2023

SWIR Series Camera User Manual

EHD imaging GmbH

8.8.2023

content

1 Product description and features

SWIR series is a TE-Cooling USB3 / GigE / MIPI / CameraLink interface short-wave infrared camera which adopts SONY SenSWIR InGaAs sensor. This camera has high quantum efficiency and high sensitivity.

SWIR series can be used in NIR-II vivo microscopic imaging, hyperspectral imaging, laser spot observation, machine vision and general infrared detection, near-infrared spot detection, spot shooting and analysis, near-infrared target recognition, fluorescence imaging, fluorescent material imaging, image contrast enhancement, night vision imaging, flame monitoring, material defect inspection, chip inspection, solar cell inspection, pharmaceutical and cosmetic inspection, food, fruit and vegetable defect inspection, grain sorting, plastic sorting, perspective inspection, etc.

The basic features of SWIR series are as follows:

- SONY SenSWIR InGaAs sensor
- Built-in TEC or External TEC cooling chip
- Precise temperature control, the temperature difference can reach 10-25 degrees Celsius
- Spectral response range: 400nm-1800nm
- 5um pixel size
- Global shutter
- Support interface: USB3 / GigE / MIPI(developing) / CameraLink(developing)
- 12-bit ADC
- 4Gb memory
- Support external IO trigger control
- High framerate exceeding official parameters

2 Camera parameters and performance

2.1 SWIR camera model parameters

Model Number	Image Sensor	Pixel Size(μm)	G Sensitivity/Dark Signal	Data Interface	FPS/Resolution-8bit	Binning	Exposure Time
MaxCam-990TE-TR SWIR1300KMA	1.3M/IMX990(M) 1/2"(6.40x5.12) Buit-in TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	USB3	108fps@1280*1024(12bit) 209fps@640*512(12bit) 200fps@1280*1024(8bit) 392fps@640*512(8bit)	1x1 1x1	15us~60s
MaxCam-990-TR SWIR1300KMB	1.3M/IMX990(M) 1/2"(6.40x5.12) External TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	USB3	108fps@1280*1024(12bit) 209fps@640*512(12bit) 200fps@1280*1024(8bit) 392fps@640*512(8bit)	1x1 1x1	15us~60s
MaxCam-991TE-TR SWIR330KMA	0.33M/IMX991(M) 1/4"(3.20x2.56) Buit-in TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	USB3	212fps@640*512(12bit) 400fps@320*256(12bit) 400fps@640*512(8bit) 753fps@320*256(8bit)	1x1 1x1	15us~60s
MaxCam-991-TR SWIR330KMB	0.33M/IMX991(M) 1/4"(3.20x2.56) External TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	USB3	212fps@640*512(12bit) 400fps@320*256(12bit) 400fps@640*512(8bit) 753fps@320*256(8bit)	1x1 1x1	15us~60s
MaxCam-990TE-TRG SWIR1300KMA-G	1.3M/IMX990(M) 1/2"(6.40x5.12) Buit-in TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	GigE	45fps@1280*1024(12bit) 135fps@640*512(12bit) 90fps@1280*1024(8bit) 253fps@640*512(8bit)	1x1 1x1	15us~60s
MaxCam-990-TRG SWIR1300KMB-G	1.3M/IMX990(M) 1/2"(6.40x5.12) External TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	GigE	45fps@1280*1024(12bit) 135fps@640*512(12bit) 90fps@1280*1024(8bit) 253fps@640*512(8bit)	1x1 1x1	15us~60s
MaxCam-991TE-TRG SWIR330KMA-G	0.33M/IMX991(M) 1/4"(3.20x2.56) Buit-in TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	GigE	137.1fps@640*512(12bit) 258.6fps@320*256(12bit) 257.8fps@640*512(8bit) 486.1fps@320*256(8bit)	1x1 1x1	50us~60s
MaxCam-991-TRG SWIR330KMB-G	0.33M/IMX991(M) 1/4"(3.20x2.56) External TEC	5x5	121mV with 1/30s 1.0mV with 1/30s	GigE	137.1fps@640*512(12bit) 258.6fps@320*256(12bit) 257.8fps@640*512(8bit) 486.1fps@320*256(8bit)	1x1 1x1	50us~60s

2.2 SWIR camera model specifications

2.2.1 MaxCam-990TE-TR

Table 1 MaxCam-990 camera specifications

Model / Parameter	MaxCam-990TE-TR
	1.31M pixels 1/2" CMOS USB3.0 industrial camera
Camera	
Sensor model	Sony IMX990-AABA-C
Sensor Type	InGaAs
Spectral Range	400nm-1700nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/2"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：200fps@1280 x 1024、392fps@640 x 512 12 Bit：108fps@1280 x 1024、209fps@640 x 512
Image Buffer	512MByte
Conversion Gain	44.3e/ADU
Dynamic range	58.7dB
Readout Noise	211e
Full Well	181.6ke
SNRmax	52.6dB
Sensitivity	121mV

Dark current	383e/s(0° C) 510e/s(10° C) 638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	USB3.0
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	25° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	Power with USB3.0 or 12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

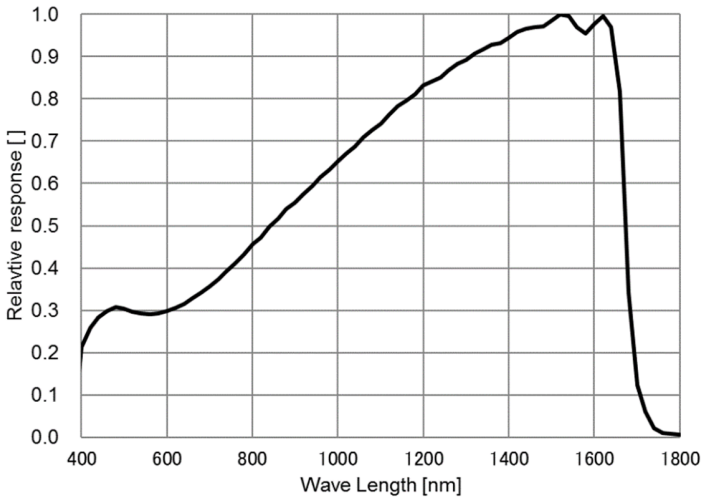

Figure 1 MaxCam-990 spectral response curve

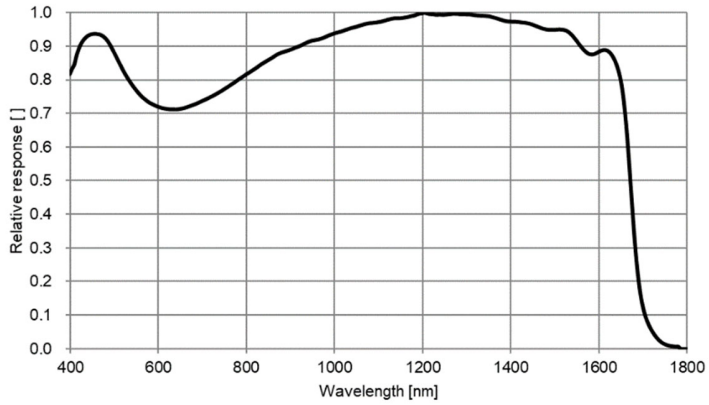

Figure 2 MaxCam-990 relative quantum efficiency

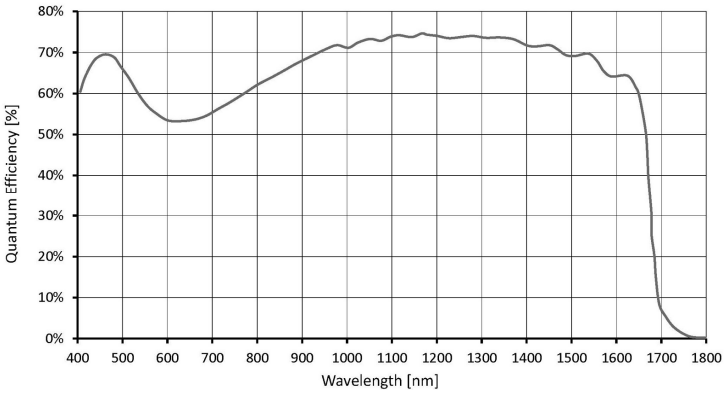

Figure 3 MaxCam-990 absolute quantum efficiency

2.2.2 MaxCam-990-TR

Table 2 MaxCam-990-TR camera specifications

Model / Parameter	MaxCam-990-TR
	1.3M pixels 1/2" CMOS USB3.0 industrial camera
Camera	
Sensor model	Sony IMX990-AABJ-C
Sensor Type	InGaAs
Spectral Range	400nm-1700nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/2"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：200fps@1280 x 1024、392fps@640 x 512 12 Bit：108fps@1280 x 1024、209fps@640 x 512
Image Buffer	512MByte
Conversion Gain	42.8e/ADU
Dynamic range	58.7dB
Readout Noise	197.6e
Full Well	175.4ke
SNRmax	52.4dB
Sensitivity	121mV
Dark current	638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	USB3.0
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	10° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	Power with USB3.0 or 12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

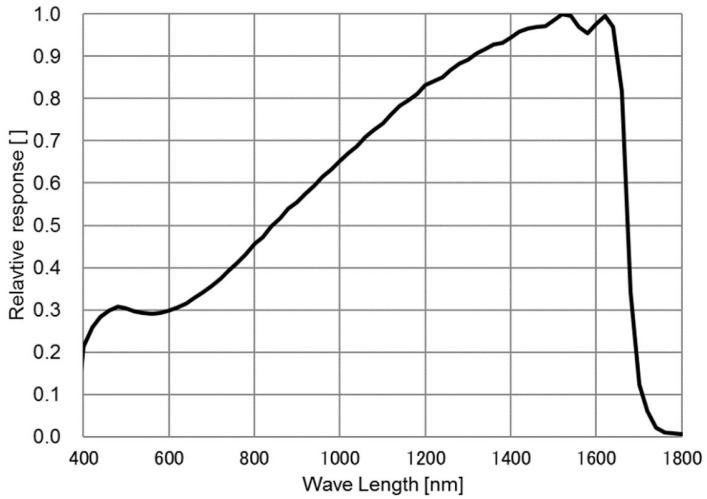

Figure 4 MaxCam-990-TR spectral response curve

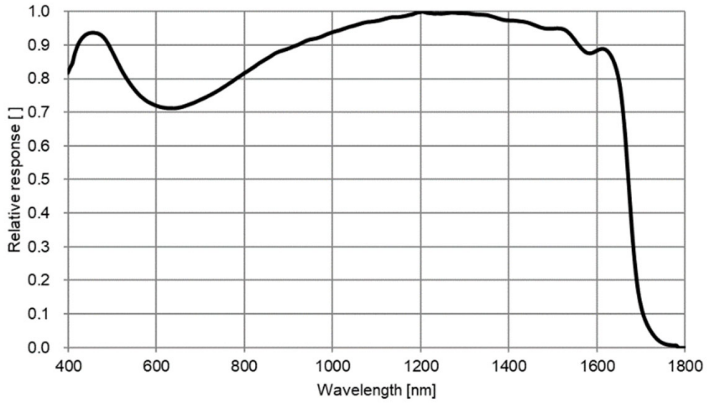

Figure 5 MaxCam-990-TR relative quantum efficiency

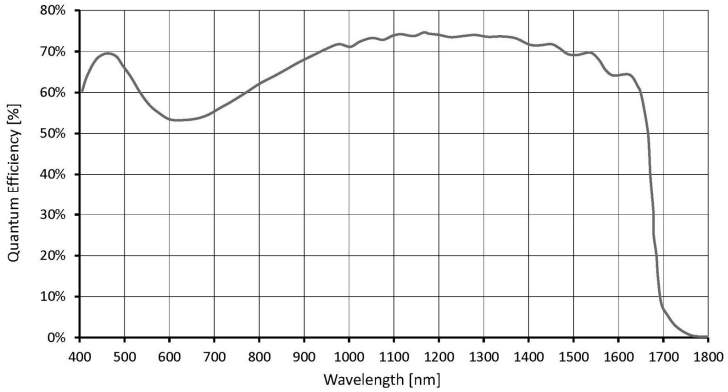

Figure 6 MaxCam-990-TR absolute quantum efficiency

2.2.3 MaxCam-991TE-TR

Table 3 MaxCam-991TE-TR camera specifications

Model / Parameter	MaxCam-991TE-TR 0.33M pixels 1/4" CMOS USB3.0 industrial camera
Camera	
Sensor model	Sony IMX991-AABA-C
Sensor Type	InGaAs
Spectral Range	400nm-1700nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/4"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：400fps@640 x 512、753fps@320 x 256 12 Bit：212fps@640 x 512、400fps@320 x 256
Image Buffer	512MByte
Conversion Gain	42.29e/ADU
Dynamic range	59.7dB
Readout Noise	176.7e
Full Well	173.23ke
SNRmax	52.39dB
Sensitivity	121mV
Dark current	383e/s(0° C) 510e/s(10° C) 638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	USB3.0
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	25° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	Power with USB3.0 or 12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

