



Aries 16

User Manual

V1.0.0



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1. Introduction

1.1. Disclaimer

To protect the legitimate rights and interests of users, please carefully read our accompanying instructions, disclaimers, and safety instructions before using our company's products. This camera user manual document contains basic information about the camera, installation instructions, product features, and maintenance, aiming to make it more convenient for users to use the TUCSEN's camera. This document is only disclosed for the above purposes. Please make sure to follow the instructions and safety instructions when operating this product.

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1.2. Safety and warning information

Operation and Use



Caution

- Do not drop, disassemble, repair or replace internal components on your own. Such action may damage the camera components or cause personal injury.
- In the event of spillage on the equipment, please disconnect the equipment and immediately contact the nearest dealer or manufacturer for technical assistance.
- Do not touch the device with wet hands, as it may cause electric shock.
- Do not let children touch the device without supervision.
- Ensure that the temperature of the camera is within the specified temperature range for use to avoid damage.

Installation and maintenance



Caution

- Please do not install it in dusty and dirty areas or near air conditioning or heaters to reduce the risk of camera damage.
- Avoid installation and operation in extreme environments such as vibration, high temperature, humidity, dust, strong magnetic fields, explosive/corrosive gases or gases.
- Do not apply excessive vibration and impact to the equipment. This may damage the equipment.
- Do not install equipment under unstable lighting conditions. Severe lighting changes can affect the quality of the images generated by the device, avoiding high-energy lasers directly hitting the camera chip.
- Do not use solvents or diluents to clean the surface of the equipment, as this will damage the surface of the casing.
- Please ensure that there is at least 10 cm of space around the device ventilation opening to ensure airflow flow. Do not block the ventilation openings of the equipment during use, otherwise it may cause internal temperature to be too high and damage the equipment.

Power

Caution

- Please use the original power adapter of the camera, as using an mismatched power source may damage the camera.
- If the voltage applied to the camera is greater than or less than the nominal voltage of the camera, the camera may be damaged or malfunction.
- Please refer to the specification table for the nominal voltage of the camera.

2. Product specifications

2.1. Packaging List

Item Name	Specification	Quantity	Image
sCMOS scientific grade camera	Aries 16	1	
Power adapter + 4-pole aviation cable	12V/8A	1	
Power adapter power cord	Three core 250V/2.5A	1	
USB 3.0 data cable	2 m	1	
USB flash drive	Software and Drivers	1	
Water pipes	2 m, OD: 6 mm, ID: 4 mm	2	
SMA trigger cable	3 m, SMA inner screw inner needle-SMA inner screw inner needle, wire RG178	4	
Optional Item Name	Specification	Quantity	Image
Cameralink frame grabber	Firebird	1	
Frame grabber cable	3 m	2	

