See the possibilities

Spark Series

User Manual

SP-20000M-USB
SP-20000C-USB

20 MP CMOS Digital Progressive Scan Monochrome and Color Camera

Document Version: Ver.1.4
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Warranty

For information about the warranty, please contact your factory representative.

Certifications

CE compliance

As defined by the Directive 2004/108/EC of the European Parliament and of the Council, EMC (Electromagnetic compatibility), JAI Ltd., Japan declares that SP-20000M-USB and SP-20000C-USB comply with the following provisions applying to its standards.
EN 61000-6-3 (Generic emission standard part 1)
EN 61000-6-2 (Generic immunity standard part 1)

FCC

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Warning

Changes or modifications to this unit not expressly approved by the party responsible for FCC compliance could void the user's authority to operate the equipment.

Supplement

The following statement is related to the regulation on “ Measures for the Administration of the control of Pollution by Electronic Information Products “ , known as “ China RoHS “. The table shows contained Hazardous Substances in this camera.

mark shows that the environment-friendly use period of contained Hazardous Substances is 15 years.

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部件名称	有毒有害物质或元素					
	铅（Pb）	汞（Hg）	镉（Cd）	六价铬（Cr(VI)）	多溴联苯（PPB）	多溴二苯醚（PBDE）
螺丝固定座	×	○	○	○	○	○
连接插头	×	○	○	○	○	○
电路板	×	○	○	○	○	○
.....	.....	.....	.....	.....	.....	.....

○：表示该有毒有害物质在该部件所有均质材料中的含量均在SJ/T11363-2006规定的限量要求以下。
×：表示该有毒有害物质至少在该部件的某一均质材料中的含量超出SJ/T11363-2006规定的限量要求。
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数字「15」为期限15年。

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螺丝固定座	×	○	○	○	○	○
光学滤色镜	×	○	×	○	○	○
连接插头	×	○	○	○	○	○
电路板	×	○	○	○	○	○
.....	.....	.....	.....	.....	.....	.....

○：表示该有毒有害物质在该部件所有均质材料中的含量均在SJ/T11363-2006规定的限量要求以下。
×：表示该有毒有害物质至少在该部件的某一均质材料中的含量超出SJ/T11363-2006规定的限量要求。
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- Contents -

Introduction

EMVA 1288

With regard to signal to noise ratio in this manual, specifications measured by EMVA 1288 are used together with specifications by a traditional measurement method.

EMVA 1288 is a more complete measurement that considers multiple noise sources, including random noise, pattern noise, and shading. Additionally, EMVA 1288 incorporates temporal variances in pixel output by capturing 100 frames of data and computing the RMS variations over the captured frames. Because of the comprehensive nature of the noise analysis and the additional consideration for RMS variances over time, EMVA 1288 SNR measurements are inherently lower than the traditional SNR measurements given by manufacturers. However, the comprehensive nature combined with rigid test parameters, means that all manufacturers' are measuring their products equally and EMVA 1288 tested parameters can be compared among different manufacturers' products.

In order to learn more about EMVA 1288, please visit http://www.emva.org

Interface

The SP-20000-USB employs a USB 3.0 interface and is in the process of being certified for compliance with the USB3 Vision standard. USB3 Vision is a new standard interface for machine vision applications being developed and managed by the AIA (Automated Imaging Association). USB3 Vision uses USB 3.0 ports that will soon be standard on most PCs (with Windows 7 service pack and Windows 8 native support expected soon). Components from different manufacturers will easily communicate with each other.

USB3 Vision also supports the GenICam™ standard which is managed by the EMVA (European Machine Vision Association). The purpose of the GenICam standard is to provide a common program interface for various machine vision cameras. By using GenICam, cameras from different manufacturers can seamlessly connect in one platform.

The maximum transfer speed of USB 3.0 is specified at 5.0 Gbps, however effective bandwidth is reduced by a number of factors including pixel format conversions and the physical interface components used. The USB3 Vision standard specifies a bandwidth of 2.8 Gbps or greater. Maximum cable length for passive cables is five meters, but this can be made longer using active cables.

As for the USB connector, SP-20000-USB uses a Micro B connector which complies with USB3.0. This connector has an additional 5-pin plug "stacked" on the side of a standard USB 2.0 Micro B connector. However, USB 2.0 cannot be used with the SP-20000-USB.

Power supply

Although the USB 3.0 interface is capable of supporting both data and power, the power supplied through the interface is not sufficient to operate the camera. A separate power supply unit must be connected to the 12-pin connector.

Computer used for SP-20000-USB series

It is necessary to use a PC equippped with a USB 3.0 interface. It is also recommended to use a PC equipped with slots of better than PC Express 2.0 x 8. Please note that the SP-20000-USB may not work properly depending on the chipset used in the PC.

1. General

The SP-20000-USB cameras are members of JAI's new "Spark Series." They provide both high resolution and a high frame rate with excellent image quality for machine vision applications. The SP-20000M-USB is a monochrome progressive scan COMS camera and the SP-20000C-USB is the equivalent Bayer mosaic progressive scan CMOS camera. Both are equipped with CMOS sensors offering a 35 mm full size image format, a resolution of 20 million pixels, and a 4:3 aspect ratio. They provide 16 frames per second for continuous scanning with 5120 x 3480 full pixel resolution for both monochrome and raw Bayer output.

8-bit, 10-bit and 12-bit outputs can be selected for both monochrome and raw Bayer formats. The new cameras feature a USB3 Vision interface. A full pixel readout or partial scan readout mode can be selected depending on applications.

The SP-20000-USB has various comprehensive functions needed for automated optical inspection applications, such as solid state device inspection or material surface inspection. They incorporate video processing functions such as a look-up table, flat field shading compensation and blemish compensation in addition to fundamental functions such as trigger, exposure setting and video level control.

The latest version of this manual can be downloaded from: www.jai.com
The latest version of the JAI SDK for the SP-20000-USB can be downloaded from: www.jai.com
For camera revision history, please contact your local JAI distributor.

2. Camera composition

The standard camera composition is as follows.

Camera body	1
Sensor protection cap	1
Dear Customer (sheet)	1

The following optional accessories are available.

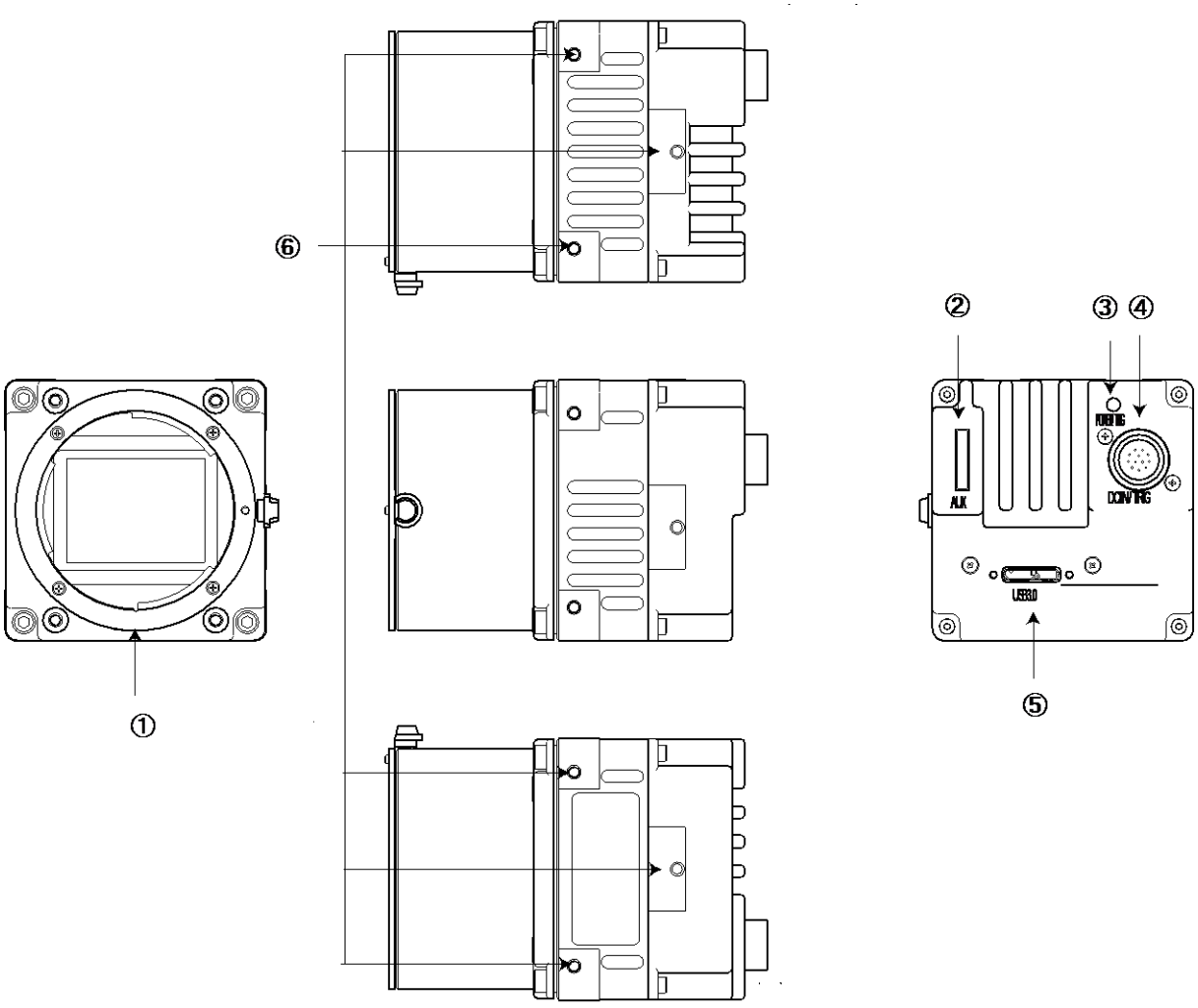
Tripod base	MP-42
Power supply unit	PD-12 series

3. Key features

- New Spark Series, 35mm full size, CMOS 20-megapixel progressive scan camera with global shutter
- Utilizes USB3 Vision interface
- Aspect ratio 4:3, 5120(H) x 3840(V) - 20 million effective pixels
- 6.4 µm square pixels
- S/N 53 dB for monochrome and 51 dB for color
- 8-bit, 10-bit or 12-bit output for monochrome and Bayer color
- 16 frames/second with full resolution in continuous operation
- Supports ROI (Region Of Interest) modes for faster frame rate
- 0 dB to +24 dB gain control for both SP-20000-USB models
- 299 µs (1/3,344) to 8 seconds exposure control in 1 µs step
- Auto exposure control
- Timed and trigger width exposure control
- PIV and sequential trigger modes for specific applications
- ALC control with combined function of AGC and auto exposure
- HDR (High Dynamic Range) function is available (Option)
- Various pre-processing circuits are provided
  Programmable LUT
  Gamma correction from 0.45 to 1.0
  Flat field correction
  Bayer white balance with manual or one-push auto (SP-20000C-USB only)
  Blemish compensation
- New Hirose 10P connector for TTL IN and OUT and LVDS IN interface
- F-mount for lens mount
- Setup by Windows XP/Vista/7 via serial communication

4. Parts locations and their functions

4.1 Parts locations and their functions



①	Lens mount	F-mount (Note *1)
②	AUX 10-pin connector	AUX Connector for TTL IN/OUT and LVDS IN
③	LED	Indication for power and trigger input
④	12-pin connector	DC and trigger input
⑤	USB 3.0 connector	Connector for interfacing USB 3.0
⑥	Mounting holes	Holes for mounting tripod base or direct installation. Depth 5 mm (Note*2)

*1) Note1: Rear protrusion on F-mount lens must be less than 14.0 mm.
*2) Note2: The part number for the tripod adapter plate (with 1/4"-20 thread) is MP-42 (option). When the camera is mounted directly using mounting holes, the length of screws must be less than 5mm. If they are longer than 5mm, they may not fasten securely due to the 5mm hole depth.

Fig. 1 Locations

4.2 Rear Panel

The rear panel mounted LED provides the following information:

- Amber: Power connected – initiating
  This light goes OFF after initiating.

- Steady green: Camera is operating in Continuous mode
- Flashing green: The camera is receiving external triggering

Note: The interval of flashing does not correspond with external trigger duration.

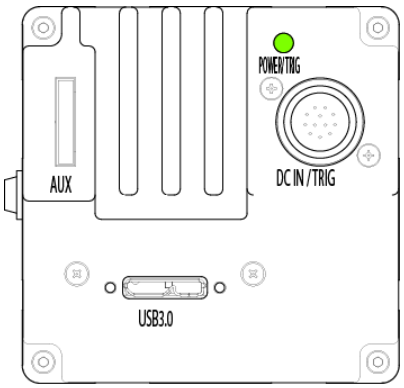


Fig. 2 Rear panel

5. Input and output

5.1 USB 3.0 Interface specifications

The SP-20000-USB employs a USB 3.0 interface for video and data transfer. USB 3.0 is an upgraded version of USB 2.0 widely used in the industry. Its transfer rate is 5 Gbps, which is 10 times faster than the 480 Mbps rate of USB 2.0. USB 3.0 employs full-duplex system which executes both transmitting and receiving at the same time. USB 3.0 has downward compatibility to USB 2.0 but in the SP-20000-USB, USB 2.0 cannot be used because the performance is not guaranteed.
The connector used for USB 3.0 in the SP-20000-USB is a Micro B Type connector with a USB 3.0 form factor.

5.2 Connectors and pin assignment

5.2.1 Digital Video Output (USB3.0 Micro B connector)

Type: ZX3600-B-10P or equivalent

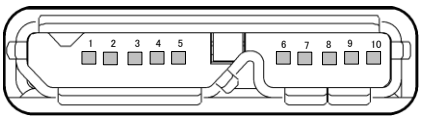


図 3. USB3.0 Micro B Connector

Table 1. USB3.0 Pin Configuration

No	I/O	Name	Note
1	I	VBUS IN	Power(VBUS) +5V
2	I/O	DM	USB2.0 Differential pair(D-)
3	I/O	DP	USB2.0 Differential pair(D+)
4		OTG ID	USB OTG ID for identifying lines
5		GND	GND
6	O	FX3 SSTXM	USB3.0 Signal Transmission line (-)
7	O	FX3 SSTXP	USB3.0 Signal Transmission line (+)
8		GND	GND
9	I	FX3 SSRXP	USB3.0 Signal Receiving line (-)
10	I	FX3 SSRXM	USB3.0 Signal Receiving line (+)

Note1: Power is not supplied through the USB 3.0 interface. Requires an external power supply.
Note2: USB 2.0 interface is not supported.

5.2.2 12-Pin connector

5.2.2.1 Figure

Type: HR-10A-10R-12PB(72) Hirose male or equivalent.

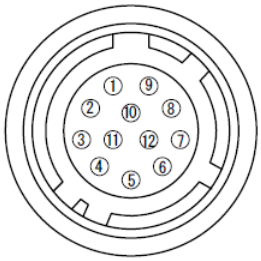


Fig.3 12-pin connector

5.2.2.2 Pin configuration

Table – 2 12-pin configuration

Pin no.	Signal	Remarks
1	GND	
2	DC input	+12V ～ +24V (note 3)
3	GND	
4	NC	
5	OPTO IN-	Line 5
6	OPTO IN+	
7	OPTO OUT -	Line 2
8	OPTO OUT+	
9	TTL out 1	Line1 (note 1)
10	TTL In 1	Line4 (note 2)
11	DC input	+12V ～ +24V (note 3)
12	GND	

Note 1) Factory default setting is Exposure Active and negative
Note 2) Factory default setting is trigger input.

5.2.3 AUX Connector Hirose 10-Pin connector

Type: HIROSE 10-Pin Connector 3260-10S3(55)

Fig. 4 Hirose 10p connector

Table-3 Pin configuration for Hirose 10P

No	I/O	Name	Note
1	O	TTL OUT2	Line8
2	O	TTL OUT3	Line9
3	I	TTL IN2	Line10
4		NC	
5		GND	
6	I	LVDS IN1+	Line11
7	I	LVDS IN1-	
8		NC	
9		GND	
10		GND	

5.3 Digital In and out inteface

In the SP-20000-USB, the software control tool can assign the necessary signals used in the system to digital inputs and outputs.

5.3.1 Line Selector

In the Line Selector, the following input and output signals can be assigned.

Table – 4 Line Selector

Line Selector item	Description
Line 1 TTL OUT 1	TTL output from #9 pin of DC In/Trigger HIROSE 12-Pin on the rear
Line 2 OPTO OUT 1	Optical output from #7 and 8 pins of DC In/Trigger HIROSE 12-Pin on the rear
Line 8 TTL OUT 2	TTL output from #1 pin “AUX” HIROSE 10-Pin on the rear
Line 10 TTL OUT 3 t	TTL output from #2 pin “AUX” HIROSE 10-Pin on the rear
NAND 0 In 1	First input at first NAND gate in GPIO
NAND 0 In 2	Second input at first NAND gate in GPIO
NAND 1 In 1	First input at second NAND gate in GPIO
NAND 1 in 2	Second input at second NAND gate in GPIO
Note: In the line source, input interfaces besides those mentioned above will be shown but the line source setting is not available. The input interface can be configured in the trigger source and the pulse generator source.	

5.3.2 Line Source

Line source signal can be selected from the following table to connect it to the line item which is selected in the line selector.

Table-5 Line Source

Line Source item	Description
Low	Connect Low Level signal to line item selected in Line Selector, **Default setting**
High	Connect High Level signal to line item selected in Line Selector
Acquisition Trigger Wait	Connect Acqusition Trigger Wait signal to line item selected in Line Selector
Acqusition Active	Connect Acqusition Active signal to line item selected in Line Selector
Frame Trigger Wait	Connect Frame Trigger Wait signal to line item selected in Line Selector
Frame Active	Connect Frame Active signal to line item selected in Line Selector
Exposure Active	Connect Exposure Active signal to line item selected in Line Selector
FVAL	Connect FVAL signal to line item selected in Line Selector
LVAL	Connect LVAL signal to line item selected in Line Selector
PulseGenerator0 Out	Connect Pulse Generator 0 signal to line item selected in Line Selector
PulseGenerator1 Out	Connect Pulse Generator 1 signal to line item selected in Line Selector
Line 4 – TTL IN 1	Connect TTL IN 1 signal to line item selected in Line Selector
Line 5 – OPTO IN 1	Connect OPTO IN 1 signal to line item selected in Line Selector
User output 0	Connect User output 0 signal to line item selected in Line Selector
User output 1	Connect User output 1 signal to line item selected in Line Selector
User output 2	Connect User output 2 signal to line item selected in Line Selector
User output 3	Connect User output 3 signal to line item selected in Line Selector
Nand0 Out	Connect NAND 0 signal to line item selected in Line Selector
Nand1 Out	Connect NAND 1 signal to line item selected in Line Selector
Line 10 TTL IN 2	Connect TTL IN 2 signal to Line 10
Line 11 LVDS IN	Connect LVDS IN signal to Line 11
Note: (1) The user output is the trigger signal generated by software in PC for the camera. (2) As for LVAL, some line items cannot be connected. Refer to “5.3.6.2 GPIO matrix table”	

5.3.3 Line Mode

Indicates the status of the item selected in Line Selector. (INPUT or OUTPUT)

5.3.4 Line Inverter

Inverts the signal polarity for the item selected in Line Selector. (False=Positive, True=Negative)

5.3.5 Line Status

Indicates the status of the selected signal (input or output) (True=High, False=Low)

5.3.6 Line Format

Indicates the interface category of input and output for the selected signal.

Category: No connect, TTL, LVDS and OPTO coupled

5.3.6 GPIO

GPIO is a general interface for input and output and controls the I/O for trigger signals and other valid signals and pulse generators. By using this interface you can control an external light source, make a delay function for an external trigger signal, or make a precise exposure setting together with a PWC trigger.

5.3.6.1 Basic block diagram

The basic block diagram is as follows.
In the SP-20000-USB, the pixel clock is 40 MHz.

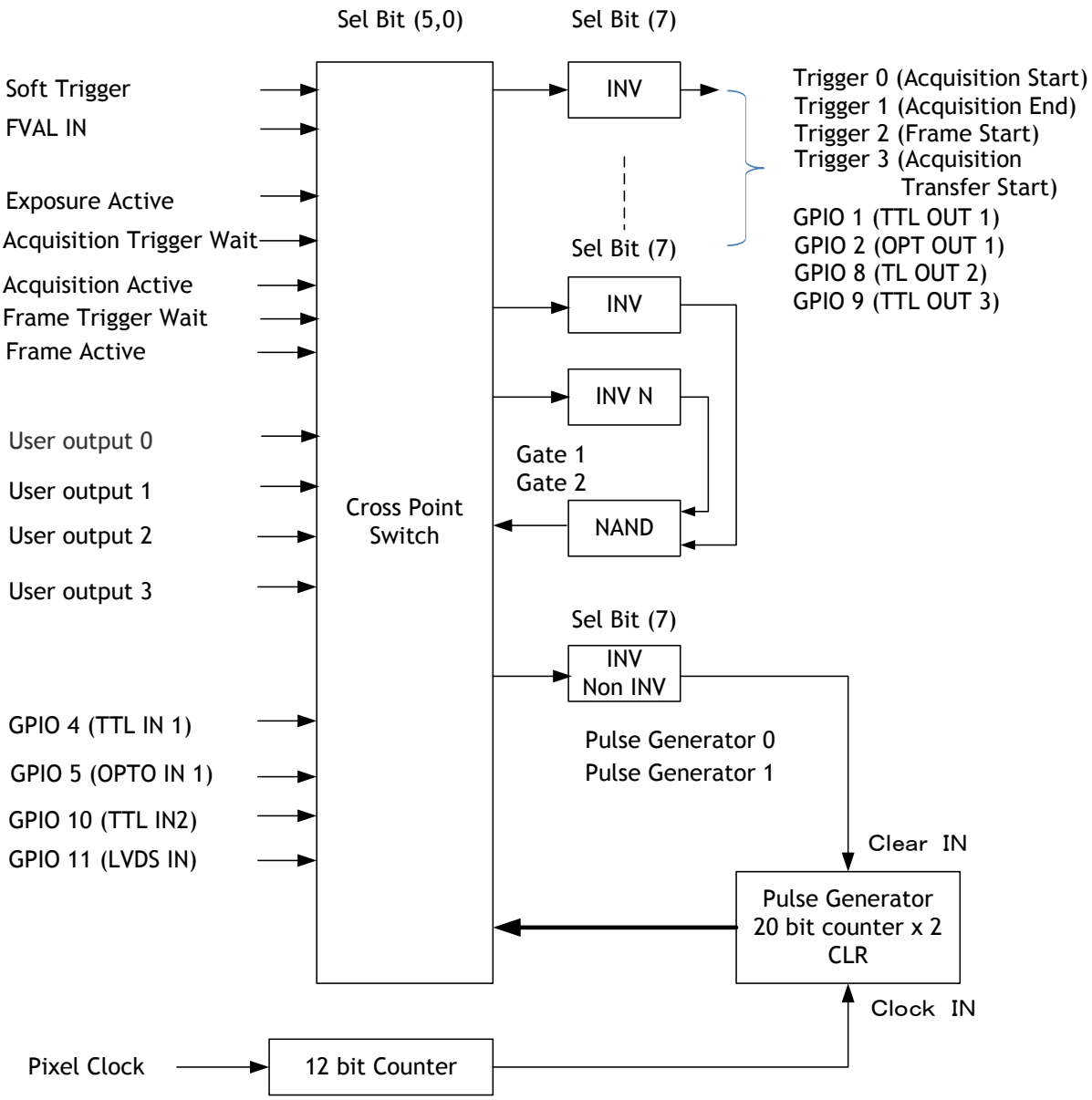


Fig.5 GPIO interface

5.3.6.2 Input and output matrix table

The relationship between input and output is as follows.

Table - 6 GPIO matrix table

Selector (Cross point switch output) / Source signal (Cross point switch input)	Trigger Selector				Line Selector								Pulse Generator Selector	
	Frame Start	Acquisition Start	Acquisition End	Acquisition Transfer Start	Line 1 - TTL OUT 1	Line 2 OPTO OUT 1	Line 8 - TTL OUT 2	Line 9 - TTL OUT 3	NAND 1 In 1	NAND 1 In 2	NAND 2 In 1	NAND 2 In 2	Pulse Generator 0	Pulse Generator 1
Low	O	O	O	O	O	O	O	O	O	O	O	O	O	O
High	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Soft Trigger	O	O	O	O	×	×	×	×	×	×	×	×	×	×
Acqusition Trigger Wait	×	×	×	×	O	O	O	O	O	O	O	O	O	O
Acqusition Active	×	×	×	×	O	O	O	O	O	O	O	O	O	O
Exposure Active	×	×	×	×	O	O	O	O	O	O	O	O	O	O
Frame Trigger Wait	×	×	×	×	O	O	O	O	O	O	O	O	O	O
Frame Active	×	×	×	×	O	O	O	O	O	O	O	O	O	O
FVAL	×	×	×	×	O	O	O	O	O	O	O	O	O	O
LVAL	×	×	×	×	×	×	×	×	×	×	×	×	O	O
Pulse Generator 0	O	O	O	O	O	O	O	O	O	O	O	O	×	O
Pulse Generator 1	O	O	O	O	O	O	O	O	O	O	O	O	O	×
Line 4 - TTL In1	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Line 5 - OPTO IN 1	O	O	O	O	O	O	O	O	O	O	O	O	O	O
NAND 0 Out	O	O	O	O	O	O	O	O	×	×	O	O	O	O
NAND 1 Out 1	O	O	O	O	O	O	O	O	O	O	×	×	O	O
User Output 0	O	O	O	O	O	O	O	O	O	O	O	O	O	O
User Output 1	O	O	O	O	O	O	O	O	O	O	O	O	O	O
User Output 2	O	O	O	O	O	O	O	O	O	O	O	O	O	O
User Output 3	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Line 10 - TTL IN 2	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Line 11 - LVDS IN	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	Trigger Source				Line Source								Pulse Generator Clear Source	

5.3.6.3 Associated GenICam Register information

GenICam Name	Access	Values	Category
Line Selector	R/W	Line1,2,4,5,7～11 NAND 0 In1 to 2 NAND 1 In1 to 2	Digital I/O
Line Mode	RO	Output Input	Digital I/O
Line Inverter	R/W	False True	Digital I/O
Line Status	RO	False True	Digital I/O
Line Source	R/W	Low High Acquisition Trigger Wait Acquisition Active Frame Trigger Wait Frame Active Exposure Active FVAL Pulse Generator0 Pulse Generator1 User Out0 User Out1 User Out2 User Out3 TTL In1 Opt In NAND0 NAND1 TTL In2 LVDS In	Digital I/O
Line Format	RO	TTL Opto Coupled	Digital I/O

5.4 Optical Interface

SP-20000-USB is equipped with opto-isolated inputs and outputs, providing galvanic separation between the camera's inputs/outputs and peripheral equipment.
In addition to galvanic separation, the opto-isolated inputs and outputs can cope with a wide range of voltages; the voltage range for inputs is +3.3V to +24V DC whereas outputs will handle +5V to +24V DC.
The following drawing is the concept of photo coupler

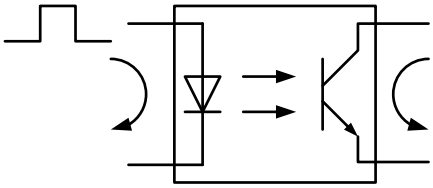


Fig.6 Photo coupler

5.4.1 Recommended External Input circuit diagram for customer

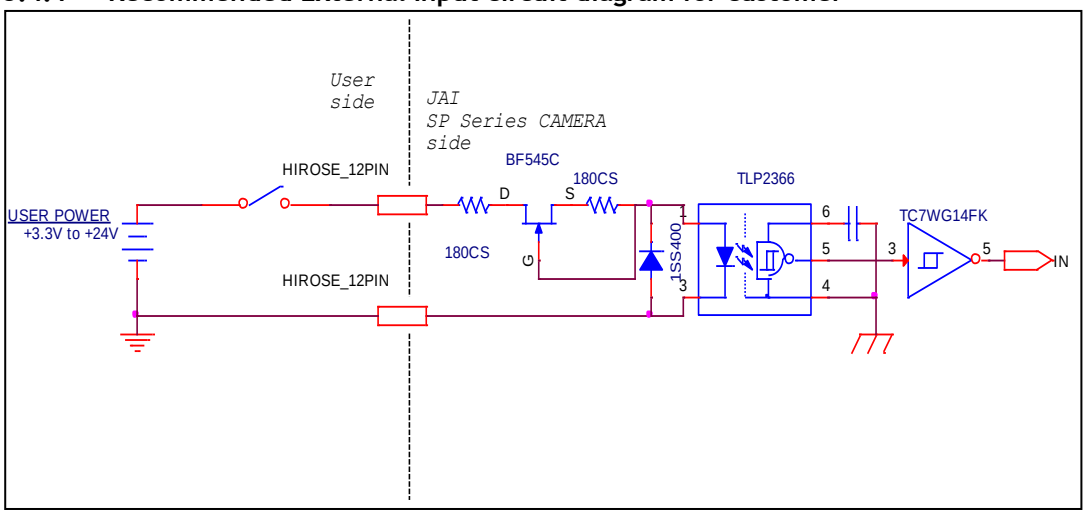


Fig.7 Example of external input circuit

5.4.2 Recommended External Output circuit diagram for customer

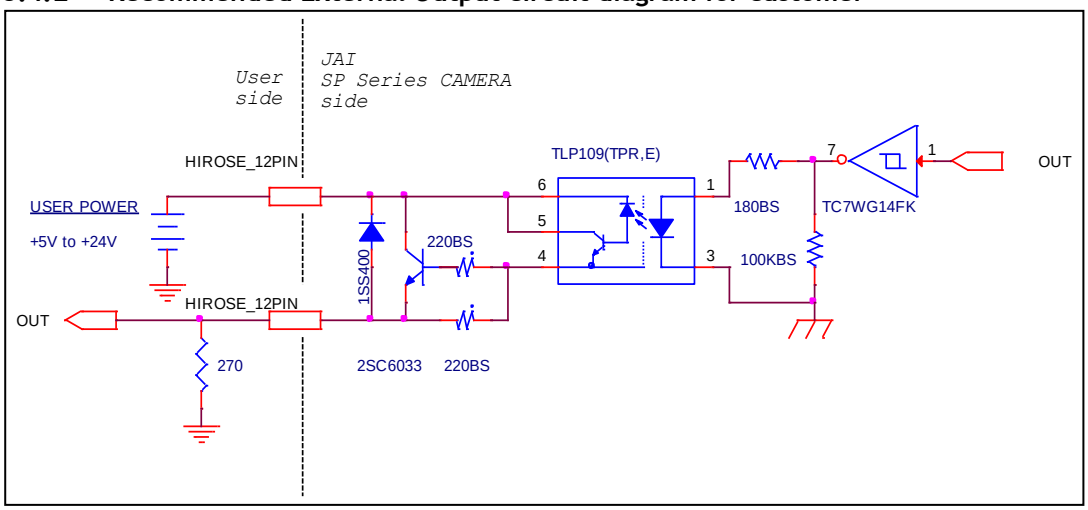
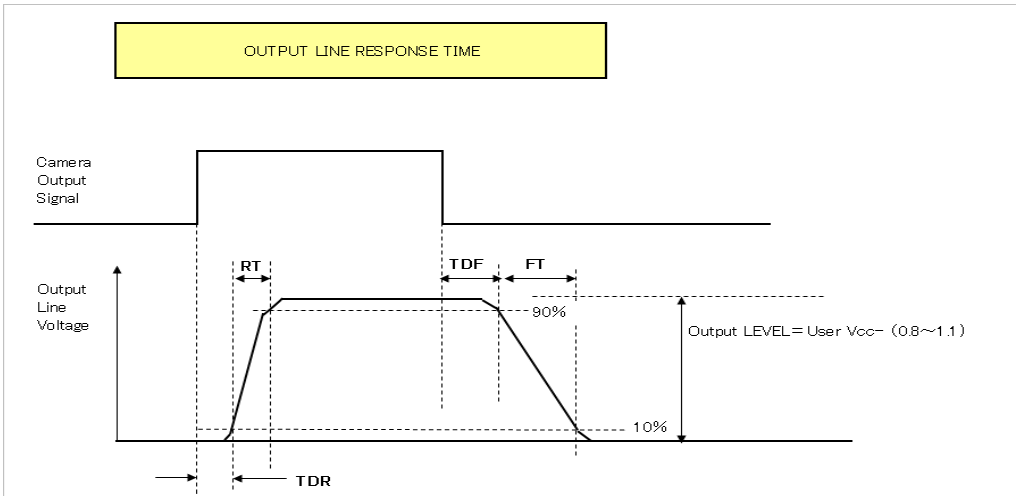


Fig.8 Example of external output circuit

5.4.3 Characteristics of optical interface

The relationship of the input signal to the output signal through the optical interface is as follows.