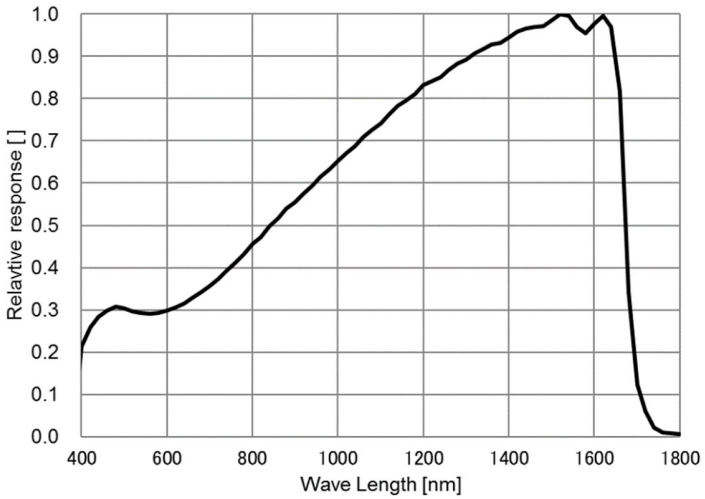

Figure 7 MaxCam-991TE-TR spectral response curve

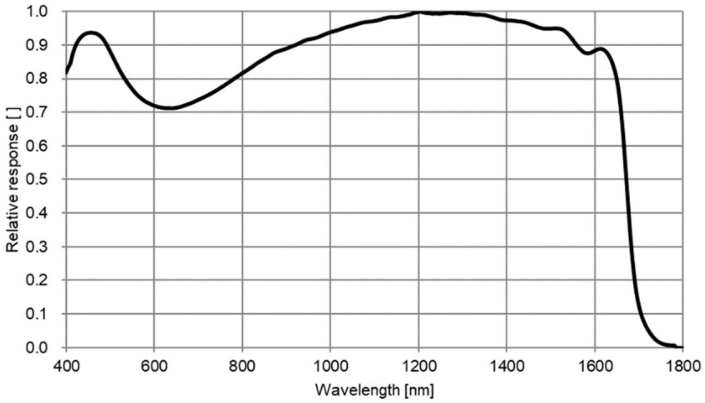

Figure 8 MaxCam-991TE-TR relative quantum efficiency

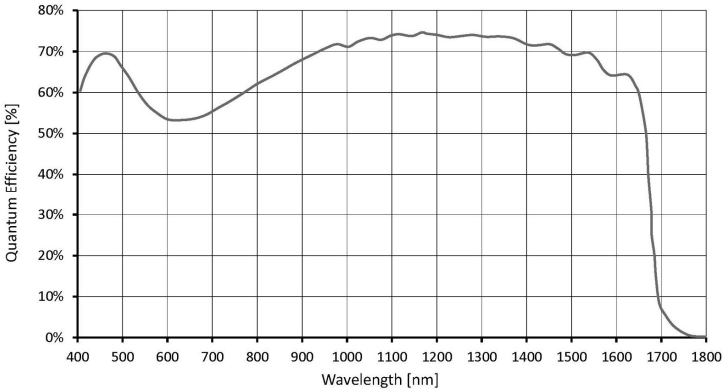

Figure 9 MaxCam-991TE-TR absolute quantum efficiency

2.2.4 MaxCam-991-TR

Table 4 MaxCam-991-TR camera specifications

Model / Parameter	MaxCam-991-TR
	0.33M pixels 1/4" CMOS USB3.0 industrial camera
Camera	
Sensor model	Sony IMX991-AABJ-C
Sensor Type	InGaAs
Spectral Range	400nm-1700nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/4"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：400fps@640 x 512、753fps@320 x 256 12 Bit：212fps@640 x 512、400fps@320 x 256
Image Buffer	512MByte
Conversion Gain	43.0e/ADU
Dynamic range	59.6dB
Readout Noise	178.8e
Full Well	176.2ke
SNRmax	52.5dB
Sensitivity	121mV
Dark current	638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	USB3.0
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	10° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	Power with USB3.0 or 12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

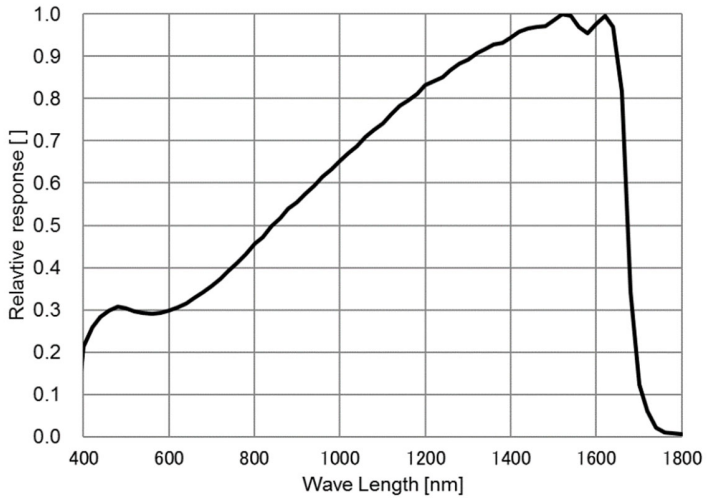

Figure 10 MaxCam-991-TR spectral response curve

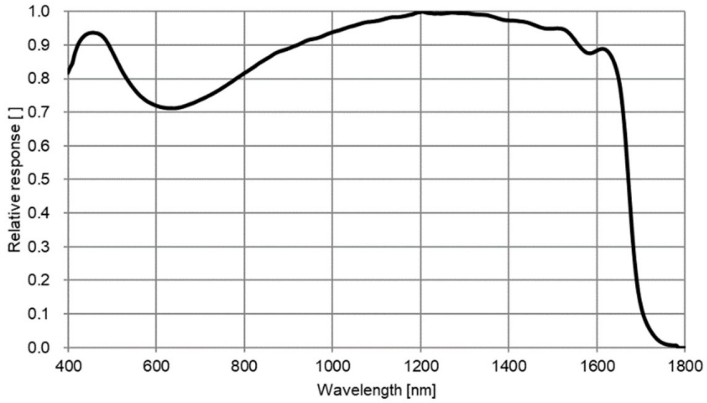

Figure 11 MaxCam-991-TR relative quantum efficiency

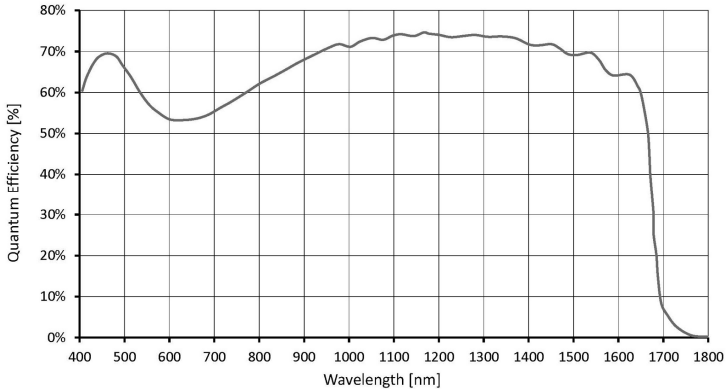

Figure 12 MaxCam-991-TR absolute quantum efficiency

2.2.5 MaxCam-990TE-TRG

Table 5 MaxCam-990TE-TRG camera specifications

Model / Parameter	MaxCam-990TE-TRG
	1.31M pixels 1/2" CMOS GigE industrial camera
Camera	
Sensor model	Sony IMX990-AABA-C
Sensor Type	InGaAs
Spectral Range	400nm-1800nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/2"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：90fps@1280 x 1024、253fps@640 x 512 12 Bit：45fps@1280 x 1024、135fps@640 x 512
Image Buffer	512MByte
Conversion Gain	44.3e/ADU
Dynamic range	58.7dB
Readout Noise	211e
Full Well	181.6ke
SNRmax	52.6dB
Sensitivity	121mV
Dark current	383e/s(0° C) 510e/s(10° C) 638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	GigE
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	25° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

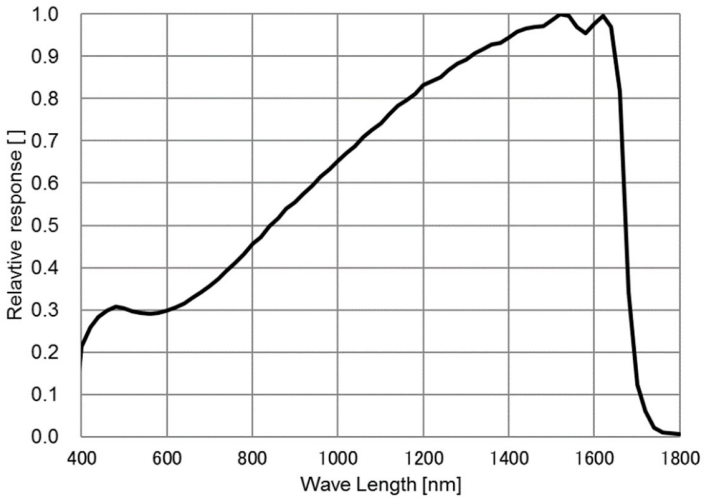

Figure 13 MaxCam-990TE-TRG spectral response curve

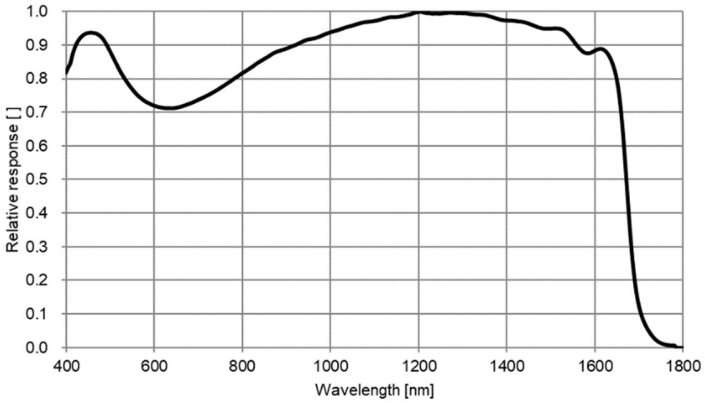

Figure 14 MaxCam-990TE-TRG relative quantum efficiency

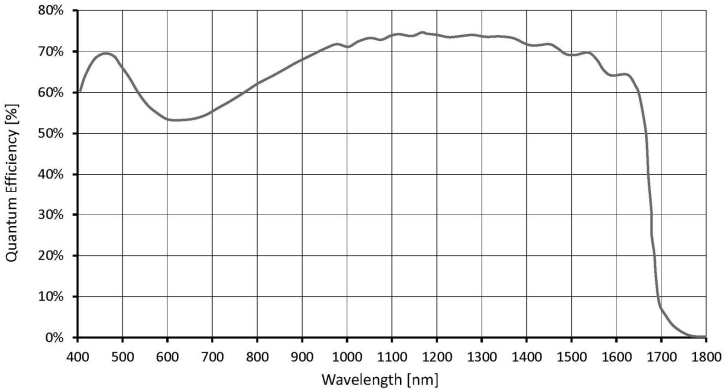

Figure 15 MaxCam-990TE-TRG absolute quantum efficiency

2.2.6 MaxCam-990-TRG

Table 6 MaxCam-990-TRG camera specifications

Model / Parameter	MaxCam-990-TRG 1.3M pixels 1/2" GigE USB3.0 industrial camera
Camera	
Sensor model	Sony IMX990-AABJ-C
Sensor Type	InGaAs
Spectral Range	400nm-1800nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/2"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：90fps@1280 x 1024、253fps@640 x 512 12 Bit：45fps@1280 x 1024、135fps@640 x 512
Image Buffer	512MByte
Conversion Gain	42.8e/ADU
Dynamic range	58.7dB
Readout Noise	197.6e
Full Well	175.4ke
SNRmax	52.4dB
Sensitivity	121mV
Dark current	638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	GigE
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	10° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

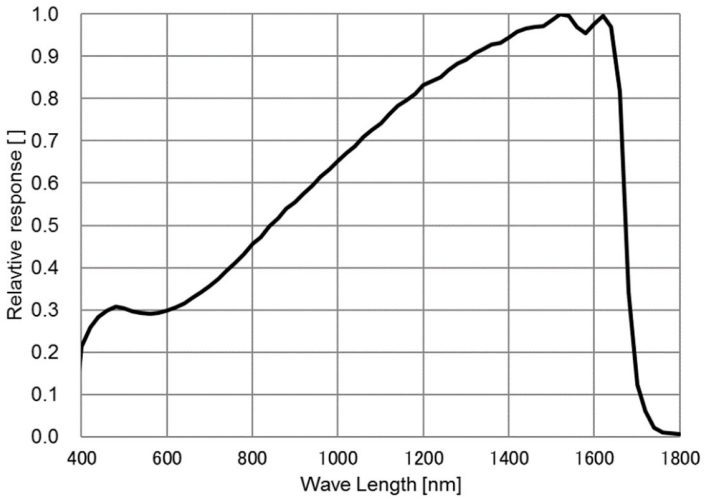

Figure 16 MaxCam-990-TRG spectral response curve

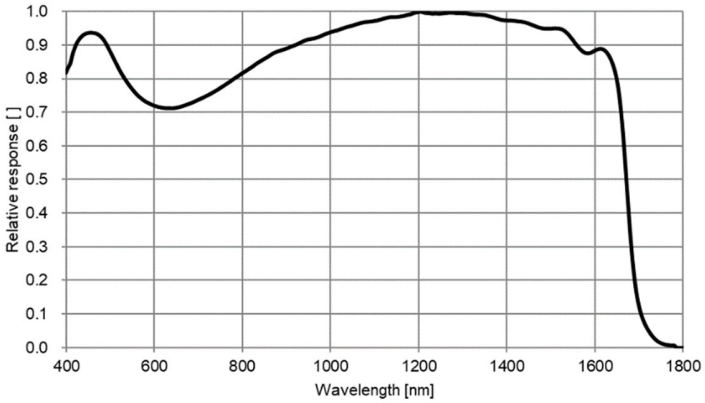

Figure 17 MaxCam-990-TRG relative quantum efficiency

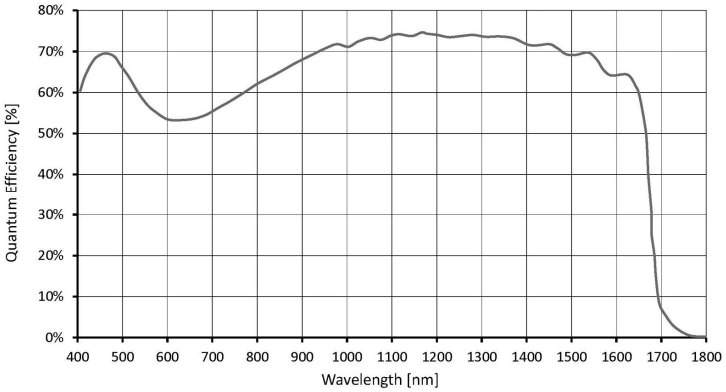

Figure 18 MaxCam-990-TRG absolute quantum efficiency

2.2.7 MaxCam-991TE-TRG

Table 7 MaxCam-991TE-TRG camera specifications

Model / Parameter	MaxCam-991TE-TRG
	0.33M pixels 1/4" CMOS GigE industrial camera
Camera	
Sensor model	Sony IMX991-AABA-C
Sensor Type	InGaAs
Spectral Range	400nm-1800nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/4"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：257.8fps@640 x 512、486.1fps@320 x 256 12 Bit：137.1fps@640 x 512、258.6fps@320 x 256
Image Buffer	512MByte
Conversion Gain	42.29e/ADU
Dynamic range	59.7dB
Readout Noise	176.7e
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Dark current	383e/s(0° C) 510e/s(10° C) 638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	GigE
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	25° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

