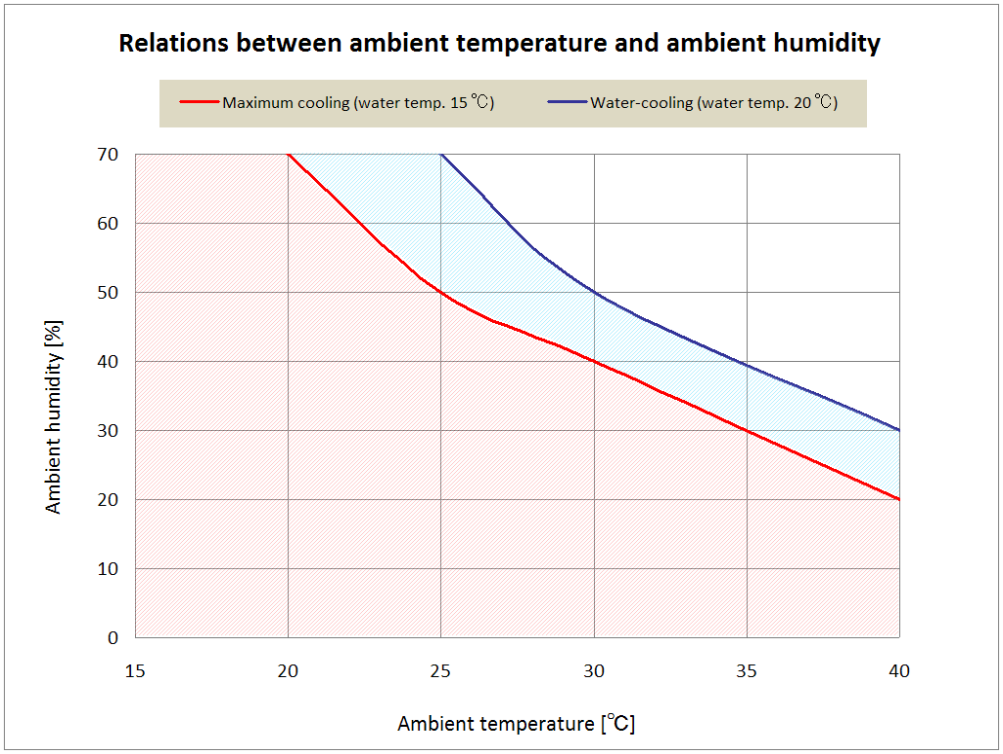


Figure 14-1

14-3 SPECTRAL RESPONSE CHARACTERISTICS (TYP.)