270Ω	User Power (VCC)			
	3.3V	5V	12V	24V
Time Delay Rise TDR (us)	0.54	0.54	0.62	0.68
Rise Time RT (us)	1.2	1.2	2	3
Time Delay Fall TDF (us)	1.5	1.5	2.4	2.1
Fall Time FT (us)	3.6	3.4	4.5	6.8

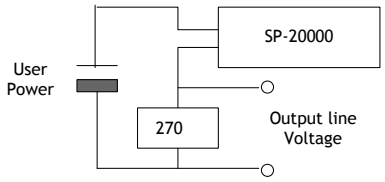


Fig.9 Optical interface characteristics

5.5 Pulse Generator

The SP-20000-USB has a frequency divider using the sensor clock as the basic clock and two pulse generators. In each Pulse Generator, various Clear settings are connected to GPIO.
The following shows Pulse Generator default settings.

Table - 7 Pulse Generator default settings

Display Name	Value							
Clock Pre-scaler	1							
Pulse Generator Selector	Pulse Generator Length	Start Point	End Point	Repeat Count	Clear Source	Clear Inverter	Clear Activation	Clear Sync Mode
- Pulse Generator 0	1	0	1	0	Off	True	Off	Async Mode
- Pulse Generator 1	1	0	1	0	Off	True	Off	Async Mode

Note: When Pulse Generator Repeat Count is set to "0", the camera is operating in free-running mode. However, based on the above default settings, Length=1, Start Point=0 and End Point=1, Pulse Generator stops at High output. Therefore, if Start Point =0 and End Point=1 are configured, Length should be "2" as the minimum active width.

5.5.1 Clock Pre-scaler

Clock pre-scaler (Divide Value) can set the dividing value of the frequency divider (12-bit length) and the sensor clock is used for this. Two built-in pulse generators work by the same clock. In the SP-20000-USB, the sensor pixel clock is 40 MHz .

5.5.2 Pulse Generator Selector

This is where you select one of the 2 pulse generators in order to set or modify its parameters.

Table - 8 Pulse Generator setting

Trigger Selector item	Description
Pulse Generator 0	If Pulse Generator 0 is selected, Length, Start Point, End Point, Repeat Count, Clear Source, Clear Inverter, Clear Activation and Clear Sync Mode of Pulse Generator 0 are displayed under the selector.
Pulse Generator 1	If Pulse Generator 1 is selected, Length, Start Point, End Point, Repeat Count, Clear Source, Clear Inverter, Clear Activation and Clear Sync Mode of Pulse Generator 1 are displayed under the selector.

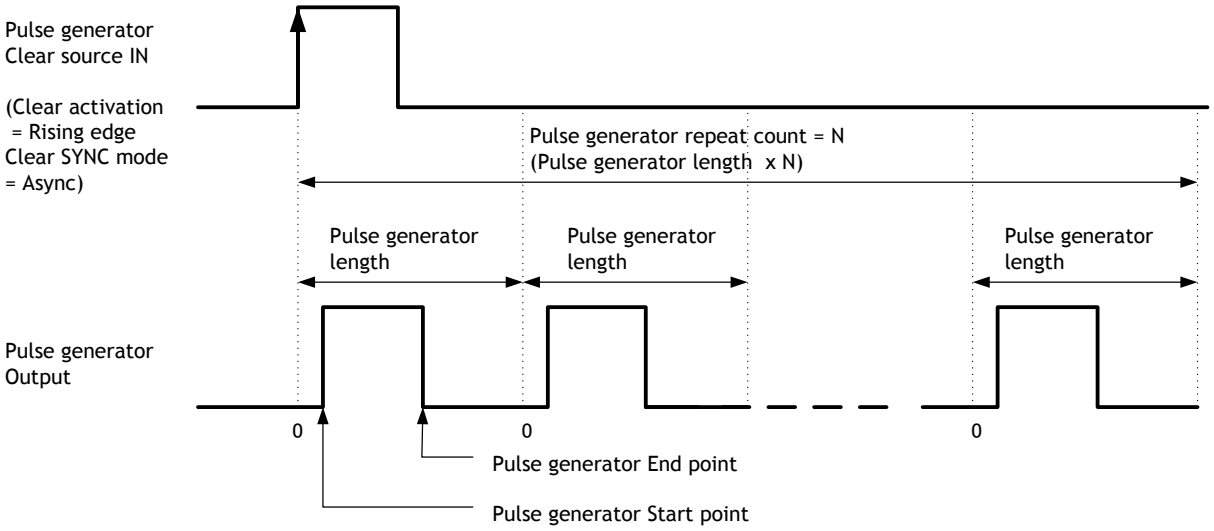


Fig.10 Pulse Generator pulse construction

5.5.3 Pulse Generator Length

Set the counter up value (number of clocks, refer to Table 12) for the selected pulse generator. If Repeat Count value is "0", and if Pulse Generator Clear signal is not input, the pulse generator generates the pulse repeatedly until reaching this counter up value.

5.5.4 Pulse Generator Start Point

Set the active output start count value for the selected pulse generator.
However, please note that a maximum jitter of 1 clock can occur for the clock which is divided in the clock pre-scaler.

5.5.5 Pulse Generator End Point

Set the active output ending count value for the selected pulse generator.

5.5.6 Pulse Generator Repeat Count

Set the repeating number of the pulse for the selected pulse generator. After Trigger Clear signal is input, the pulse generator starts the count set in Repeat Count. Accordingly, an active pulse which has a start point and end point can be output repeatedly.
However, if Repeat Count is set to "0", it works as a free-running counter.

5.5.7 Pulse Generator Clear Activation

Set the clear conditions of clear count pulse for the selected pulse generator.

5.5.8 Pulse Generator Clear Sync Mode

Set the counter clear method for the selected pulse generator.
In the case of Async Mode, if the clear signal is input during the length setting value, the counter will stop counting according to the clear signal input.
In the case of Sync Mode, if the clear signal is input during the length setting value, the counter will continue to count until the end of the length setting value and then clear the count.
Both modes clear the repeat count when the counter is cleared.

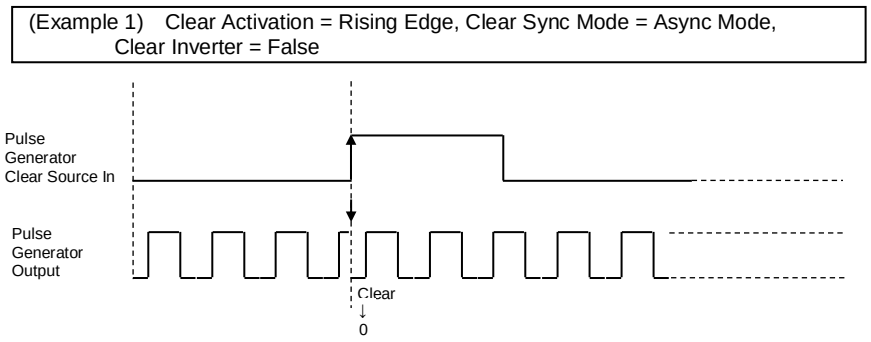


Fig.11 Counter clear in Async mode

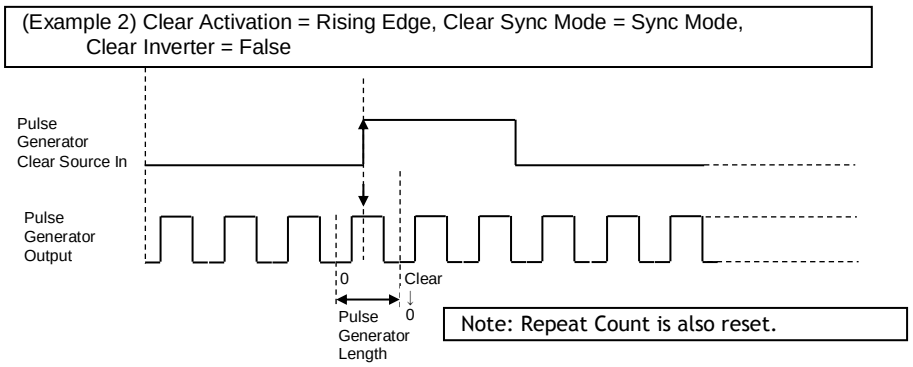


Fig.12 Counter clear in Sync mode

5.5.9 Pulse Generator Clear Source

The following clear sources can be selected as the pulse generator clear signal.

Tabel - 9 Pulse generator clear source

Pulse Generator Clear Source item	Description
Low	Connect Low level signal to Clear Source for the selected pulse generator. **Default setting**
High	Connect High level signal to Clear Source for the selected pulse generator.
Software	Connect Software signal to Clear Source for the selected pulse generator.
Acqusition Trigger Wait	Connect Acquisition Trigger Wait signal to Clear Source for the selected pulse generator.
Acquisition Active	Connect Acquisition Active signal to Clear Source for the selected pulse generator.
Frame Trigger Wait	Connect Frame Trigger Wait signal to Clear Source for the selected pulse generator.
Frame Active	Connect Frame Active signal to Clear Source for the selected pulse generator.
Exposure Active	Connect Exposure Active signal to Clear Source for the selected pulse generator.
FVAL	Connect FVAL signal to Clear Source for the selected pulse generator.
PulseGenerator0 Out	Connect Pulse Generator 0 output to Clear Source for the selected pulse generator.
PulseGenerator1 Out	Connect Pulse Generator 1 output to Clear Source for the selected pulse generator.
Line 4 - TTL IN 1	Connect TTL IN 1 signal to Clear Source for the selected pulse generator.
Line 5 – OPTO IN1	Connect OPTO IN 1 signal to Clear Source for the selected pulse generator.
Nand0 Out	Connect NAND 0 output signal to Clear Source for the selected pulse generator.
Nand1 Out	Connect NAND 1 output signal to Clear Source for the selected pulse generator.
User Output 0	Connect User Output 0 signal to Clear Source for the selected pulse generator.
User Output 1	Connect User Output 1 signal to Clear Source for the selected pulse generator.
User Output 2	Connect User Output 2 signal to Clear Source for the selected pulse generator.
User Output 3	Connect User Output 3 signal to Clear Source for the selected pulse generator.
Line 10 TTL IN 2	Connect TTL 2 IN signal to LINE 10.
Line 11 LVDS IN	Connect LVDS 1 IN signal to Line 11

Note: The pulse generator output cannot be used as the clear input to the same pulse generator. Refer to “5.3.6.2.GPIO matrix table”.

5.5.10 Pulse Generator Inverter

Clear Source Signal can have polarity inverted.

5.5.11 Pulse Generator setting parameters

Table - 10 Pulse Generator setting parameters

Display Name	Value
Clock Pre-scaler	1 to 4096
Pulse Generator Clock (MHz)	[Pixel Clock: 40 MHz]÷[Clock Pre-scaler]
Pulse Generator Selector	- Pulse Generator 0
	- Pulse Generator 1
- Pulse Generator Length	1 to 1048575
- Pulse Generator Length (ms)	([Clock Source]÷[Clock Pre-scaler]) $^{-1}$ x [Pulse Generator Length]
- Pulse Generator Frequency (Hz)	[Pulse Generator Length (ms)] $^{-1}$
- Pulse Generator Start Point	0 to 1048574
- Pulse Generator Start Point (ms)	([Clock Source]÷[Clock Pre-scaler]) $^{-1}$ x [Pulse Generator Start Point]
- Pulse Generator End Point	1 to 1048575
- Pulse Generator End Point (ms)	([Clock Source]÷[Clock Pre-scaler]) $^{-1}$ x [Pulse Generator End Point]
- Pulse Generator pulse-width (ms)	[Pulse Generator End Point (ms)]－[Pulse Generator Start Point (ms)]
- Pulse Generator Repeat Count	0 to 255
- Pulse Generator Clear Activation Clear Mode for the Pulse Generators	- Off
	- High Level
	- Low level
	- Rising Edge
	- Falling Edge
- Pulse Generator Clear Sync Mode	- Async mode
	- Sync mode
- Pulse Generator Clear Source	- Low
	- High
	- Software
	- Acquisition Trigger Wait
	- Acquisition Active
	- Frame Trigger Wait
	- Frame Active
	- Exposure Active
	- FVAL
	- PulseGenerator0
	- PulseGenerator1
	- Line 4 – TTL IN 1
	- Line 5 – OPTO IN 1
	- NAND0 Out
	- NAND1 Out
	- User Output 0
	- User Output 1
	- User Output 2
	- User Output 3
	- Line 10 - TTL 2 In
	- Line 11 - LVDS 1 In
- Pulse Generator Inverter(Polarity) Pulse Generator Clear Inverter	- False
	- True

Note: 1. If Pulse Generator Repeat Count is set to “0”, the pulse generator works in free-running mode.
2. The output of the same pulse generator cannot be connected to Clear input.

Table – 11 Associated GenICam register information

GenICam Name	Access	Values	Category
Pre-scaler	R/W	1 to 4096	Pulse Generators
Pulse Generator Selector	R/W	PG0 to PG1	Pulse Generators
Pulse Generator Length	R/W	0 to 1048575	Pulse Generators
Pulse Generator Start Point	R/W	0 to 1048575	Pulse Generators
Pulse Generator End Point	R/W	0 to 1048575	Pulse Generators
Pulse Generator Repeat Count	R/W	0 to 255	Pulse Generators
Pulse Generator Clear Activation	R/W	Free Run High Level Low Level Rising Edge Falling Edge	Pulse Generators
Pulse Generator Clear Source	R/W	Low High Soft Acquisition Trigger Wait Acquisition Active Frame Trigger Wait Frame Active Exposure Active FVAL PG0 to 1 User out 0 to 3 TTL in Opto1 in NAND 0 to 1	Pulse Generators
Pulse Generator Invertor	R/W	True False	Pulse Generators
Pulse Generator Sync Mode	R/W	Async Mode Sync Mode	Pulse Generators

6. Sensor layout, output format and timing

6.1 Sensor layout

The CMOS sensors used in the SP-20000-USB have the following pixel layout.

6.1.1 Monochrome sensor

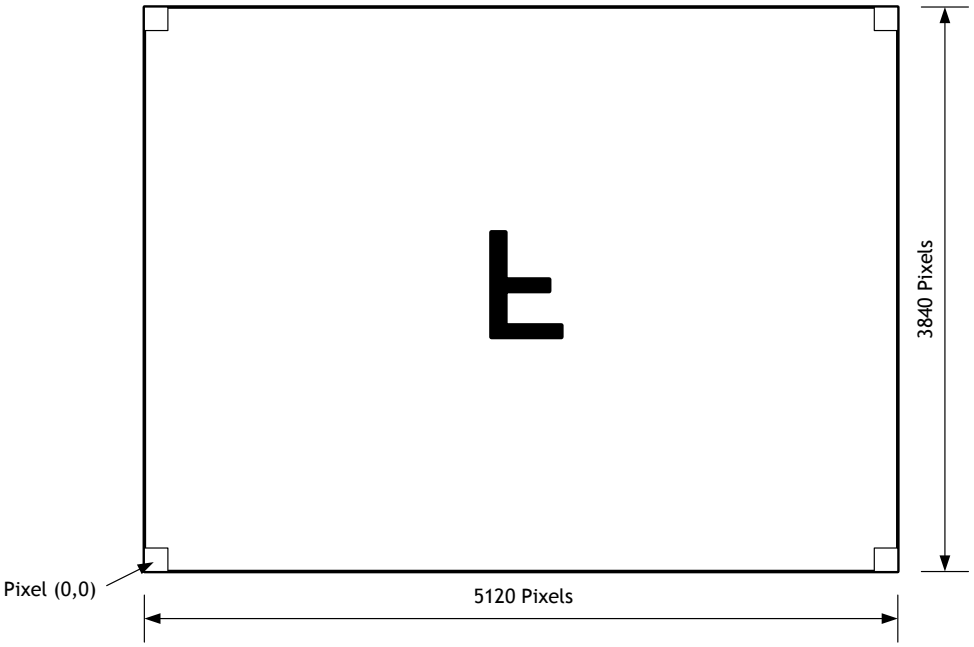


Fig. 13 Monochrome sensor layout

6.1.2 Bayer sensor

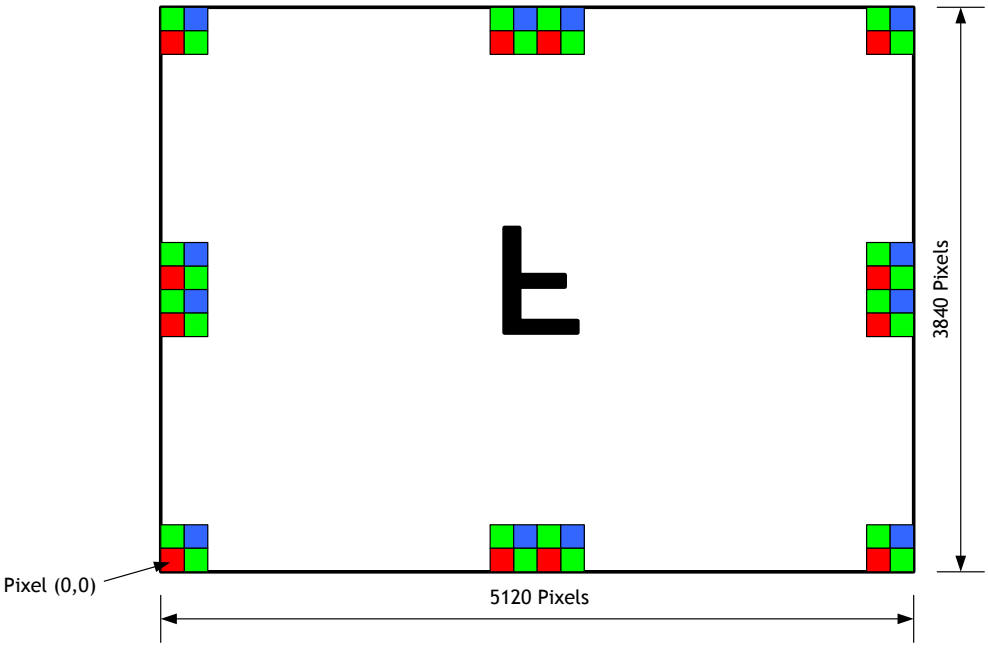


Fig. 14 Color sensor layout

6.2 Camera output format (Tap Geometry)

Table - 11 Output format

Camera output format	Pixel format	Refer to drawing
1X-1Y	8-bit, 10-bit, 12-bit, 10bit_Packed, 12bit_Packed	6.2.1

Note: The camera output description is based on GenICam SFNC Ver.1.5.1.

6.2.1 1X-1Y

1X-1Y is 1-tap readout system specified in GenICam Tap Geometry and it outputs as the following.

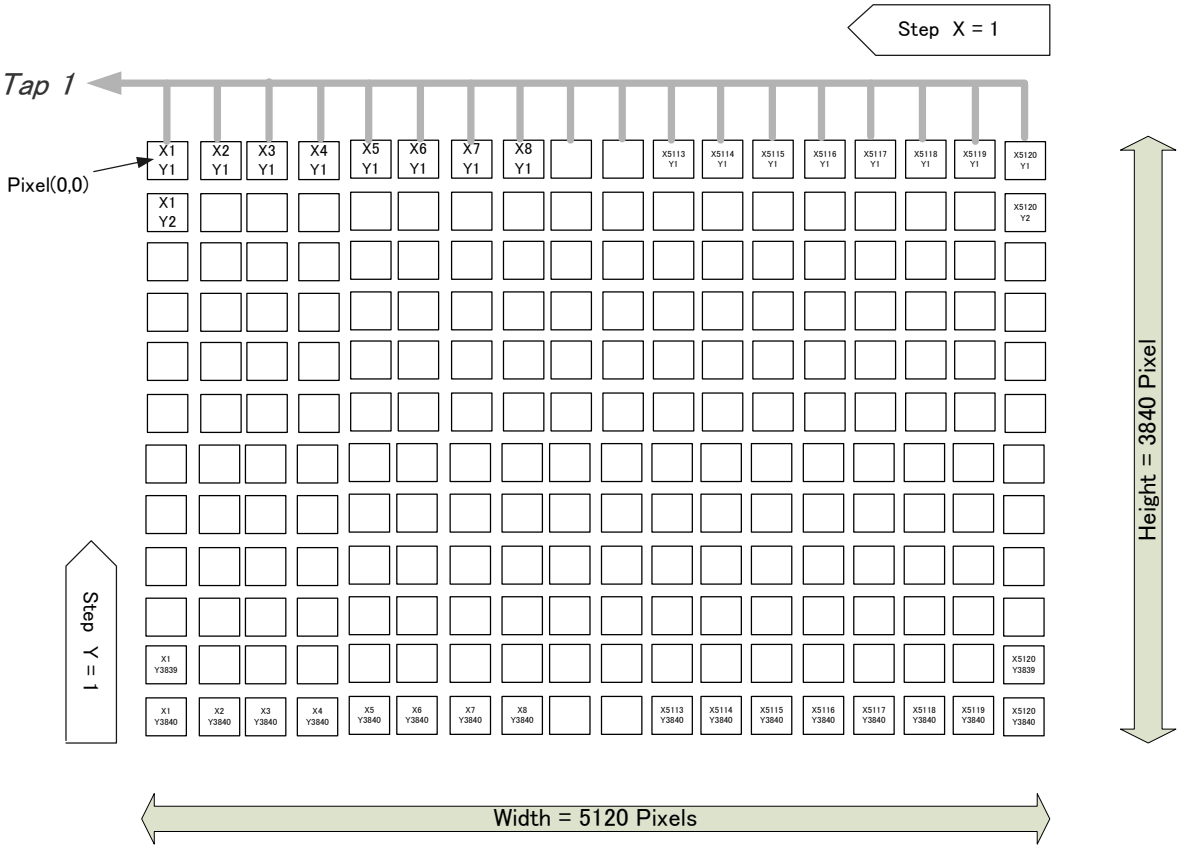


Fig. 15 1X-1Y output system

6.2.2 Pixel Type

In the SP-20000-USB, Pixel Type conforms with the AIA USB3 Vision standard.

SP-20000M-USB	SP-20000C-USB
Mono8	BayerRG8
Mono10, Mono10_Packed	BayerRG10, BayerRG10_Packed
Mono12, Mono12_Packed	Bayer12, Bayer12_Packed

6.3 Output timing and output image

6.3.1 Horizontal timing

The horizontal frequency depends on the link configuration. The following chart and tables explain the details.
In the SP-20000M-USB, the horizontal frequency does not change when horizontal binning is effective, and therefore, the frame rate is not increased.
In the following tables, Binning OFF is represented by 1 and Binning ON is 2.

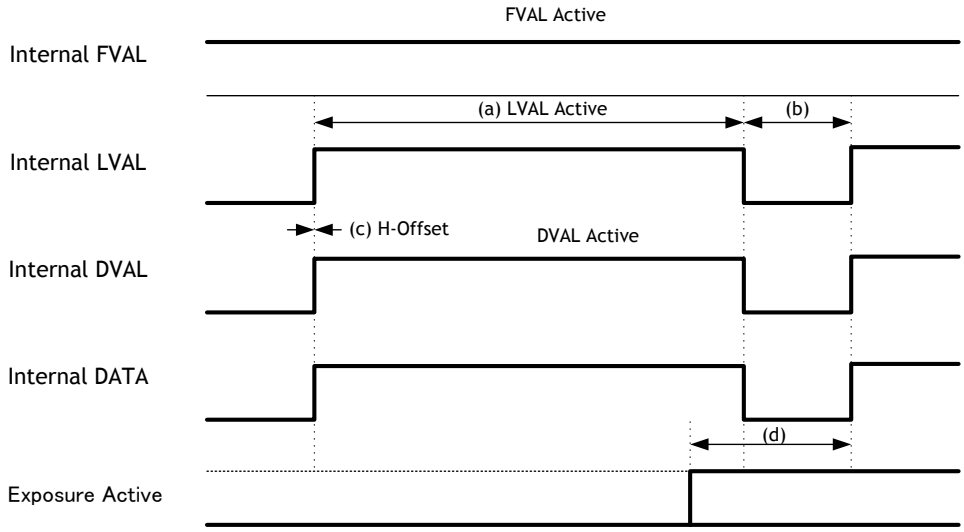


Fig.16 Horizontal timing

Table – 12 Horizontal format in continuous trigger (1/2)

Camera Settings						(a)	(b)	(c)	(d)			Step
ROI				Binning		LVAL Active	LVAL Non-Active	H-Offset	Exposure Active Start to LVAL Active Start			Step (Typ.)
Width	Offset X	Height	Offset Y	Horizontal	Vertical	[Unit: Clock]	[Unit: Clock]	[Unit: Clock]	[Unit: us]			LSB
5120	0	3840	0	1	1	640	1	0	7.8			16
5120	0	1920	0	1	2	640	642	0	7.8	or	23.8	16
2560	0	3840	0	2	1	320	321	0	7.8			16
2560	0	1920	0	2	2	320	962	0	7.8	or	23.8	16

Note: (1) The horizontal frequency is not doubled if horizontal binning is ON.
(2) If vertical binning is ON, the horizontal frequency becomes half.
(3) H-Offset: The period from the LVAL Active start to DATA Active start
(4) If the next frame is exposed while the image is read out in the vertical binning mode, the exposure control is controlled by 0.5 line.
(5) "(d) Exposure Active Start to LVAL Active Start" has 1 clock difference due to the jitter in LVAL Non Active period.
(6) LVAL signal connected GPIO does not chage by setting of Binning Horizontal and/or Binning Vertical

Table – 13 Horizontal format in continuous trigger (2/2)

Camera Settings						1Line Total Clock	Horizontal Frequency	Horizontal Period
ROI				Binning				
Width	Offset X	Height	Offset Y	Horizontal	Vertical	[Unit: Clock]	[Unit: kHz]	[Unit: us]
5120	0	3840	0	1	1	641	62.402	16.025
5120	0	1920	0	1	2	1282	31.201	32.050
2560	0	3840	0	2	1	641	62.402	16.025
2560	0	1920	0	2	2	1282	31.201	32.050

6.3.2 Vertical timing

In Continuous Trigger operation, the output timing relationship is as follows.
The SP-20000M-USB supports H-Binning and V-Binning functions, but the frame rate is not increased.
In the following tables, Binning OFF is represented by 1 and Binning ON is 2.