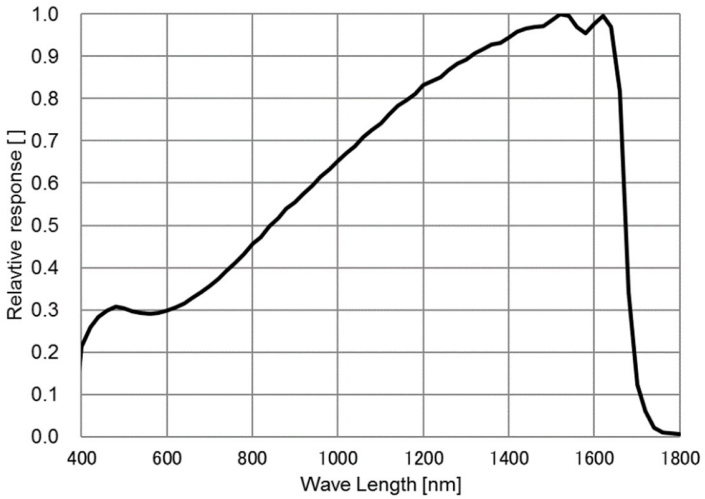


Figure 19 MaxCam-991TE-TRG spectral response curve

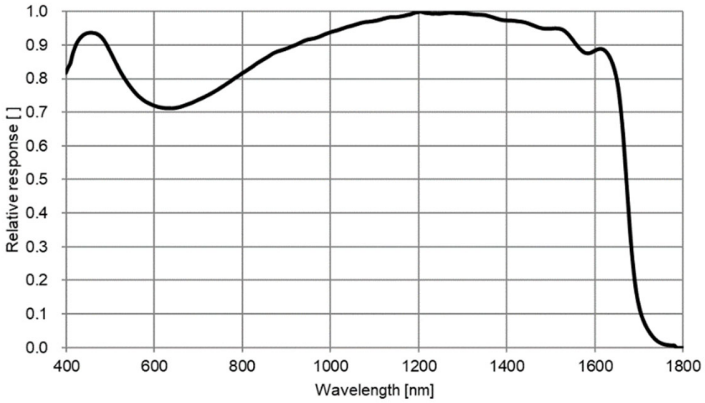


Figure 20 MaxCam-991TE-TRG relative quantum efficiency

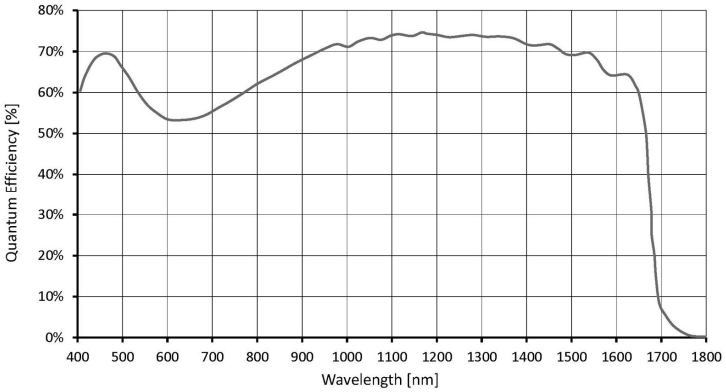


Figure 21 MaxCam-991TE-TRG absolute quantum efficiency

2.2.8 MaxCam-991-TRG

Table 8 MaxCam-991-TRG camera specifications

Model / Parameter	MaxCam-991-TRG
	0.33M pixels 1/4" CMOS GigE industrial camera
Camera	
Sensor model	Sony IMX991-AABJ-C
Sensor Type	InGaAs
Spectral Range	400nm-1800nm
Pixel size	5.0 μm x 5.0 μm
Sensor size	1/4"
ADC	12 Bit / 8 Bit
Frame rate	8 Bit：257.8fps@640 x 512、486.1fps@320 x 256 12 Bit：137.1fps@640 x 512、258.6fps@320 x 256
Image Buffer	512MByte
Conversion Gain	43.0e/ADU
Dynamic range	59.6dB
Readout Noise	178.8e
Full Well	176.2ke
SNRmax	52.5dB
Sensitivity	121mV
Dark current	638e/s(20° C)
Gain range	1x-15x
Exposure time	15μs-60sec
Shutter	Global shutter
Binning	Software2x2, 3x3, 4x4
Data interface	GigE
Digital I/O	One optical-coupling isolated input, one optical-coupling isolated output, two non-isolated input and output
Data Format	8bit / 12bit
Cooling performance	10° C below ambient temperature
Optical filter	400-1800nm(default); 1030-1800nm(optional)
CRA	2.35 Deg
General specification	
Power supply	12V Power adapter
Power consumption	<2.1W(without cooling) / <25W(cooling)
Temperature	Working temperature -20~60℃, storage temperature -40~85℃
Humidity	20%-80%, no condensation
Size	80mm×80mm×45.5mm
Weight	<390g
Lens mount	C-mount
Software	EHDView/ SDK
Operating system	Win32/WinRT/Linux/macOS/Android
Certification	CE, FCC

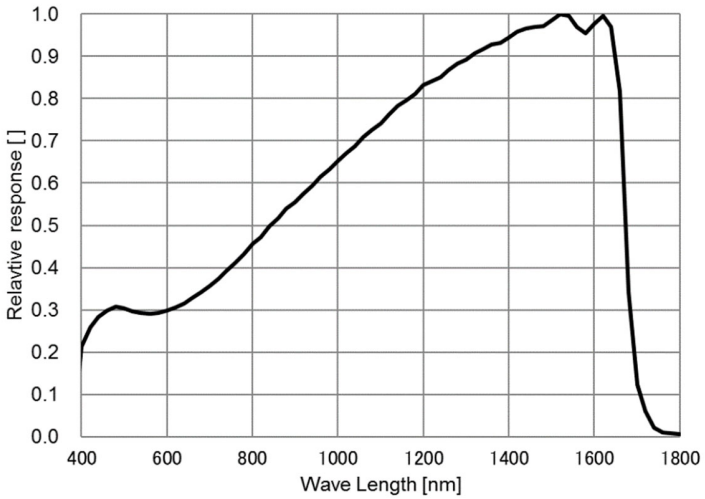


Figure 22 MaxCam-991-TRG spectral response curve

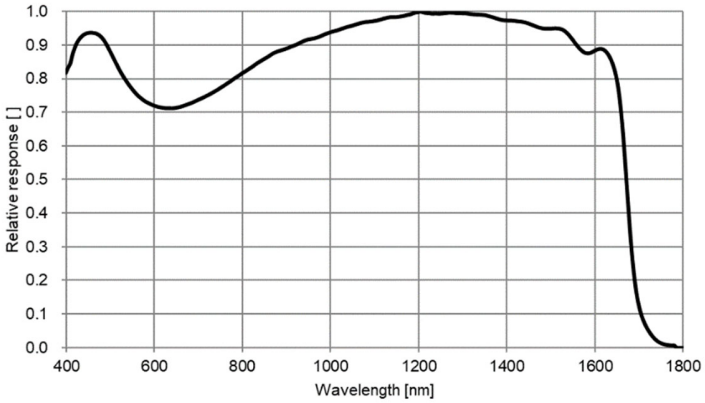


Figure 23 MaxCam-991-TRG relative quantum efficiency

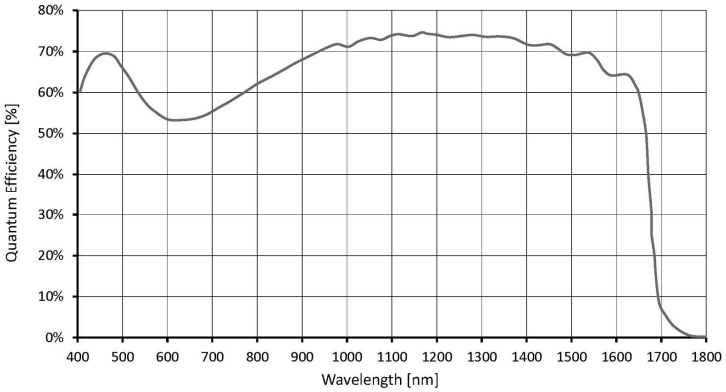


Figure 24 MaxCam-991-TRG absolute quantum efficiency

2.3 GigE camera specification

The GigE camera requires the host card's jumbo frame mode to be enabled to achieve the highest frame rate.

Ensure that the IP addresses of the GigE camera and PC network card are in the same network segment.

Support multiple cameras to work simultaneously and synchronize acquisition through external trigger interfaces.

2.4 Camera capture mode

Camera operation mode support: Video Mode or Trigger Mode.

Camera Trigger Mode supports: Soft Trigger Mode(Software) or External Trigger Mode(Isolated input, GPIO0, GPIO1, Counter or PWM).

2.5 Bit depth and ROI control

SWIR series has a built-in 12bit ADC, and the camera also supports hardware ROI. The smaller the ROI size, the faster the frame rate.

2.6 Bandwidth and precise frame rate control

2.6.1 Bandwidth

SWIR series supports bandwidth adjustment from 1% to 100%. As shown in Figure 25, the camera is with 100% bandwidth by default, and you can drag the slider to set the desired bandwidth.

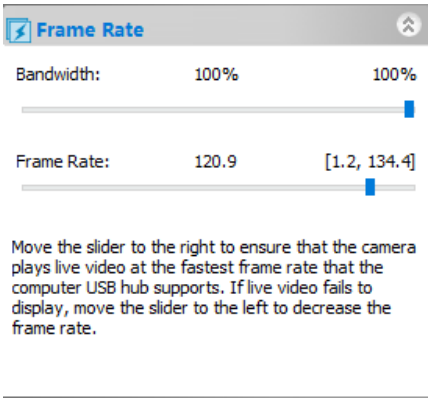


Figure 25 Bandwidth and precise frame rate settings

2.6.2 Precise frame rate control

SWIR series supports precise frame rate control. The frame rate range will vary based on bandwidth, bit depth, resolution, ROI. As shown in Figure 25, the current frame rate can be set by dragging the Bandwith or Frame Rate slider bar left or right.

2.7 DDR3 buffer

SWIR series has a built-in 512MB (4Gb) DDR3 buffer, which can effectively improve the stability of USB3.0 / GigE data transmission and ensure that the camera does not lose frames when working.

2.8 Binning

SWIR series supports additive or averaged 1x1 to 8x8 digital binning, and averaged 1x1 to 2x2 hardware binning. Hardware binning can achieve higher frame rates than software binning.

2.9 DC12V power supply and cooling system

When the DC12V power supply is plugged in, both the camera cooling system and the imaging system use a unified 12V power supply.

For USB camera, when the DC12V power supply is disconnected, the camera cooling system stops working, and the imaging system will automatically switch to the USB 5V power supply and the camera can work normally in passive cooling mode.

For GigE camera, when the DC12V power supply is disconnected, the camera cant work.

The cooling system of SWIR series has a built-in or external TEC cooling for the sensor. It uses an external heat dissipation structure and a fan to assist heat dissipation. The working temperature can be adjusted to a specific value, and the effective cooling temperature can be lower than the ambient temperature by 10 - 25 °C. The efficient cooling system guarantees extremely low dark current levels.

The TEC system is controlled by PID algorithm, so that the TEC can be accurately adjusted to the target temperature, and the temperature deviation is 0.1°C.

2.10 Camera performance analysis

The performance of the camera can be evaluated by e-/ADU, Readout Noise, Full Well and Dynamic Range.

e-/ADU: The electron signal of the CCD/CMOS camera is converted into a digital signal through a series of circuits such as readout, amplification, and analog-to-digital converter. The converted digital signal unit is called ADU. The conversion factor is e-/ADU.

Readout Noise: Readout noise is the most important reference indicator for measuring camera performance. Low readout noise usually means better signal-to-noise ratio and better image quality. Readout noise occurs when electrons go through steps such as analog-to-digital conversion, amplification, and processing to create an image during readout.

Full Well: The maximum capacity of how many electrons could be held by each pixel of the camera. Under the same conditions of noise and A/D conversion, the larger the full-well charge capacity of the sensor, the wider the dynamic range.

Dynamic Range: Dynamic range is specified as the maximum achievable signal divided by the camera noise, where the signal strength is determined by the full-well capacity and noise is the sum of dark and readout noises.. Dynamic range represents the camera's ability to display the brightest and darkest parts of an image and how much there is variation between the two. There may be one part of an image that is completely black and another part that is completely saturated.