2.2. Quantum efficiency curve

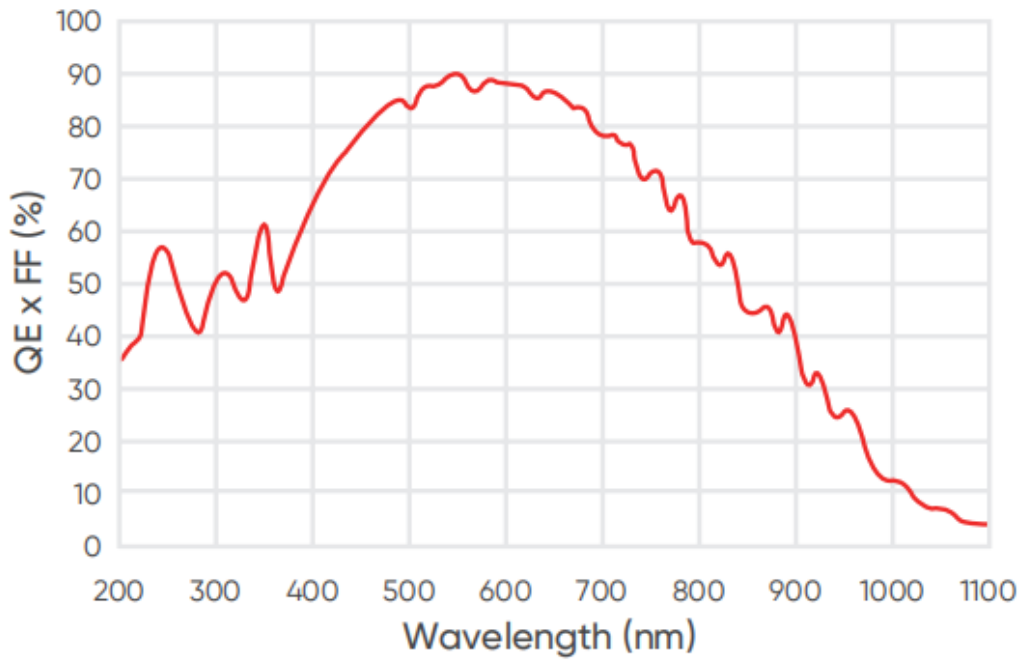


Figure 2-1 Quantum efficiency curve of Aries 16

2.3. Quartz window curve

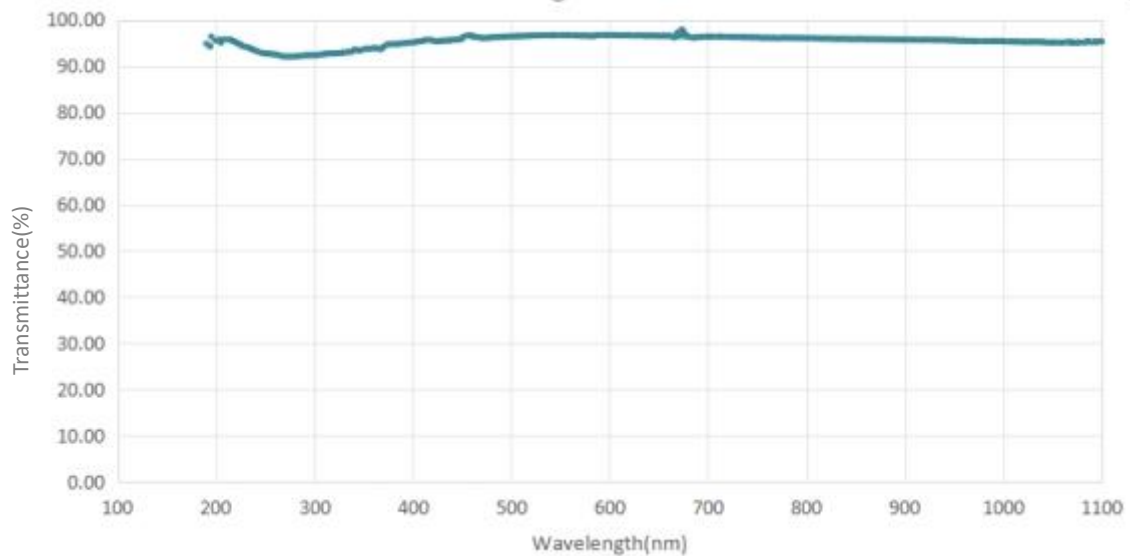


Figure 2-2 Transmission curve of a quartz window

2.4. Camera power and signal connection

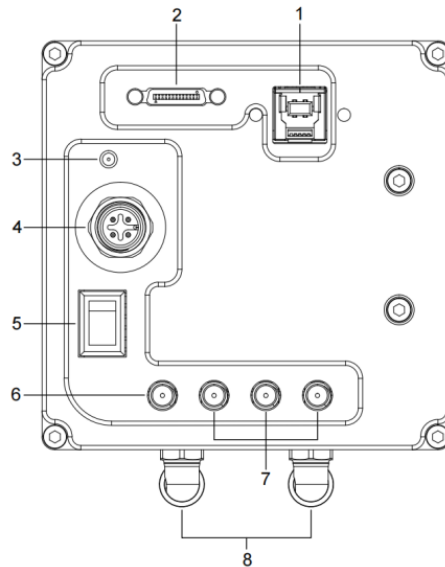


Figure 2-3 Camera interface diagram

No.	Name	Fuction
1	USB 3.0 interface	Camera data transfer
2	Cameralink interface	camera data transfer
3	Indicator light	Indicate the camera status, press F2 to control the light on or off of the indicator light Red: Camera powered on Orange *: Normal operation
4	DC12V	Power interface
5	Switch	Control camera power
6	TRIG.IN	External trigger input interface (SMA interface)
7	TRIG.OUT	The default output signals are as follows: TRIG OUT1: Read end signal TRIG OUT2: Global exposure signal TRIG OUT3: Exposure start signal The above trigger output signal types support customer customization settings
8	Water-cooling pipe fittings	Water-cooled pipe connections

***Note:**

If the software has been shut down but the camera light remains orange, it indicates that the camera has not been fully released and needs to be completely exited from the camera thread or be restarted before the indicator light will return to red.