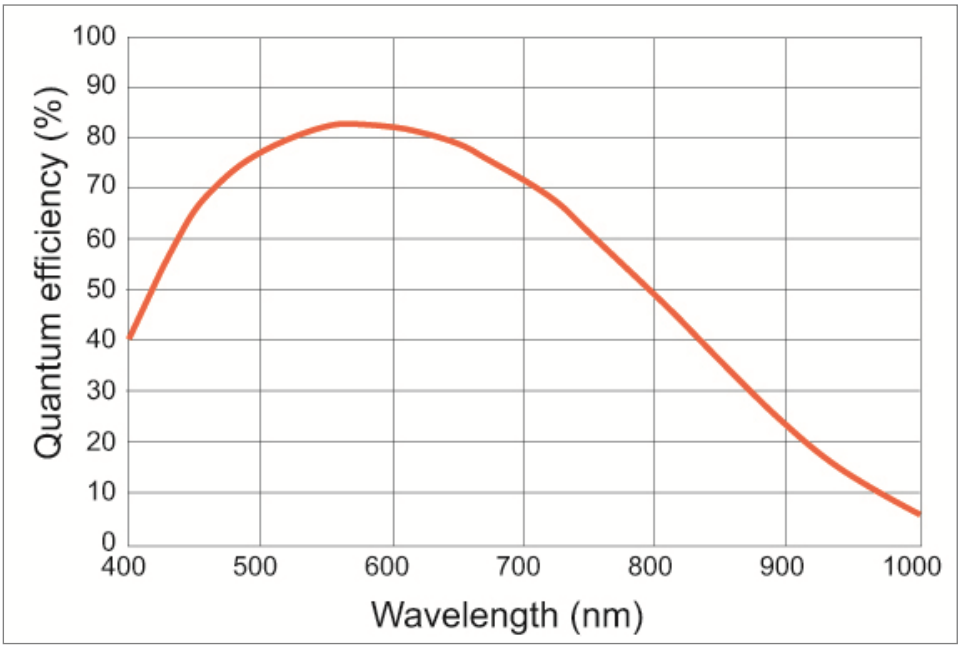


Figure 14-2

14-4 INTERFACE SPECIFICATIONS

(1) Camera Link interface

The camera transfers 80 bit data in parallel (8 bit x 10 port). It is an extended interface of Camera Link full configuration Standard.

1. Pin assignments of Camera Link connector 1 (SDR-26)

Camera connector	Frame grabber connector	Channel Link signal	Camera connector	Frame grabber connector	Channel Link signal
1	1	Inner Shield	14	14	Inner Shield
2	25	X0-	15	12	X0+
3	24	X1-	16	11	X1+
4	23	X2-	17	10	X2+
5	22	Xclk-	18	9	Xclk+
6	21	X3-	19	8	X3+
7	20	SerTC+	20	7	SerTC-
8	19	SerTFG-	21	6	SerTFG+
9	18	CC1-	22	5	CC1+
10	17	CC2+	23	4	CC2-
11	16	CC3-	24	3	CC3+
12	15	CC4+	25	2	CC4-
13	13	Inner Shield	26	26	Inner Shield

2. Pin assignments of Camera Link connector 2 (SDR-26)

Camera connector	Frame grabber connector	Channel Link signal	Camera connector	Frame grabber connector	Channel Link signal
1	1	Inner Shield	14	14	Inner Shield
2	25	Y0-	15	12	Y0+
3	24	Y1-	16	11	Y1+
4	23	Y2-	17	10	Y2+
5	22	Yclk-	18	9	Yclk+
6	21	Y3-	19	8	Y3+
7	20	Terminated	20	7	Terminated
8	19	Z0-	21	6	Z0+
9	18	Z1-	22	5	Z1+
10	17	Z2-	23	4	Z2+
11	16	Zclk-	24	3	Zclk+
12	15	Z3-	25	2	Z3+
13	13	Inner Shield	26	26	Inner Shield