For SWIR series, when describing camera performance, Gain Value In xxx% mode, here use xxx as the x - axis (Gain Value)

$$Rel\ Gain(dB) = 20 * log_{10}[xxx(Gain\ Value)/100]$$

$$\text{xxx(Gain Value)} = 100 \times 10^{(\text{Rel Gain(dB)}/20}$$

The performance parameters of the camera are as follows:

- Maximum resolution
- RAW 12 Bit mode
- Temperature : 5°C

Table 9 MaxCam-990TE-TR camera performance parameters

Gain Value	100	125	158	199	251	316	398	501	603	794	1000	1258	1500
Rel Gain (dB)	0.00	1.91	3.93	5.94	7.94	9.96	11.99	14.05	16.07	18.10	20.15	22.07	23.70
e-/ADU	44.32	35.56	28.21	22.37	17.76	14.08	11.15	8.79	6.97	5.52	4.36	3.49	2.90
Read Noise (e-)	210.89	209.29	209.71	208.16	207.64	205.12	203.76	202.01	199.78	197.93	198.65	198.47	198.65
Full Well (ke-)	181.55	145.64	115.53	91.64	72.76	57.68	45.68	36.02	28.55	22.60	17.85	14.30	11.86
DR (stop)	9.75	9.44	9.11	8.78	8.45	8.14	7.81	7.48	7.16	6.84	6.49	6.17	5.90

Table 10 MaxCam-990-TR camera performance parameters

Gain Value	100	125	158	199	251	316	398	501	603	794	1000	1258	1500
Rel Gain (dB)	0.00	1.25	1.57	1.97	2.47	3.12	3.91	4.92	6.20	7.77	9.72	11.94	14.32
e-/ADU	42.82	34.37	27.32	21.75	17.31	13.73	10.95	8.71	6.91	5.51	4.40	3.59	2.99
Read Noise (e-)	197.63	196.91	195.76	198.17	195.23	195.78	195.14	196.15	193.04	195.82	203.27	208.32	208.36
Full Well (ke-)	175.41	140.77	111.90	89.07	70.90	56.25	44.84	35.67	28.30	22.57	18.04	14.69	12.25
DR (stop)	9.79	9.48	9.16	8.81	8.50	8.17	7.84	7.51	7.20	6.85	6.47	6.14	5.88

Table 11 MaxCam-991TE-TR camera performance parameters

Gain Value	100	125	158	199	251	316	398	501	603	794	1000	1258	1500
Rel Gain (dB)	0.00	1.89	3.91	5.88	7.88	9.89	11.88	13.87	15.85	17.84	19.82	21.66	23.23
e-/ADU	42.29	34.00	26.98	21.48	17.07	13.54	10.77	8.57	6.82	5.43	4.32	3.49	2.92
Read Noise (e-)	174.99	169.28	172.01	171.45	170.73	169.36	168.80	170.65	173.33	176.87	184.04	189.99	187.34
Full Well (ke-)	173.23	139.27	110.49	87.99	69.90	55.47	44.11	35.08	27.92	22.23	17.69	14.31	11.95
DR (stop)	9.95	9.68	9.33	9.00	8.68	8.36	8.03	7.68	7.33	6.97	6.59	6.24	6.00

Table 12 MaxCam-991-TR camera performance parameters

Gain Value	100	125	158	199	251	316	398	501	603	794	1000	1258	1500
Rel Gain (dB)	0.00	1.90	3.90	5.91	7.91	9.93	11.92	13.93	15.92	17.90	19.94	21.70	23.21
e-/ADU	43.01	34.57	27.45	21.79	17.30	13.72	10.91	8.65	6.88	5.48	4.33	3.54	2.97
Read Noise (e-)	178.78	178.53	179.35	178.94	178.17	174.61	174.78	172.38	176.29	181.30	186.37	196.79	197.80
Full Well (ke-)	176.17	141.60	112.42	89.26	70.86	56.18	44.67	35.44	28.18	22.43	17.74	14.49	12.18
DR (stop)	9.94	9.63	9.29	8.96	8.64	8.33	8.00	7.68	7.32	6.95	6.57	6.20	5.94

2.11 Lens design guidelines

Information on lens selection is provided below.

The sensor imaging and the lenses are shown in Figure 26 and Figure 27.

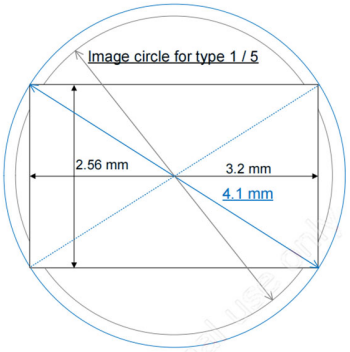


Figure 26 IMX991 relationship between image circle and pixel area

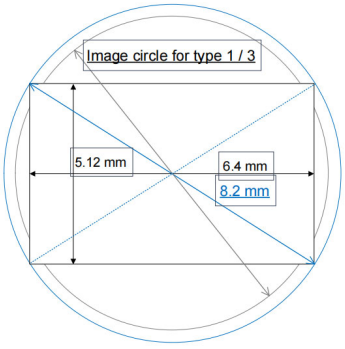


Figure 27 IMX990 relationship between image circle and pixel area

The following figure recommends the characteristics of CRA when the image height is from 0-100%.

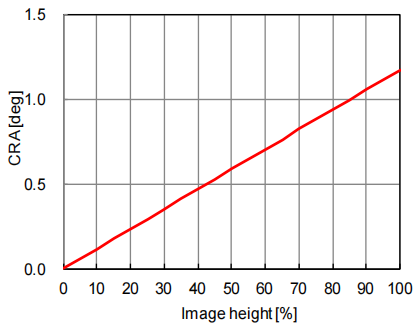


Figure 28 IMX991 CRA characteristics

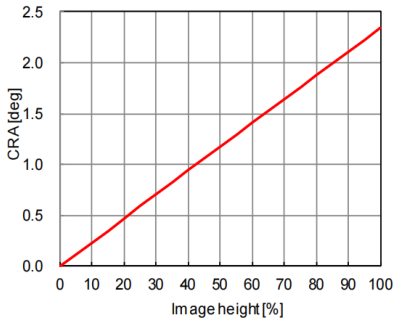


Figure 29 IMX990 CRA characteristics

Table 13 CRA(Chief Ray Angle) characteristics

IMX991			IMX990		
Image height		CRA (deg)	Image height		CRA (deg)
(%)	(mm)		(%)	(mm)	
0	0.00	0.00	0	0.00	0.00
5	0.10	0.06	5	0.20	0.12
10	0.20	0.12	10	0.41	0.23
15	0.31	0.18	15	0.61	0.35
20	0.41	0.23	20	0.82	0.47
25	0.51	0.29	25	1.02	0.59
30	0.61	0.35	30	1.23	0.70
35	0.72	0.41	35	1.43	0.82
40	0.82	0.47	40	1.64	0.94
45	0.92	0.53	45	1.84	1.06
50	1.02	0.59	50	2.05	1.17
55	1.13	0.65	55	2.25	1.29
60	1.23	0.70	60	2.46	1.41
65	1.33	0.76	65	2.66	1.53
70	1.43	0.82	70	2.87	1.64
75	1.54	0.88	75	3.07	1.76
80	1.64	0.94	80	3.28	1.88
85	1.74	1.00	85	3.48	1.99
90	1.84	1.06	90	3.69	2.11
95	1.95	1.12	95	3.89	2.23
100	2.05	1.17	100	4.10	2.35

2.12 Filter

The SWIR series uses two filters: the long wave pass filter LPF390H and the long wave pass filter LP1000H.

LPF390H: D25X1MM cuts off 200-375HR- pass through 400-1800HT-T90-OD5

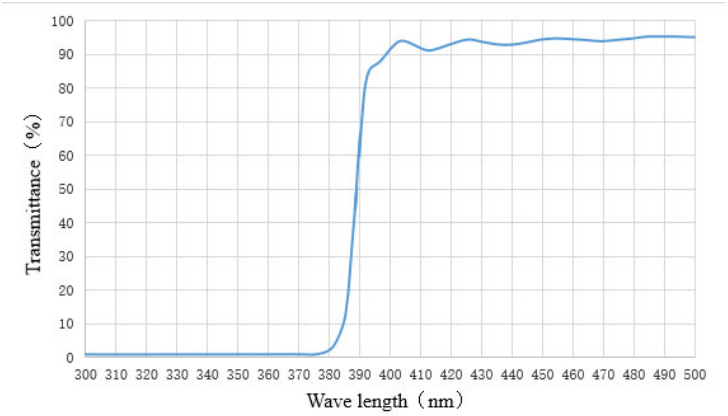


Figure 30 Long wave pass filter LPF390H transmittance curve

LP1000H: D25x2MM 200-980HR-1030-1800NM T90-OD5

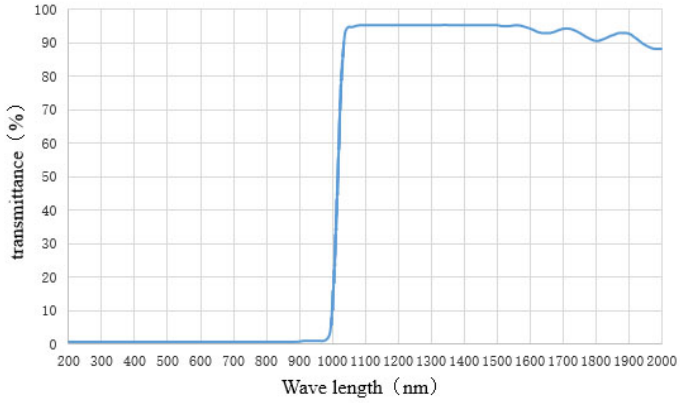


Figure 31 Long wave pass filter LP1000H transmittance curve

3 Camera size and design

3.1 Camera dimensions

USB camera and GigE camera dimensions are shown in Figure 32 and Figure 33.

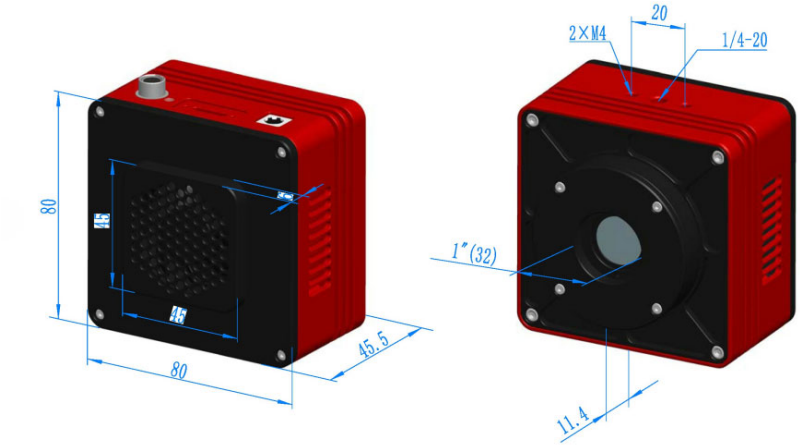


Figure 32 SWIR series' USB camera interface dimensions

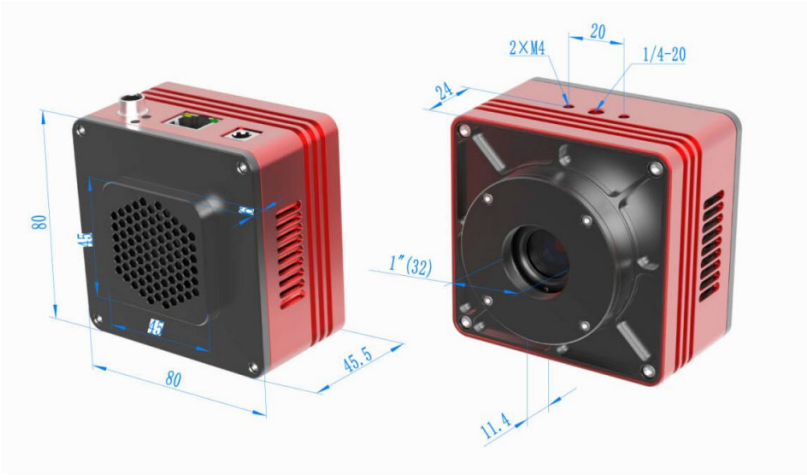


Figure 33 SWIR series' GigE camera interface dimensions

Table 14 SWIR series' dimensions specification

Parameter	Specification
Size	80*80*45.5mm
Mount	C mount

3.2 Camera ports for connection and power supply

3.2.1 USB camera

The appearance of the USB camera is shown in Figure 34, and the connection ports are shown in Table 15.

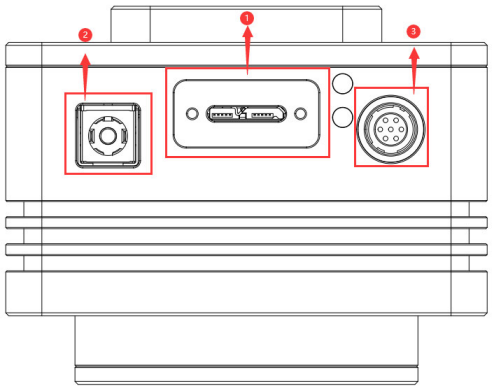


Figure 34 USB camera design and its ports

Table 15 USB camera interface specification

Item	Specification
1	USB3.0 port
2	DC 12V power slot
3	External IO connection port

3.2.2 GigE camera

The appearance of the GigE camera is shown in Figure 35, and the connection ports are shown in Table 16.