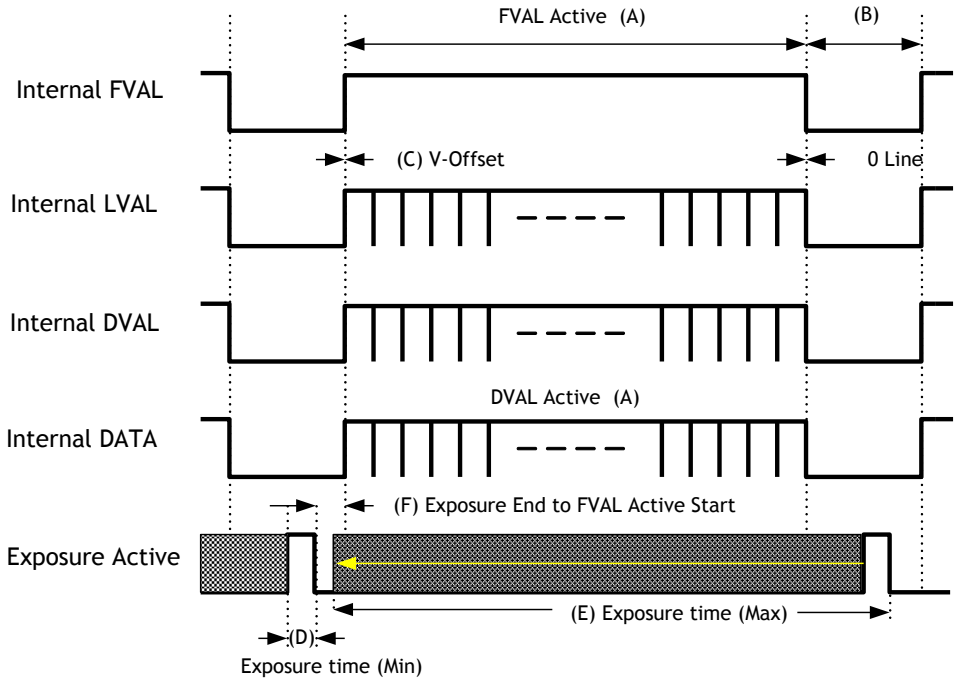


Fig. 17 Vertical timing relationship

Table – 14 Vertical format in Continuous Trigger (1/2)

Camera Settings								(A)	(B)	(C)	(D)
Pixel Format	Acquisition Frame Rate	ROI				Binning		FVAL Active	FVAL Non -Active	V -Offset	Exposure Time (Min)
		Width	Offset X	Height	Offset Y	Horizontal	Vertical	[Unit: Line]	[Unit: Line]	[Unit: Line]	[Unit: us]
8 Bit Monochrome / 8 Bit Bayer	16	5120	0	3840	0	1	1	3840	60.28	0	10.0
		5120	0	1920	0	1	2	1920	30.14		
		2560	0	3840	0	2	1	3840	60.28		
		2560	0	1920	0	2	2	1920	30.14		
10/12 Bit Monochrome / 10/12 Bit Bayer	8	5120	0	3840	0	1	1	3840	3960.41	0	10.0
		5120	0	1920	0	1	2	1920	30.14		
		2560	0	3840	0	2	1	3840	60.28		
		2560	0	1920	0	2	2	1920	30.14		
10 Bit Monochrome Packed / 10 Bit Bayer Packed	12.8	5120	0	3840	0	1	1	3840	1035.31	0	10
		5120	0	1920	0	1	2	1920	30.14		
		2560	0	3840	0	2	1	3840	60.28		
		2560	0	1920	0	2	2	1920	30.14		

12 Bit Monochrome Packed / 12 Bit Bayer Bayer Packed	10.6667	5120	0	3840	0	1	1	3840	2010.35	0	10
		5120	0	1920	0	1	2	1920	30.14		
		2560	0	3840	0	2	1	3840	60.28		
		2560	0	1920	0	2	2	1920	30.14		

Table – 15 Vertical format in Continuous Trigger (2/2)

Camera Settings								Frame Rate	(E) Exposure Time (Max.)	(F) Exposure End to FVAL Active Start	
Pixel Format	Acquisition Frame Rate	ROI				Binning					
		Width	Offset X	Height	Offset Y	Horizontal	Vertical	[Unit: Hz]	[Unit: us]	[Unit: Line]	[Unit: us]
8 bit Mono chrome / 8bit Bayer	16	5120	0	3840	0	1	1	16.000	ROUNDDOWN([Acquisition Frame Rate Raw] - 250us = 62500-250 = 62250	19.0	305.225
		5120	0	1920	0	1	2			9.5	305.225
		2560	0	3840	0	2	1			19.0	305.225
		2560	0	1920	0	2	2			9.5	305.225
10/12 bit Mono chrome / 10/12 bit Byer	8	5120	0	3840	0	1	1	7.9999	ROUNDDOWN([Acquisition Frame Rate Raw] - 250us IF 5120(H)x3840(V) = 125000-250 = 124750	19.0	305.225
		5120	0	1920	0	1	2	16.000		9.5	305.225
		2560	0	3840	0	2	1	16.000		19.0	305.225
		2560	0	1920	0	2	2	16.000		9.5	305.225
10 Bit Monochrome Packed / 10 Bit Bayer Packed		5120	0	3840	0	1	1	12.800	ROUNDDOWN([Acquisition Frame Rate Raw] - 250us IF 5120(H)x3840(V) = 78125-250 = 77875	19.0	305.225
		5120	0	1920	0	1	2	16.000		9.5	305.225
		2560	0	3840	0	2	1	16.000		19.0	305.225
		2560	0	1920	0	2	2	16.000		9.5	305.225
12 Bit Monochrome Packed / 12 Bit Bayer Bayer Packed		5120	0	3840	0	1	1	16.667	ROUNDDOWN([Acquisition Frame Rate Raw] - 250us IF 5120(H)x3840(V) = 93750-250 = 93500	19.0	305.225
		5120	0	1920	0	1	2	16.000		9.5	305.225
		2560	0	3840	0	2	1	16.000		19.0	305.225
		2560	0	1920	0	2	2	16.000		9.5	305.225

Note: (1) In the SP-20000-USB, the frame rate control is done in steps of 1 µs unit. Therefore, FVAL Non Active conversion has tolerance.
(2) Even if the horizontal binning is ON, the horizontal frequency is not doubled. Therefore, the vertical frequency is not increased.
(3) If the vertical binning is ON, the horizontal frequency becomes half. Therefore, if the height is half, the vertical frequency is not doubled.
(4) In the SP-20000-USB, the frame rate can be varied in steps of 1 µs. "(B) FVAL NON Active" in table 14 will vary accordingly.
(5) V-Offset: The period from FVAL Active Start to 1st LVAL Active Start

6.3.3 ROI (Region Of Interest)

In the SP-20000-USB, a subset of the image can be output by setting Width, Height, Offset-X, and Offset-Y. If the height is decreased, the number of lines read out is decreased and as the result, the frame rate is increased. However, in the horizontal directon, the horizontal frequency is not changed if the width is decreased. In the SP-20000-USB, the minimum width is “8” and minimum height is “2”.

Setting example (1)
Binning Horizontal = 1
Binning Vertical = 1
Mirroring = Off

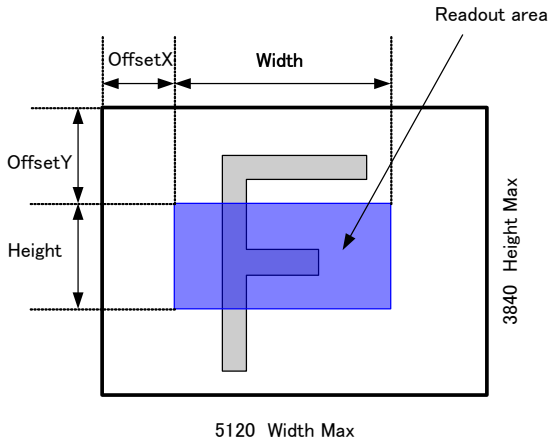
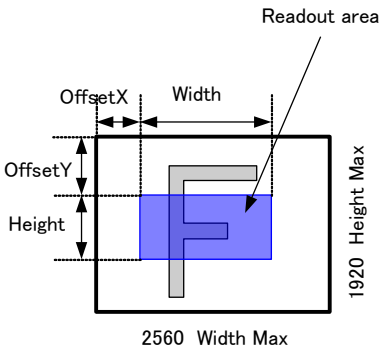


Fig. 18 Setting example (No binning)

Setting example (2)
Binning Horizontal = 2
Binning Vertical = 2
Mirroring = Off



Note: Binning is available only for SP-20000M-USB.
Binning can be used in horizontal, vertical, or both directions.

Fig.19 Setting example (with Binning)

Table – 16 Trigger / ROI setting examples

Setting reference	Camera Settings						Width Max	Height Max	Max Offset X Value	Width and Offset X Step	Max Offset Y Value	Height Step	Offset Y Step
	ROI				Binning								
	Width	Offset X	Height	Offset Y	Horizontal	Vertical							
Full Line	5120	0	3840	0	1	1	5120	3840	0	8	0	2	2
2/3 Screen - Center	3408	856	2560	640	1	1	5120	3840	1712	8	1280	2	2
1/2 Screen - Center	2560	1280	1920	960	1	1	5120	3840	2560	8	1920	2	2
1/4 Screen - Center	1280	1920	960	1440	1	1	5120	3840	3840	8	2880	2	2
1/8 Screen - Center	640	2240	480	1680	1	1	5120	3840	4480	8	3360	2	2
Full Line	2560	0	1920	0	2	2	2560	1920	0	8	0	2	2
2/3 Screen - Center	1712	424	1280	320	2	2	2560	1920	856	8	640	2	2
1/2 Screen - Center	1280	640	960	480	2	2	2560	1920	1280	8	960	2	2
1/4 Screen - Center	640	960	480	720	2	2	2560	1920	1920	8	1440	2	2
1/8 Screen - Center	320	1120	240	840	2	2	2560	1920	2240	8	1680	2	2

Note: Setting restrictions

1. [Width Max] = 5120, [Height Max] = 3840 (H and V Binning Off) (If it is On, the value is 1/2)
2. [Max Offset X Value] = [Width Max] - [Width] : Maximum value which Offset X can be set
3. [Max Offset Y Value] = [Height Max] - [Height] : Maximum value which Offset Y can be set
4. [Width and Offset X Step] : The step number which Width and horizontal offset can be shifted
5. [Height and Offset Y Step] : The step number which Height and vertical offset can be shifted

6.3.4 Mirroring function

SP-20000-USB has the ability to reverse the image vertically, horizontally, or both vertically and horizontally. If ROI readout is used, ROI image can be read out after the image is reversed.
The following drawings are setting examples of mirror image.

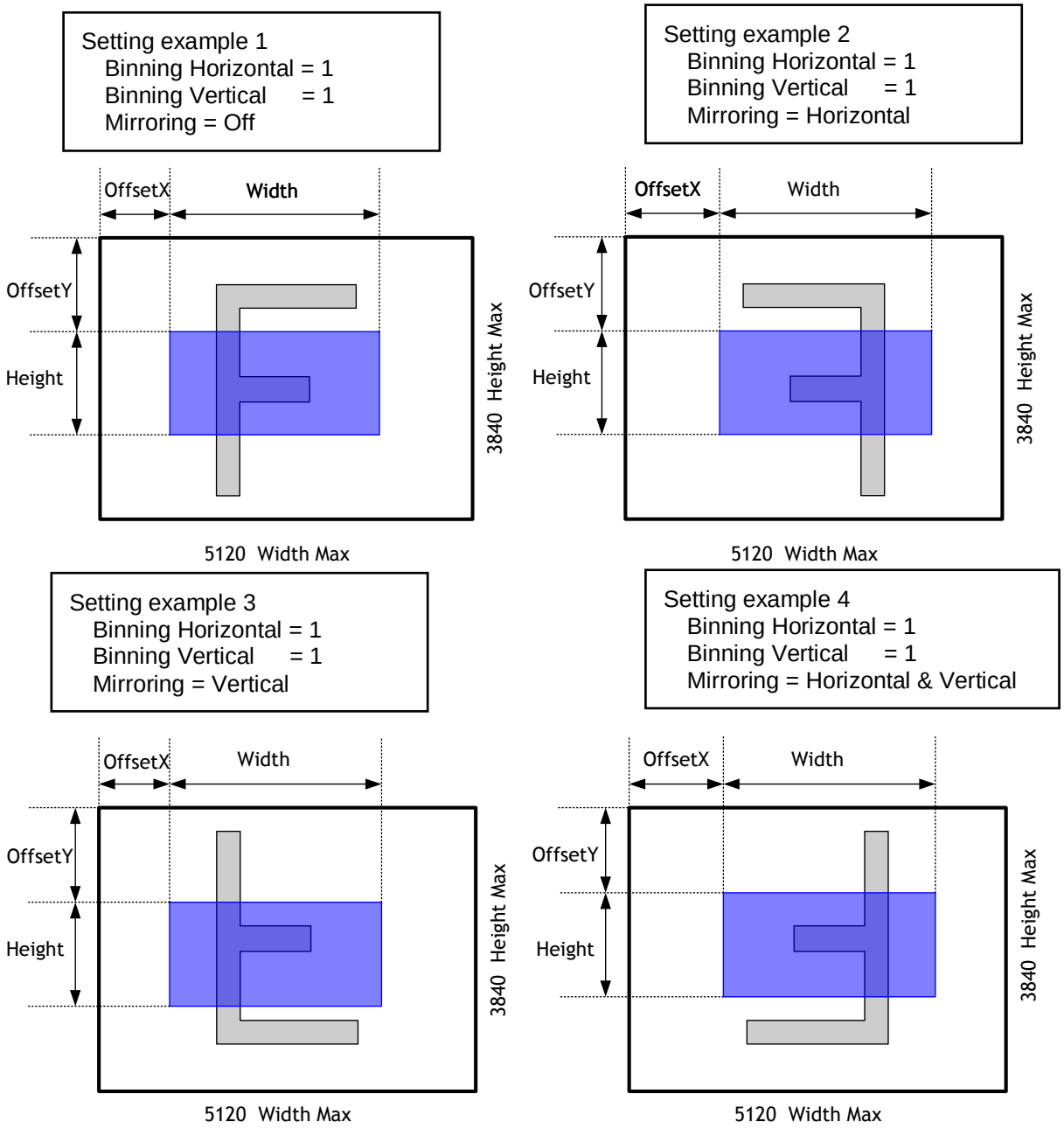


Fig 20 Mirror setting examples

Table – 17 The start pixel and line for SP-20000C-USB

	Start Line	Start Pixel
OFF	R & G	R
Horizontal	R & G	G
Vertical	B & G	G
Horizontal & Vertical	B & G	B

6.3.5 Multi ROI function

This function divides one frame image into a maximum of 8 images vertically and reads out all areas in one frame. In this function, width is the same for all 8 images. The multi ROI function is enabled if [Video Sending Mode] is set to “Multi ROI”.

Table – 18 Multi ROI Index table default values

Multi ROI Index Max	1		
Multi ROI Width	5120		
Multi ROI Index Selector	Multi ROI		
	Height	Offset	
		X	Y
- Index 1	1	0	0
- Index 2	1	0	0
- Index 3	1	0	0
- Index 4	1	0	0
- Index 5	1	0	0
- Index 6	1	0	0
- Index 7	1	0	0
- Index 8	1	0	0

6.3.5.1 Multi ROI setting parameters

(1) Multi ROI Index Max : Setting value 1 ～ 8

Maximum 8 ROI settings are possible in a frame. Set Index 1 through 8 in Multi ROI Index table as an application requires.

(2) Multi ROI Width

The setting range and Step number are the same as the normal ROI setting in which [Width] plus [Offset X] should be equal to [Width Max]. In Multi ROI operation, the maximum offset value in index 1 to index 8 is the object in this calculation.

(3) Multi ROI Index Selector :

Index 1 to 8 can be selected. [Height], [Offset X], and [Offset Y] of the selected Multi ROI Index are displayed and can be set.

(4) Multi ROI Offset X :

Offset X can be set for each ROI area of Multi ROI Index 1 to 8.
The restriction for setting Step and other factors are the same as the normal ROI setting.
As described before, in Multi ROI operation, Multi ROI Width is a common width setting for Multi ROI Index 1 to 8.

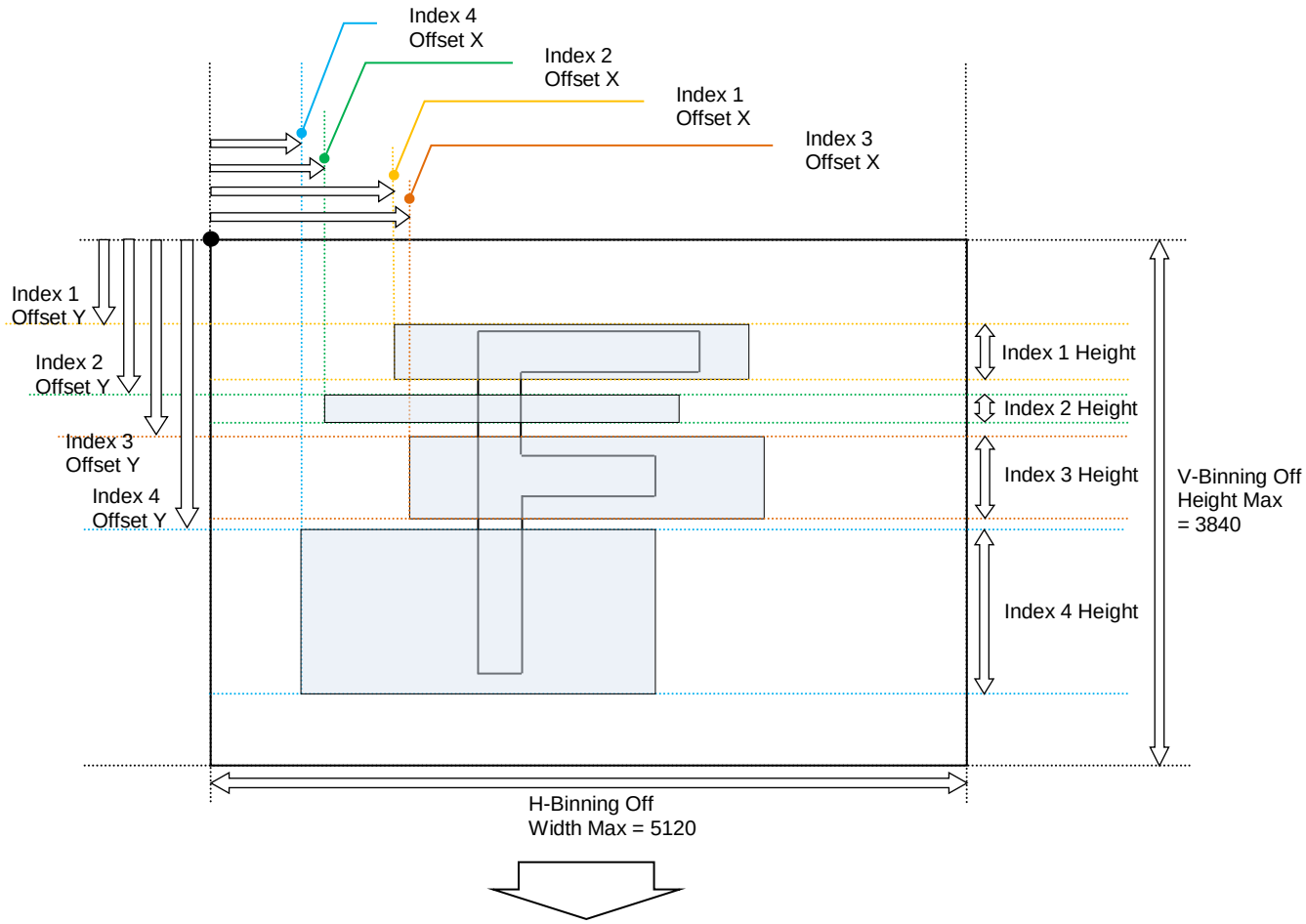
(5) Multi ROI Height :

Height can be set for each ROI area of Multi ROI Index 1 to 8.
The restriction for setting Step and other factors are the same as the normal ROI setting.
The sum of Muliti ROI Height values for index 1 to 8 should be less than Height Max.

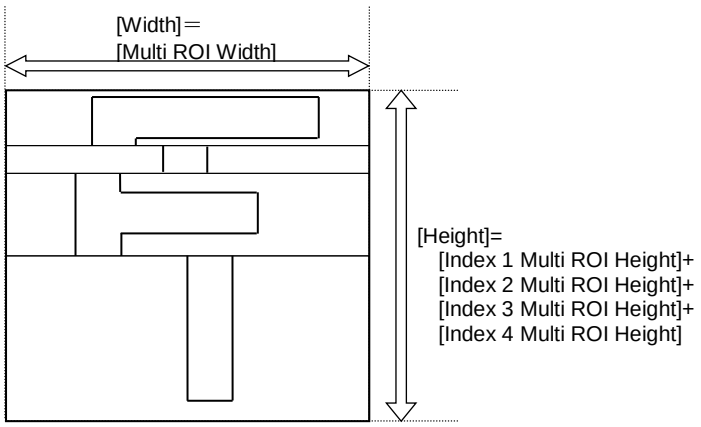
(6) Multi ROI Offset Y :

Offset Y can be set for each ROI area of Multi ROI Index 1 to 8.
The restriction for setting Step and other factors is the same as the normal ROI setting.

ROI setting explanation if Multi ROI Index Max is set to 4



Video output of Multi ROI



Note:
If Multi ROI function is used, the frame grabber board that is used should be set as follows.
Horizontal pixel number is [Multi ROI Width]. Vertical pixel number is the total of [Multi ROI Height] to be expected as configured.

Fig. 21 Multi ROI output image

6.3.5.2 Associated GenICam register information

Table – 19 Associated GenICam register information

GenICam Name	Access	Values	Category
Video Send Mode Selector	R/W	Normal Trigger Sequence Command Sequence Multi	JAI-Custom
Multi ROI Index	R/W	Index 1 to Index 8	JAI-Custom
Multi ROI Width	R/W	8 to 5120	JAI-Custom
Multi ROI Offset X	R/W	0 to 5120 – Multi ROI Width	JAI-Custom
Multi ROI Height	R/W	2 to 3840	JAI-Custom
Multi ROI Offset Y	R/W	0 to 3840 – Multi ROI Height	JAI-Custom
Multi ROI Index Max	R/W	1 to 8	JAI-Custom

6.4 Digital output bit allocation

Tanble – 19 Digital output video level

CCD out		Digital Out		
		8-bit	10-bit	12-bit
Black	0%	8LSB	32LSB	128LSB
Monochrome	100%	222LSB	890LSB	3560LSB
Color				
Monochrome	115%	255LSB	1023LSB	4095LSB
Color				

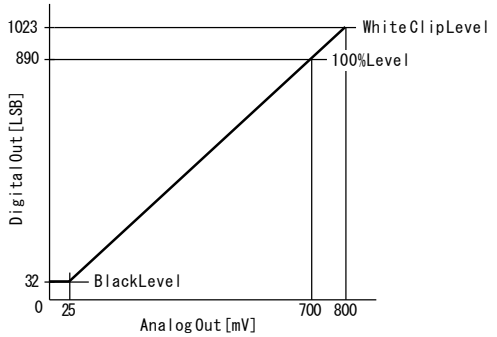


Fig. 22 Bit allocation (10-bit)

7. Operating modes

7.1. Acquisition control (change the frame rate)

7.1.1 Acquisition Mode

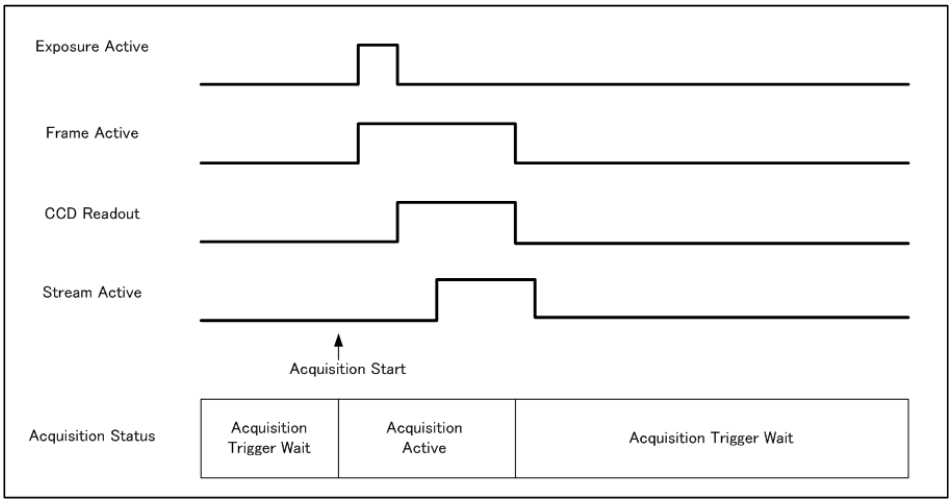
In the SP-20000M-USB and SP-20000C-USB, the following three acquisition modes are available.

Single frame :	One frame can be output by AcqusitionStart command
Multi frames :	The number of frames specified in Acquistion Frame Count, are output by AcquisitionStart command
Continuous :	Images are continuously output by AcquisitionStart command until AcqusitionStop command is input.

7.1.1.1 Single Frame

In single frame mode, executing the AcquisitionStart command causes one frame to be captured. After one frame is captured, this operation is automatically stopped.
In order to restart the capture, it is necessary to input the AcquisitionStart command again. BlockID is not reset until AcquisitionStop is input and is incremented when the AcquisitionStart command is called.
In the case of PIV operation, single frame mode is not available.

◆ Normal single frame operation
1) AcquisitionStart command is input
2) AcquisitionActive becomes “TRUE” (accepts capture)
3) 1 frame is output
4) AcquisitionActive becomes “FALSE” (stop capturing)
5) Output is stopped



Note: This figure is if the trigger mode is OFF, and when the trigger mode is ON, FrameActive becomes True at different AcquisitionActive timing.
Fig.23 Single Frame operation

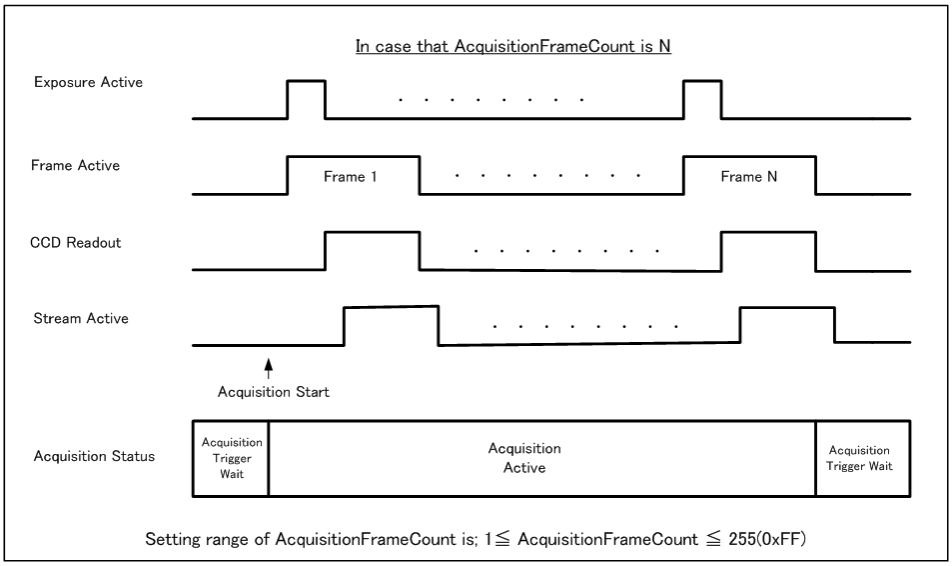
◆ Forcing acquisition to stop
While AcquisitionActive is “TRUE”, if AcquisitionStop or AcquisitionAbort is initiated, AcquisitionActive becomes “FALSE” (stop capturing).
However, if AcqusitionStop command is initiated during image output period, AcqusitionActive becomes “FALSE” (stop capturing) after image output is completed.

Associated functions: AcquisitionStart、AcquisitionStop

7.1.1.2 Multi Frames

In this mode, the AcquisitionStart command captures the number of frames which are specified by AcquisitionFrameCount. If JAI_PIV is configured, it is necessary to set an even number.

◆ Normal multi-frame operation
1) AcquisitionStart command is input
2) AcquisitionTriggerWait becomes effective
3) AcquisitionActive becomes "TRUE" (accepts capture)
4) Output N frames as specified by AcquisitionFrameCount
5) AcquisitionActive becomes "FALSE". Then the output stops. (See the following diagram)



Note: This figure is if the trigger is set to ON, and when the trigger is OFF, FrameActive becomes True at the same timing of AcquisitionActive.

Fig.24 . Multi Frame operation

◆ Forcing acquisition to stop
While AcquisitionActive is "TRUE", if AcquisitionStop or AcquisitionAbort is initiated, AcquisitionActive becomes "FALSE" (stop capturing).
Once the operation is set to "FALSE", the internal FrameCount is reset.
However, if AcqusitionStop command is initiated during image output period, AcqusitionActive becomes "FALSE" (stop capturing) after image output is completed.
Once, AcqusitionActive becomes "FALSE", the internal count is reset.