3. Camera Link bit assignments

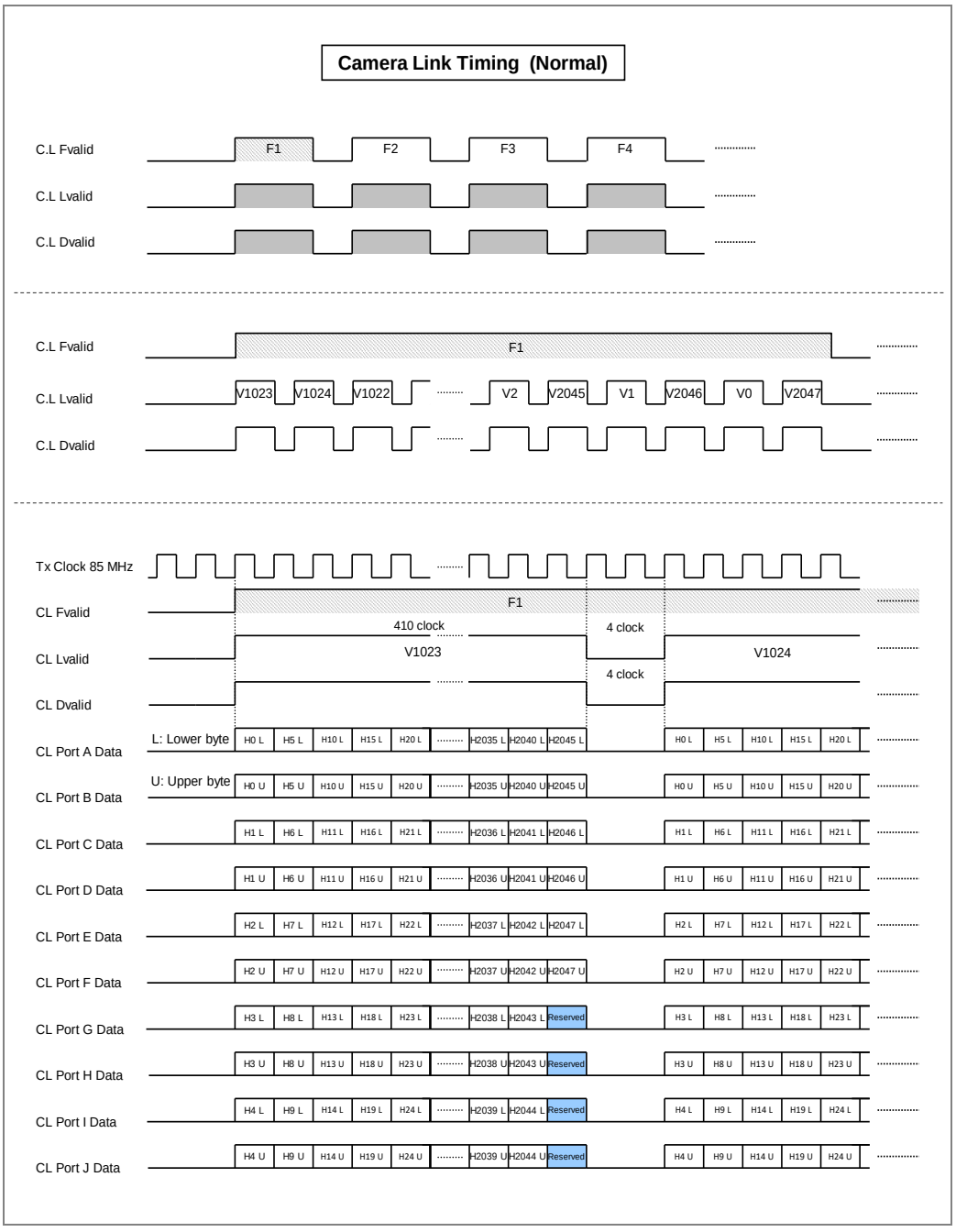
28 bit solution pin name	Port	Plug No.1, Channel Link X	Port	Plug No.2, Channel Link Y	Port	Plug No.3, Channel Link Z
TxIN0	Port A0	D0_0	Port D2	D1_10	Port G5	D3_5
TxIN1	Port A1	D0_1	Port D3	D1_11	Port G6	D3_6
TxIN2	Port A2	D0_2	Port D4	D1_12	Port G7	D3_7
TxIN3	Port A3	D0_3	Port D5	D1_13	Port H0	D3_8
TxIN4	Port A4	D0_4	Port D6	D1_14	Port H1	D3_9
TxIN5	Port A5	D0_5	Port D7	D1_15 (MSB)	Port H2	D3_10
TxIN6	Port A6	D0_6	Port E0	D2_0	Port H3	D3_11
TxIN7	Port A7	D0_7	Port E1	D2_1	Port H4	D3_12
TxIN8	Port B0	D0_8	Port E2	D2_2	Port H5	D3_13
TxIN9	Port B1	D0_9	Port E3	D2_3	Port H6	D3_14
TxIN10	Port B2	D0_10	Port E4	D2_4	Port H7	D3_15 (MSB)
TxIN11	Port B3	D0_11	Port E5	D2_5	Port I0	D4_0
TxIN12	Port B4	D0_12	Port E6	D2_6	Port I1	D4_1
TxIN13	Port B5	D0_13	Port E7	D2_7	Port I2	D4_2
TxIN14	Port B6	D0_14	Port F0	D2_8	Port I3	D4_3
TxIN15	Port B7	D0_15 (MSB)	Port F1	D2_9	Port I4	D4_4
TxIN16	Port C0	D1_0	Port F2	D2_10	Port I5	D4_5
TxIN17	Port C1	D1_1	Port F3	D2_11	Port I6	D4_6
TxIN18	Port C2	D1_2	Port F4	D2_12	Port I7	D4_7
TxIN19	Port C3	D1_3	Port F5	D2_13	Port J0	D4_8
TxIN20	Port C4	D1_4	Port F6	D2_14	Port J1	D4_9
TxIN21	Port C5	D1_5	Port F7	D2_15 (MSB)	Port J2	D4_10
TxIN22	Port C6	D1_6	Port G0	D3_0	Port J3	D4_11
TxIN23	Port C7	D1_7	Port G1	D3_1	Port J4	D4_12
TxIN24	LVAL	LVAL	Port G2	D3_2	Port J5	D4_13
TxIN25	FVAL	FVAL	Port G3	D3_3	Port J6	D4_14
TxIN26	Port D0	D1_8	Port G4	D3_4	Port J7	D4_15 (MSB)
TxIN27	Port D1	D1_9	LVAL	LVAL	LVAL	LVAL
TxCLKIn	PClk	Pixel Clock A,B,C	PClk	Pixel Clock D,E,F	PClk	Pixel Clock G,H,I,J