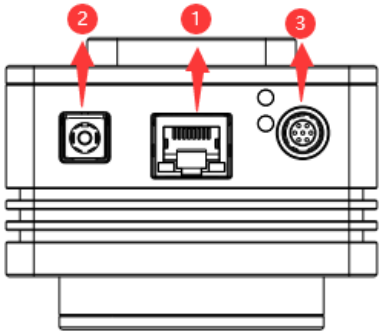


Figure 35 GigE camera design and its ports

Table 16 GigE camera interface specification

Item	Specification
1	GigE port
2	DC 12V power slot
3	External IO connection port

3.3 Packing list

3.3.1 USB camera packing list

Figure 36 SWIR series' USB camera packing information

Table 17 SWIR series' USB camera packing list

Standard Packaging List	
A	External box for B(not shown in this figure) Carton size: L:28.2cm W:25.2cm H:16.7cm
B	3-A safety equipment case: L:28cm W:23cm H:15.5cm (1pcs, 2.8Kg/ box)
C	One SWIR series USB camera
D	Power cord. National standard, American standard, European standard, British standard power cord (D1, D2, D3, D4) for choosing
E	Power adapter: Input: AC 100~240V 50Hz/60Hz, Output: DC 12V 3A
F	High-speed USB3.0 A male to B male gold-plated connector cable/1.5m
G	One external trigger control cable
H	USB flash disk (with driver and application software in it)

3.3.2 GigE camera packing list

Figure 37 SWIR series' GigE camera packing information

Table 18 SWIR series' GigE camera packing list

Standard Packaging List	
A	External box for B(not shown in this figure) Carton size: L:28.2cm W:25.2cm H:16.7cm
B	3-A safety equipment case: L:28cm W:23cm H:15.5cm (1pcs, 2.8Kg/ box)
C	One SWIR series GigE camera
D	Power cord. National standard, American standard, European standard, British standard power cord (D1, D2, D3, D4) for choosing
E	Power adapter: Input: AC 100~240V 50Hz/60Hz, Output: DC 12V 3A
F	One external trigger control cable
G	GigE cable: G1:3m G2:5m G3:10m(G4：50m not shown in this figure)
H	USB flash disk (with driver and application software in it)

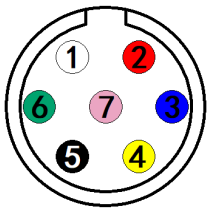
4 External IO connector and electrical characteristics

4.1 Pin signal

USB camera and GigE camera external IO connector is shown in Figure 38, and the pin signal definitions of the external IO connector are listed in Table 19.

Figure 38 SWIR series side appearance information

Table 19 SWIR series camera pin signal definitions



Color	Pin	Signal	Description of the signal
White	1	GDN	Direct-coupled signal ground
Red	2	12V	12VDC power input
Blue	3	OPTO_GND	Opto-isolated signal ground
Yellow	4	DIR_GPIO0	Direct-coupled General Purpose I/O (Software configurable input/output) (line2)
Black	5	DIR_GPIO1	Direct-coupled General Purpose I/O (Software configurable input/output) (line3)
Green	6	OPTO_IN	Opto-isolated input signal (line0)
Pink	7	OPTO_OUT	Opto-isolated output signal (line1)

4.2 I/O electrical characteristics

4.2.1 Opto-isolated input circuit (line0)

In the I/O control of the camera, the opto-isolated input circuit is shown in Figure 39.

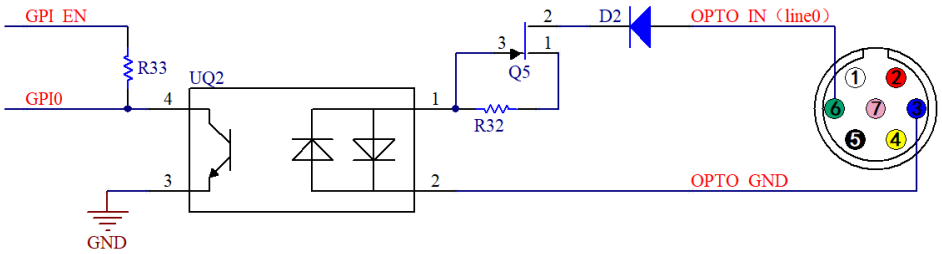


Figure 39 Opto-isolated input circuit

Logic 0 input level: 0~2.2VDC (OPTO_IN pin)

Logic 1 input level: 3.3~24VDC (OPTO_IN pin)

Maximum input current: 30mA

When the input level is between 2.2V and 3.2V, the circuit operation state is uncertain, please do not let SWIR

camera work within this voltage range.

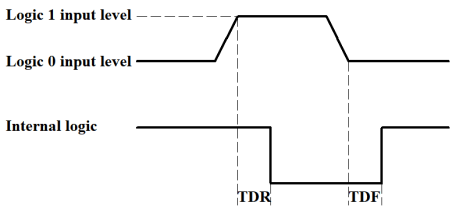


Figure 40 Input logic levels

Input rise delay (TDR): 6us

Input fall delay (TDF): 6us

4.2.2 Opto-isolated output circuit (line1)

In the camera I/O control, the opto-isolated output circuit is shown in Figure 41.

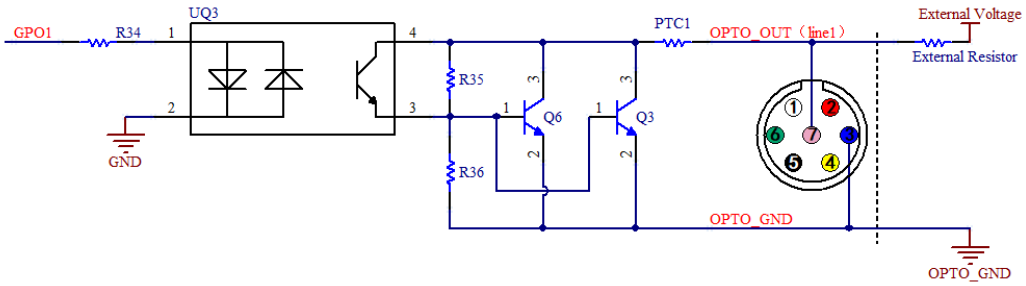


Figure 41 Optocoupler output circuit

The opto-isolated output maximum current is 30mA.

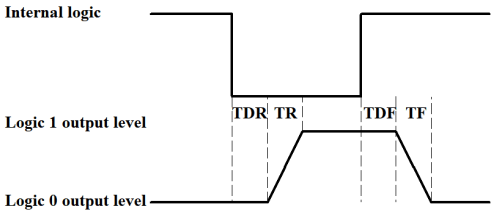


Figure 42 Output logic levels

The electrical characteristics of the opto-isolated output (external voltage 5V, external resistor 1K) are shown in Table 20.

Table 20 Opto-isolated output signal's electrical characteristics

Parameter name	Parameter notation	Parameter value
Output logic low	VL	742mV
Output logic high	VH	4.134V
Output rise time	TR	4us
Output fall time	TF	1.8us
Output rise delay	TDR	12us
Output fall delay	TDF	2us

The output of the corresponding output current and VL when using different voltages and resistors in external

circuit are shown in Table 21.

Table 21 Opto-isolated output logic's low levels parameters

External voltage	External resistor	VL	Output current
3.3V	1KΩ	510mV	2.82mA
5V	1KΩ	742mV	4.31mA
12V	2.4KΩ	795mV	4.68mA
24V	4.7KΩ	850mV	4.97mA

4.2.3 Input and output I/O circuit (line2/line3)

The non-isolated configurable input and output I/O circuits are shown in Figure 43 and Figure 44.

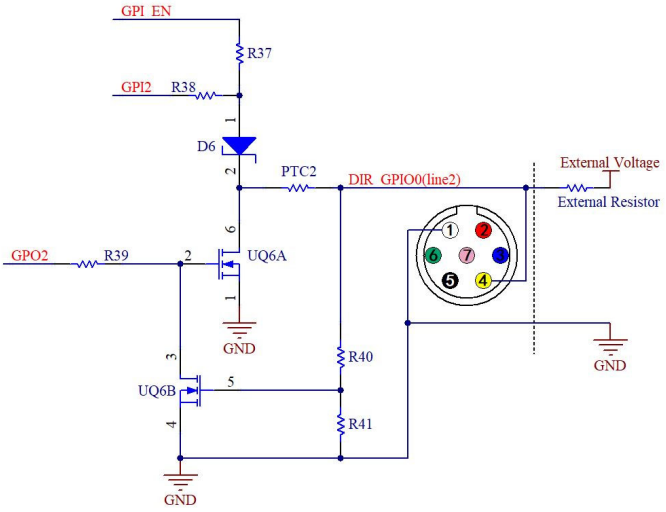


Figure 43 Non-isolated configurable input and output I/O circuit (line2)

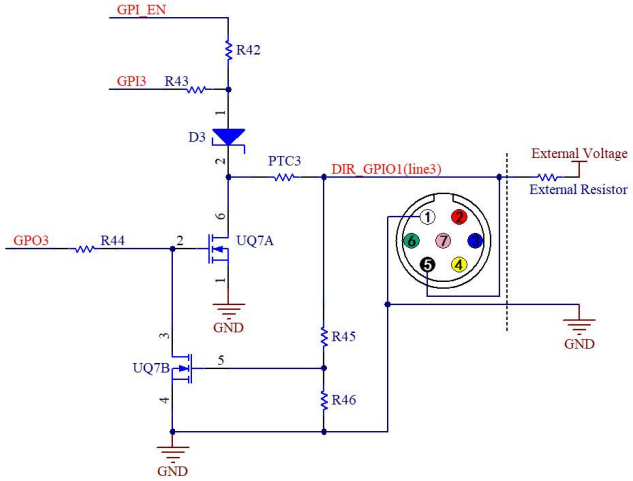


Figure 44 Non-isolated configurable input and output I/O circuit (line3)

1. Line2/line3 is set as input pin

Logic 0 input level: 0~0.6VDC (DIR_GPIO0/DIR_GPIO1 pins)

Logic 1 input level: 2.0~24VDC (DIR_GPIO0/DIR_GPIO1 pins)

Maximum input current: 25mA

When the input level is between 0.6V and 2.0V, the circuit action state is uncertain, please avoid the input voltage range working in this range.

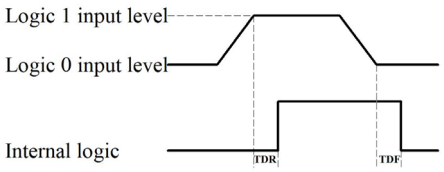


Figure 45 Input logic levels

To prevent damage to the GPIO pins, please connect the pin GND first, and then input voltage to the Line2 pin.

Input rise delay (TDR): 0.02us

Input fall delay (TDF): 0.02us

2.Line2/line3 are set as output pins

The maximum current allowed through this pin is 25mA.

When the ambient temperature is 25 degrees Celsius, the relationship between the external voltage, resistance and low-level valtage output is shown in Table 22.

Table 22 Non-isolated output Logic's low level parameters

External voltage	External resistor	VL (GPIO)
3.3V	1KΩ	0.11V
5V	1KΩ	0.167V
12V	2.4KΩ	0.184V
24V	4.7KΩ	0.385V

The external pull-up voltage is 5V, the pull-up resistor is 1KΩ, and the GPIO is configured to output the logic level and electrical characteristics as shown in Figure 46.

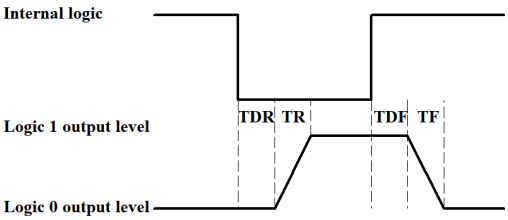


Figure 46 Output logic levels

Table 23 Non-isolated output electrical characteristics

Parameter name	Parameter notation	Parameter value
Output rise time	TR	0.08us
output fall time	TF	0.02us
Output rise delay	TDR	0.1us
Output fall delay	TDF	0.04us

5 Trigger Mode and its Configuration

5.1 Video mode and Trigger mode

The trigger function can be found on the Capture & Resolution group on the Camera Sidebar in EHDView. When the camera is opened, it is in Video Mode as shown in Figure 47 on the left. In Video Mode, Auto Exposure, Exposure Target, Exposure Time and Gain can be set. One can switch to Trigger Mode by checking the Trigger Mode check box.

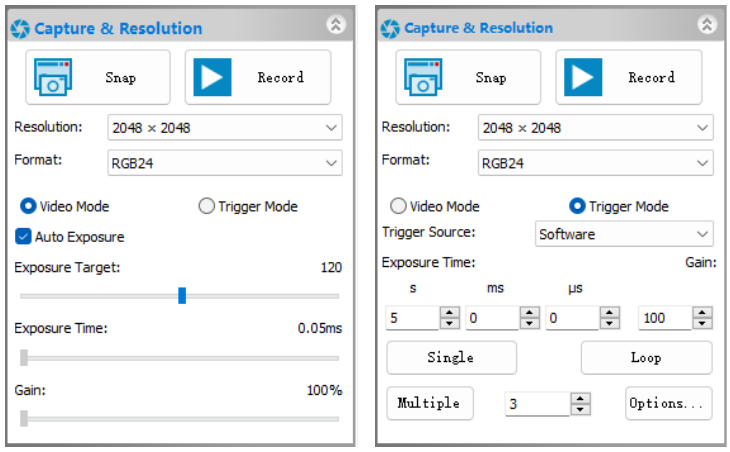


Figure 47 Video Mode and Trigger Mode on the Capture & Resolution group in EHDView

After the Trigger Mode is checked, the Capture & Resolution group will switch to Trigger Mode as shown in Figure 47 on the right. Where, the Trigger Source, Exposure Time, Gain, Single, Loop, Multiple, Frame Box, and Options can be set.

5.2 Trigger Sources and their capture style

The Trigger Source can be any external input signal inputted into the camera which is called Hardware (Trigger Source), it can also be a command from the application which is called Software (Trigger Source). For the Software Trigger Source, it can be Single, Loop, Multiple, or Sequence style. Figure 48 shows the possible Trigger Sources. Table 24 shows the designed Trigger Source descriptions and possible capture styles for ToupTek camera.