◆ Acqusition Frame Count : Can be set in the range of 1 to 255

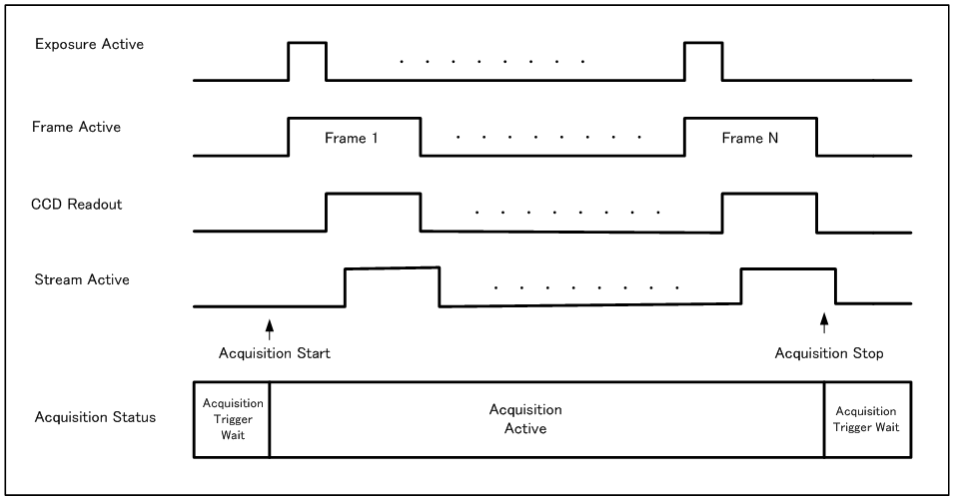
Associated functions: AcquisitionStart、AcquisitionFrameCount、AcquisitionStop

7.1.1.3 Continuous

In this mode, when the AcquisitionStart command is set, the image is continuously output at the current frame rate. This is the default setting for the SP-20000M-USB and SP-20000C-USB.

◆ Normal continuous operation
1) AcquisitionStart command is input
2) AcquisitionTriggerWait becomes effective
3) AcquisitionActive becomes "TRUE"
4) Images begin outputting continuously
5) AcquisitionStop command is sent
6) AcquisitionActive becomes "FALSE". At this moment, the output stops.

However, if AcqusitionStop command is initiated during image output period, AcqusitionActive becomes "FALSE" (stop capturing) after image output is completed.



Note: This figure is if the trigger is set to ON, and when the trigger is OFF, FrameActive becomes True at the same timing of AcquisitionActive.

Fig.25 Continuous operation

◆ Forcing acquisition to stop
If AcquisitionStop is executed and the video is already output when the camera receives the stop command, AcquisitionACtive becomes False (disabling the capture) after the video output is completed.

Associated functions：AcquisitionStart、AcquisitionStop

7.1.2 Acquisition Start

This is the command to start the capture.

7.1.3 Acquisition Stop

This is the command to stop the capture.

7.1.4 Acquisition control

With Trigger OFF and in free-running mode, the default frame rate of the camera is based on the specified ROI. The smaller the ROI, the faster the default frame rate. However, it is possible to specify a free-running frame rate that is slower than the default rate. This can be useful when a longer exposure time is needed for a specific ROI.
Modification of the frame rate is done by entering a value in the AcquisitionFrameRate control corresponding to the frequency (Hz) of the frame capture. Allowed values range from the fastest frame rate supported by the specified ROI (default) to a maximum of 0.125 Hz (fps).

The setting range is:

Shortest	to	Longest
The reciprocal of the time required to read out all pixels in the area set by ROI or The reciprocal of the time to transmit one frame data	to	0.125 Hz (fps)

Note:
1. If the trigger is set to ON, this function is not available.
2. The value for setting is the frame frequency (Hz).
3. The minimum interval of a frame depends on reading out line numbers set by ROI. If the setting value is less than time required for the minimum period, this setting is ignored and camera operates at the minimum period.

Self-running (Trigger OFF) works under the following conditions.
Exposure Mode: OFF
Exposure Mode: Timed and Frame start OFF
Exposure mode: Trigger width and Frame start OFF.

7.1.4.1 Upper limit of Frame Rate

Table 20 Upper limint od Frame Rate

Pixel Forma	Binning		Width	Height	Sensor Clock [Unit : MHz]	H-Clock [Unit: Clock]	Acquisition Frame Rate (Max. Value)	Payload Size	How many Bytes is used for image data 1 pixel (Note3)
	Horizontal	Vertical							
8 Bit Monochrome	1	1	5120	3840	40	641	16	19660800	1 Byte
	2	1	2560	3840	40	641	16	9830400	1 Byte
	1	2	5120	1920	40	1282	16	9830400	1 Byte
	2	2	2560	1920	40	1282	16	4915200	1 Byte
10/12 Bit Monochrome	1	1	5120	3840	40	641	8	39321600	2 Byte
	2	1	2560	3840	40	641	16	19660800	2 Byte
	1	2	5120	1920	40	1282	16	19660800	2 Byte
	2	2	2560	1920	40	1282	16	9830400	2 Byte
10 Bit Monochrome Packed	1	1	5120	3840	40	641	12.8	24576000	1.25 Byte
	2	1	2560	3840	40	641	16	12288000	1.25 Byte
	1	2	5120	1920	40	1282	16	12288000	1.25 Byte
	2	2	2560	1920	40	1282	16	6144000	1.25 Byte
12 Bit Monochrome Packed	1	1	5120	3840	40	641	10.6667	29491200	1.5 Byte
	2	1	2560	3840	40	641	16	14745600	1.5 Byte
	1	2	5120	1920	40	1282	16	14745600	1.5 Byte
	2	2	2560	1920	40	1282	16	7372800	1.5 Byte

Note: 1) In the SP-20000-USB, the indicated horizontal pixel number is changed if H-Binning is used or the number of width is reduced. However, the internal horizontal frequency is not changed and accordingly, the frame rate is not increased.

2) In the SP-20000-USB, if V-Binning is used, the height max is reduced to 1/2 but the horizontal frequency of 1 line is also reduced to 1/2. Accordingly, the frame rate is not increased.

3) At [Pixel Format] = 8-bit Monochrome, 1 pixel of Image data uses 1 Byte. At [Pixel Format] = 10/12-bit Monochrome, 1 pixel of image data uses 2 Bytes. In the SP-20000-USB, the frame rate is restricted to 1/2 when the data value is doubled if the pixel format is changed.

4) This table is if Exposure Mode is set to OFF

7.1.4.2 Calculation formula of Frame Rate (In Continuous Trigger operation)

Table – 21 Calculation of frame rate Raw in Continuous Trigger

Camera Settings		Minimum Value Setting Calculation Formula
Pixel Format	Binning Vertical	[Unit : us]
8 bit Mono chrome / 8bit Bayer	1 (Off)	The maximum band width of USB is: [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The data rate by ROI setting is [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) Then as comparing with [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Frame Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8
		(2) IF [USB Limit] > [USB Rate] [Frame Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Frame Rate]
	2 (On)	The Data rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) Then as comparing with [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Trigger Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8
		(2) IF [USB Limit] > [USB Rate] [Frame Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Frame Rate]
10/12 bit Mono chrome / 10/12 bit Bayer	1 (Off)	The maximum band width of USB is: [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The Data rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 2 Then as comparing with [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Frame Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 2
		(2) IF [USB Limit] > [USB Rate] [Frame Rate] = ((([Height] x 641) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Trigger Rate]
	2 (On)	The Data rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 12205) ÷ 40MHz) x 2 Then as comparing with [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Frame Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 2
		(2) IF [USB Limit] > [USB Rate] [Frame Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Frame Rate]

Camera Settings		Minimum Value Setting Calculation Formula [Unit : us]
Pixel Format	Binning Vertical	
10 bit Monochrome Packed / 10 bit Bayer Packed	1 (Off)	The maximum band width of USBis: [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The data rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.25 Then as comparing with [USB Limit] and [USB Rate]
		(1) If [USB Limit] < [USB Rate], [Frame Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.25
		(2) If [USB Limit] > [USB Rate], [Frame Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Frame Rate]
	2 (On)	The data rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.25 Then as comparing with [USB Limit] and [USB Rate]
		(1) If [USB Limit] < [USB Rate], [Frame Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.25
		(3) If [USB Limit] > [USB Rate], [Frame Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Frame Rate]
12 bit Monochrome Packed / 12 bit Bayer Packed	1 (Off)	The maximum band width of USBis: [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The data rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.5 Then as comparing with [USB Limit] and [USB Rate]
		(1) If [USB Limit] < [USB Rate], [Frame Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.5
		(2) IF [USB Limit] > [USB Rate], [Frame Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Trigger Rate]
	2 (On)	The data rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.5 Then as comparing with [USB Limit] and [USB Rate]
		(1) If [USB Limit] < [USB Rate], [Frame Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.5
		(3) If [USB Limit] > [USB Rate], [Frame Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
		[Frame Rate Raw] = 1/ [Frame Rate]

7.2. Exposure control

This function sets how to expose the object.

7.2.1 Exposure Mode

The exposure mode can be selected from the following three ways.

Table – 24

Exposure Mode setting	Exposure operation
OFF	No exposure control (Self-running operation)
Timed	Exposure operation at the value set in Exposure Time. Setting value is usec unit. ・If Trigger Mode setting is OFF, the camera is in self-running operation. ・If Trigger Mode setting is ON, the exposure operation depends on the setting of Trigger Option.
Trigger Width	The exposure is controlled by the pulse width of the external trigger. ・Trigger Mode is forced to ON.

In the trigger operation, Exposure Mode must be set other than OFF and Trigger Mode of Frame Start must be ON.
If Exposure Mode is set at Timed, the exposure operation can be selected as follows by setting Trigger Option

Table – 25 Trigger option

Trigger Option setting	Exposure operation
OFF	Timed (EPS) mode
PIV	PIV (Particle Image Velocimetry) mode

The operation resulting from the combination of Exposure Mode, Trigger Option and Trigger Mode is as follows.

Table – 26 The combination of Exposure Mode, Trigger Option and Trigger Mode

Exposure Mode	Trigger Option	Trigger Mode (Frame Start)	Operation
OFF	N/A	N/A	Self-running operaion Exposure control by Exposure Time is not possible
Timed	OFF	OFF	Self-running operaion Exposure control by Exposure Time is not possible
		ON	Timed (EPS) Operation Exposure can be controlled by Exposure Time
	PIV	Forced to ON	PIV Operation Exposure can be controlled by Exposure Time
Trigger Width	N/A	Forced to ON	Exposure is controlled by the pulse width of the external trigger

Table – 27 Associated GenICam register information

GenICam Name	Access	Values	Category
Exposure Mode	R/W	Off Timed TriggerWidth	Acquisition Control
Trigger Mode	R/W	Off On	Acquisition Control
Trigger Option	R/W	Off PIV	JAI-Custom

7.2.2 ExposureTime

This command is effective only when Exposure Mode is set to Timed. It is for setting exposure time. The setting step for exposure time is 1 μsec per step.

Minimum: 10 μsec (Note: Actual exposure time is 299μsec)
Maximum: 8 seconds (When Frame Start Trigger Mode is ON)

Note: The actual exposure time is added 289μsec against the setting exposure value due to the sensor characteristics. However, the exposure active signal to be output, is not the actual exposure time but the setting exposure value.

The sensor exposure time = Exposure + 289μs

Note:
In free-running mode with the Frame Start Trigger set to OFF, the maximum setting value of the exposure time is limited by the frame rate setting.
Although 8 seconds is the maximum frame rate setting, the upper limit of the exposure time setting value is 7,999,750 μsec, which is 250 μsec shorter than the maximum.
In EPS trigger operation, where Exposure Time is not influenced by the frame rate setting, the upper limit is 8 seconds.
However, please note the following:
For the sensor used in the SP-20000-USB, the black level tends to increase based on the exposure time and the temperature of the sensor. The SP-20000-USB compensates this black shift inside the camera but the following are the maximum ambient temperatures which guarantee the performance at 8 sec of exposure time.
SP-20000M-USB: Up to 25°C of ambient temperature
SP-20000C-USB: Up to 15°C of ambient temperature

Table – 28 Associated GenICam register information

GenICam Name	Access	Values	Category
Exposure Mode	R/W	Off Timed TriggerWidth	Acquisition Control
Exposure Time	R/W	10 to 8000000 [us]	Acquisition Control
Exposure Time Raw	R/W	10 to 8000000 [us]	Acquisition Control

7.2.3 Behavior if Trigger Overlap is set to Readout

In the SP-20000-USB, if the accumulation of the next frame starts while the current image is read out, the varied value of accumulation time is changed to 1 Line period inside the camera. This is done so that the accumulation start signal will not affect the output signal while it is overlapped.

However, the shutter noise at the exposure start period will appear on images. It is approximately 70LSB/10-bit as the maximum.

Table – 23 Modes where the exposure control becomes 1L if overlap occurs

JAI Custom Naming	Trigger Mode	Trigger Overlap
Continuous Trigger	Off	(don't care)
EPS Trigger / LVAL SYNC Reset	On	Readout
HDR	Off / On	Readout, if the trigger mode is ON.

Table – 24 Formula of the exposure time maximum value at the continuous trigger

Camera Settings Binning Vertical	Continuous Trigger [Exposure Time Max] setting calculation formula [Unit : us]
1 (Off)	[Acquisition Frame Rate Raw] - 250us
2 (On)	[Acquisition Frame Rate Raw] - 250us
Note: The sensor used in the SP-20000-USB does not have a function of Shutter OFF. If [Frame Start]-[Trigger Mode] is OFF or [Exposure Mode] is OFF, the camera operates at the maximum exposure time based on the above formula.	

7.2.3 ExposureAuto

This is a function to control the exposure automatically. It is effective only for Timed.
ALC Reference controls the brightness.

There are three modes: OFF, Once and Continuous.

OFF:	No exposure control
Once:	Exposure adjusts when the function is set, then remains at that setting
Continuous:	Exposure continues to be adjusted automatically

In this mode, the following settings are available.

ALC Speed:	Rate of adjustment can be set (common with Gain Auto)
ASC Max:	The maximum value for the exposure time to be controlled can be set
ASC Min:	The minimum value for the exposure time to be controlled can be set
ALC Reference:	The reference level of the exposure control can be set (common with Gain Auto)
ALC Channel area:	The measurement area of the exposure control can be set

Table – 30 Associated GenICam register information

GenICam Name	Access	Values	Category
ASC	R/W	Off Continuous Once	Acquisition Control
ASC Max	R/W	100 to 8000000	JAI-Custom
ASC Min	R/W	100 to 8000000	JAI-Custom

7.3. Trigger operation

The trigger operation can be configured by the combination of Trigger Mode, Exposure Mode and Trigger Option. The following table shows the various combinations and the resulting operation.

Table - 25 Trigger operation settings

Trigger Selector						JAI Custom Trigger Mode Name	Operation
Frame Start		Trigger Option	Acquisition Start	Acquisition End	Acquisition Transfer Start		
Trigger Mode	Exposure Mode		Trigger Mode	Trigger Mode	Trigger Mode		
Off	Off	Off	Off	Off	Off	Continuous Trigger	Self running operation with the maximum exposure time per the frame rate
Off	Timed	Off	Off	Off	Off	Continuous Trigger	Self running operation with a user-set exposure time.
On	Timed	Off	Off	Off	Off	EPS Trigger	Externally triggerred operation with a user-set exposure time
On	Timed	PIV	Off	Off	Off	PIV Trigger	Externally triggerred operation for PIV
On	Trigger Width	Off	Off	Off	Off	PWC Trigger	Externally triggerred operation with a pulse width exposure time
Off	Off / Timed	Off	On	Off	Off	Continuous Trigger	Start Continuous Trigger operation by the input of Trigger Source in Acquisition Start
Off	Off / Timed	Off	On	Off	Off	Continuous Trigger	Start Continuous Trigger operation by the input of Trigger Source in Acquisition Start
Off	Off / Timed	Off	On	On	Off	Continuous Trigger	Start Continuous Trigger operation by the input of Trigger Source in Acquisition Start. If Acquisition mode is Continuous, Trigger Source Input of Acquisition END can stop acquisition.
Off	Off / Timed	Off	On	Off	On	Continuous Trigger	The image captured at Trigegr Source input of Acquisition Start can be stored in the memory, and its image can be read out with the delay by Trigger Source Input of Transfer Start. Please note that the frame number read out continuously is 2 frames.

7.3.1 Trigger Selector

Selects the trigger operation. In the SP-20000-USB, the following trigger operation can be selected as the trigger.

Table – 26 Trigger selector

Trigger Selector Item	Description
Frame Start	Frame Start Trigger operation
Acquisition Start	Acqusition Start Trigger operation
Acqusition End	Acqusition End Trigger operation
Acqusition Transfer Start	Delayed readout of the Video by Acquisition Transfer Start Trigger

7.3.2 Trigger Mode

Select either free-running operation or external trigger operation.

OFF: Self-running operation
ON: External trigger operation

7.3.1 TriggerSource

Select the trigger source to be used for trigger operation from the following table.

Table – 27 Trigger Source

Trigger Source Item	Description
Low	Connect LOW level signal to the selected trigger operation **Default setting**
High	Connect HIGH level signal to the selected trigger operation
Soft Trigger	Connect Soft Trigger signal to the selected trigger operation Trigger can be input manually by the execution of the software trigger Trigger software is available on each trigger source.
PulseGenerator0 Out	Connect Pulse generator 0 signal to the selected trigger operation
PulseGenerator1 Out	Connect Pulse generator 1 signal to the selected trigger operation
Line 4 - TTL 1 In	Connect TTL 1 IN signal to the selected trigger operation
Line -5 – OPTO IN 1	Connect OPTO IN 1 signal to the selected trigger operation
Nand 0 Out	Connect NAND 0 OUT signal to the selected trigger operation
Nand1 Out	Connect NAND 1 OUT signal to the selected trigger operation
User Output 0	Connect User Output 0 signal to the selected trigger operation. 0 or 1 status can be sent by User 0 command from PC(Host side).
User Output 1	Connect User Output 1 signal to the selected trigger operation. 0 or 1 status can be sent by User 0 command from PC(Host side).
User Output 2	Connect User Output 2 signal to the selected trigger operation. 0 or 1 status can be sent by User 0 command from PC(Host side).
User Output 3	Connect User Output 3 signal to the selected trigger operation. 0 or 1 status can be sent by User 0 command from PC(Host side).
Line 10 TTL IN 2	Connect TTL 2 IN signal to Line 10
Line 11 LVDS IN	Connect LVDS 1 IN signal to Line 11

7.3.2 TriggerActivation

This command can select how to activate the trigger.

Rising edge: At the rising edge of the pulse, the trigger is activated.
Falling edge: At the falling edge of the pulse, the trigger is activated.
Level High: During the high level of trigger, the accumulation is activated
Level Low: During the low level of trigger, the accumulation is activated

If Exposure Mode is set to Trigger Width, Level High or Level Low must be used.
Table - 28 Trigger Activation

Camera Settings				JAI Custom Trigger Mode Name	Trigger Activation Setting			
Trigger Selector	Trigger Mode	Exposure Mode	Trigger Option		Rising Edge	Falling Edge	Level High	Level Low
Frame Start	On	Timed	Off	EPS Trigger	○	○	×	×
	On	Timed	PIV	PIV Trigger	○	○	×	×
	On	Trigger Width	Off	PWC Trigger	×	×	○	○

7.3.3 Triggeroverlap

This function defines whether or not a trigger pulse can be accepted while data is being read out.
OFF : The trigger pulse is not accepted during sensor readout.
Read Out : The trigger pulse can be accepted during sensor readout.

7.4. Normal continuous operation (Timed Exposure Mode/Trigger Mode OFF)

This is used for applications which do not require triggering.
For the video timing, refer to chapter 6.3.

Table – 29 Typical Minimum interval (Pixel format : 8-bit)

Trigger Mode	Readout Mode	Time (Min. Trigger Period)			
		8bit	10bit/12bit	10bit_Packed	12bit_Packed
Timed Exposure Mode Trigger Mode OFF	Full	62.500 ms 16.000 fps	125.002 ms 8.000 fps	78.125 ms 12.800 fps	93.747 ms 10.667 fps
	ROI Center 2/3	41.990 ms 23.815 fps	8.000 ms 18.028 fps	41.990 ms 23.815 fps	41.990 ms 23.815 fps
	ROI Center 1/2	31.734 ms 31.512 fps	31.734 ms 31.512 fps	31.734 ms 31.512 fps	31.734 ms 31.512 fps
	ROI Center 1/4	16.231 ms 61.612 fps	16.350 ms 61.162 fps	16.350 ms 61.162 fps	16.350 ms 61.162 fps
	ROI Center 1/8	8.658 ms 115.50 fps	8.658 ms 115.50 fps	8.658 ms 115.50 fps	8.658 ms 115.50 fps
	V Binning ON (Full) (Note1)	62.500 ms 16.000 fps	62.500 ms 16.000 fps	62.500 ms 16.000 fps	62.500 ms 16.000 fps

Note 1 : SP-20000M-USB only

7.5. Timed mode (EPS operation)

This mode allows a single image frame to be captured with a preset exposure time by using the external trigger. An additional setting determines if the trigger pulse can be accepted during the exposure period.

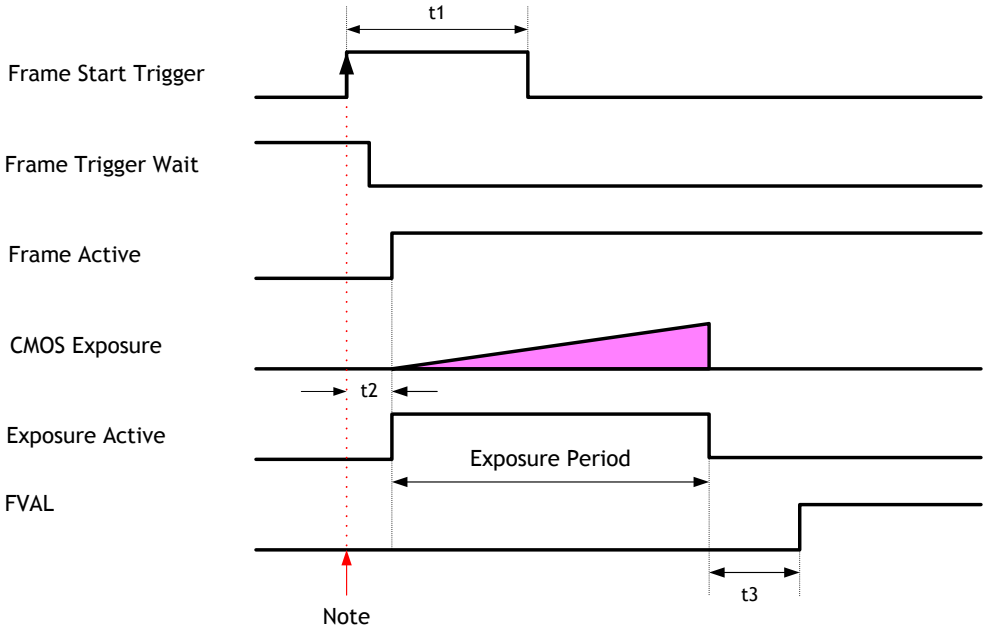
Basic settings to use this mode
Trigger Mode = ON
Exposure Mode = Timed
Trigger Option = Off
Trigger Overlap = OFF

Table - 30 Typical Trigger minimum interval (Pixel format: 8-bit)

Trigger Mode	Readout Mode	Time (Min. Trigger Period)			
		8bit	10bit/12bit	10bit_Packed	12bit_Packed
Timed Exposure Mode Trigger Mode On	Full	≧62.53 ms	≧125.03 ms	≧78.16 ms	≧93.78 ms
	ROI Center 2/3	≧42.02 ms	≧ 55.50 ms	≧42.02 ms	≧42.02 ms
	ROI Center 1/2	≧31.75 ms	≧ 31.76 ms	≧31.76 ms	≧31.76 ms
	ROI Center 1/4	≧16.35 ms	≧ 16.38 ms	≧16.38 ms	≧16.38 ms
	ROI Center 1/8	≧ 8.66 ms	≧ 8.70 ms	≧ 8.69 ms	≧ 8.69 ms
	V Binning ON (Full) (Note 1)	≧62.55 ms	≧ 62.55 ms	≧62.55 ms	≧62.55 ms

Note1 : SP-20000M-USB only
Note2 : The above table is if Trigger Overlap is set to Readout.

7.5.1 If Overlap setting is OFF



Note: The trigger pulse is accepted during Frame Trigger Wait being active if the trigger overlap is OFF. When the trigger is accepted, the trigger wait is inactive until the readout is completed.

Fig. 26 Timed (EPS) Overlap = OFF

Table – 31 Timing values

Timed (EPS) Mode, Trigger Overlap = Off			
	Camera Settings		
	Vertical Binning	Exposure Active Signal source	Pixel Format = 8/10/12 bit Monochrome、8/10/12 bit Bayer Color
t1	-		2L(Min.)
t2	-	TTL Out	1.820 us ～ 1.850 us
		Inside camra	490 ns ～ 520 ns
t3	1 (Off)	TTL Out	306,050 us
		Inside camera	305.200 us
	2 (On)	TTL Out	306,050 us
		Inside camera	305.200 us

Note: (1) Because jitter occurs during triggering, t2 has tolerance in time.
(2) If the exposure signal is used as TTL OUT, the timing is delayed against the timing inside camera. Especially, the phase delay is large at the rising edge.

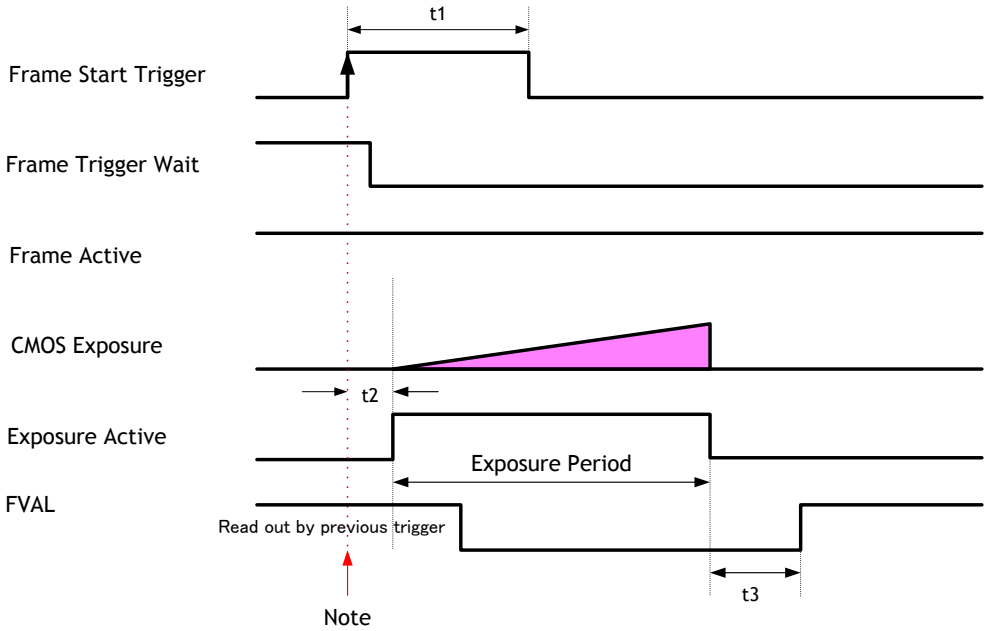
Table – 32 Minimum trigger interval calculation formula (Trigger Overlap: OFF)

Camera Settings		Trigger Mode=“On”、Exposure Mode=“Timed”、Trigger Overlap=“Off” Minimum Trigger Period Setting Caluculation Formula [Unit：us]
Pixel Format	Binning Vertical	
8 bit Mono chrome / 8bit Bayer	1 (Off)	Maximum USB Band Width is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40 MHz) As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate], [Trigger Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8
		(2) IF [USB Limit] > [USB Rate] [Trigger Rate] = 1/((([Height] x 641) + 38580 ÷ 40 MHz)
		[Trigger Period] = (1/ ([Trigger Rate])+[Exposure Time:10us ~8s] + 16.025 us
	2 (On)	Data Rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40 MHz) As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate], [Output Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8
		(2) IF [USB Limit] > [USB Rate], [Output Rate] = 1/((([Height] x 1282) + 38580) ÷ 40 MHz)
		[Trigger Period] = (1/ [Output Rate])+[Exposure Time:10 us ~8s] + 32.050 us
10/12bit Mono chrome / 10/12bit Bayer	1 (Off)	Maximum USB Band Width is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40 MHz) x 2 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate], [Readout Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 2
		(2) IF [USB Limit] > [USB Rate], [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40 MHz)
		[Trigger Period] = (1/ [Readout Rate])+[Exposure Time:10us ~8s] + 16.025 us
	2 (On)	Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40 MHz) x As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate], [Readout Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 2
		(2) IF [USB Limit] > [USB Rate], [Readout Rate] = 1/((([Height] x 1282) + 38580) ÷ 40 MHz)
		[Trigger Period] = (1/ [Readout Rate]) + [Exposure Time:10 us ~8s] + 32.050 us

Table – 32 (Cont) Minimum trigger interval calculation formula (Trigger Overlap: OFF)

Camera Settings		Trigger Mode= "On" 、Exposure Mode= "Timed" 、Trigger Overlap= "Off" Minimum Trigger Period Setting Calculation Formula [Unit : us]
Pixel Format	Binning Vertical	
10 bit Monochrome Packed / 10 bit Bayer Packed	1 (Off)	Maximum USB Bandwidth is; [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.25 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.25
		(2) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ [Readout Rate])+[Exposure Time:10us ~8s] + 16.025 us
	2 (On)	Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.25 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.25
		(3) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ [Readout Rate]) + [Exposure Time:10us ~8s] + 32.050 us
12 bit Monochrome Packed / 12 bit Bayer Packed	1 (Off)	Maximum USB Bandwidth is; [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.5 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.5
		(3) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ [Readout Rate])+[Exposure Time:10us ~8s] + 16.025 us
	2 (On)	Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.5 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.5
		(2) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ [Readout Rate]) + [Exposure Time:10us ~8s] + 32.050 us

7.5.2 If Overlap setting is Readout



Note: If the trigger overlap is Readout mode, Frame Trigger Wait is active on FVAL period of the previous trigger. In this period, the next trigger can be accepted. After receiving this trigger pulse, Frame Trigger Wait becomes inactive.