3. Features and Functions

3.1. Camera Introduction

Aries 16 has made a significant breakthrough in the sensitivity performance of back-illuminated sCMOS cameras. By adopting a 16µm large pixel design, the sensitivity is increased by over 5 times compared to the typical 6.5µm pixel size, greatly enhancing low-light detection capability. The readout noise is as low as 0.9 e-, making it capable of replacing EMCCD cameras in extreme low-light applications.

3.2. Structure and operation of sCMOS

The scientific Complementary Metal Oxide Semiconductor (sCMOS) camera is a specialized camera for scientific research and high performance image acquisition. It combines the advantages of CMOS and charge-coupled device (CCD) technologies with high speed, low noise and high sensitivity. It is widely used in scientific research, biomedical imaging, optical microscopy and other fields.

The structure of an sCMOS camera sensor typically includes the following components:

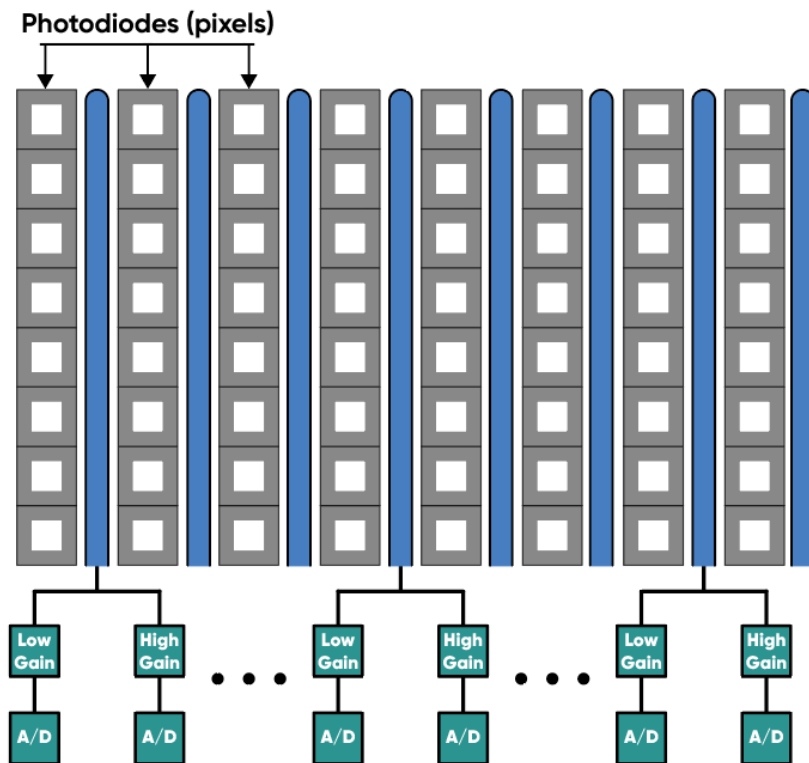


Figure 3-1 sCMOS camera sensor structure

- 1) Light-sensitive sensor array: sCMOS cameras use sCMOS sensor arrays (also known as image sensors) to capture light signals. These sensors consist of many photosensitive

units that convert light into charge signals.