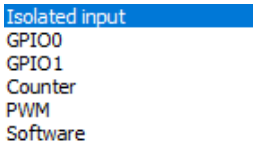
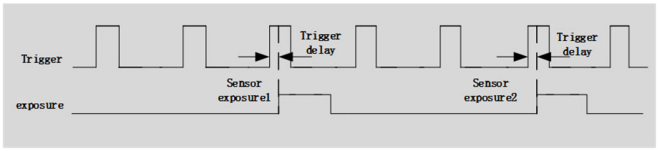
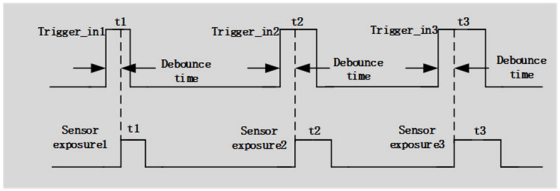
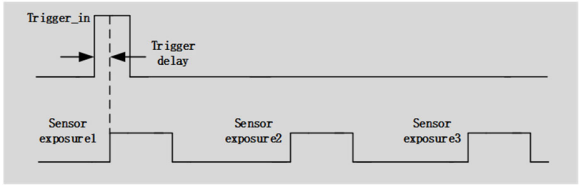


Figure 48 Possible Trigger Sources

Table 24 Description of possible Trigger Sources and their capture styles

Trigger Source	Description
Isolated input	Logic 0 input level: 0~2.2VDC; Logic 1 input level: 3.3~24VDC;. Maximum input current: 30mA;
GPIO0	Logic 0 input level: 0~0.6VDC (DIR_GPIO0/DIR_GPIO1 pins); Logic 1 input level: 2.0~24VDC (DIR_GPIO0/DIR_GPIO1 pins); Maximum input current: 25mA; If **GPIO0** is chosen as **Trigger Source**, it should be configurated as **Input** in the **GPIO Mode**'s combo box on the **Options>IO Control** page;
GPIO1	Logic 0 input level: 0~0.6VDC (DIR_GPIO0/DIR_GPIO1 pins); Logic 1 input level: 2.0~24VDC (DIR_GPIO0/DIR_GPIO1 pins); Maximum input current: 25mA; If **GPIO1** is chosen as **Trigger Source**, it should be configurated as **Input** in the **GPIO Mode**'s combo box on the **Options>IO Control** page;

Counter	**Counter** refers to the operation mode in which the camera can divide the frequency of the external input trigger signal through the preset **Counter Value** and perform image acquisition according to the customer's logic. For example, when the counter value(Counter Value: 3 [1,1023]) is set to 3, the camera needs to receive 3 trigger signals to trigger once;  When **Counter** is chosen in **Trigger Source** combo box in the **Capture & Resolution** group, the **Counter Source** can be **Isolated input**, **GPIO0** or **GPIO1** which can be chosen on **Options>IO Control** page; If **GPIO0** or **GPIO1** is chosen in the **Counter Source** combo box on **Options>IO Control** page. It should be configured as **Input** in the **GPIO Mode** combo box; Check **Options>IO Control** page's **Line Select** related items and **Counter** related items for details;
PWM	**PWM** refers to the operation mode in which the camera exposure time is controlled by the input trigger signal's pulse width;  **PWM Trigger Source** can be **Isolated input**, **GPIO0** or **GPIO1**. If **GPIO0** or **GPIO1** is chosen in the **PWM Source** combo box on the **Options>IO Control** page, it should be configured as **Input** in the **GPIO Mode** combo box; Check **Options>IO Control** page's **Line Select** related items and **PWM** related items for details;
Software	When **Software** trigger is chosen, the client software can send the command through USB3.0 to trigger, acquire and transfer images, In ToupView, **Single**, **Loop**, **Multiple,** or **Sequence** can be used to send the **Software** trigger command; If the **Plan** or **Hardware** is chosen in the **Type** combo box on the **Options>Sequence** page, the **Multiple** button will switch to **Sequence** button and the camera will use the **Exposure Time** and **Gain** in the **Sequence table** on this page one by one to capture the specified frames. Check **Single**, **Loop**, **Multiple,** or **Sequence** on **Capture & Resolution** group for the **Software** capture operations; Check **Options>Sequence** page and **Options>Advanced** page for the related **Sequence** and **Software** capture setup options;
Single	When **Single** is clicked, the camera will start to capture the image. At the same time the **Single** button will switch to **Stop** button. Clicking **Stop** button to stop the current **Single** capture operation, the **Stop** button will switch to **Single** button again for the next capture operation; Note: 1) The captured frames will always **Show in the video window** to prevent too many captures; 2) Enabled when **Software** in the **Trigger Source** combo box is chosen or **Always enable software trigger** checkbox is checked on the **Options>Advanced** property page;
Loop	When **Loop** is clicked, the camera will start to capture the image continuously and the **Loop** button will switch to **Stop** button. Clicking **Stop** button to stop **Loop** captures and the **Stop** button will switch to **Loop** button for the next **Loop** capture operation; Note: 1)The captured frames will always **Show in the video window** to prevent too many captures; 2)Enabled to capture continually when **Software** in the **Trigger Source** combo box is chosen or **Always enable software trigger** checkbox is checked on the **Options>Advanced** property page;
Multiple	**Multiple** refers to the operation mode in which the camera receives **Software** trigger signal or command and exports multiple frames of images. An edit box with spin(we call it **Frames Box**) is designed and affiliated to the **Multiple** button (Multiple 3 Options...) for the setting of the frames to be captured; The **Frames Box** can be set in the range of 1~ 65535. If the **Frames Box** is 3, a three-frame image will be captured and exported;  Note: 1)**Multiple** capture is enabled to capture continually when **Software** in the **Trigger Source** combo box is chosen; 2) **Multiple** capture is enabled when **Always enable software trigger** is checked on the **Options>Advanced** property page, no matter whether **Trigger Source** is **Software** or **Hardware** on the **Capture & Resolution** group; 3) If the **Plan** or **Hardware** is chosen in the **Type** combo box on the **Options>Sequence** page, the **Multiple** button will switch to **Sequence** button and the camera will use the **Exposure Time** and **Gain** in the **Sequence table** on this page. The captured frames will be displayed either in **Show in the video window**, or **Show in a new window** or **Save to disk** which can be specified on **Options>Output** page;

Sequence	When **Sequence** is clicked, the camera will start to capture the image until the specified frames in the **Frames Box** are captured. At the same time the **Sequence** button will switch to **Stop** button. Clicking **Stop** button will stop the current **Sequence** capture and the **Stop** button will switch to **Sequence** again for the next **Sequence** capture operation; Note: 1) Switched from **Multiple** to **Sequence** to capture the specified frames in the edit box with spin(**Frames Box**) when **Plan** or **Hardware** in the **Type** combo box is chosen on the **Options>Sequence** property page; 2)If the **Plan** or **Hardware** is chosen in the **Type** combo box on the **Options>Sequence** page, the **Sequence** button will be enabled and the capture will use the **Exposure Time** and **Gain** in the **Sequence table** list below one by one on the **Options>Sequence** page; 3) If the **Plan** or **Hardware** is chosen in the **Type** combo box on the **Options>Sequence** page and **Always enable software trigger** is checked on the **Options>Advanced** property page, the **Sequence** button will not switch to **Multiple** button and will be enabled only when the still in Sequence enable 4)If the **Plan** is chosen in the **Type** combo box on the **Options>Sequence** page and the **Software** is chosen in the **Trigger Source** combo box, the **Sequence** button will be enabled. 5)If the **Hardware** is chosen in the **Trigger Source** combo box, the **Sequence** button will be disabled, but the **Frame Box** will still be enabled and the **Sequence** will switch to the **Hardware Sequence** capture. One **Hardware** trigger signal will capture the specified frames on the **Frame Box** using the **Exposure Time** and **Gain** in the **Sequence table** on **Options>Sequence** page; 6)Check **Options>Sequence** page for the related **Sequence** setup options;

5.3 The trigger capture and IO Control configurations

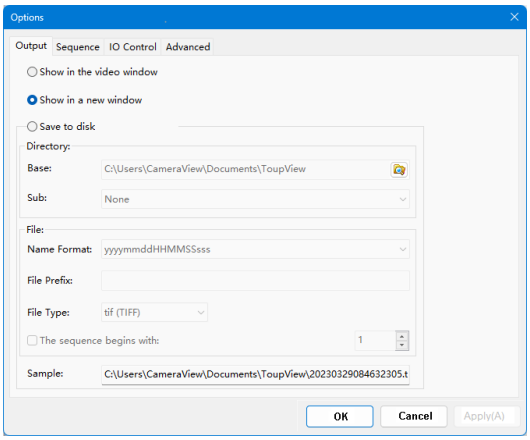


Figure 49 Options>Output page

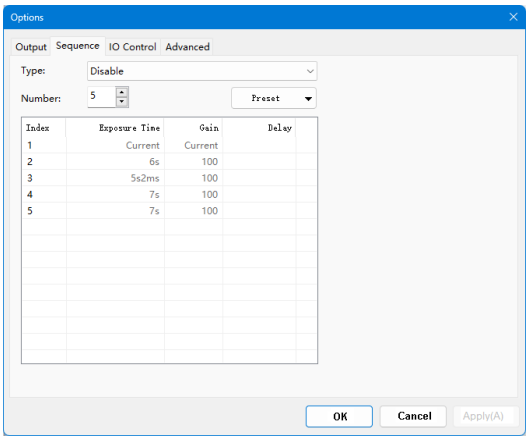


Figure 50 Options>Sequence page

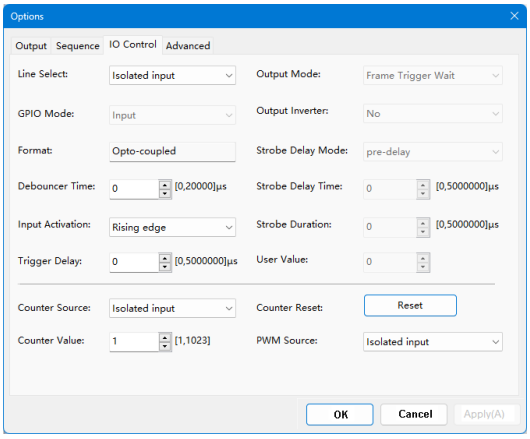


Figure 51 Options>IO Control page

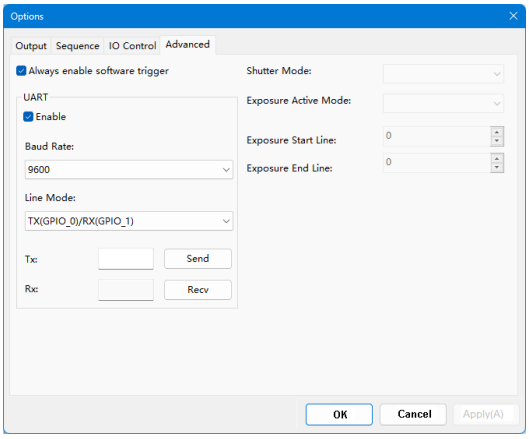


Figure 52 Options>Advanced page

The Trigger Source can be Isolated input, GPIO0, GPIO1(when configured as input), Counter, or PWM which can be configurated on the Options property sheet. Also the camera's Isolated output, GPIO0 or GPIO1(can be configurated as Output) can be used as Output or UART (GPIO0, GPIO1 only) applications. All of these configurations can be realized on the Options property sheet described in Table 25 below.

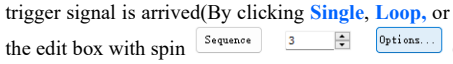
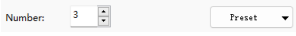
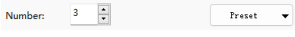
About the captured file operation style, one can find it on the Option>Output page;

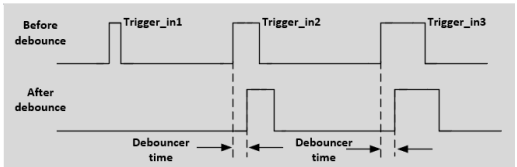
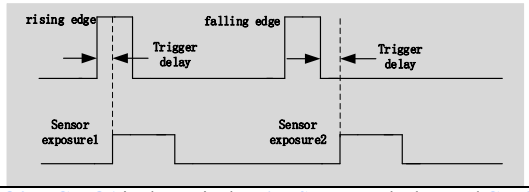
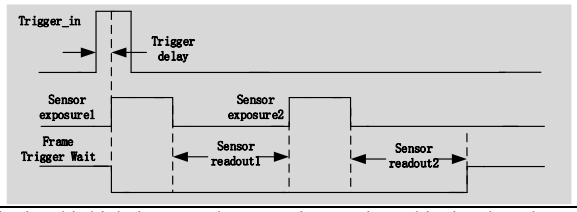
About the Sequence setup, one can find it on the Option>Sequence page;

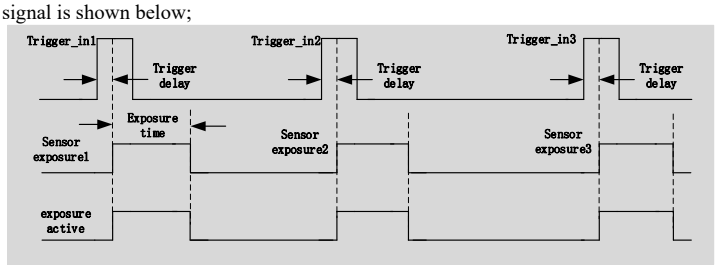
About the camera pin IO Control style, one can find it on the Options>IO Control page;

About the Always enable software trigger and UART setup, Shutter Mode, and Exposure Active Mode, one can find it on the Options>Advance page.