Fig. 27 Overlap Readout

Table - 33 Timing values

	Camera Settings		
	Vertical Binning	Exposure Active Signal source	Pixel Format = 8/10/12 bit Monochrome、8/10/12 bit Bayer Color
t1	-		2L(Min.)
t2	-	TTL Out	1,870 us ～ 1.870 us + 1 Line(16.025ms)
		Inside camera	490 ns ～ 490 ns + 1 Line(16.025ms)
t3	1 (Off)	TTL Out	306,100 us
		Inside camera	305.200 us
	2 (On)	TTL Out	306,100 us
		Inside camera	305.200 us

Note: (1) Because jitter occurs during triggering, t2 has tolerance in time.
(2) If the exposure signal is used as TTL OUT, the timing is delayed against the timing inside camera. Especially, the phase delay is large at the rising edge.

Table - 34 Minimum trigger interval formula Overlap: calculation (Trigger Readout)

Camera Settings		Trigger Mode=“On”、Exposure Mode=“Timed”、Trigger Overlap=“Off”
Pixel Format	Binning Vertical	Minimum Trigger Period setting calculation Formula [Unit：us]
8 bit Monochrome / 8bit Bayer	1 (Off)	IF (1/[Trigger Overlap=Off Readout Rate]) ＋16.025 us ＋ 10 us － 260 us ≧ [Exposure Time] MIN.. ＝ (1/[Trigger Overlap=Off Readout Rate]) + 16.025 us ＋ 10 us
		IF (1/[Trigger Overlap=Off Readout Rate]) ＋16.025 us＋ 10 us － 260 us ＜ [Exposure Time] MIN.＝ [Exposure Time] ＋ 260 us
	2 (On)	IF (1/[Trigger Overlap=Off Readout Rate]) ＋32.050 us＋ 10 us － 260 us ≧ [Exposure Time] MIN.＝ (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10 us
		IF (1/[Trigger Overlap=Off Output Rate]) ＋ 32.050 us ＋ 10 us － 26 0us ＜ [Exposure Time] MIN.＝ [Exposure Time] ＋ 260 us
10/12bit Monochrome / 10/12bit Bayer	1 (Off)	IF (1/[Trigger Overlap=Off Output Rate]) ＋16.025 us＋ 1 0us － 260 us ≧ [Exposure Time] MIN.＝ (1/[Trigger Overlap=Off Output Rate]) ＋ 16.025 us ＋ 10 us
		IF [Trigger Overlap=“Off” Output Period] ＋16.025 us＋ 10 us － 260 us ＜ [Exposure Time] MIN.＝ [Exposure Time] ＋ 260 us
	2 (On)	IF (1/[Trigger Overlap=Off Output Rate]) ＋32.050 us ＋ 10 us － 260 us ≧ [Exposure Time] MIN.＝ (1/[Trigger Overlap=Off Output Rate]) ＋32.050 us ＋ 10 us
		IF [Trigger Overlap=“Off” Trigger Period] ＋32.050 us ＋ 10 us － 260 us ＜ [Exposure Time] MIN.＝ [Exposure Time] ＋ 260 us

Table – 34 (Cont) Minimum trigger interval calculation formula (Trigger Overlap: Readout)

Camera Settings		Trigger Mode=“On”、Exposure Mode=“Timed”、Trigger Overlap=“Off” Minimum Trigger Period setting calculation formula [Unit：us]
Pixel Format	Binning Vertical	
10 Bit Monochrome Packed / 10 Bit Bayer Packed	1 (Off)	IF (1/[Trigger Overlap=Off Readout Rate]) ＋16.025us ＋ 10us － 260us ≧ [Exposure Time] ＝ (1/[Trigger Overlap=Off Readout Rate]) + 16.025us ＋ 10 us
		IF (1/[Trigger Overlap=Off Readout Rate]) ＋16.025us＋ 10us － 260us ＜ [Exposure Time] ＝ [Exposure Time] ＋ 260 us
	2 (On)	IF (1/[Trigger Overlap=Off Readout Rate]) ＋32.050 us＋ 10us － 260us ≧ [Exposure Time] ＝ (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10us
		IF (1/[Trigger Overlap=Off Output Rate]) ＋ 32.050 us ＋ 10us － 260us ＜ [Exposure Time] ＝ [Exposure Time] ＋ 260 us
12 Bit Monochrome Packed / 12 Bit Bayer Packed	1 (Off)	IF (1/[Trigger Overlap=Off Output Rate]) ＋16.025 us＋ 10us － 260us ≧ [Exposure Time] ＝ (1/[Trigger Overlap=Off Output Rate]) ＋ 16.025us ＋ 10us
		IF [Trigger Overlap=“Off” Output Period] ＋16.025 us＋ 10us － 260us ＜ [Exposure Time] ＝ [Exposure Time] ＋ 260 us
	2 (On)	IF (1/[Trigger Overlap=Off Output Rate]) ＋32.050 us ＋ 10us － 260us ≧ [Exposure Time] ＝ (1/[Trigger Overlap=Off Output Rate]) ＋32.050us ＋ 10us
		IF [Trigger Overlap=“Off” Trigger Period] ＋32.050 us ＋ 10us － 260us ＜ [Exposure Time] ＝ [Exposure Time] ＋ 260 us

7.5.3 GPIO TTL output timing if Trigger Overlap is OFF

Frame Start -Trigger Mode = “On”, Exposure Mode = “Timed”, Trigger Overlap =OFF

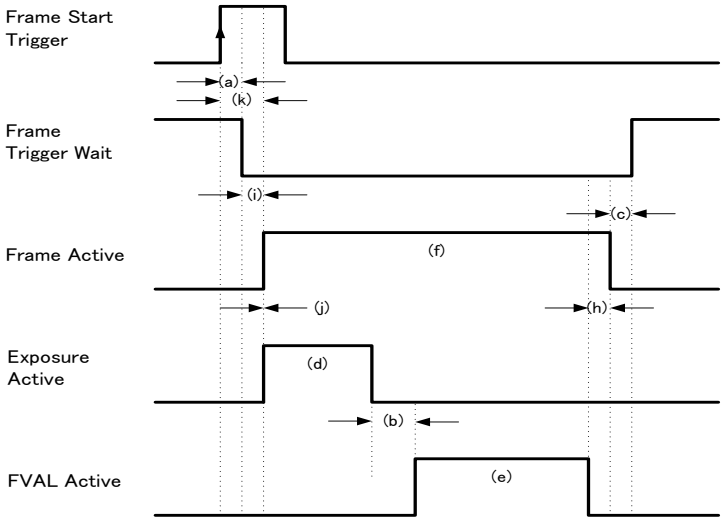


Fig. 28 GPIO TTL OUT timing

Table - 35 GPIO Out timing (Reference) (Trigger Overlap= OFF)

	Region	Pixel Format		Note
	Region	Pixel Format		Note
		10bit Mono/Bayer Packed	12bit Mono/Bayer Packed	
(a)	Frame Start Trigger to Frame Trigger Wait Falling Edge	1.00 us 306.60 us	← ←	If Frame Start Trigger is input from TTL I/F IN 1 ( ) is the phase relationship
(b)	Exposure Active Falling Edge to FVAL Raising Edge	306.60 us (305.20 us)	←	( ) is the phase relationship between the exposure time and FVAL inside camera
(c)	Frame Active Falling Edge to Frame Trigger Wait Rising Edge	1.40 us 8.60 us	← ←	 If Exposure Time = 10.
(d)	Exposure Active	8.60 us (10.00000 us) 61.53430 ms	← ← ←	If Exposure Time = 10. ( ) is the exposure time inside camera If Binning off and Height=3840
(e)	FVAL Active	61.53430 ms (61.53570 ms)	←	If Binning off and Height=3840 (Varies by the vertical ROI)
(f)	Frame Active	78.130 ms	93.760 ms	If Exposure Mode = Timed
(h)	FVAL Falling Edge to Frame Active Falling Edge	16.280 ms (16.280 ms) 1.11900 us	31.910 ms (31.910 ms) ←	This may vary by binning setting and ROI setting. The phase of Frame Active End Edge may vary by 1 us against FVAL Active End. ( ) is the phase relationship against FVAL Active End.
(i)	Frame Trigger wait Falling Edge to Frame Active Rising Edge	1.11900 us 0.1 us	← ←	
(j)	Frame Active Rising Edge to Exposure Active Rising Edge	0.1 us 2.10 us	← ←	 Exposure Active at TTL I/F output
(k)	Frame Start Trigger to Exposure Active Raising Edge	2.10 us (0.50 us) 1.70 us	← ← ←	Exposure Active at TTL I/F output ( ) is the exposure phase relationship inside camera If the polarity is Active High
-	Exposure Active Start Edge : Internal / TTL Out Phase Difference	1.70 us 0.30 us	← ←	If the polarity is Active High If the polarity is Active High
-	Exposure Active End Edge : Internal / TTL Out Phase Difference	0.30 us	←	If the polarity is Active High

Note: The figures in ( ) are the comparison between the exposure time inside camera and Exposure Active

7.5.6 GPIO TTL output timing if Trigger Overlap is Readout

Frame Start -Trigger Mode = “On” , Exposure Mode = “Timed” , Trigger Overlap = “Readout”

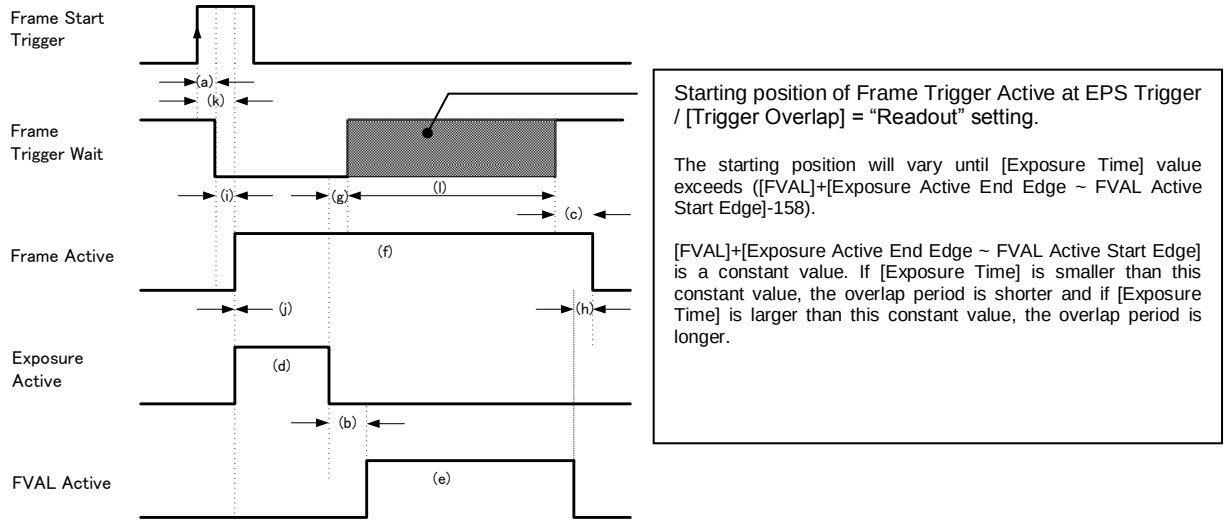


Fig. 29 GPIO timing (Overlap = Readout)

Table - 36 GPIO output timing(Reference) (Trigger Overlap = Readout)

	Region	Pixel Format		Note
		8bit Monochrome	10bit /12bit Monochrome	
(a)	Frame Start Trigger to Frame Trigger Waite Falling Edge	1.00 us	←	
(b)	Exposure Active Falling Edge to FVAL Raising Edge	306.70 us (305.20 us)	←	This is changed by Link Configuration setting.
(c)	Frame Trigger Wait Rising Edge to Frame Active Falling Edge	6.90 us	←	fs Exposure Time=10 us
(d)	Exposure Active	8.60 us (10.00 us)	←	If Exposure Time=10 us ( ) is the exposure time inside camera
(e)	FVAL Active	61.530 ms (61.540 ms)	←	If Binning off and Height = 3840 (Varies by the vertical ROI setting)
(f)	Frame Active	62.510 ms	125.010 ms	If Exposure Mode = Timed and ExposureTime = 10us
(g)	Exposure Active Falling Edge to Frame Trigger Wait Rising Edge	4.10 us (4.40 us)	←	
(h)	FVAL Falling Edge to Frame Active Falling Edge	658.80 us (659.00 us)	63.150 ms (63.150 ms)	This may vary by binning setting and ROI setting. The phase of Frame Active End Edge may vary by 1 us against FVAL Active End.
(i)	Frame Trigger wait Falling Edge to Frame Active Rising Edge	1.20 us	←	
(j)	Frame Active Rising Edge to Exposure Active Rising Edge	0.10 us	←	
(k)	Frame Start Trigger to Exposure Active Rising Edge	2.20 us (0.50 us)	←	Exposure Active at TTL I/F output ( ) is the exposure phase relationship inside camera
(l)	Frame Trigger Wait Rising Edge Variableness	62.490 ms	125.000 ms	Varies by Exposure Time setting
-	Exposure Active Start Edge : Internal / TTL Out Phase Difference	1.70 us	←	
	Exposure Active End Edge : Internal /TTL Out Phase Difference	0.30 us	←	

Note: (1) In order to explain the phase relationship of Frame Trigger Wait and Frame Active, the timing in this table reflects the condition that the trigger input is not overlapped in the previous video readout.
(2) Figures in ( ) are the comparison between the exposure time inside camera and Exposure Active.

	Region	Pixel Format		Note
		8bit Monochrome	10bit /12bit Monochrome	
(a)	Frame Start Trigger to Frame Trigger Waite Falling Edge	1.00 us	←	
(b)	Exposure Active Falling Edge to FVAL Raising Edge	306.70 us (305.20 us)	←	This is changed by Link Configuration setting.
(c)	Frame Trigger Wait Rising Edge to Frame Active Falling Edge	6.90 us	←	fs Exposure Time=10 us
(d)	Exposure Active	8.60 us (10.00 us)	←	If Exposure Time=10 us ( ) is the exposure time inside camera
(e)	FVAL Active	61.530 ms (61.540 ms)	←	If Binning off and Height = 3840 (Varies by the vertical ROI setting)
(f)	Frame Active	78.130 ms	93.760 ms	If Exposure Mode = Timed and ExposureTime = 10us
(g)	Exposure Active Falling Edge to Frame Trigger Wait Rising Edge	4.10 us (4.40 us)	←	
(h)	FVAL Falling Edge to Frame Active Falling Edge	16.280 us (16.280 us)	31.920 ms (31.910 ms)	This may vary by binning setting and ROI setting. The phase of Frame Active End Edge may vary by 1 us against FVAL Active End.
(i)	Frame Trigger wait Falling Edge to Frame Active Rising Edge	1.20 us	←	
(j)	Frame Active Rising Edge to Exposure Active Rising Edge	0.10 us	←	
(k)	Frame Start Trigger to Exposure Active Rising Edge	2.20 us (0.50 us)	←	Exposure Active at TTL I/F output ( ) is the exposure phase relationship inside camera
(l)	Frame Trigger Wait Rising Edge Variableness	78.110 ms	93.740 ms	Varies by Exposure Time setting
-	Exposure Active Start Edge : Internal / TTL Out Phase Difference	1.70 us	←	
	Exposure Active End Edge : Internal /TTL Out Phase Difference	0.30 us	←	

Note: (1) In order to explain the phase relationship of Frame Trigger Wait and Frame Active, the timing in this table reflects the condition
that the trigger input is not overlapped in the previous video readout.
(2) Figures in ( ) are the comparison between the exposure time inside camera and Exposure Active.

7.6 Trigger width mode (PWC)

In this mode, the exposure time is equal to the trigger pulse width. Accordingly, longer exposure times are supported. Additional settings determine if the trigger pulse can be accepted during the exposure period.

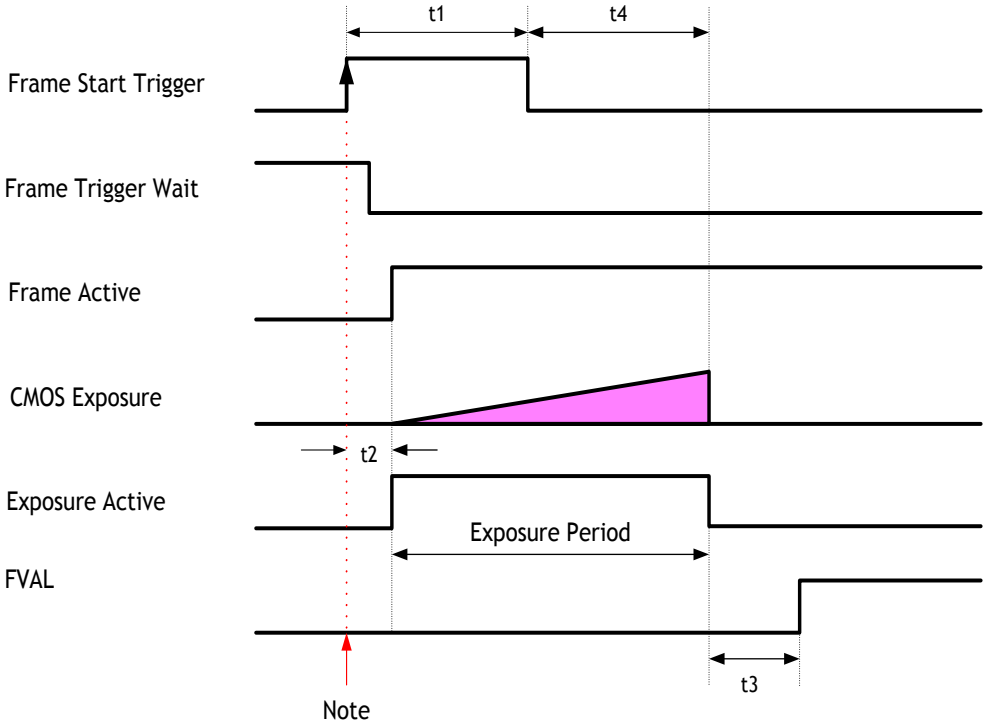
Basic settings to use this mode
Trigger Mode = ON
Exposure Mode = Trigger Width

Table - 37 Typical Minimum trigger interval (Pixel Format : 8-bit)

Trigger Mode	Readout Mode	Time (Min. Trigger Period)			
		8bit	10bit/12bit	10bit_Packed	12bit_Packed
Trigger Width Exposure Mode	Full	≧62.53 ms	≧125.03 ms	≧78.16 ms	≧93.78 ms
	ROI Center 2/3	≧42.02 ms	≧ 55.50 ms	≧42.02 ms	≧42.02 ms
	ROI Center 1/2	≧31.75 ms	≧ 31.76 ms	≧31.76 ms	≧31.76 ms
	ROI Center 1/4	≧16.35 ms	≧ 16.38 ms	≧16.38 ms	≧16.38 ms
	ROI Center 1/8	≧ 8.66 ms	≧ 8.70 ms	≧ 8.69 ms	≧ 8.69 ms
	V Binning ON (Full) (Note 1)	≧62.55 ms	≧ 62.55 ms	≧62.55 ms	≧62.55 ms

Note1 : SP-20000M-USB only
Note2 : The above table is if Trigger Overlap is Readout.

7.6.1 If Overlap setting is OFF



Note: The trigger pulse is accepted during Frame Trigger Wait being active if the trigger overlap is OFF. When the trigger is accepted, the trigger wait is inactive until the readout is completed.

	Camera Settings		
	Vertical Binning	Exposure Active Signal source	Pixel Format 8/10/12 Monochrome, 10/12 Monochrome_Packed 8/10/12 Bayer, 10/12 Bayer_Packed
t1			10μs (min)
t2	-	TTL Out	1.700 us ～ 1.720 us
		Inside camera	370 ns ～ 390 ns
t3	1 (Off)	TTL Out	306.04000 us
		Inside camera	305.22300 us
	2 (On)	TTL Out	306.04000 us
		Inside camera	305.22300 us
t4	-	TTL Out	3110 us ～ 3140 us
		Inside camera	2600 us ～ 2630 us
Actual Exposure time difference	-	TTL Out	1.390 us ～ 1.440 us
		Inside camera	2.210 us ～ 2.260 us

Note: 1. The jitter from the trigger occurs at both the exposure start edge and exposure end edge.
2. The real exposure time difference is an additional period of exposure time against TTL trigger input. (t4) - (t2) ≒ The real exposure time difference

Fig. 30 Overlap = OFF

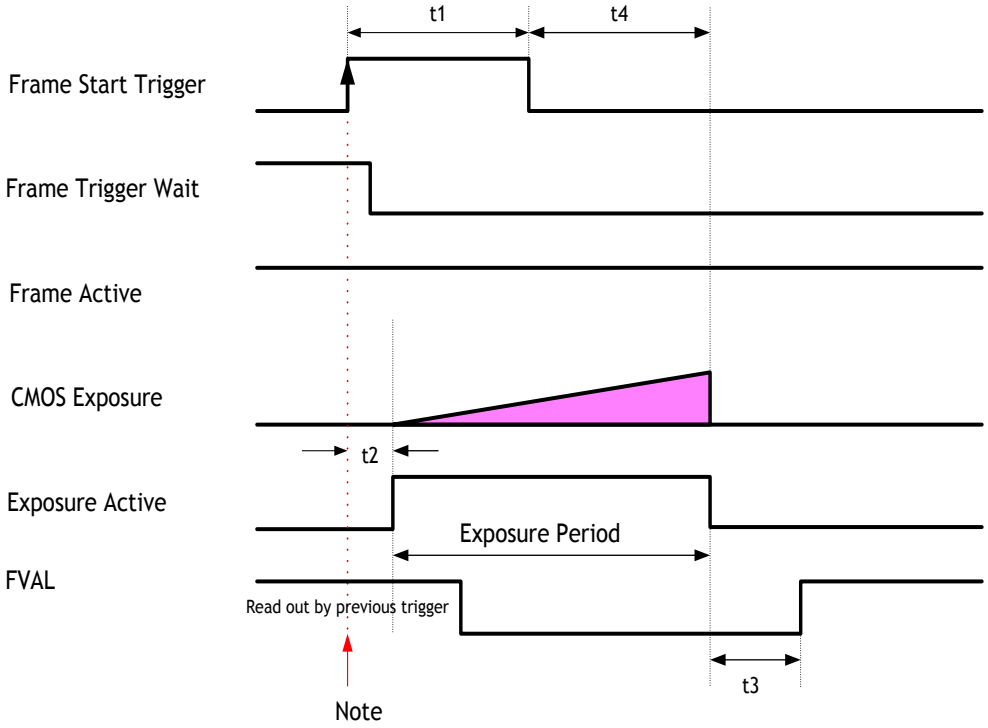
Table 40. Minimum trigger interval calculation formula (Trigger Overlap=OFF)

Camera Settings		PWC Trigger / Trigger Overlap = Off Minimum Trigger Interval Calculation Formula [Unit : us]
Pixel Format	Binning Vertical	
8 bit Mono chrome / 8bit Bayer	1 (Off)	The maximum USB bandwidth is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40 MHz) As comparing [USB Limit] and [USB Rate] (1) IF [USB Limit] < [USB Rate], [Readout Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 (2) IF [USB Limit] > [USB Rate], [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40 MHz) [Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10 us~])) + 16.025 us
	2 (On)	The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40 MHz) As comparing [USB Limit] and [USB Rate], (1) IF [USB Limit] < [USB Rate], [Readout Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 (4) IF [USB Limit] > [USB Rate], [Readout Rate] = 1/((([Height] x 1282) + 38580) ÷ 40 MHz) [Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10 us~])) + 32.050 us
10/12bit Mono chrome / 10/12bit Bayer	1 (Off)	The maximum USB bandwidth is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40 MHz) x 2 As comparing [USB Limit] and [USB Rate], (1) IF [USB Limit] < [USB Rate], [Readout Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 2 (4) IF [USB Limit] > [USB Rate], [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40 MHz) [Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10 us~])) + 16.025 us
	2 (On)	The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40 MHz) x 2 As comparing [USB Limit] and [USB Rate], (1) IF [USB Limit] < [USB Rate], [Readout Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 2 (2) IF [USB Limit] > [USB Rate], [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40 MHz) [Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10 us~])) + 32.050 us

Table 40 (Cont) Minimum trigger interval calculation formula (Trigger Overlap=OFF)

Camera Settings		[Unit : us]
Pixel Format	Binning Vertical	
10 Bit Monochrome Packed / 10 Bit Bayer Packed	1 (Off)	The maximum USB bandwidth is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.25 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.25
		(2) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10us~])) + 16.025 us
	2 (On)	The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.25 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.25
		(2) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10us~])) + 32.050us
12 Bit Monochrome Packed / 12 Bit Bayer Packed	1 (Off)	The maximum USB bandwidth is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.5 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.5
		(2) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10us~])) + 16.025 us
	2 (On)	The Data Rate by ROI setting is: [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.5 As comparing [USB Limit] and [USB Rate]
		(1) IF [USB Limit] < [USB Rate] [Readout Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.5
		(2) IF [USB Limit] > [USB Rate] [Readout Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
		[Trigger Period] = (1/ ([Readout Rate] + [Trigger Pulse Width: 10us~])) + 32.050us

7.6.2 If Overlap setting is Readout



Note: If the trigger overlap is Readout mode, Frame Trigger Wait is active during FVAL period of the previous trigger. In this period, the next trigger can be accepted. After receiving this trigger pulse, Frame Trigger Wait becomes inactive.

Timinmg values

	Camera Settings		
	Vertical Binning	Exposure Active Signal source	Pixel Format 8/10/12 Monochrome, 10/12 Monochrome_Packed 8/10/12 Bayer, 10/12 Bayer_Packed
t1			10 us (min)
t2	-	TTL Out	1.710 us ~ 1.710 us + 1Line(16.025 us)
		Inside camera	370 ns ~ 370 ns + 1Line(16.025 us)
t3	1 (Off)	TTL Out	306.030 us
		Inside Camera	305.220 us
	2 (On)	TTL Out	306.030 us
		Inside camera	305.220 us
t4	-	TTL Out	3.110 us ~ 3.140 us
		Inside camera	2.600 us ~ 2.630 us
(t4)-(t2) : Exposure time difference	-	TTL Out	-14.260 us ~ 1.430 us
		Inside camera	-13.790 us ~ 2.260 us

Note:.1. The jitter from the trigger occurs at both the exposure start edge and exposure end edge.
2. The exposure start edge has 1 line jitter at receiving trigger in order not to influence the video signal.