LVAL (Line Valid signal)	This signal show the period during which the line part of the image data from CMOS image sensor is in effect. This is “ON” when during the period the line is active.
FVAL (Frame Valid signal)	This signal shows the period during which the vertical part of the image data from CMOS image sensor is in effect. This is “ON” during the period the frame is active.
D0_0 to D4_15 (Digital image data)	This is the image signal data from CMOS image sensor converted A/D. ”D0 to D4” has 16 bit data in each. MSB shows the most significant bit. Refer to 14-5 “OUTPUT TIMING SPECIFICATIONS” for details.

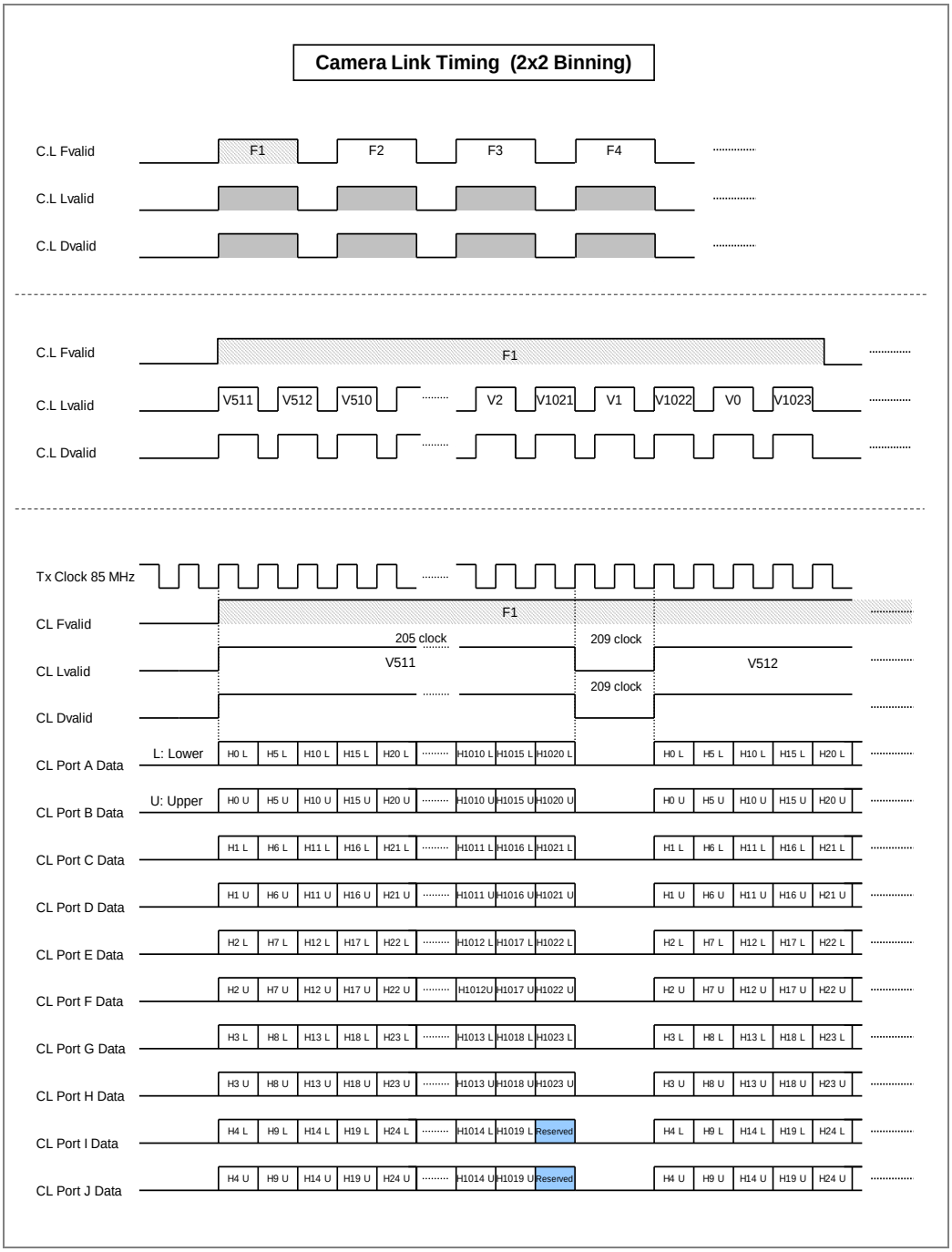
14-5 OUTPUT TIMING SPECIFICATIONS

The following shows output timing specifications for 16 bit digital output.