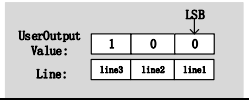
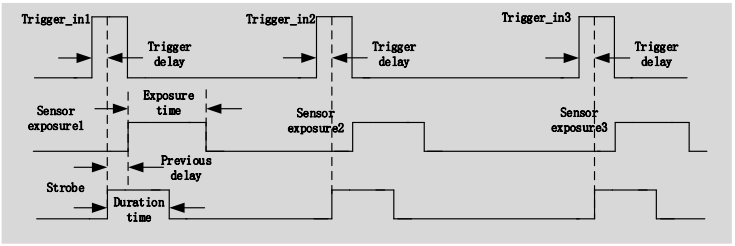
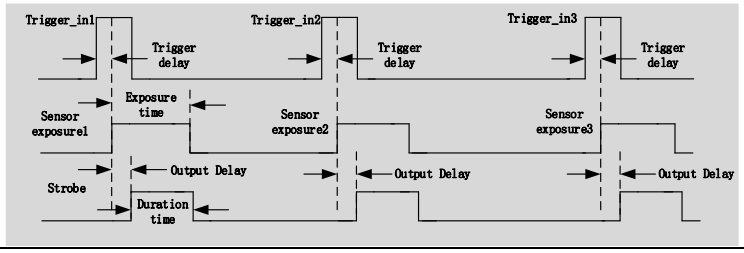
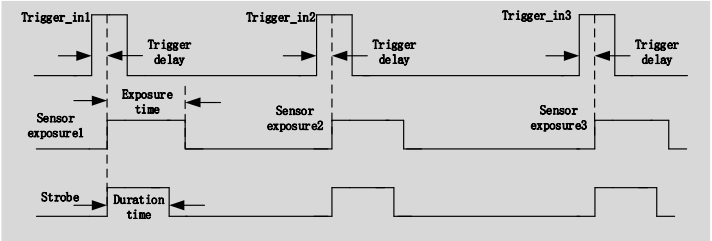
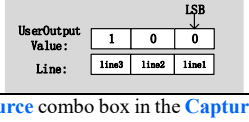
Table 25 Options property sheet for Trigger Source or camera pin configuration

Pages	Items	Descriptions
Output page	**Output Destination**	Used to set the captured frame's **Output** destination, can be **Show in the video window**, **Show in a new window** or **Save to disk**; When **Save to disk** is checked, the  button will be enabled clicking it to choose the **Base** directory, clicking the **Sub** combo box's dropdown button to choose the **Sub** directory; The **File Name Format**, **File Prefix**, **File Type,** and even **The sequence begin with** can be chosen, set, or defined. Note: 1)Valid only for **Sequence** or **Multiple** capture setup; 2)For **Single** or **Loop** capture, the captured image will be always displayed on the video window;
Sequence page	**Type** Disable Plan Hardware	**Disable**: If the **Disable** button is chosen in the **Type** combo box on the **Options>Sequence** page, the **Sequence** button on the **Capture & Resolution** page will switch to **Multiple** button;
		Plan: 1)If **Plan** is chosen in the **Type** combo box on the **Options>Sequence** page, the **Multiple** button on the **Capture & Resolution** group will switch to **Sequence** button; 2) If the **Software Trigger Source** is chosen in the **Capture & Resolution** group or the **Always enable software trigger** is checked on the **Options>Advanced** property page, the **Sequence** button will be enabled After the **Software** trigger signal is arrived(By clicking **Single**, **Loop,** or **Sequence** button), the camera will capture frames specified in the edit box with spin  (we call it **Frames Box**) affiliated to the **Sequence** button; The whole captures will use the **Exposure Time**, **Gain** and **Delay** in the **Sequence table** list under  one by one by the software; 3) If the **Disable** button is chosen in the **Type** combo box on the **Options>Sequence** page, the **Sequence** button on the **Capture & Resolution** page will switch to **Multiple** button; 4) The **Sequence** button will be enabled only when a) the **Plan** in the **Type** combo box is chosen on the **Options>Sequence** page and b) he **Software Trigger Source** is chosen in the **Capture & Resolution** group or c) **Always enable software trigger** is checked on the **Options>Advanced** property page;
		Hardware: 1) if **Hardware** is chosen in the **Type** combo box on the **Options>Sequence** page, the **Multiple** button on the **Capture & Resolution** group will switch to **Sequence** button and will be disabled for **Hardware** trigger. But users can still set the frames number in the **Frame Box** on the **Capture & Resolution** group; 2) After the **Hardware** trigger signal arrives, the camera will capture frames specified in the edit box with spin  (we call it **Frame Box**) affiliated to the **Sequence** button; The whole capture will use the **Exposure Time**, **Gain** (**Delay** is not used) in the **Sequence table** list under  one by one but stored in the camera hardware for the quick operation; 3) If the **Disable** button is chosen in the **Type** combo box on the **Options>Sequence** page, the **Sequence** button on the **Capture & Resolution** page will switch to **Multiple** button. 4) The **Sequence** button is always disabled if a) The **Hardware** is chosen in the **Type** combo box on the **Options>Sequence** page and b)the **Hardware Trigger Source** is chosen in the **Capture & Resolution** group; 5) The **Sequence** button will be enabled if a) the **Software Trigger Source** is chosen in the **Capture & Resolution** group or b) the **Always enable software trigger** checkbox is checked on the **Options>Advanced** property page, in this case, both the **Plan** and **Hardware Sequence** capture are supported;
	Number	The possible **Sequence**(capture) frames to be captured. If the **Number** is larger than the **Sequence Number** in the **Frames Box** on the **Capture & Resolution** group, the other **Indices** will be executed at the next **Sequence** operation one by one recycled;
	Index	The order of the **Number** group;
	Exposure Time	The camera **Exposure Time** for the specified capture **Index** in the **Sequence** capture;
	Gain	The camera **Gain** for the specified capture **Index** in the **Sequence** capture;
	Delay	The **Delay** time for the specified capture **Index** in the **Plan Sequence** capture(Valid for **Plan Sequence** capture only);
	Preset	Choosing **Save** to save the current **Sequence table**'s settings; Clicking **Management** to **Rename** the saved **Sequence table**'s setting files or **Remove** them from the **Management** list;

<table>
<tr><td rowspan="7">IO Control page</td><td>Line Select</td><td>Choosing which line to set. Can be Isolated input, Isolated output, GPIO0 or GPIO1 et al;</td></tr>
<tr><td>GPIO Mode</td><td>To configure whether the line selected in Line Select is for Input or Output. Only GPIO0 or GPIO1 can be configured as either Input or Output;
If Isolated input or Isolated output is chosen, the GPIO Mode will be specified as Input or Output (Not configurable) respectively;</td></tr>
<tr><td>Format</td><td>Specify the current selected signal's Format in the Line Select combo box, can be Opto-coupled(Isolated input, Isolated output)or TTL (GPIO0 or GPIO1)for clarity(Unconfigurable);</td></tr>
<tr><td>Debouncer Time</td><td>Since there may be a glitch in the external trigger input signal if it directly enters into the internal logic circuit of the camera, it will cause false triggering, so the input trigger signal should be debounced. In addition, the effective pulse width of the trigger signal input by the user should be greater than the Debouncer Time, otherwise, the trigger signal will be ignored;
When Isolated input, GPIO0 or GPIO1 is chosen in the Line Select combo box and GPIO0 or GPIO1 is configured as Input in the GPIO Mode combo box, the Debouncer Time will be enabled for the user to input the Debounter Time between 0 to 20000us;
 
</td></tr>
<tr><td>Input Activation</td><td>When Isolated input, GPIO0 or GPIO1 is chosen in the Line Select combo box and GPIO0 or GPIO1 is configured as Input in the GPIO Mode combo box; The Input Activation combo box will be enabled to configure the Input Activation as either Rising Edge or Falling Edge;
 
</td></tr>
<tr><td>Trigger Delay</td><td>When Isolated input, GPIO0 or GPIO1 is chosen in the Line Select combo box and GPIO0 or GPIO1 is configured as Input in the GPIO Mode combo box, the Trigger Delay will be enabled for the user to input the Trigger Delay time between 0 to 5000000us;
If the Trigger Delay time is set to 1000000us, the camera will wait for 1s to capture the image after receiving the trigger signal;</td></tr>
<tr><td>Output Mode
Frame Trigger Wait
Exposure Active
Strobe
User Output</td><td>When Isolated output, GPIO0 or GPIO1 is selected in the Line Select combo box and GPIO0 or GPIO1 is configured as Output in the GPIO Mode combo box, the Output Mode will be enabled. It can be Frame Trigger Wait, Exposure Active, Strobe, or User Output. The chosen mode can be used for diversified applications;
The Frame Trigger Wait signal is pulled low at the start of exposure and pulled high when the last frame of data is read out. The trigger signal input by the user should be in the valid period. If the user inputs a trigger signal when the signal is low, the trigger signal input at this time will be ignored. The following example is the case when Burst Count = 2, as shown below;
 

Exposure Active: when this signal is high, it means the sensor is exposing. This signal can be used to control an external mobile device to remain stationary or move at low speed while the camera is at exposure. The timing diagram of the exposure valid signal is shown below;
 

When the relative position of the camera and the object to be photographed changes, you can refer to Exposure Active</td></tr>
</table>

		signal to prevent the captured image from being affected by movement and focus adjustment during the exposure process;
		When Strobe is chosen, **Strobe Delay Mode**, **Strobe Delay Time**, **Strobe Duration** will be enabled;
		When User Output is chosen, **User Value** will be enabled. lines3, line2, line1 are the combination of **GPIO1, GPIO0** and **Isolated output** respectively. If **User Value** is 001, then line **GPIO1** and **GPIO0** will be disabled and **Isolated output** will be enabled; 
	Output Inverter	When **Isolated output**, **GPIO0** or **GPIO1** is selected in the **Line Select** combo box and **Output** is chosen for **GPIO0** or **GPIO1** in the **GPIO Mode** combo box, the **Output Inverter** will be enabled to configure the current selected line's output as either inverted or not(**Yes** or **No**).
	Strobe Delay Mode	Strobe can be used to control external devices such as the strobe, and the effective level duration, delay time, and pre-delay time of the strobe signal can be set; When the **Output Mode** is **Strobe**, **Strobe Delay Mode** will be enabled. It can be **pre-delay** or **delay**;
	Strobe Delay Time	When exposure starts, the strobe does not take effect immediately, and the output is delayed according to the value set by **Strobe Delay Time** which is between 0 to 5000000us. The **Strobe Delay Mode** can be **pre-delay** or **delay**; It is described below; pre-delay:  delay: 
	Strobe Duration	The high level duration of the strobe is determined by the **Strobe Duration** which is between 0 to 5000000us as shown below; 
	User Value	Users can input a value at **User Value** edit box with spin to control the line as disable or enable. Enabled when **User Output** is chosen in the **Output Mode** combo box. The logical value 0 or 1's combination of **GPIO1**(line3), **GPIO0**(line2) and **Isolated output**(line1); When the output mode is selected as **User Output**, the user can input a value at **User Value** edit box to control the corresponding line output with 0 or 1; The value here is only valid for the lower three bits of a binary. For example, when line 1 and line 3 are set to **User Output** mode, and its **User Value** is set to 4 ('b100), then line 3 outputs 1, and line 1 outputs 0, as shown below. 
	Counter Source	When **Counter** is chosen in the **Trigger Source** combo box in the **Capture & Resolution** group, the **Counter Source** can be chosen from **Isolated input**, **GPIO0** or **GPIO1** in this combo box on the **Option>IO Control** page;

	Counter Value	The **Counter Value** is used to divide the frequency of the external input trigger signal when the **Counter Trigger Source** is chosen in the **Capture & Resolution** group; See **Counter** in Table 24 for detail;
	Counter Reset	Click **Reset** button can clear the current counting process and begin a new one;
	PWM Source	When **PWM** is chosen in the **Trigger Source** combo box in the **Capture & Resolution** group, the **PWM Source** can be from **Isolated input, GPIO0,** or **GPIO1** in this combo box et al. ;
Advanced page	**Always enable software trigger**	When this button is checked, no matter whether **Trigger Source** is **Software** or **Hardware**, the software trigger buttons(**Single**, **Loop**, **Multiple**) are always enabled; If the **Plan** or **Hardware** is chosen in the **Type** combo box on the **Options>Sequence** page, the **Multiple** button will switch to **Sequence** button; The **Sequence** button will be enabled if a)the **Software Trigger Source** is chosen in the **Capture & Resolution** group or b) the **Always enable software trigger** checkbox is checked on the **Options>Advanced** property page, in this case, both the **Plan** and **Hardware Sequence** captures are supported;
	UART	There is a serial port function on the **Advanced** page, which can be used to communicate with external devices via serial port. Check **Enable** to enable this function. When enabled, **GPIO0** and **GPIO1** can only be used as **UART** transfers; The **Baud Rate** supports 9600-115200. **Cable Select** can configure **GPIO0** and **GPIO1**, which can be configured as **TX** or **RX** respectively. Setting a value at **TX**, clicking **Send** to send the set value out; click **Accept** at **RX** to receive the value from the external device;
	Shutter Mode	Enabled if the camera supports. Users can select **Rolling Shutter** or **Global Reset**;
	Exposure Active Mode	Enabled if the camera supports. Users can select **Specified lines** or **Common exposure time**;
	Exposure Start Line	Enabled when **Specified lines** in the **Exposure Active Mode** combo box is selected. To configure when the Exposure Active signal is valid;
	Exposure End Line	Enabled when **Specified lines** in the **Exposure Active Mode** combo box is selected. To configure when the Exposure Active signal is invalid;

6 Cooling

There is a Cooling group on the left sidebar in ToupView. To enable the Cooling function, an external 12V power supply is required. By default, the TEC is turned on. One can set the Target Temperature. After entering the value, click "Apply", and the sensor temperature will gradually approach to the Target Temperature. At the same time, ToupView can display the current temperature in real time. And the cooling effect can reach about 10-25 degrees lower than the ambient temperature, as shown in Figure 53.

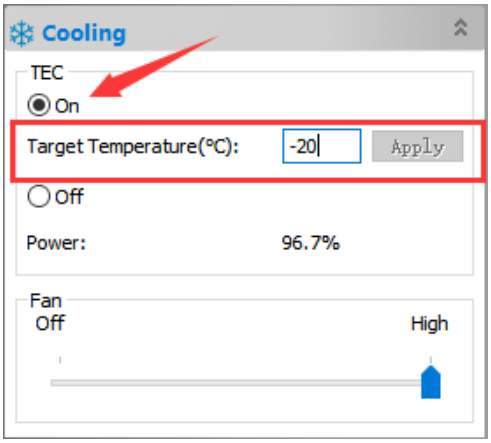


Figure 53 TEC settings

The Fan has two gears from Off to High. When High, the Fan speed reaches the highest. When Off, the Fan is turned off, the TEC is also turned off, and the power is 0, as shown in Figure 54.