Fig. 31 Overlap: Readout

Table – 38 Minimum trigger interval calculation formula (Trigger Overlap = Readout)

Camera Settings		PWC Trigger / Trigger Overlap = Readout [Unit : us]
Pixel Format	Binning Vertical	
8 bit Mono chrome / 8bit Bayer	1 (Off)	IF (1/[Trigger Overlap=Off Read Rate]) ＋ 16.025 us ＋ 10 us － 260 us ≧ [Trigger Pulse Width] MIN.＝ (1/[Trigger Overlap=Off Read Rate]) ＋ 16.025 us ＋ 10 us
		IF (1/[Trigger Overlap=Off Readout Rate]) ＋16.025 us ＋ 10 us － 260 us ＜[Trigger Pulse Width] MIN.＝ [Trigger Pulse Width]＋260 us
	2 (On)	IF (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10 us － 260 us ≧ [Trigger Pulse Width] MIN.＝(1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10 us
		IF (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10 us － 260 us ＜[Trigger Pulse Width] MIN.＝ [Trigger Pulse Width] ＋ 260 us
10/12 bit Mono chrome / 10/12 bit Bayer	1 (Off)	IF (1/[Trigger Overlap=Off Readout Rate]) ＋ 16.025 us ＋ 10 us － 260 us ≧ [Trigger Pulse Width] MIN.＝ (1/[Trigger Overlap=Off Readout Rate]) ＋ 16.025 us ＋ 10 us
		IF (1/[Trigger Overlap=Off Readout Rate]) ＋ 16.025 us ＋ 10 us － 260 us ＜ [Trigger Pulse Width] MIN.＝[Trigger Pulse Width] ＋ 260 us
	2 (On)	IF (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10 us － 260 us ≧ [Trigger Pulse Width] MIN.＝ (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10 us
		IF (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050 us ＋ 10 us － 260 us ＜[Trigger Pulse Width] MIN.＝[Trigger Pulse Width] ＋ 260 us

Table – 38 (Cont) Minimum trigger interval calculation formula (Trigger Overlap = Readout)

Camera Settings		[Unit : us]
Pixel Format	Binning Vertical	
10 Bit_Packed Monochrome / 10 Bit_Packed Bayer	1 (Off)	IF (1/ [Trigger Overlap=Off Read Rate]) ＋ 16.025us ＋ 10us － 260us ≧ [Trigger Pulse Width] ＝ (1/[Trigger Overlap=Off Read Rate]) ＋ 16.025us ＋ 10us
		IF (1/ [Trigger Overlap=Off Readout Rate]) ＋16.025us ＋ 10us － 260us ＜[Trigger Pulse Width] ＝ [Trigger Pulse Width]＋260us
	2 (On)	IF (1/ [Trigger Overlap=Off Readout Rate]) ＋ 32.050us ＋ 10us － 260us ≧ [Trigger Pulse Width] ＝(1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050us ＋ 10us
		IF (1/ [Trigger Overlap=Off Readout Rate]) ＋ 32.050us ＋ 10us － 260us ＜[Trigger Pulse Width] ＝ [Trigger Pulse Width] ＋ 260us
12 Bit_Packed Monochrome / 12 Bit_Packed Bayer	1 (Off)	IF (1/ [Trigger Overlap=Off Readout Rate]) ＋ 16.025us ＋ 10us － 260us ≧ [Trigger Pulse Width] ＝ (1/[Trigger Overlap=Off Readout Rate]) ＋ 16.025us ＋ 10us
		IF (1/ [Trigger Overlap=Off Readout Rate]) ＋ 16.025us ＋ 10us － 260us ＜ [Trigger Pulse Width] ＝[Trigger Pulse Width] ＋ 260us
	2 (On)	IF (1/ [Trigger Overlap=Off Readout Rate]) ＋ 32.050us ＋ 10us － 260us ≧ [Trigger Pulse Width] ＝ (1/[Trigger Overlap=Off Readout Rate]) ＋ 32.050us ＋ 10us
		IF (1/ [Trigger Overlap=Off Readout Rate]) ＋ 32.050us ＋ 10us － 260us ＜[Trigger Pulse Width] ＝[Trigger Pulse Width] ＋ 260us

7.7 PIV (Particle Image Velocimetry)

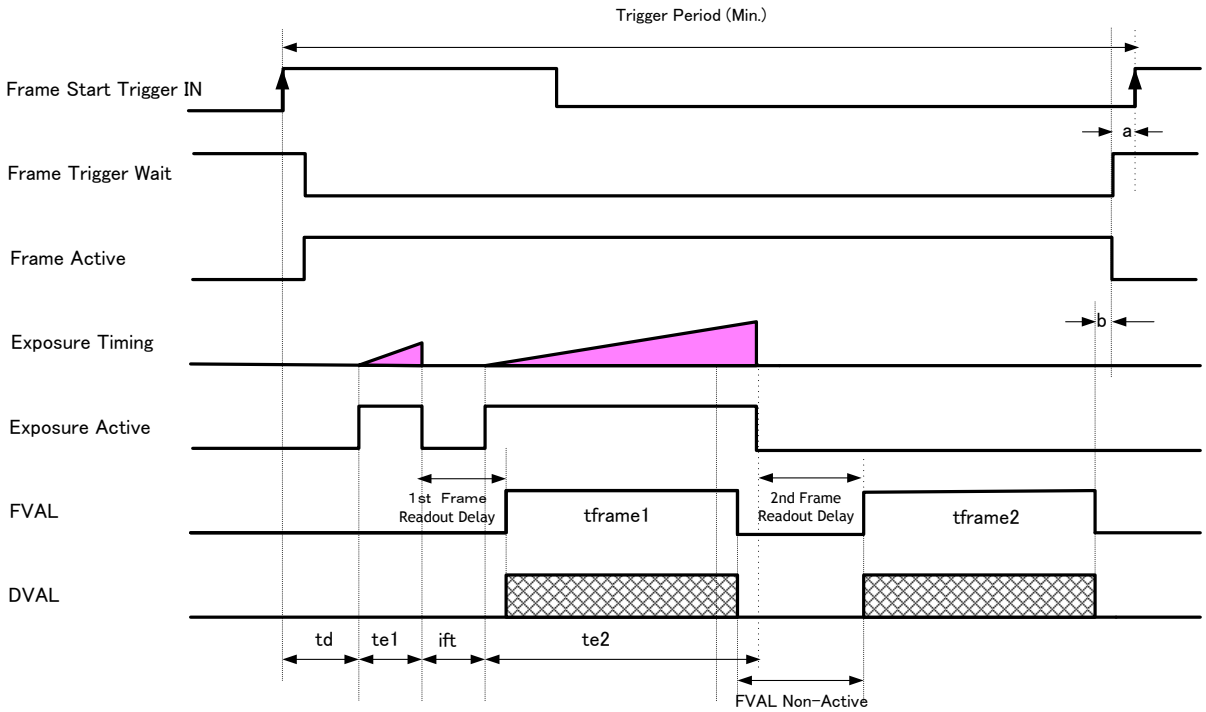
The Particle Image Velocimetry mode can be used in applications where 2 images need to be taken with a very short time interval. It can only be used with strobe flash as illumination. The first accumulation time is 10 μsec to 33 msec. Then, the second exposure will be taken. The first strobe is activated during the first exposure duration and the second strobe is pulsed while the first frame is being read out. In this way, two strobe flashes generate two video outputs.

Basic settings to use this mode
Trigger Mode = ON
Exposure Mode = Timed
Trigger Option = PIV

Table – 40 Typical Minimum trigger interval

Trigger Mode	Readout Mode	Time (Min. Trigger Period)			
		8bit	10bit/12bit	10bit_Packed	12bit_Packed
PIV mode	Full	≧125.16 ms	≧250.01 ms	≧156.26 ms	≧187.51 ms
	ROI Center 2/3	≧ 84.14 ms	≧110.95 ms	≧ 84.14 ms	≧ 84.14 ms
	ROI Center 1/2	≧ 63.63 ms	≧ 63.63 ms	≧ 63.63 ms	≧ 63.63 ms
	ROI Center 1/4	≧ 32.86 ms	≧ 32.86 ms	≧ 32.86 ms	≧ 32.86 ms
	ROI Center 1/8	≧ 17.47 ms	≧ 17.47 ms	≧ 17.47 ms	≧ 17.47 ms
	V Binning ON (Full) (Note 1)	≧125.18 ms	≧125.18 ms	≧ 125.18 ms	≧ 125.18 ms

Note 1. This is Trigegr Overlap=OFF. Trigegr Overlap mode=Readout is not available
Note 2. SP-20000M-USB only



Note 1. The exposure time for the first frame (te1) can be set by [Exposure Time].
Note 2. The second exposure time (te2) varies by ROI setting and Binning setting, but is not affected by [Exposure Time] setting.

Fig. 32 PIV mode timing

Table – 41 PIV trigger mode specifications (Common)

time name	Description	Exposure Active Signal Source	Time Pixel Format = 8/10bit Monochrome, 8/10 Bayer 10bit Monochrome/Bayer_Packed
td	Exposure Beginning delay	TTL Out	2.1100 us
		Internal	403.00 ns~ 427.00 ns
te1	First exposure time period	-	10 us ～ ≒1 Frame ([Height]=3840： us Max) ＝ [Exposure Time Settings]
		TTL Out	8.624 us ~ 66.41537 7ms
		Internal	10.050 us ~ 66.416815 ms
itf	Inter framing time	TTL Out	307.010 us
		Internal	305.575 us
te2	Second exposure time	TTL Out	≒1 frame (1) IF V-Binning is Off, ＝((([Height]×641) - 1) ÷ 40 MHz) - 2.050 us + 128.773 us
		Internal	＝((([Height]×641) - 1) ÷ 40 MHz) - 0.348 us + 128.780 us
		TTL Out	(2) IF V-Binning is On, ＝((([Height]×1282) - 2) ÷ 40 MHz) - 2.050 us + 128.773 us
		Internal	＝((([Height]×1282) - 2) ÷ 40 MHz) - 0.348 us + 128.780 us
tframe1	First Frame read out	-	(1) IF V-Binning is Off [FVAL Active] ＝((([Height]×641) - 1) ÷ 40 MHz
		-	(2) IF V-Binning is On, [FVAL Active] ＝((([Height]×1281) - 2) ÷ 40 MHz
tframe2	Second Frame read out	Internal	[FVAL Active] (sam as tframe1)
-	1st Frame Readout Delay	TTL Out	V-Binning Off / V-Binning On = 304.971 us
		Internal	V-Binning Off / V-Binning On = 305.224 us
-	2nd Frame Readout Delay	TTL Out	V-Binning Off / V-Binning On = 304.971 us
		Internal	V-Binning Off / V-Binning On = 305.224 us
-	FVAL Non-Active	-	V-Binning Off / V-Binning On = 433.999 us (1) V-Binning Off = 27.0826 Line (2) V-Binning On = 13.5413 Line

Table - 42 PIV trigger mode specifications (8-bit)

time name	Description	Exposure Active Signal Source	Time **Pixel Format = 8-bit Monochrome, 8-bit Bayer**
-	Trigger Period (Min.)		The maximum USB bandwidth is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps
			(1) IF V-Binning is Off, The Data Rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40 MHz) As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate], [Output Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8
			b) IF [USB Limit] > [USB Rate], [Output Rate Rate] = 1/((([Height] x 641) + 38580) ÷ 40 MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10 us ~8s]) + 130 us + 16.025 us
			(2) IF V-Binning is On, The Data Rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40 MHz) As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate] , [Output Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8
			b) IF [USB Limit] > [USB Rate], [Output Rate] = 1/((([Height] x 1282) + 38580) ÷ 40 MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10 us ~8s]) + 130 us + 32.050 us
(a)	2nd FVAL Active End ~ Frame Active End	-	(1) IF V-Binning is Off, = (2/ ([Output Rate]) - (2 x ((([Height] x 641) + 38580) ÷ 40 MHz)
			(2) IF V-Binning is On = (2/ ([Output Rate]) - (2 x ((([Height] x 1282) + 38580) ÷ 40 MHz)
(b)	Frame Active End ~ Frame Trigger Wait Restart	-	2.10 us

Table -43 PIV trigger mode specifications (10-bit/12-bit)

time name	Description	Exposure Active Signal Source	Time Pixel Format = 10bit Monochrome, 10bit Bayer
-	Trigger Period (Min.)		The maximum USB bandwidth is : [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps
			(1) IF V-Binning is Off, The Data Rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40 MHz) x 2 As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate], [Output Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 2
			b) IF [USB Limit] > [USB Rate], [Output Rate] = 1/((([Height] x 641) + 38580) ÷ 40 MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10 us ~8s]) + 130 us + 16.025 us
			(2) IF V-Binning is On, The Data Rate by ROI setting is : [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40 MHz) x 2 As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate], [Trigger Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 2
			b) IF [USB Limit] > [USB Rate], [Output Rate] = 1/((([Height] x 1282) + 38580) ÷ 40 MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10 us ~8s]) + 130 us + 32.050 us
(a)	2nd FVAL Active End ~ Frame Active End	-	(1) IF V-Binning is Off = (2/ ([Output Rate]) - (2 x ((([Height] x 641) + 38580) ÷ 40 MHz)
(b)	Frame Active End ~ Frame Trigger Waite Restart	-	2.10 us

Table – 44 PIV trigger mode specifications (10-bit_Packed)

time name	Description	Exposure Active Signal Source	Time
			Pixel Format = 10 Bit Monochrome Packed、10 Bit Bayer Packed
-	Trigger Period (Min.)		The maximum USB bandwidth is; [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps
			(1) IF V-Binning Off The data rate by ROIsettingis, [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.25 As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate], [Output Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.25
			b) IF [USB Limit] > [USB Rate] [Output Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10us ~8s]) + 130us + 16.025 us
			(2) IF V-Binning On The Data Rate by ROI setting is; [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.25 As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate], [Trigger Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.25
			b) IF [USB Limit] > [USB Rate], [Output Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10us ~8s]) + 130us + 32.050 us
(a)	2nd FVAL Active End ~ Frame Active End	-	(1) V-Binning Off = (2/ ([Output Rate]) - (2 x ((([Height] x 641) + 38580) ÷ 40MHz)
(b)	Frame Active End ~ Frame Trigger Waite Restart	-	2.10 us

Table – 45 PIV trigger mode specifications (12-bit_Packed)

time name	Description	Exposure Active Signal Source	Time
			Pixel Format = 12 Bit Monochrome Packed、12 Bit Bayer Packed
-	Trigger Period (Min.)		The maximum USB bandwidth is; [USB Limit] = 5120 x 3840 x 8bit x 16.00 fps = 2516582400 bps
			(1) IF V-Binning Off, The Data Rate by ROI setting is, [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 641) + 38580) ÷ 40MHz) x 1.5 As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate], [Output Rate] = [USB Limit] ÷ [Width] ÷ [Height] ÷ 8 ÷ 1.5
			b) IF [USB Limit] > [USB Rate] [Output Rate] = 1/((([Height] x 641) + 38580) ÷ 40MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10us ~8s]) + 130us + 16.025 us
			(2) IF V-Binning On The Data Rate by ROI setting is, [USB Rate] = [Width] x [Height] x 8 ÷ ((([Height] x 1282) + 38580) ÷ 40MHz) x 1.5 As comparing [USB Limit] and [USB Rate],
			a) IF [USB Limit] < [USB Rate] [Trigger Rate] = [USB Limit] ÷ [Width] ÷ ([Height] x 2) ÷ 8 ÷ 1.5
			b) IF [USB Limit] > [USB Rate] [Output Rate] = 1/((([Height] x 1282) + 38580) ÷ 40MHz)
			[Trigger Period] = (2/ ([Output Rate])+[Exposure Time:10us ~8s]) + 130us + 32.050 us
(a)	2nd FVAL Active End ~ Frame Active End	-	(1) V-Binning Off = (2/ ([Output Rate]) - (2 x ((([Height] x 641) + 38580) ÷ 40MHz)
(b)	Frame Active End ~ Frame Trigger Waite Restart	-	2.10 us

7.8 Sequence ROI Trigger

7.8.1 Sequence ROI Trigger mode

This is a function to capture images in sequence based on preset ROI, Exposure Time, Gain and other parameters in the sequence index table.

Basic settings to use this mode
Acquisition mode: Continuous
Trigger selector: Frame Start
Trigger mode: ON
Exposure mode: Timed
Video send mode selector: Trigger Sequence or Command Sequence

7.8.2 Video Send Mode

In the video send mode, ther are four modes which are Normal, Trigger Sequence, Command Sequence and Multi ROI. As for Multi ROI, please refer to 6.3.5 Multi ROI function.
In order to execute Sequence ROI trigger, Sequence Trigger or Command Sequence should be selected in the video send mode.

7.8.3 Trigger Sequence

In this mode, while the previous trigger operation (Index table) is activating, the next trigger cannot be overlapped. Sequence index table must be through index 0 and after index 0 is performed, the next index can be operated.

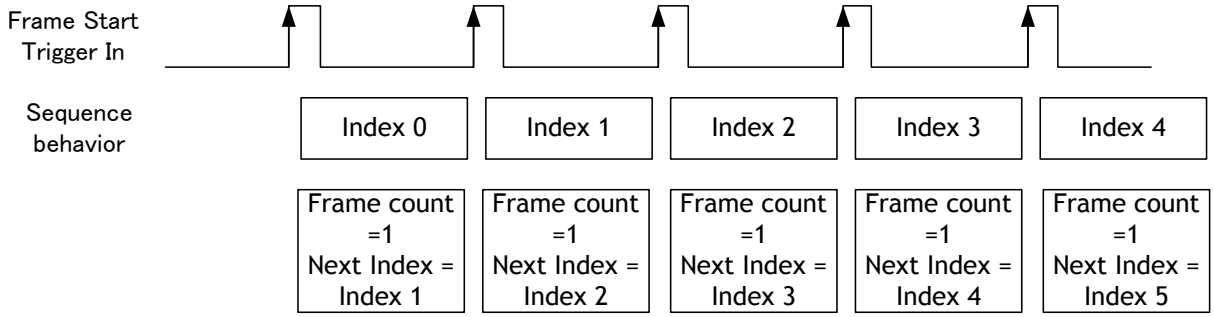


Fig. 33 Behavior of Sequence Trigger

7.8.4 Command Sequence

In this mode, after the acquisition starts, the index table is executed by the external trigger in accordance with the Next Sequence Index Command. In this case, Sequence ROI Frame Count and Sequence ROI next index commands in the index table are ignored.

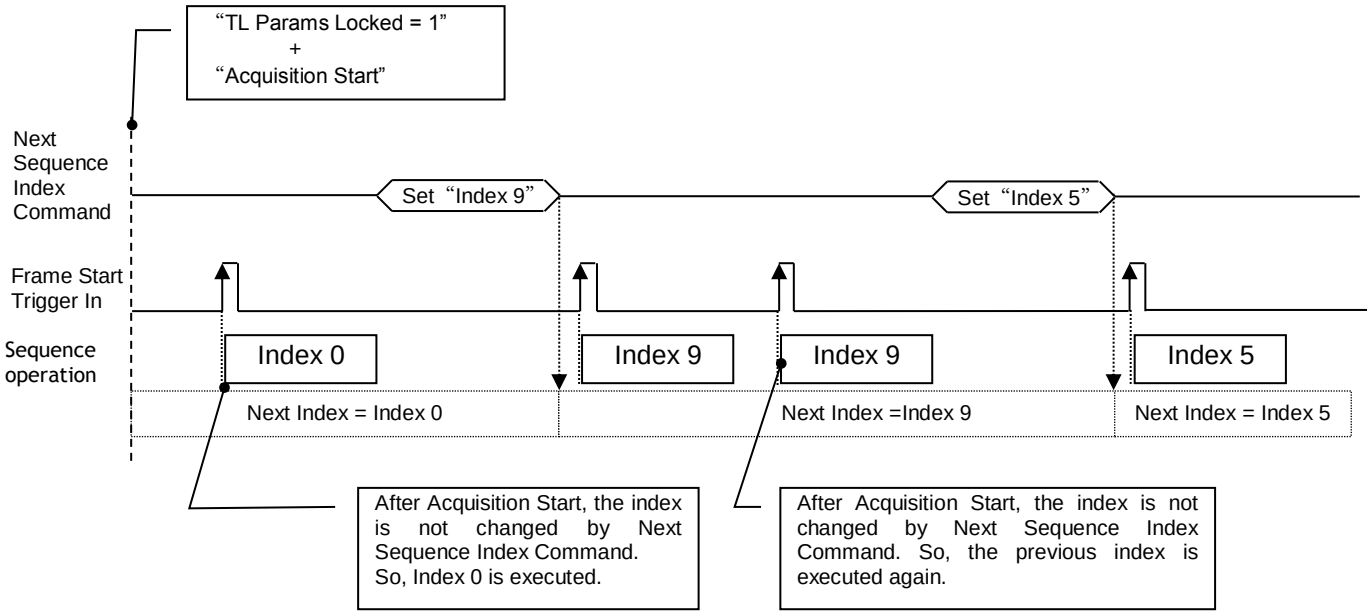


Fig. 34 Behavior of Command Sequence

7.8.5 Typical minimum trigger interval of Sequence ROI Trigger

Table - 44 Typical Minimum trigger interval (Pixel Format: 8-bit)

Trigger Mode	Readout Mode	Time (Min. Trigger Period)			
		8-bit	10-bit/12-bit	10bit_Packed	12bit_Packed
Sequential Timed Exposure Mode (Note 1)	Full	≧62.53 ms	≧125.03 ms	≧78.16 ms	≧93.78 ms
	ROI Center 2/3	≧42.02 ms	≧ 55.50 ms	≧42.02 ms	≧42.02 ms
	ROI Center 1/2	≧31.75 ms	≧ 31.76 ms	≧31.76 ms	≧31.76 ms
	ROI Center 1/4	≧16.35 ms	≧ 16.38 ms	≧16.38 ms	≧16.38 ms
	ROI Center 1/8	≧ 8.66 ms	≧ 8.70 ms	≧ 8.69 ms	≧ 8.69 ms
	V Binning ON (Full) (Note 2)	≧62.55 ms	≧ 62.55 ms	≧62.55 ms	≧62.55 ms

Note 1. Overlap mode=Readout is not available. Please do not set the exposure time to Readout mode.
Note 2. SP-20000M-USB only
Note 3. The minimum interval calculation assumes that the exposure time for all sequences are equal. If there are differences, it is necessary to add the difference to the calculation. If the exposure times are different, it is recommended to organize the exposure times from the shortest exposure to the longest one in order to operate faster.
Note 4. The above interval is if the exposure time is set to 10 μs.

7.8.6 Defaul Sequence Index Table

Table – 45 In Trigger Sequence, Sequence Index table (Default)

Video Send Mode Selector	Trigger Sequence													
Sequence ROI Index \	Sequence ROI													
	Width	Height	Offset		Gain Selector			Exposure Time	Black Level	Binning		LUT Enable	Frame Count	Next Index
			X	Y	Gain (ALL)	Red	Blue			Horizontal	Vertical			
- Index 0	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 1	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 2	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 3	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 4	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 5	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 6	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 7	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 8	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
- Index 9	5120	3840	0	0	100	0	0	180000	0	1 (Off)	1 (Off)	Off	1	Index 0
Sequence Repetition	1													
Next Sequence Index	Index 0													

7.8.7 Sequence ROI setting parameters

Setting parameters for Sequence ROI are as follows.

(1) Sequence ROI Index Selector
In Sequence ROI Index Selector, Index 0 to 9 can be selected.
Sequence ROI – Width, Height, Offset X, Offset Y, Gain Selector - Gain/Red/Blue, Exposure Time, Black Level, Binning Horizontal, Binning Vertical, LUT Enable, Frame Count, Next Index for the selected index are displayed.

(2) Sequence ROI Width
Set the width of sequence ROI. The setting range is 8 to 5120 Pixels.
Rules for setting area and step number are the same as the normal ROI mode set by [Video Send Mode] =“Normal”.

(3) Sequence ROI Height
Set the height of sequence ROI. The setting range is 2 to 3840 lines.
Rules for setting area and step number are the same as the normal ROI mode set by [Video Send Mode] =“Normal”.

(4) Sequence ROI Offset X
Set Offset X of sequence ROI.
Sequence ROI Binning Horizontal =1 (Off):
Setting range is 0 to (5120 - [Sequence ROI Width])
Sequence ROI Binning Horizontal =2 (On):
Setting range is 0 to (2560 - [Sequence ROI Width])
The limitations of step number and other factors are the same as the normal ROI mode set by [Video Send Mode] =“Normal”.

(5) Sequence ROI Offset Y
Set Offset Y of sequence ROI.
Sequence ROI Binning Vertical =1 (Off):
Setting range is 0 to (3840 - [Sequence ROI Height])
Sequence ROI Binning Vertical =2 (On):
Setting range is 0 to (1920 - [Sequence ROI Height])
The limitations of step number and other factors are the same as the normal ROI mode set by [Video Send Mode] ="Normal".

(6) Sequence ROI Gain Selector
In Sequence ROI Gain Selector, the gain settings for each index are available.
SP-20000C-USB: Gain (ALL), Red, and Blue can be set.
SP-20000M-USB: Only Gain is displayed and can be set.

(7) Sequence ROI Black Level
Black Level setting is available for each index.

(8) Sequence ROI Exposure Time
Exposure Time setting is available for each index.

(9) Sequence ROI Binning Horizontal
ON or OFF of Horizontal Binning for each index can be set.

(10) Sequence ROI Binning Vertical
ON or OFF of Vertical Binning for each index can be set.

(11) Sequence ROI LUT Enable
Enable or disable of LUT function for each index 0 to 9 can be set.

(12) Sequence ROI Frame Count
This can set how many times the seleted index is repeated. This is applied to each index. Triggers are input according to numbers set in Frame Count and index is repeated and moves to the next index. Therefore, the same number of triggers as Frame Count must be input.

(13) Sequence ROI Next Index
When Command Sequence is selected in the [Video Send Mode] selector, it is possible to use this parameter to set the index which will execute after the currently executing index. In this case, after the acquisition starts and the external trigger is input, the index table always starts from index 0. Accordingly, after the repeated cycle of index 0 set by Frame Count is completed, the next index can be set as required. However, if Sequence ROI Next Index is set to OFF, the index is not changed and only the Sequence Repetition parameter is applied.

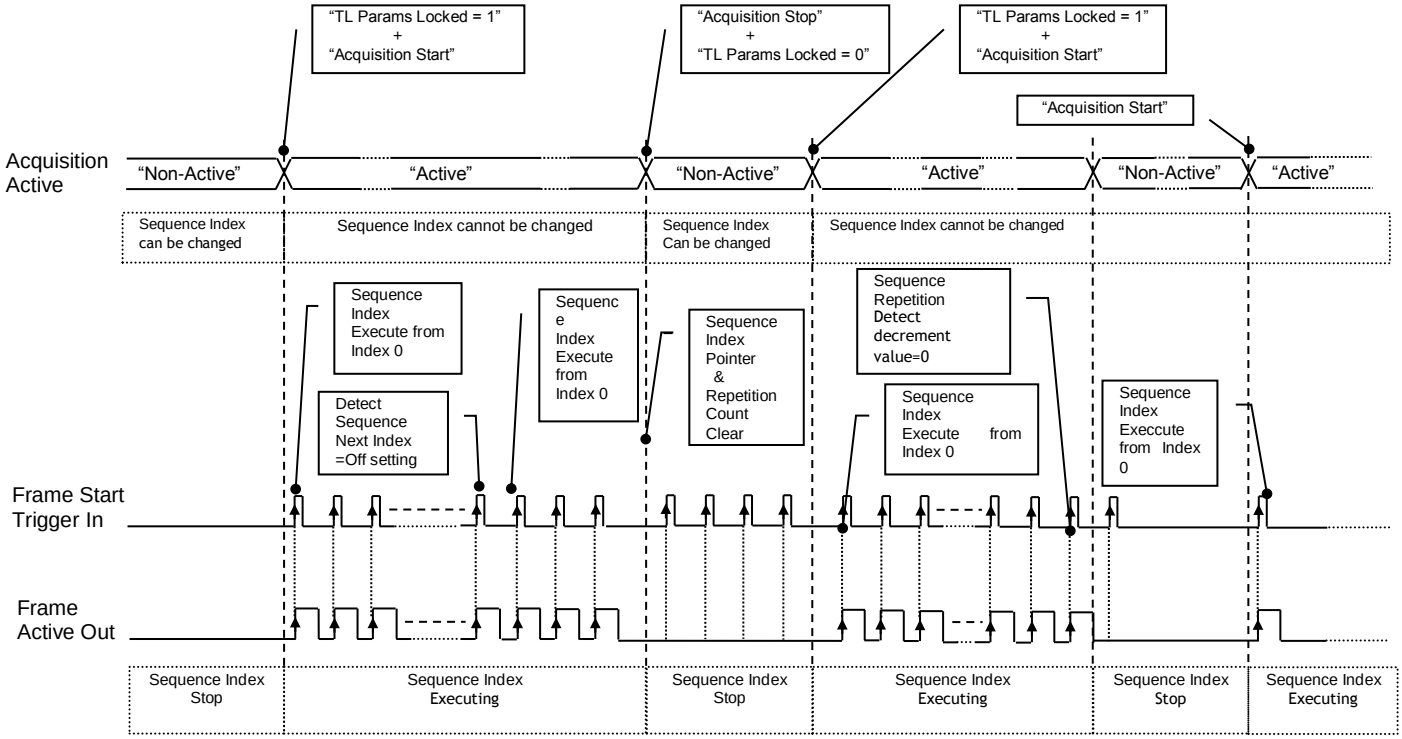


Fig.35 Sequence ROI trigger timing chart

(14) Sequence Repetition

If Trigger Sequence is selected, and if the Sequence ROI Next Index parameter for the Index Table is set to OFF, the value of Sequence Repetition becomes valid. The entire Index Table will then repeat as set in Sequence Repetition.

After the acquisition sarts, the index table is executed from Index 0 by the external trigger. And when the Index Table is finished, the value of Sequence Repetition is decremented internally. In this case, if the result of the decrement is not "0", the index table starts from Index 0 again. If the result of the decrement is 0, the status changes to Acquisition Stop and can not accept the external trigger.

The following chart shows the flow chart.

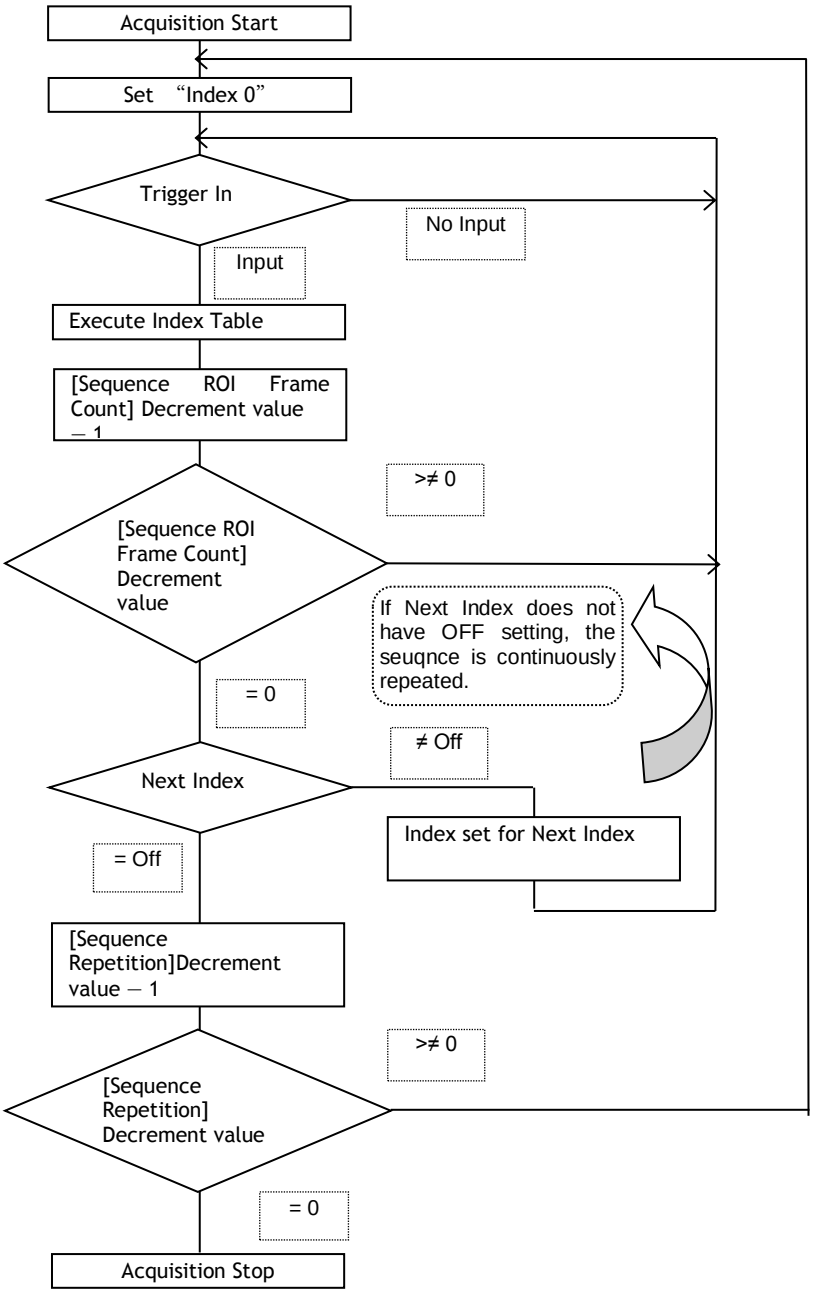


Fig.36 Sequence Trigger Flow Chart

(15) Next Sequence Index

If the [Video Send Mode] selector is set to “Command Sequence,” [Next Sequence Index] can be used. When the index is changed in the [Next Sequence Index］ selector, the [Next Sequence Index] command value can be transmitted to the camera manually as a GenICam setting.