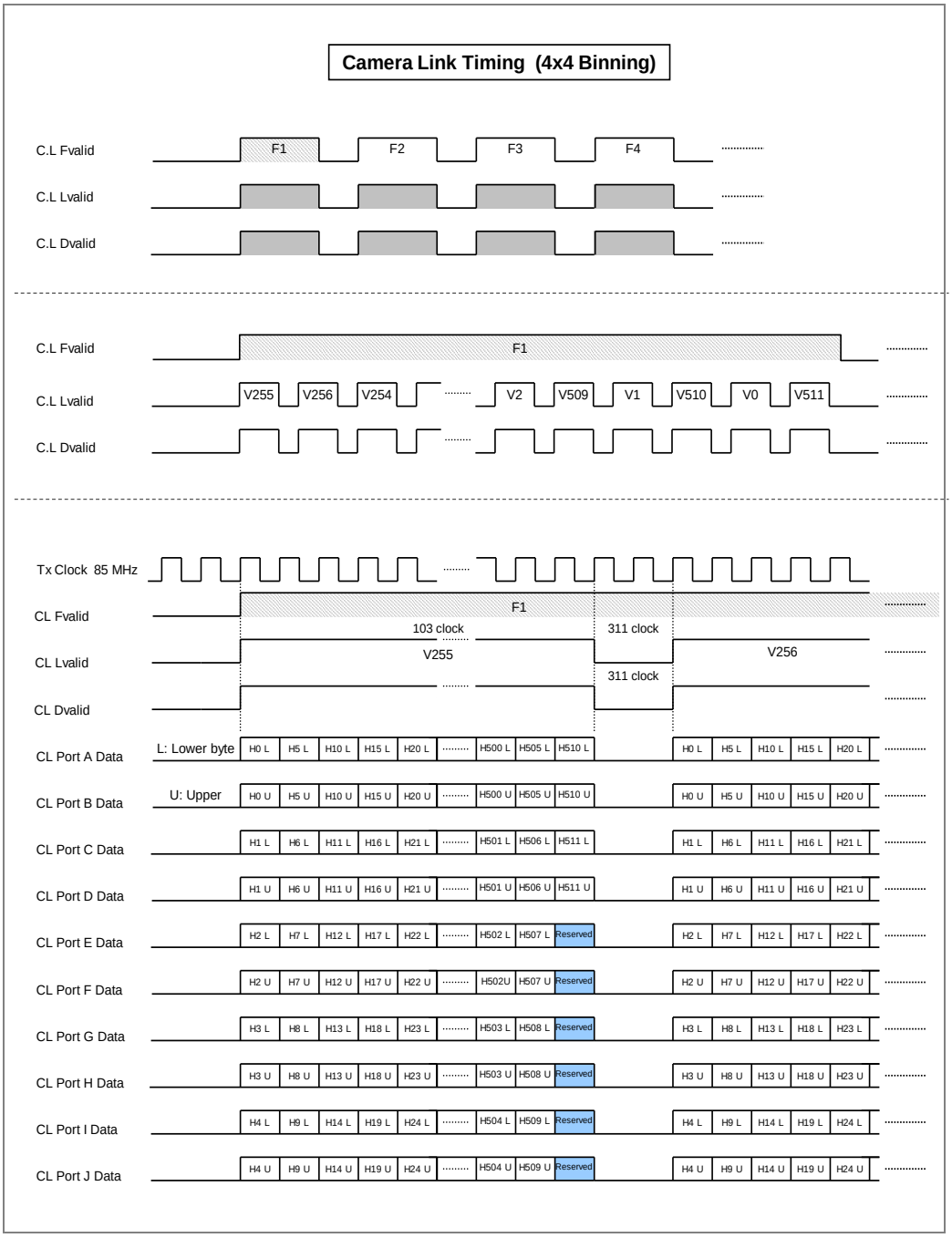
(1) Normal readout



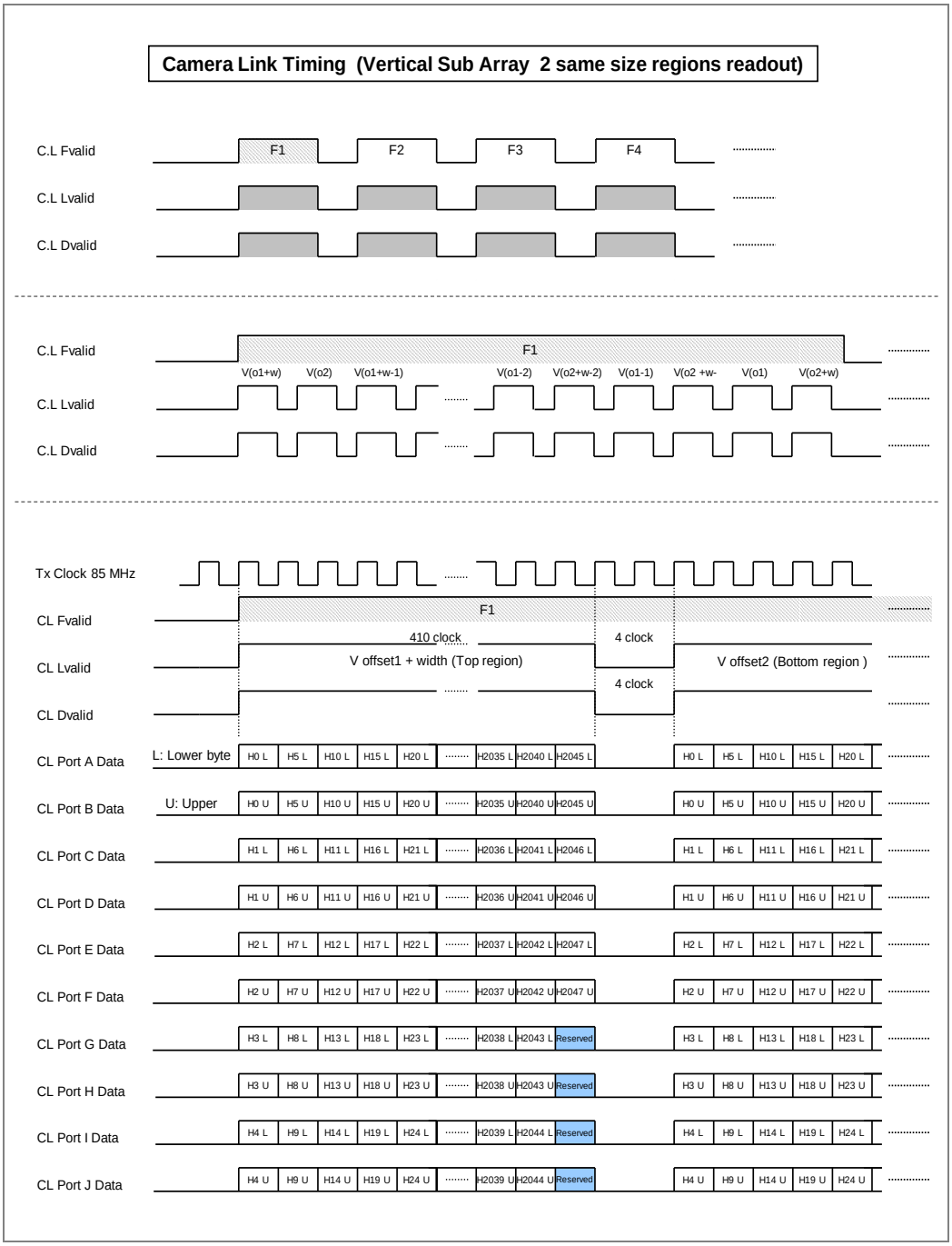
(2) 2x2 binning readout



(3) 4x4 binning readout

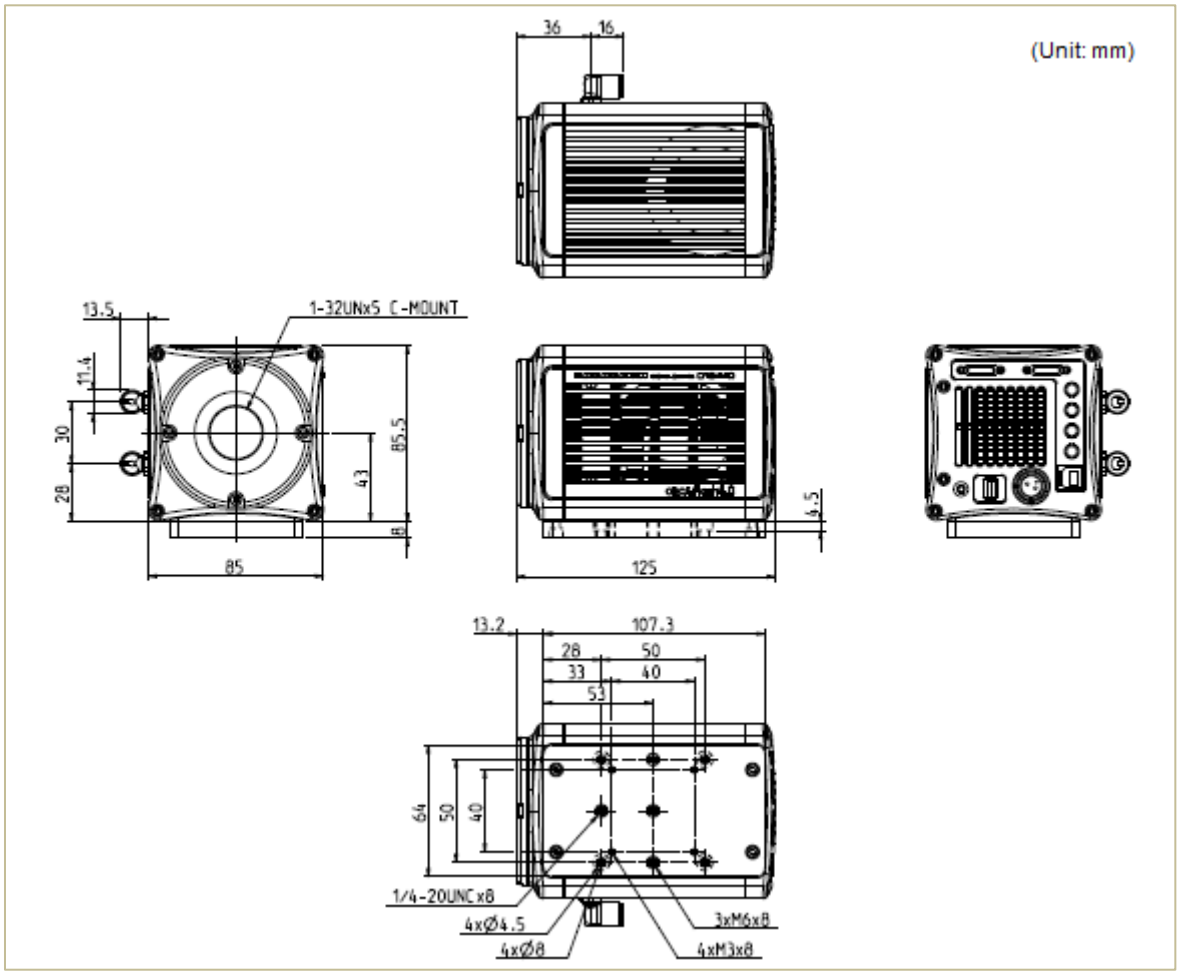


(4) Sub-array readout