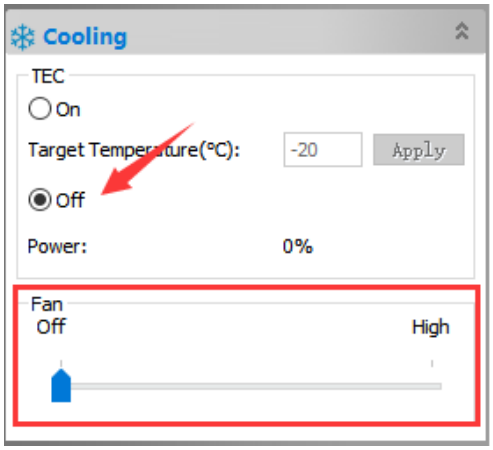


Figure 54 Fan settings

When the TEC is turned on, the Fan will automatically turn on preventing the abnormal situation such as the housing temperature is too high if the Fan stops running when the TEC is working; when the Fan is turned off, the TEC will automatically turn off.

7 Application

7.1 Application installation

In terms of software, customers are welcome to visit our website: https://www.ehd.de/products/driver/driver.htm to download the latest EHDView. SWIR series can also be used with ASCOM, DirectShow interface. If the third-party software is compatible with these interfaces, customers can also download software drivers from our website and install them into the third-party software.

7.2 Introduction to EHDView

EHDView is a professional software that integrates camera control, image acquisition and processing, image browsing and analysis functions. ToupView has the following characteristics:

- x86: XP SP3 and above ; CPU supports SSE2 and above
- x64: Win7 and above
- Support video mode and Trigger Mode (Raw format or RGB format)
- Automatic capture and quick recording capabilities
- Supports multiple languages
- Hardware ROI and digital binning capabilities
- Rich image processing functions, such as image stitching, real-time overlay, flat field correction, dark field correction, etc.
- Supports all EHD MaxCam, SCA, SCM & ICM cameras

7.2.1 User interface design

- The menus and toolbars are properly set to ensure quick operation
- Professionally integrated with 5 sidebars - Camera, Folders, Undo/Redo, Layers, Measure
- Comfortable operation method (double-click or right-click context menu)
- Detailed help manual

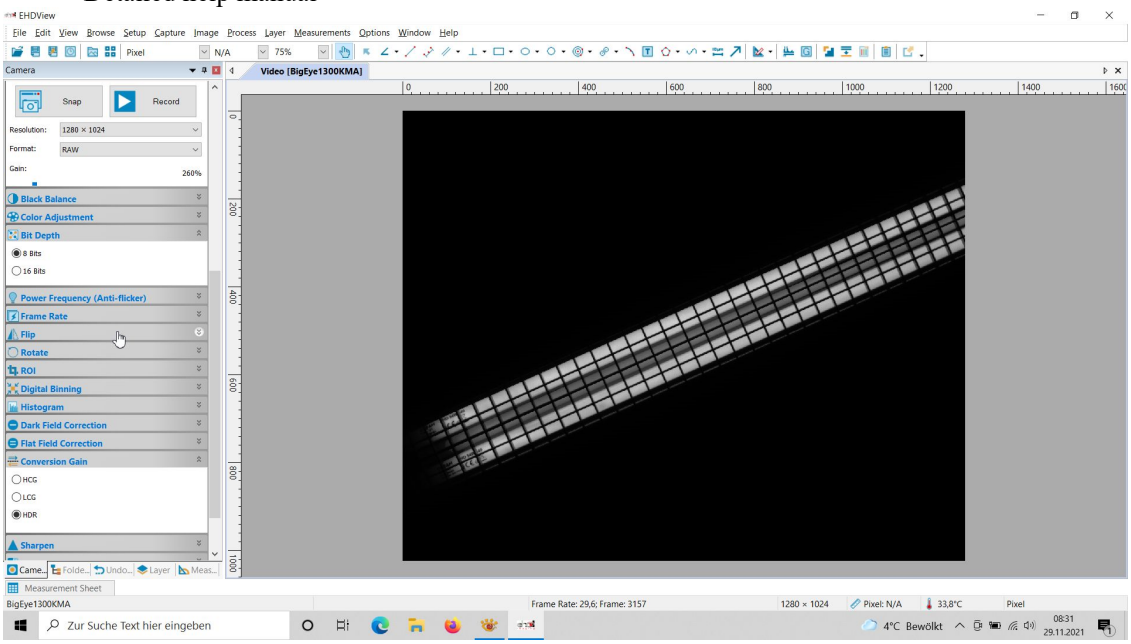


Figure 55 ToupView video window

7.2.2 Professional Camera Control Sidebar

Capture & Resolution	Set up live and still capture, snap images, or record video
Exposure & Gain	Auto exposure (preset exposure target value), manual exposure (exposure time can be manually entered and set by slider); gain up to 5 times

White Balance	Advanced one-click smart white balance settings, and you can adjust white balance by manually setting color temperature and color
Color Adjustment	Color, saturation, brightness, contrast, gamma initial high-speed adjustment function
Frame Rate Control	For different computer and USB performance, the camera can be super compatible by adjusting the frame rate
Flip	Select "Horizontal" or "Vertical" to adjust the sample orientation to ensure the same orientation as the visual system
Sampling	Neighborhood averaging can improve the signal-to-noise ratio of the video stream; while the sampling extraction mode can ensure the sharpness of the video stream. Supports histogram expansion of video stream, image negative and positive switching, grayscale calibration, and sharpness factor calculation to facilitate video focusing
Bit Depth	8, 12-bit switching, 8-bit is the basic Windows image format. 12-bit has higher image quality but reduces frame rate
Roi	ROI, Region of interest. This function can set the ROI value of the video window. After the ROI group is expanded, a rectangular box will appear in the middle of the video window, and the ROI can be changed. The mouse can adjust the size of the ROI. If there is no problem with the ROI, click "Apply" to set the video to the size of the ROI, and the default value will be restored to the original size.
Dark Field Correction	To enable darkfield correction, you should first capture a field image, then click Enable. Check Enable to enable darkfield correction. Uncheck it to disable darkfield correction
Cooling	Set TEC Target Temperature, fan on/off
Parameter Save	Load, save, overwrite, load, export custom camera panel controls (including calibration information, exposure parameters and color settings information, etc.)

7.2.3 Professional and practical image processing functions

Video Function	Various video professional processing functions: video broadcasting, timing capture, video recording, video watermarking, watermark mobile alignment, watermark rotation alignment, video grid overlay, video measurement, video scaling, gray scale calibration, video high dynamic (HDR), video depth of field extension, video image stitching, video scale, date, etc.
Image Processing and Enhancement	Image contrast control and adjustment, image denoising, various image filtering algorithms, image mathematical morphology algorithms, image rotation, image scaling and image printing, etc.
Image Overlay	The ToupView image overlay denoising function introduces advanced image matching technology. Users only need to record a short video of the image to be superimposed, and they can superimpose and output high fidelity in the case of displacement, rotation and magnification change between multiple frames of the video. images, easy to use

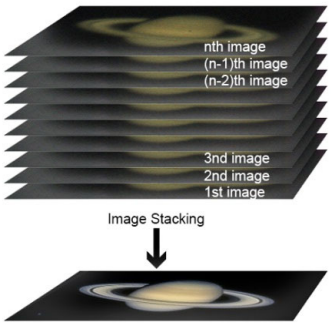


Figure 56 Image overlay denoising

7.2.4 Super compatibility

Camera Video Interface	Provide Twain, DirectShow, Labview, SDK installation package (native C++, C#)
Supported Operating Systems	Compatible with Microsoft® Windows® XP / Vista / 7 / 8 /10 /11(32 & 64 bit), Mac OSX, Linux
Language Support	Language support can be added manually, currently supports English, Simplified Chinese, Traditional Chinese, German, Japanese, Russian, French, Italian, Polish, Turkish

7.2.5 Basic hardware requirements

PC Basic Configuration Requirements	CPU: Intel Core 2 2.8GHz or higher
	RAM: 2GB or more
	USB Port: USB3.0 / USB 2.0
	Monitor: 17" or higher
	CD-ROM

8 Software development instructions

8.1 SDK description

The download link of the SDK is as follows:

https://www.ehd.de/products/driver/driver.htm

8.1.1 SDK support platform

- Win32:
  x86: XP SP3 and above; the CPU needs to support at least the SSE2 instruction set.

  x64: Win7 and above.

  arm: Win10 and above.

  arm64: Win10 and above.
- WinRT: x86, x64, arm, arm64; Windows 10 and above.
- macOS: x86 and x64 bundle; macOS 10.10 and above.
- Linux: core 2.6.27 and above.
  x86: The CPU needs to support at least the SSE3 instruction set; GLIBC 2.8 and above.

  x64: GLIBC 2.14 and above.

  armel: GLIBC 2.17 and above; compiled by toolchain arm-linux-gnueabi (version 4.9.2).

  armhf: GLIBC 2.17 and above; compiled by toolchain arm-linux-gnueabihf (version 4.9.2).

  arm64: GLIBC 2.17 and above; compiled by toolchain aarch64-linux-gnu (version 4.9.2).
- Android: arm, arm64, x86, x64; compiled by android-ndk-r18b.

8.1.2 Introduction to SDK content

EHDCam series cameras support a variety of APIs, including: Native C/C++,.NET/C#/VB.NET, Python, Java, DirectShow, Twain, LabView, Matlab, etc. Compared with other APIs, Native C/C++ API as a low-level API is characterized by using pure C/C++ development without relying on other runtime libraries. The interface is simple and the control is flexible. This SDK zip package contains all the resources and information needed. The directory is as follows:

- inc:
  nncam.h, the C/C++ header file.
- win: Microsoft Windows platform file
  - dotnet:

    nncam.cs, supports C#. nncam.cs uses P/Invoke to call nncam.dll. Please copy nncam.cs to your C# project for use.

    nncam.vb, supports VB.NET. nncam.vb uses P/Invoke to call nncam.dll. Please copy nncam.vb to your VB.NET project for use.

  - x86:

    nncam.lib, x86 lib file.

    nncam.dll, x86 dynamic library file.

    democpp.exe, x86 C++ demo execute the procedure.
- x64:
  nncam.lib, x64 lib file.

nncam.dll, x64 dynamic library file.

democpp.exe, x64 C++ demo execute the procedure.

- arm:
nncam.lib, arm lib file.

  nncam.dll, arm dynamic library file.

- arm64:
nncam.lib, arm64 lib file.

  nncam.dll, arm64 dynamic library file.

- winrt:
They can be applied for Dynamic library files of WinRT/ UWP (Universal Windows Platform)/ Windows Store App. They are compatible with Windows Runtime and can be referenced by Universal Windows Platform apps. If you use C# to develop UWP, you can use the nncam.cs wrapper class.

  Please pay attention to the Device Capability of uwp. Refer to how to add USB device capabilities to the app manifest. (Microsoft seems to limit the Device entry under DeviceCapability to no more than 100) demouwp.zip is a simple example of uwp. Please modify vid and pid. under DeviceCapability in the file Package.appxmanifest before compiling the run example.

- Drivers: (Cameras produced after 2017.1.1 support WinUSB, and drivers no longer need to be installed on Windows 8 and above)
The x86 folder contains the x86 kernel-mode driver files, including toupcam.cat, toupcam.inf and toupcam.sys.

  The x64 folder contains the x64 kernel-mode driver files, including toupcam.cat, toupcam.inf and toupcam.sys.

- samples:
1. democpp, C++ example. This example demonstrates enumerating devices, opening devices, previewing videos, capturing images, setting resolution, triggering, saving images to files in various image formats (.bmp,.jpg,.png, etc.), wmv format video recording, Trigger ModeTrigger Mode, IO control and so on. This example uses the Pull Mode mechanism. To keep the code clean, the WTL library used by the examples can be downloaded from this link http://sourceforge.net/projects/wtl/.

  2. demopush, C++ example, using the Push Mode mechanism, StartPushModeV3.

  3. demomfc, a simple C++ example, uses MFC as a GUI library, supports opening devices, previewing videos, capturing images, setting resolution, saving images to files in various image formats (.bmp,.jpg,.png, etc.), etc. This example uses the Pull Mode mechanism.

  4. demowinformcs1, take C# winform for example, it supports opening devices, previewing videos, capturing images, saving images to files, and setting white balance. This example uses the Pull Mode mechanism, StartPullModeWithWndMsg.

  5. demowinformcs2, take C# winform for example, it supports opening devices, previewing videos, capturing images, saving images to files, and setting white balance. This example uses the Pull Mode mechanism, StartPullModeWithCallback.

  6. demowinformcs3, take C# winform for example, it supports opening devices, previewing videos, capturing images, saving images to files, and setting white balance. This example uses the Push Mode mechanism, StartPushMode.

  7. demowinformvb, take VB.NET winform for example, it supports opening devices, previewing videos, capturing images, saving images to files, and setting white balance. This example uses the Pull Mode mechanism.

- linux: Linux platform files

Udev: 99-nncam.rules, udev rule file.

Please refer to: http://reactivated.net/writing_udev_rules.html.

- c#: nncam.cs, Support. Net Core C#. nncam.cs uses P/Invoke to call libnncam.so. Please copy nncam.cs to your C# project for use.
- x86: libnncam.so, x86 version so file.
- x64: libnncam.so, x64 version so file.
- armel: libnncam.so, armel version so file, toolchain is arm-linux-gnueabi.
- armhf: libnncam.so, armhf version so file, toolchain is arm-linux-gnueabihf.
- arm64: libnncam.so, arm64 version so file, toolchain is aarch64-linux-gnu.
- android: libnncam.so for four architectures of Android platform arm, arm64, x86, x64.
- mac: macOS platform files.
- python: nncam.py and example code.
- java: nncam.java and example code (console and Swing).
- doc: SDK usage documentation, Simplified Chinese, English.
- sample:
- de emosimplest, the simplest example, is about 60 lines of code.
- demoraw, RAW data and still shots, about 120 lines of code.
- extras:
- directshow: DirectShow SDK and demo program.
- twain: TWAIN SDK.
- labview: Labview SDK and demo program.
- matlab: MatLab demo program.