The index sent by the [Next Sequence Index] command is the index that will be executed when the next trigger is input.

Please note that if [Video Send Mode] selector is set to Command Sequence, [Sequence ROI Frame Count] and [Sequence ROI Next Index] in the index table are disabled and ignored.

If the [Video Send Mode Selector] is set to Command Sequence and if the trigger is input even though [Next Sequence Index] command is not transmitted after the acquisition starts, Index 0 is executed.

If an index transmitted by [Next Sequence Index] command is executed as the result of trigger input, and if a subsequent trigger is input with no new [Next Sequence Index] command transmitted, the same index is excuted again.

Table – 46 Associated GenICam register information

GenICam Name	Access	Values	Category
Video Send Mode Selector	R/W	Normal Mode Sequence Mode1 Multi Mode Sequence Mode2	JAI-Custom
Sequence ROI Index	R/W	Index 0 to Index 9	JAI-Custom
Sequence Repetition	R/W	1 to 255	JAI-Custom
Sequence ROI Frame Count	R/W	1 to 255	JAI-Custom
Sequence ROI Next Index	R/W	Index 0 to Index 9 Off	JAI-Custom
Sequence ROI Width	R/W	8 to 5120	JAI-Custom
Sequence ROI Height	R/W	2 to 3840	JAI-Custom
Sequence ROI OffsetX	R/W	0 to (5120 – Sequence ROI Width)	JAI-Custom
Sequence ROI OffsetY	R/W	0 to (3840 – Sequence ROI Height)	JAI-Custom
Sequence ROI Gain	R/W	100 to 1600	JAI-Custom
Sequence Exposure Time	R/W	10 to Acquisition Frame rate Raw	JAI-Custom
Sequence ROI H Binning	R/W	1 or 2	JAI-Custom
Sequence ROI V Binning	R/W	1 or 2	JAI-Custom
Sequence ROI LUT Enable	R/W	0 or 1	JAI-Custom
Sequence ROI Black Level	R/W	-256 to 255	JAI-Custom
Sequence ROI Gain Red (for Color Model)	R/W	-4533 to 17713	JAI-Custom
Sequence ROI Gain Blue (for Color Model)	R/W	-4533 to 17713	JAI-Custom
Next Sequence Index	R/W	Index 0 to Index 9	JAI-Custom

7.9. Acqusition Transfer Start Trigger

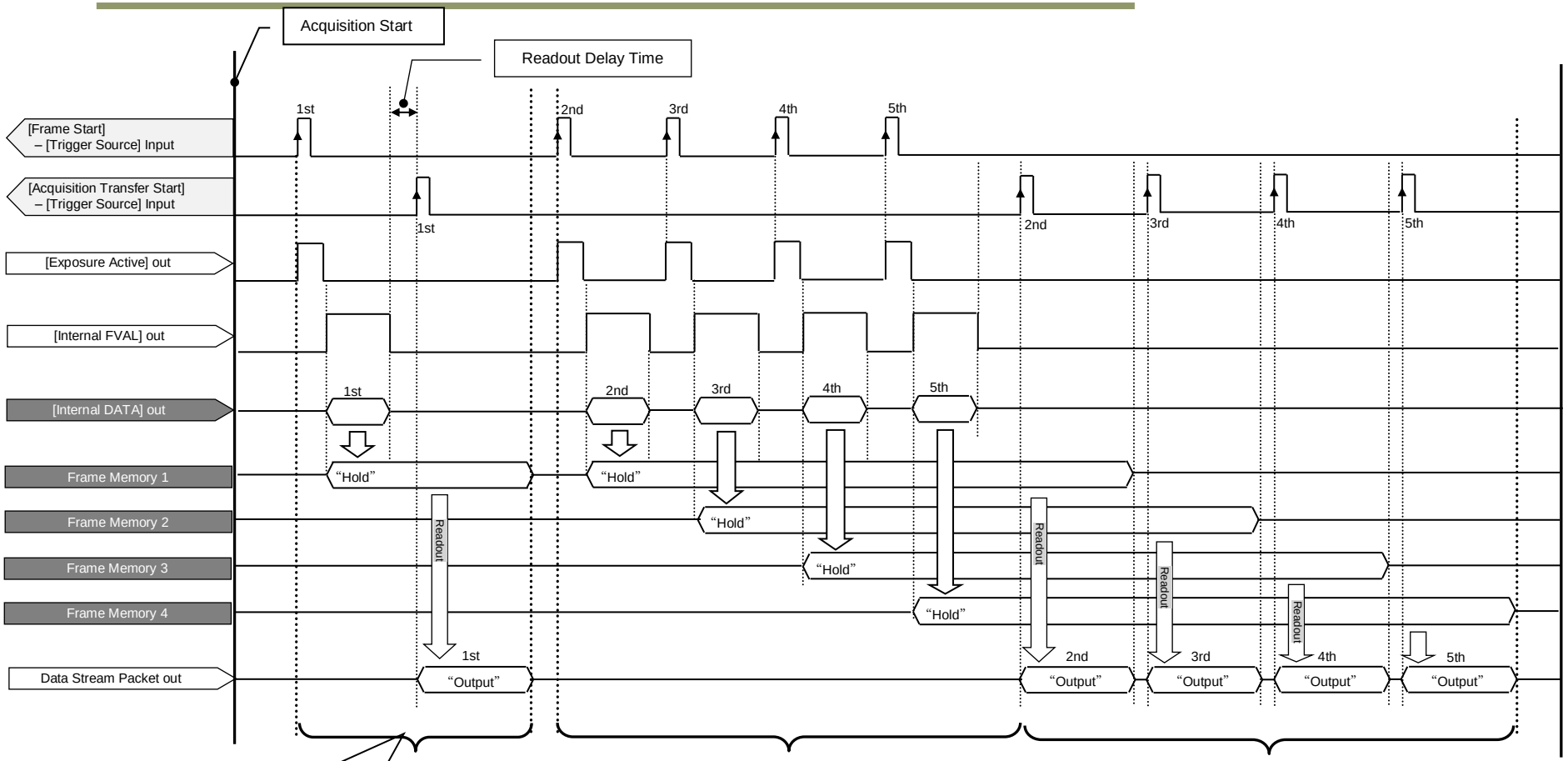
The acquisition transfer start trigger is a JAI Custom function which controls the readout of the captured image from the memory inside the camera by the external trigger input.
This function is enabled by setting Trigger Mode ON in Frame Start or Acquisition Start.
Then Trigger Mode in Acquisition Transfer Start is set to ON. Now the image stored in the memory can be read out by the trigger signal input through Trigger Source. In the SP-20000-USB, 4 frames can be stored and read out.

The examples in next two pages use the setting of "[Frame Start] –[Trigger Mode]=ON".

Settings for examples

[Acquisition Mode]= "Continuous"
[Frame Start] -[Trigger Mode]= "On"
-[Trigger Overlap]= "Off"
[Exposure Mode]= "Timed"
[Acquisition Transfer Start]-[Trigger Mode]= "On"

In the case of "[Acquisition Start]-[Trigger Mode]= ON" and " [Acquisition Mode]= "Single Frame" ",the behavior is similar to the above.
In the case of "[Acquisition Start]-[Trigger Mode]= ON" and "[Acquisition Mode]= Except "Single Frame", please note that in the SP-20000-USB has the memory for 4 frames.

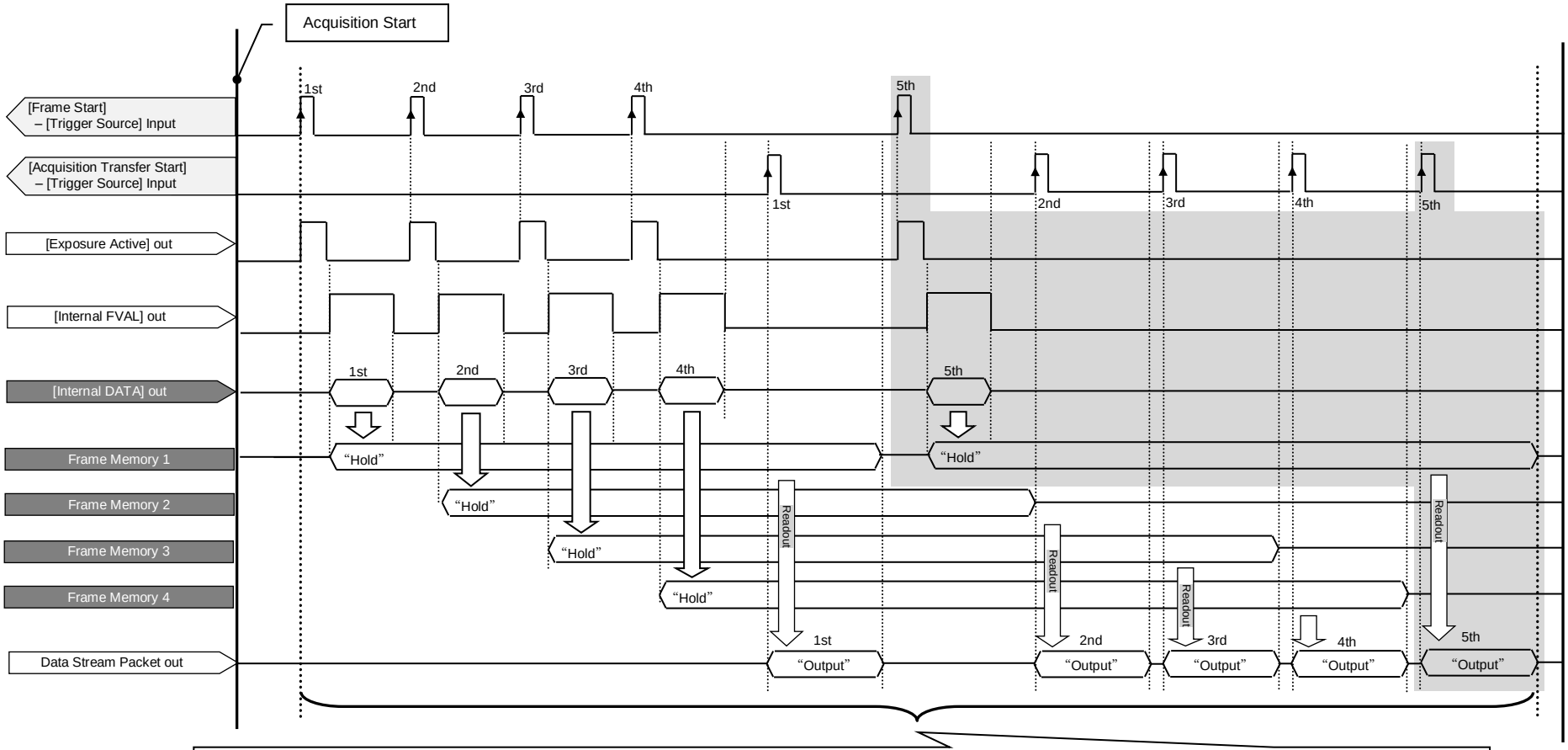


Example 1.
After [Frame Start] - [Trigger Source] signal is input to store image, [Acquisition Transfer Start] - [Trigger Source] signal is input to initiate readout.

Example 2.
Keep maximum 4 frames and read them out in order later
(1) [Frame Start Trigger]-[Trigger Source]
Apply 4 triggers (Maximum) by keeping the minimum trigger interval rule.

Example 2 (Cont).
(2) By inputting [Acquisition Transfer Start]-[Trigger Source] signal, stored images are read out in order.
The first stored image is read out first.

Fig.37 Example 1 and Example 2



Example 3. How 4 memories can store image again

(1) Apply " [Frame Start Trigger]-[Trigger Source] Trigger signal" four times.
(2) Apply "[Acqusition Transfer Start]-[Trigger Source] signal once. By doing this input, the first stored image can be readout. And the memory which stores the first image becomes available to store a new image.
(3) Apply "[Frame Start Trigger]-[Trigger Source] Trigger signal" once (This is fifth trigger signal). Then the image can be stored in memory.
(4) Apply "[Acqusition Transfer Start]-[Trigger Source] signal" twice. Those two signals clear the next two memories.

Fig. 38 Example 3

7.10. Operation and function matrix

Table - 46 Operation and function matrix

Exposuer Mode	Trigger mode	Trigger Option	V-Binning (Note1)	H-Binning (Note1)	Exposure control	ROI	Auto White Balance (Note2)	Auto Gain	Auto Exposure	Trigger Overlap	Video Send Mode		HDR (Note 5)
											Multi ROI	Sequence ROI	
OFF (Note3)	OFF	OFF	1	1	×	○	○	○	×	×	○	×	×
			2	2	×	○	○	○	×	×	○	×	×
Timed (Note 3)	OFF	OFF	1	1	○	○	○	○	○	×	○	×	○
			2	2	○	○	○	○	○	×	○	×	○
Timed (Note 4)	ON	OFF	1	1	○	○	○	○	○	○	○	○	○
			2	2	○	○	○	○	○	○	○	○	○
Trigger Width (Note4)	ON	OFF	1	1	×	○	×	×	×	○	○	×	×
			2	2	×	○	×	×	×	○	○	×	×
Timed (Note4)	ON	PIV	1	1	×	○	×	×	×	×	○	×	×
			2	2	×	○	×	×	×	×	○	×	×

(Note1) SP-20000M-USB only
(Note2) SP-20000C-USB only
(Note3) Continuous trigger operation
(Note4) External trigger operaion
(Note5) HDR is an optional function

8. Other functions

8.1 Black level control

This function adjusts the setup level.
Variable range: -256 to +2553LSB (at 10-bit output)

8.1.1 Black Level Selector

The following items can be adjusted.

Monochrome:	Black Level All
Color:	Black Level All/ Black Level Red/ Black Level Blue

8.1.2 Black Level

The black level can be adjusted in the following range.

Monochrome:	Black Level All : -256 ～+255
Color:	Black Level All : -256 ～+255
	Black Level Red: -128 ～+127
	Black Level Red: -128 ～+127

8.1.3 Auto black control

The auto black control function is used to automatically adjust the black level of the sensor, which may vary due to temperature changes and/or the exposure time.
It can adjust up to 30% of the video output level.

It has three modes which have different compensation values and the user can choose an appropriate mode depending on the application.
As the dynamic range of the sensor depends on the compensation value of the black level, for best results it is recommended that the camera be used under low temperature conditions, i.e., less than 30°C and with exposure times of less than 1 frame, in order to maintain an appropriate dynamic range.

Auto: The compensation value can be automatically varied up to 30%. In this mode, the dynamic range is the smallest.

Limit: In this mode, the limit of the black level compensation value can be set in the range of 0% to 30% by 1% steps. If the camera is used in an environment with little temperature change or short exposure time, this mode can automatically provide an appropriate balance between black level compensation and dynamic range by setting the upper limit of the black level compensation.

Fix: In this mode, the camera automatically saves the temperature and the status of the exposure time just before this mode is set. Then, it sets the appropriate black level compensation value and the maximum dynamic range in accordance with the saved conditions. After this automatic adjustment, the compensation value, which is indicated by percentage, can be read out.
In this mode, the black level compensation value is fixed. It is recommended to use this mode if the temperature and exposure time are stable. If the black level varies due to temperature change and/or exposure time variation, it is necessary to set this mode again in order to learn the new environmental conditions. If the environmental conditions are expected to be varied, it is recommended to use Auto or Limit mode.

8.1.4 Associated GenICam register information

Table – 47 Associated GenICam register information

GenICam Name	Access	Values	Category
Black Level Selector	R/W	Digital All	Analog Control
Black Level Raw	R/W	-256 to 255	Analog Control

8.2 Gain control

The SP-20000M-USB can adjust the master gain level (DigitalGainAll) from x1 (0dB) to 16 times (+24dB) using x1 (0dB) as the reference (Factory default).
In the SP-20000C-USB, the master gain level (DigitalGainAll) can be adjusted from x1 (0dB) to 16 times (+24dB) and R and B gains can be adjusted in the range of 0.45 times (-7dB) to 3.16 times (+ 10dB) using the master gain as the reference.

Resolution: Master Gain: x0.01 /Step
Blue/Red Gain: x0.00017 /Step

In the SP-20000-USB, the digital gain is entirely used for adjusting the gain. Therefore, if a high gain setting is used, breaks in the histogram may occur.

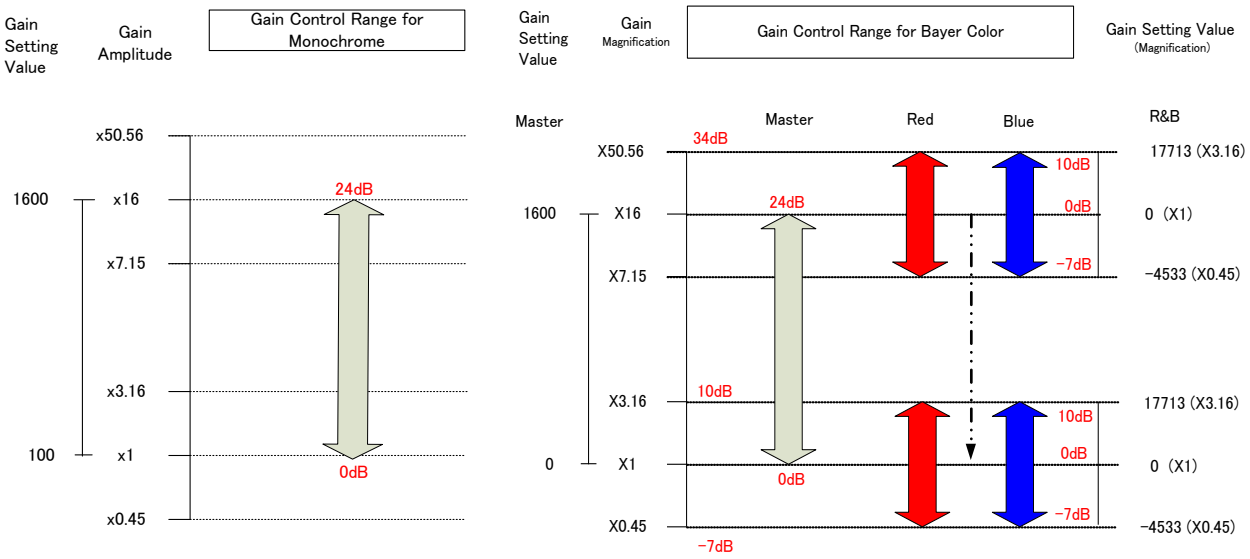
In the SP-20000C-USB, the color temperature adjusting range is specified in order to maintain the maximum dynamic range which the sensor has. Therefore, if the white balance is adjusted out of the specified color temperature adjusting range and if the gain setting is less than the following conditions, the sensor output may clip before it is saturated.

The guideline of settings at which the sensor output is clipped

At Gain 0 dB : -2995 (approx. x0.6)

The guideline for R and B gain

Color temperature	R Gain setting	B Gain setting
3000K	-2110 (approx. x0.74)	16828 (approx. x3)
9000K	18057 (approx.. x3.2)	-29936 (approx. x0.6)



The above drawing shows the relationship between gain setting value (command), gain amplitude and dB indication. For example, the gain amplitude “x3.16” equals 10dB.

Fig.39 Gain control

8.2.1 Gain Selector

The following parameters can be set.

Monochrome:	Digital All
Color:	Digital All / Digital Red/ Digital Blue

8.2.2 Gain

The range for adjustment is as follows.

Monochrome:	Digital All : 100 ～ 1600 (0dB ～24dB)
Color:	Digital All : 100 ～ 1600 (0dB ～24dB)
	Digital Red: -4533 ～ +17713 (-7dB ～ +10dB)
	Digital Blue: -4533 ～ +17713 (-7dB ～ +10dB)

8.2.3 Gain Auto

This provides automatic control of the gain level.
This is controlled by the command ALC Reference.
There are three modes.

OFF:	Adjust manually.
Once:	Operate only one time when this command is set
Continuous:	Operate the auto gain continuously

The following detailed settings are also available.

ALC Speed:	The rate of adjustment of GainAuto can be set. (Common with Exposure Auto)
Gain Auto Max:	The maximum value of GainAuto control range can be set
Gain Auto Min:	The minimum value of GainAuto control range can be set
ALC Reference:	The reference level of Gain Auto control can be set (Common with Exposure Auto)
ALC channel area:	The measurement area of GainAuto control can be set, either entire area or individual section (Common with Exposure Auto)

High Left	High Mid-left	High Mid-right	High Right
Mid-High Left	Mid-High Mid-left	Mid-High Mid-right	Mid-High Right
Mid-Low Left	Mid-Low Mid-left	Mid-Low Mid-right	Mid-Low Right
Low Left	Low Mid-left	Low Mid-right	Low Right

Fig.40 Detection area

8.2.4 Balance White Auto

This is a function to adjust white balance by controlling red and blue gain automatically.
The operation can be selected from the following methods.

OFF:	Manual adjustment
Once:	Performs auto white balancing once when this function is called.
Continuous:	Continuously adjusts white balance.

The controlled area can be set in AWB Channel Area. This is the same as ALC channel area.

8.2.5 Associated GenICam register information

Table – 47 Associated GenICam register information

GenICam Name	Access	Values	Category
Gain Auto	R/W	Off Continuous Once	Analog Control
ALC Speed	R/W	1 to 8	JAI-Custom
ALC Reference	R/W	1 to 100	JAI-Custom
Gain Auto Max	R/W	100 to 1600	JAI-Custom
Gain Auto Min	R/W	100 to 1599	JAI-Custom
ALC Channel Area ALL	R/W	Off On	JAI-Custom
ALC Channel Area Low Right	R/W	Off On	JAI-Custom
ALC Channel Area Low Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area Low Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area Low Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Left	R/W	Off On	JAI-Custom
ALC Channel Area High Right	R/W	Off On	JAI-Custom
ALC Channel Area High Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area High Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area High Left	R/W	Off On	JAI-Custom

8.3. LUT

This function can be used to convert the input to the desired output characteristics.
The Look-Up Table (LUT) has 256 points for setup. The output level can be created by multiplying the gain data by the input level.

8.3.1 LUT Mode

Can be set to OFF, gamma (see section 8.4), or Lookup Table.

8.3.2 LUT Index

This represents the "starting" or "input" pixel value to be modified by the Lookup Table. The SP-20000-USB has a 256-point Lookup Table, meaning the index points are treated like an 8-bit image with 0 representing a full black pixel and 255 representing a full white pixel. The index points are automatically scaled to fit the internal pixel format of the camera. This is common for all output configurations.

8.3.3 LUT Value

This is the "adjusted" or "output" pixel value for a given LUT index. It has a range of 0 to 4095 (12-bit) and is automatically scaled to the bit depth of the current operating mode (8-bit or 10-bit).
Note: linear interpolation is used if needed to calculate LUT values between index points. In the color mode, the LUT function works individually for each color, R,G and B.

Output Data = Video IN x LUT data

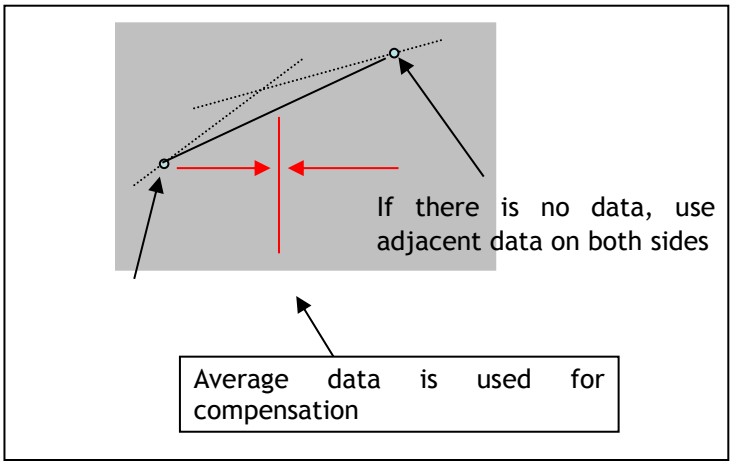


Fig.41 LUT data processing method

8.3.4 Associated GenICam register information

Table – 48 Associated GenICam register information

GenICam Name	Access	Values	Category
Gamma	R/W	0 to 7	Analog Control
JAI LUT Mode	R/W	Off Gamma LUT	Analog Control
LUT Selector	R/W	Mono (for mono) Red/Green/Blue (for Color)	LUT Control
LUT Index	R/W	0 to 255	LUT Control
LUT Value	R/W	0 to 4095	LUT Control

8.4 Gamma

This command is used to set gamma between gamma 0.45 and gamma 1.0(OFF).
16 steps are provided. The gamma value is an approximate value.

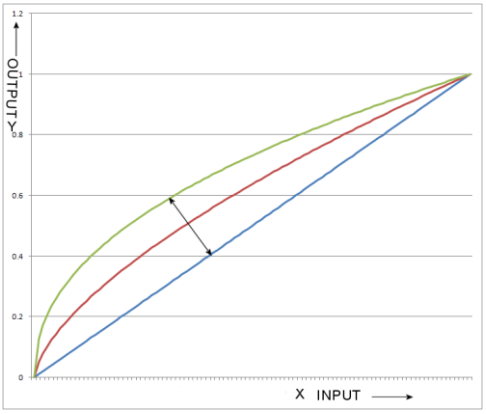


Fig.42 Gamma correction

8.5 Shading Correction

This function compensates for shading (non-uniformity) caused by the lens or the light source used. This compensation can be performed even if shading issues are not symmetrical in horizontal and/or vertical directions.

There are two methods of correction.

Flat shading correction:
The method to compensate the shading is to measure the highest luminance level in the image and use that data as the reference. Luminance levels of other areas are then adjusted so that the level of the entire area is equal. Compensation is performed using a grid of 20 blocks (H) x 15 blocks (V). Each block has 256 pixels x 256 pixels. The complementary process is applied to produce the compensation data with less error.

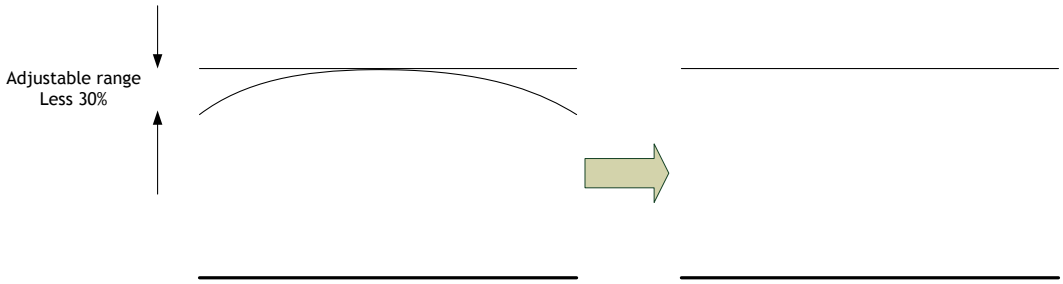


Fig.43 Concept drawing of Flat shadingcorrection

Color shading correction (For SP-20000C-USB only):
In this case, R channel and B channel are adjusted to match with G channel characteristics. The block grid for compensation is 20 blocks (H) x 15 blocks (V) and each block contains 256 x 256 pixels. The complementary process is applied to produce the compensation data with less error.

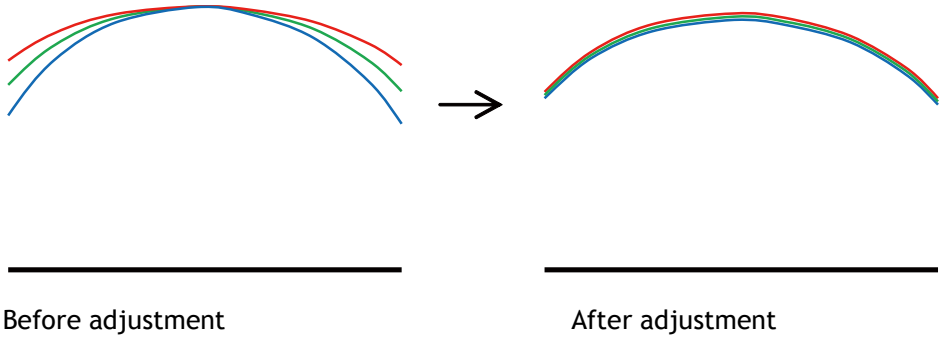


Fig. 44 Concept drawing of Color shadingcorrection

Note: Under the following conditions, the shading correction circuit may not work properly.

- If there is some area in the image with a video level less than 70%
- If part of the image or the entire image is saturated
- If the highest video level in the image is less than 300LSB (at 10-bit output)

Table – 50 Associated GenICam register information

GenICam Name	Access	Values	Category
Shading Mode (Only Color Model)	R/W	Flat Shading Color Shading	JAI-Custom
Perform Shading Correct	WO	True	JAI-Custom
Shading Mode	R/W	Off User1 User2 User3	JAI-Custom

8.6 Blemish compensation

The SP-20000-USB has a blemish compensation circuit. This function compensates blemishes on the CMOS sensor (typically pixels with extremely high response or extremely low response). This applies to both monochrome and color versions. Pixels that fulfill the blemish criteria can be compensated by averaging the data from pixels in both adjacent columns and, in the case of the SP-20000C-USB, the defective pixels can be compensated by averaging the data from the same Bayer color pixels in adjacent columns. The number of pixels that can be compensated is up to 1000 pixels.