- 2) Gain amplifier: Each photosensitive unit in an sCMOS camera is equipped with an independent gain amplifier to amplify the charge signal and convert it into a voltage signal.
- 3) Analog-to-digital converter (ADC): The amplified analog signal is digitized through an analog-to-digital converter (ADC) inside the camera, converting it into a digital signal for further processing and storage.

sCMOS cameras typically also include an image processing unit for performing image enhancement, correction, and other image processing algorithms. The digitized image undergoes these processes to obtain higher-quality images.

The operation process of an sCMOS camera is as follows:

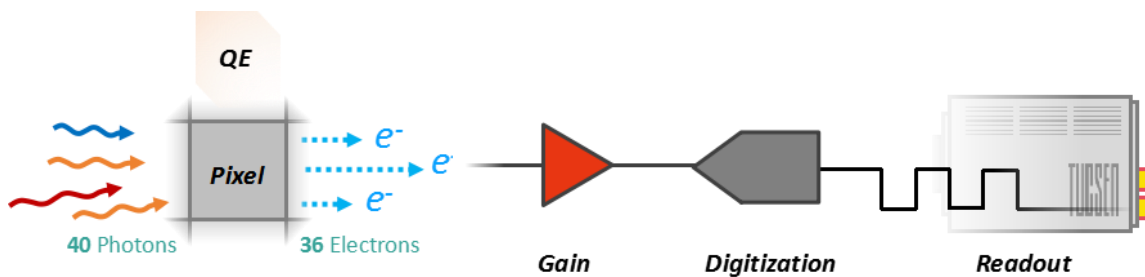


Figure 3-2 sCMOS operation process

- 1) Light signal capture: When photosensitive units are exposed to light, the light is converted into charge signals and stored in each unit.
- 2) Signal amplification: The charge signals from each photosensitive unit are amplified by corresponding gain amplifiers and converted into voltage signals.
- 3) Digitization: The amplified analog signals are converted into digital signals by an ADC for processing and storage.
- 4) Image processing: The digital signals undergo various algorithmic processes such as denoising, enhancement, and color correction through the image processing unit.
- 5) Data output: Processed image data can be transmitted to computers or other devices for display, analysis, and storage through various interfaces such as USB, Ethernet, etc.

3.3. Shutter Mode

Aries 16 camera supports Rolling shutter readout and Global Reset readout. In Rolling shutter readout, the camera reads out rows sequentially, with different rows exposed at the same

time, but with different starting exposure time points between rows, and the difference in exposure time points between neighboring rows is also known as the line time (T_{line}).

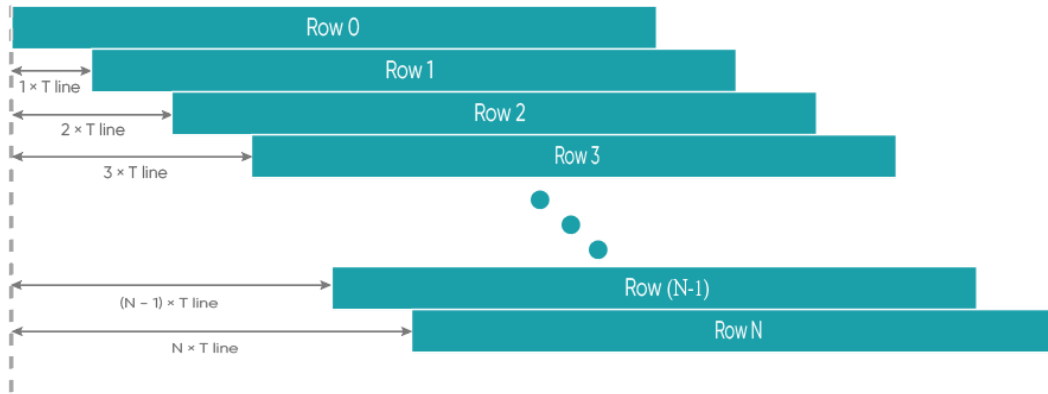


Figure 3-3 Rolling shutter diagram

In rolling shutter mode, if the camera is not synchronized with external light sources or if flickering light sources are present, it may result in striped images. This effect is especially noticeable with short exposure times (Please refer to the FAQ for solutions).