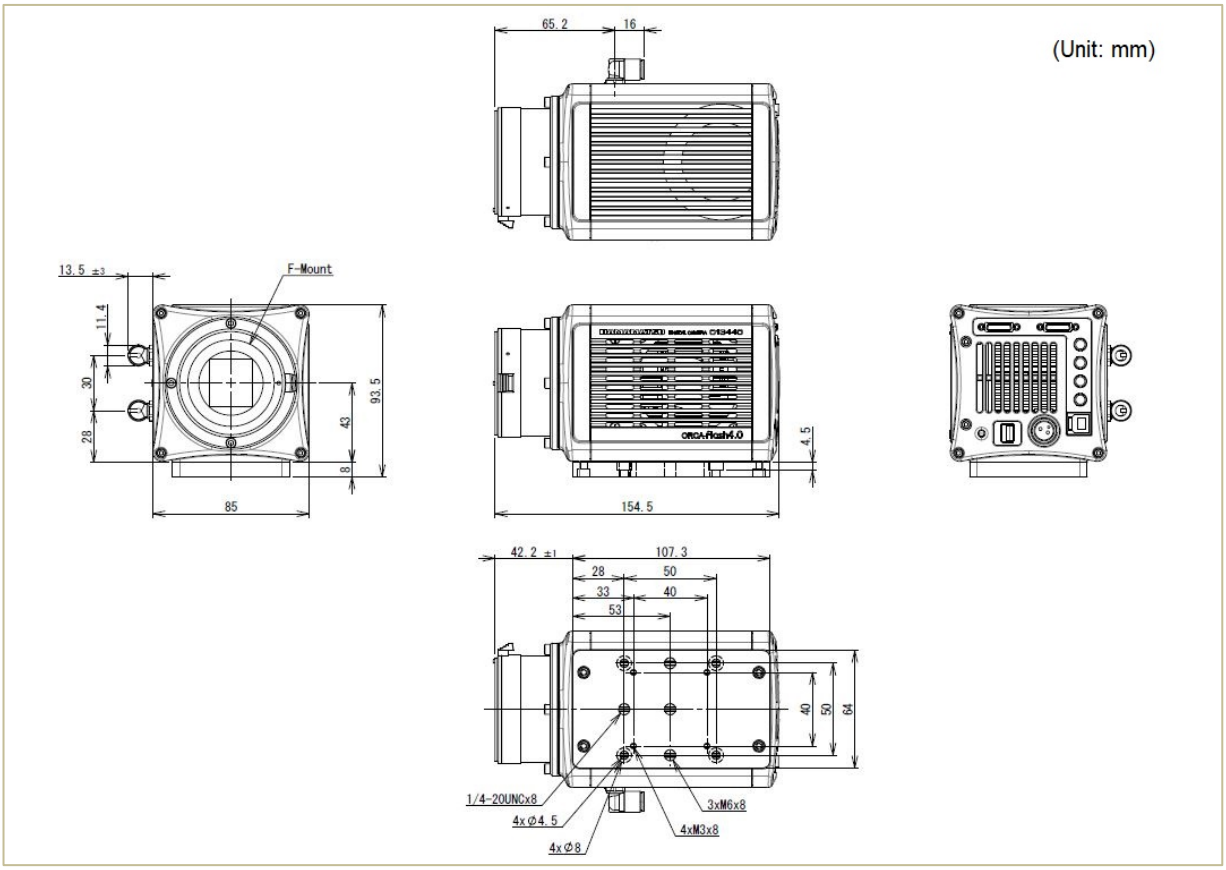


15. DIMENSIONAL OUTLINES

15-1 C13440-20CU



15-2 C13440-20CU01



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

HAMAMATSU PHOTONICS K. K., Systems Division

812 Joko-cho, Higashi-ku, Hamamatsu City, Shizuoka Pref., 431-3196, Japan
Telephone (81) 53-431-0124, Fax: (81) 53-435-1574
E-mail: export@sys.hpk.co.jp

Local contact information worldwide can be found at:
www.hamamatsu.com

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- *If one of the following is found, please contact Hamamatsu. (refer to the local contact information).*
  - *Contents of the manual are illegible, incorrect or missing.*
  - *Pages of the manual are missing or in the wrong order.*
  - *The manual is unclean.*