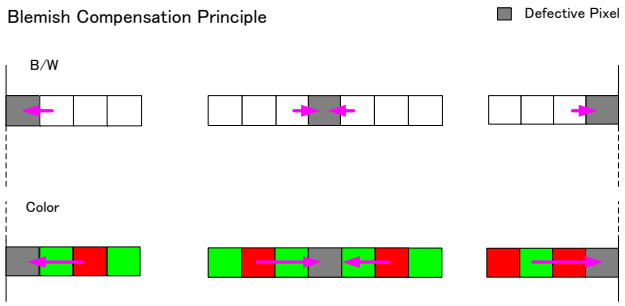


Fig. 45 Blemish compensation

If several defective pixels occur in series, 3 pixels in monochrome and 2 same color pixels in color can be compensated.

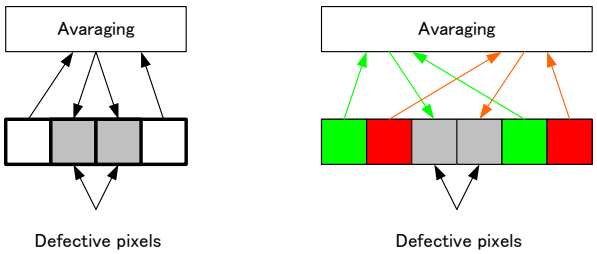


Fig. 46 Compensation if defective pixels are in series

Table - 51 Associated GenICam register information

GenICam Name	Access	Values	Category
Blemish Reduction Enable	R/W	False True	JAI-Custom
Blemish Reduction Calibration	WO	True	JAI-Custom
Blemish Detect Threshold	R/W	0 to 100	JAI-Custom
Blemish Detect Position Index	R/W	0 to 1000	JAI-Custom
Blemish Detect Position X	R/W	0 to 5119	JAI-Custom
Blemish Detect Position Y	R/W	0 to 3839	JAI-Custom

8.7 ALC

In the SP-20000-USB, auto gain and auto exposure can be combined to provide a wide ranging automatic exposure control from dark to bright or vice versa.
The functions are applied in the sequence shown below and if one function is disabled, the remaining function will work independently.

If the lighting condition is changed from bright to dark ASC → AGC
If the lighting condition is changed from dark to bright AGC → ASC

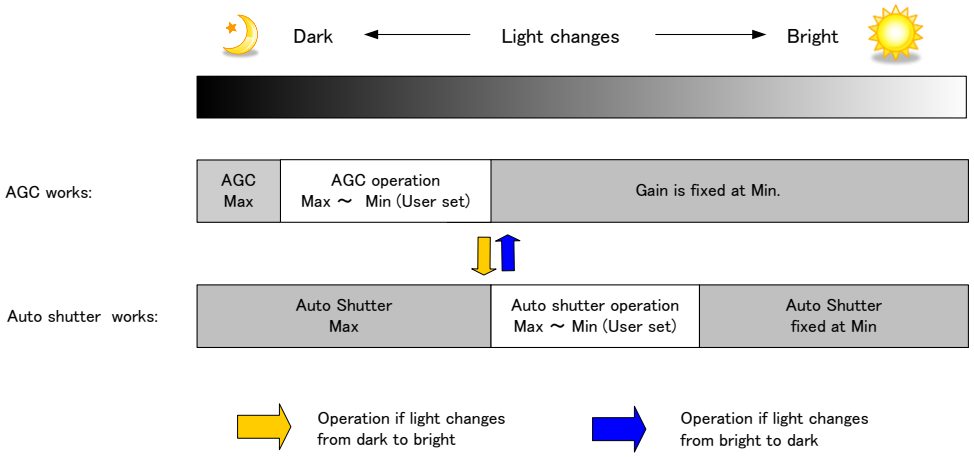


Fig.47 ALC function

ALC Reference will determine the target video level for AGC and Auto Exposure. For instance, if ALC Reference is set to 100% video level, AGC and/or Auto Exposure will function to maintain 100% video level.

Table - -52 Associated GenICam register information

GenICamName	Access	Values	Category
Exposure Auto	R/W	Off Continuous Once	Acquisition Control
Gain Auto	R/W	Off Continuous Once	Analog Control
ALC Speed	R/W	1 to 8	JAI-Custom
ALC Reference	R/W	1 to 100	JAI-Custom
ASC Max	R/W	101 to 8000000	JAI-Custom
ASC Min	R/W	100 to 999999	JAI-Custom
AGC Max	R/W	100 to 1600	JAI-Custom
AGC Min	R/W	100 to 1599	JAI-Custom
ALC Area Enable ALL	R/W	Off On	JAI-Custom
ALC Channel Area Low Right	R/W	Off On	JAI-Custom
ALC Channel Area Low Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area Low Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area Low Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle Low Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area Middle High Left	R/W	Off On	JAI-Custom
ALC Channel Area High Right	R/W	Off On	JAI-Custom
ALC Channel Area High Middle Right	R/W	Off On	JAI-Custom
ALC Channel Area High Middle Left	R/W	Off On	JAI-Custom
ALC Channel Area High Left	R/W	Off On	JAI-Custom

8.8 HDR function (Option)

The SP-20000M-USB has a High Dynamic Range function which utilizes built-in sensor characteristics. If [Exposure Mode] is set to "Timed" and then [HDR Mode] is set to "On", the High Dynamic Range function is activated. In this mode, it is possible to determine the input level of knee point(s) by using the exposure time as the reference. 1 or 2 knee points can be defined.

Setting parameters
Knee Point 1
Knee Point 2
Knee Slope 2
Knee Slope 3

Concept drawing to set knee point(s)

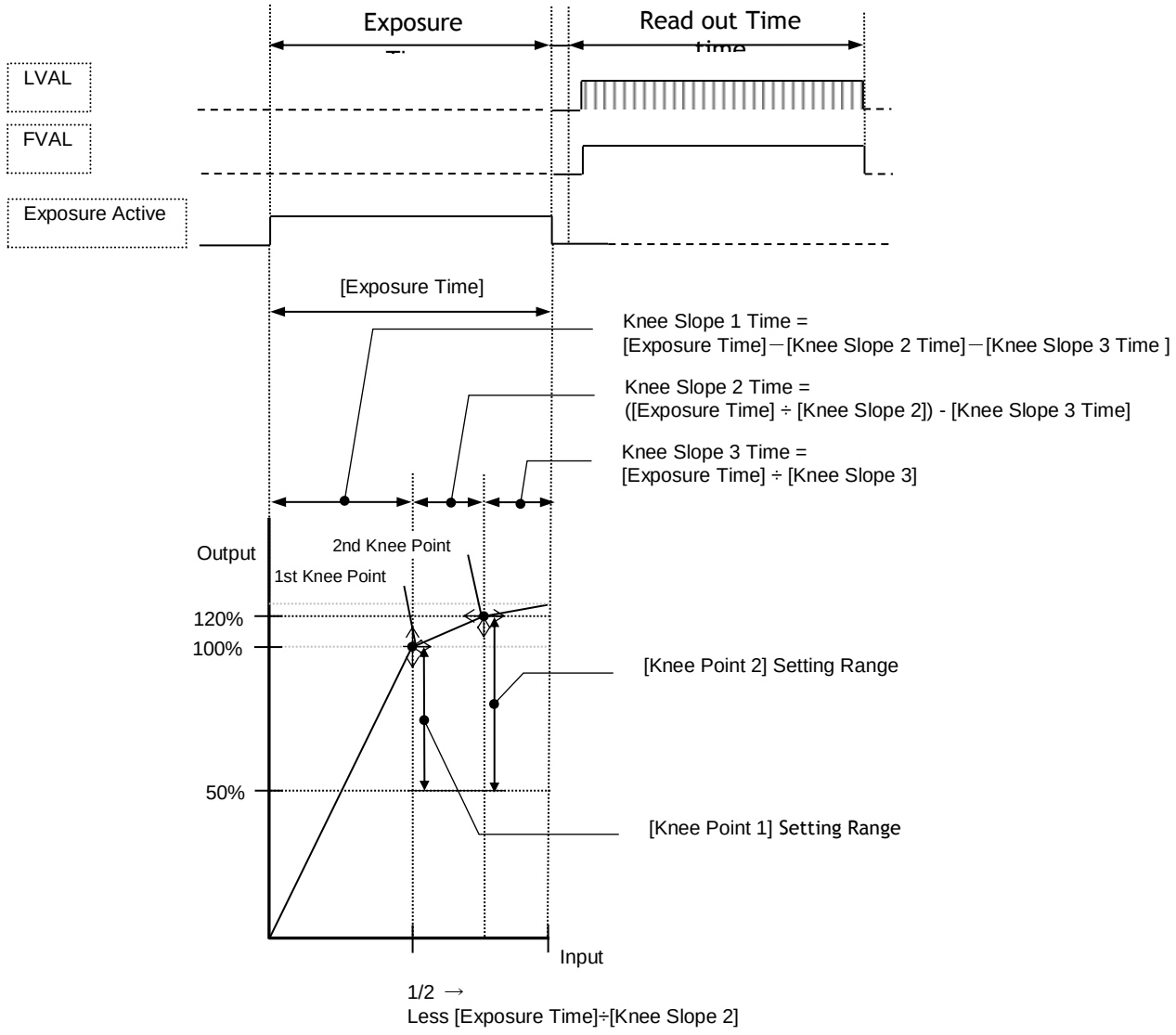


Fig. 48 HDR operation

Table – 47 HDR function

Setting item	Setting value		Description
HDR Mode	On / Off		If [Exposure Mode] is set to "Timed", On or OFF [HDR Mode]
Exposure Time	10 ~ 8000000	[Unit: us]	Determine the exposure time of HDR. The knee point on HDR operation can be determined using the exposure time as the reference
Knee Point 1	10 ~ 120 (Step=1)	[Unit: %]	Set the output level of Knee Point 1. The following relation must be kept. [Knee Point 1] ≦ [Knee Point 2]
Knee Point 2	10 ~ 120 (Step=1)	[Unit: %]	Determine the output level of Knee Point 2.
Knee Slope 2	2~ 16 (Step =1)		Set the position of Knee Point 1 based on the exposure time. Knee slope 2 value means the dividing value of the exposure time. The position of Knee Point 1 has the following relation: [Exposure Time Value]−([Exposure Time Value] ÷[Knee Slope 2 Value])
Knee Slope 3	2 ~ 16 (Step =1)		Set the position of Knee Point 2 based on the exposure time. Knee slope 3 value means the dividing value of the exposure time. The position of Knee Point 2 has the following relation: [Exposure Time Value]−([Exposure Time Value] ÷[Knee Slope 3 Value])
			The following shows the relation between Knee Point 1 and Knee Slope 2 and 3.
			(1) 2 Knee Points and 3 Knee Slopes [Knee Slope 2] ≦ [Knee Slope 3]
			(2) 1 Knee Point and 2 Knee Slopes [Knee Slope 2] ＞ [Knee Slope 3] and [Knee Point1] ＞ [Knee Point 2]
			(3) No Knee Point and 1 Knee Slope [HDR Mode] ="Off"
Read Slope Number Command	-		To read the number of Knee points generated by the setting of [Knee Point 1], [Knee Point 2], [Knee Slope 2] and [Knee Slope 3].

9. Camera Control Settings

9.1 Camera Control Tool

In the SP-20000-USB, control of all camera functions is done by the JAI SDK and Control Tool software. All controllable camera functions are stored in an XML file inside of the camera. The JAI SDK and Control Tool software can be downloaded from www.jai.com.

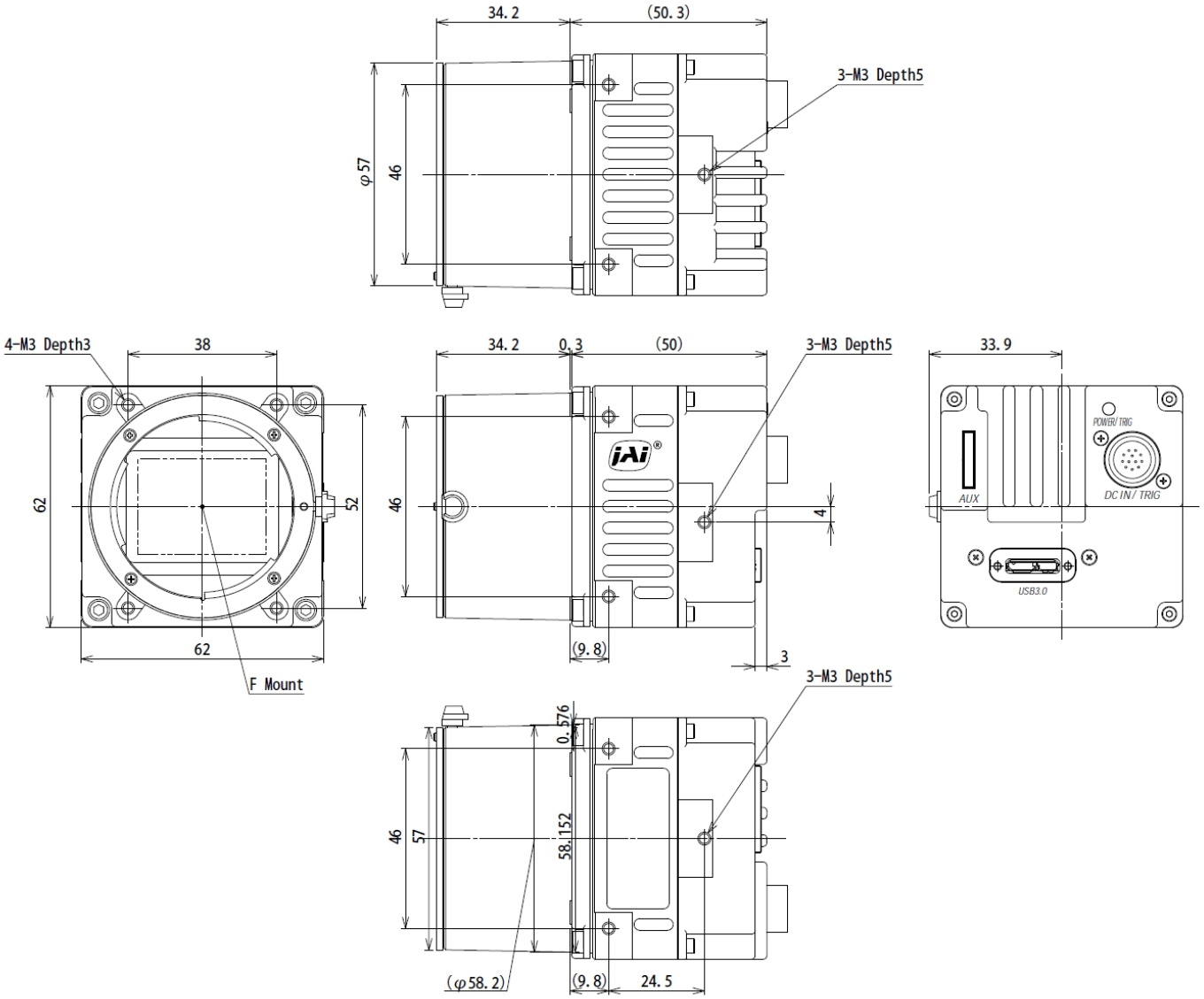
9.2 Camera Default Settings

When the camera is connected to PC and JAI SDK 2.0 is started up, XML file which stores default settings of the camera is downloaded to JAI_SDK camera control tool.

The default settings of SP-20000-USB is as follows.

Image Format	Bit allocation	8-bit
	Width	5120
	Height	3840
	Binning Horizontal	1(OFF)
	Binning Vertical	1(OFF)
Acquisition Control	Acquisition mode	Continuous
	Acquisition Frame Rate	16
Trigger Selector		Acquisition Start
	Trigger Mode	OFF
	Trigger Activation	Rising Edge
	Trigger Source	Low
Trigger Overlap		OFF
Exposure Control	Exposure Mode	OFF
Gain	Gain	1
	Gain Auto	OFF
Gamma		0
Video Send Mode		Normal

10. External appearance and dimensions



Dimensions tolerance : ±0.3mm
Unit : mm

Fig. 49 Appearance and Dimensions

11. Specifications

11.1. Camera spectral response

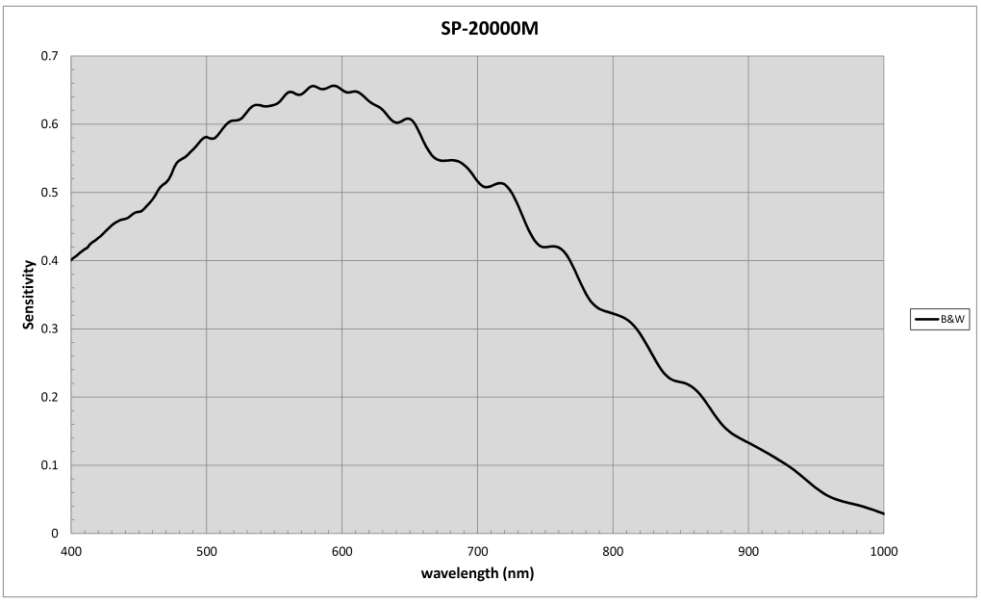


Fig.50 SP-20000M-USB Spectral response

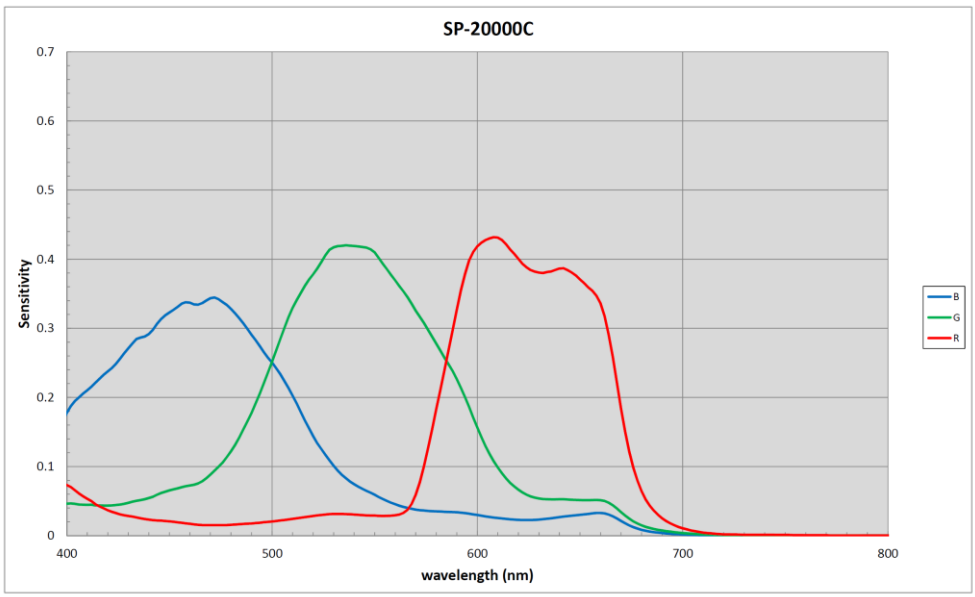


Fig.51

11.2. Specification table

Specifications			SP-20000M-USB	SP-20000C-USB
Scanning system			Progressive scan	
Synchronization			Internal	
Interface			USB 3.0 (USB3 Vision 1.0)	
Image sensor (CMV-20000)			35mm Monochrome CMOS	35mm Bayer color CMOS
Aspect ratio			4:3	
Effective image size			32.77 (h) x 24.58 (v) mm 41mm diagonal	
Cell size			6.4 (h) x 6.4 (v) μm	
Effective Image output pixel			5120 (h) x 3840 (v)	5120 (h) x 3840 (v)
Pixel clock			40 MHz	
Acquisition Frame rate (Maximum shown. Minimum is 0.125 fps for all configurations.)			16 fps : 8-bit	16 fps : 8-bit
			8 fps : 10-bit	8 fps : 10-bit
			8 fps : 12-bit	8 fps : 12-bit
			12.8 fps : 10bit_Packed	12.8 fps : 10bit_Packed
			10.666 fps : 12bit_Packed	10.666 fps : 12bit_Packed
EMVA 1288 Parameters Absolute sensitivity Maximum SNR			10-bit output format 16.05 p (λ = 525 nm) 40.24dB	10-bit output format 18.14 p (λ = 530 nm) 38.32dB
SN ratio (Traditional Method)			53 dB (Typical) (0dB gain, Black))	51 dB (Typical) (0dB gain, Green Pixel Black)
Image Output Format Digital	Full image		5120 (h) x 3840 (v)	Bayer 5120 (h) x 3840 (v)
	ROI	Height	2 ～3840 lines, 2 line / step	2 ～3840 lines, 2 lines / step
		OFFSET Y	0 ～3838 lines, 2 line / step	0 ～3838 lines , 2 lines / step
		Width	8 ～ 5120 pixels, 8 pixel/step	8 ～ 5120 pixels, 8 pixel/step
		OFFSET X	0 ～ 5112 pixels, 8 pixel/step	0 ～ 5112 pixels, 8 pixel/step
	Binning	H-1	5120 pixels (H)	5120 pixels (H)
		H-2	2560 pixels (H) * Frame rate is not changed	—
		V-1	3840 lines (V)	3840 lines (V)
		V-2	1920 lines (V) * Frame rate is not changed	—
	Pixel format		8-bit , 10-bit ,12-bit 10bit_Packed, 12bit_Packed	Bayer 8-bit , 10-bit ,12-bit, 10bit_Packed, 12bit_Packed
Video Send Mode			Normal, Trigger Sequence, Command Sequence, Multi ROI	
Acquisition Mode			Continuous / Single frame / Multi frame	
Trigger selector	Acquisition		Acqusition Start / Acquisition End /Frame Start / Acquisition Transfer Start	
	Exposure		Frame Start	
	Transfer		Acqusition Transfer Start	
Trigger option			OFF (Timed), PIV(Timed PIV)	
Trigger Overlap			OFF , Readout (Only for Frame Start),	
Trigger input signal			Line4(TTL 1), Line 5 (Opt In 1), Pulse Generator 0/1 Soft Trigger, Line 10 (TTL 2), Line 11 (LVDS), User Output 0/1/2/3	
Exposure Mode	Timed		299 μs (Min) ～ 8 sec. (Max)、 Step: 1 μs	
	Trigger Width		299 μs (Min) ～ ∞ (Max)	
Auto exposure			OFF / Once / Continuous	
Exposure Auto response speed			1 ～ 8	

HDR (Option)		Two slopes can be set. Slope: Can be set 2 times to 16 times	
Digital I/O		Line Selector (12-Pin and AUX 10-Pin): GPIO IN / GPIO OUT	
Black level adjust	Reference	33.5LSB 10-bit (Average of 100*100)	
	Adj. range	-256 ～ 255LSB 10-bit	
	Resolution	1 STEP = 1LSB	
Auto Black Control	Mode	Auto/ Limit / Fix	
	Limit	0% to 30%	
Gain Adjust	Manual adj. range	0dB ～+24dB, X0.01/step	0dB ～+24dB、X0.01/step
	WB gain	—	R / B : -7dB to +10dB, 0.001dB/ step
	WB area	—	4 x 4
	Preset xcolor temp.	—	4600K, 5600K, 6500K
	WB range	—	3000K ～ 9000K
	White balance	—	OFF, Once, continuous
Blemish comp.	Detection	Detect white blemish above the threshold value (Black blemish is detected only by factory)	
	Compensation	Complement by adjacent pixels	
	Correct Numbers	Up to 1000 pixels	
ALC		AGC and Auto Exposure can be combined and automatically controlled	
Gamma		0.45 ～ 1.0 (16 steps are available)	
LUT		OFF: γ=1.0, ON= 256 points can be set	
Shading compensation		Flat field Block based （256 x 256 pixels）	Flat field, Color shading Block based （256 x 256 pixels）
Power supply	Power input	DC+12V to +24V ± 10% (at the input terminal) VBUS IN = 5V ± 10%	
	Cuurent	450mA (12V input, Normal Operation, Full) 480mA (12V input, Normal Operation, 8 lines ROI)	
	Power consumption	5.4W (12V input, Normal Operation, Full) 5.8W (12V input, Normal Operation, 8 lines ROI)	
Lens mount		F mount, Rear protrusion of the lens is less than 40mm.	
Flange back		F mount : 46.5 mm, Tolerance 0 to -0.05 mm	
Optical filter		Protection glass : Not provided	Optical Low Pass filter ＋ IR cut filter (Half value is 670nm)
Operating temperature / Humidity (Performance guaranteed)		-5°C to +45°C / 20 – 80% (no-condensing)	
Operating temperature / Humidity		-45°C to +70°C / 20 – 80% (no-condensing)	
Storage Temp. / Humidity		-45°C to +70°C / 20% - 80 % (no-condensing)	
Regulation		CE (EN61000-6-2 and EN61000-6-3), FCC part 15 class B, RoHS, WEEE	
Housing Dimensions		62 x 62 x 84.5 mm (W x H x D) (excluding protrusion)	
Weight		350 g	

Note 1) Approximately 5 minutes pre-heating is required to achieve these specifications.
Note 2) The above specifications are subject to change without notice.

Appendix

1. Precautions

Personnel not trained in dealing with similar electronic devices should not service this camera.
The camera contains components sensitive to electrostatic discharge. The handling of these devices should follow the requirements of electrostatic sensitive components.
Do not attempt to disassemble this camera.
Do not expose this camera to rain or moisture.
Do not face this camera towards the sun, extreme bright light or light reflecting objects.
When this camera is not in use, put the supplied lens cap on the lens mount.
Handle this camera with the maximum care.
Operate this camera only from the type of power source indicated on the camera.
Power off the camera during any modification such as changes of jumper and switch setting.

2. Typical Sensor Characteristics

The following effects may be observed on the video monitor screen. They do not indicate any fault of the camera, but are associated with typical sensor characteristics.

V. Aliasing
When the CMOS camera captures stripes, straight lines or similar sharp patterns, jagged edges may appear on the monitor.

Blemishes
All cameras are shipped without visible image sensor blemishes.
Over time some pixel defects can occur. This does not have a practical effect on the operation of the camera. These will show up as white spots (blemishes).
Exposure to cosmic rays can cause blemishes to appear on the image sensor. Please take care to avoid exposure to cosmic rays during transportation and storage. It is recommended using sea shipment instead of air flight in order to limit the influence of cosmic rays on the camera. Pixel defects/blemishes also may emerge due to prolonged operation at elevated ambient temperature, due to high gain setting, or during long time exposure. It is therefore recommended to operate the camera within its specifications.

Patterned Noise
When the sensor captures a dark object at high temperature or is used for long time integration, fixed pattern noise may appear on the video monitor screen.

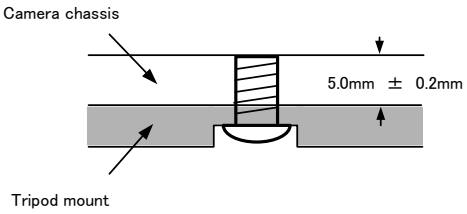
3. Caution when mounting a lens on the camera

When mounting a lens on the camera dust particles in the air may settle on the surface of the lens or the image sensor of the camera. It is therefore important to keep the protective caps on the lens and on the camera until the lens is mounted. Point the lens mount of the camera downward to prevent dust particles from landing on the optical surfaces of the camera. This work should be done in a dust free environment. Do not touch any of the optical surfaces of the camera or the lens.

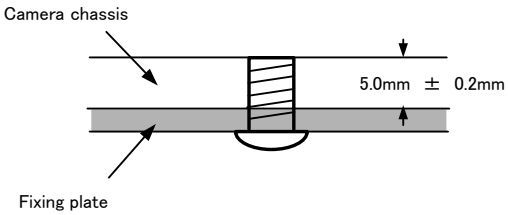
4. Caution when mounting the camera

When you mount the camera on your system, please make sure to use screws of the recommended length described in the following drawing. Longer screws may cause serious damage to the PCB inside the camera.

If you mount the tripod mounting plate, please use the provided screws.



Attaching the tripod mount



Mounting the camera to fixing plate

5. Exportation

When exporting this product, please follow the export regulation of your own country.

6. References

1. This manual and a datasheet for SP-20000M-USB / SP-20000C-USB can be downloaded from www.jai.com
2. Camera control software can be downloaded from www.jai.com

Manual change history

Date	Revision	Changes
April 2014	Preliminary	New release
July 2014	Ver.1.0	Release
Sept. 2014	Ver.1.1	Review Spectral response
Oct. 2014	Ver. 1.2	Revise B/W spectral response with wider wave length range
Mar. 2015	Ver. 1.3	Add 12-bit function , HDR is an optional function
May 2015	Ver. 1.4	Add thedescription of the optical interface

User's Record

Camera type: **SP-20000M-USB / SP-20000C-USB**

Revision: **……..**

Serial No. **……..**

Firmware version. **……..**

For camera revision history, please contact your local JAI distributor.

User's Mode Settings.

User's Modifications.

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