In Global Reset readout mode, the rolling shutter camera can achieve an effect similar to that of a global shutter camera. The Global Reset function first resets the pixel array of the entire chip simultaneously, then exposes all rows simultaneously. After the exposure, data is read out row by row, with corresponding exposure time increasing row by row. In an ideal application, the light source should be turned off immediately after the exposure of the first row to avoid obtaining images with uneven brightness. This mode is suitable for applications that require synchronized signals and can be used to capture transient objects.

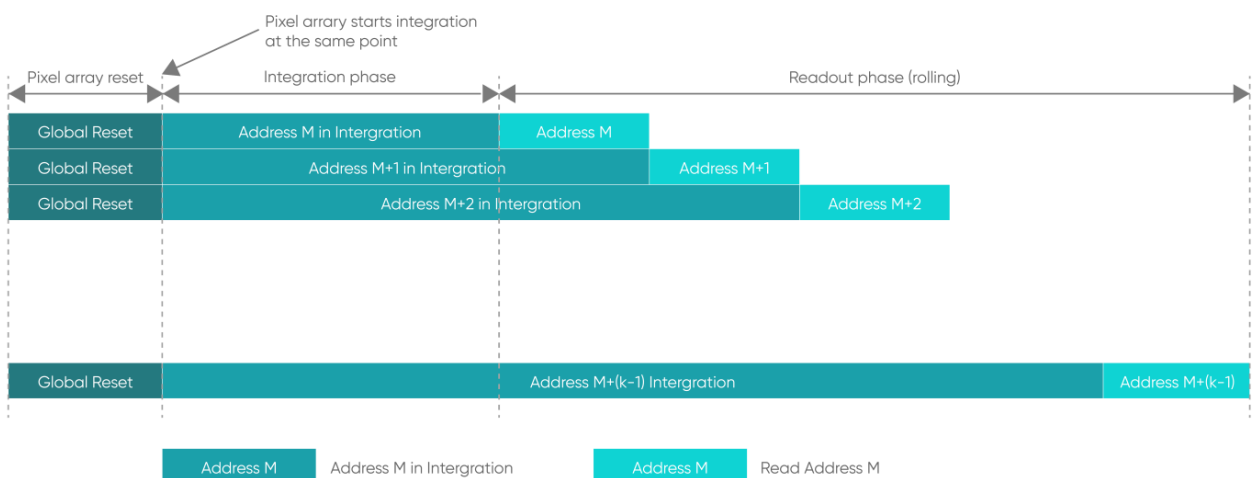


Figure 3-4 Global Reset diagram

3.4. Front-Illuminated and Back-Illuminated sCMOS Technology

Cameras based upon sCMOS technology typically use two types of chips: front-illuminated (FSI) and back-illuminated (BSI). In front-illuminated cameras, light entering the pixels must pass through metal circuit structures before being detected. Due to the non-transparency of metal circuit structures, early cameras had only about 30-40% quantum efficiency (QE). Later, with the introduction of microlenses, light was focused through the conductors onto the photosensitive silicon, increasing QE to around 70%. Some advanced front-illuminated cameras can even achieve a peak QE of around 84%.

Back-illuminated cameras reverse this sensor design by placing the metal circuitry behind the photosensitive silicon layer, allowing incident photons to directly strike the thin photosensitive silicon layer. This process innovation significantly increases the peak QE of back-illuminated cameras and improves imaging quality in low-light environments. Due to the thin photosensitive silicon layer of back-illuminated pixels, there are higher process requirements and production difficulties compared to front-illuminated ones.

Aries 16 camera adopts a back-illuminated chip, achieving a peak QE of around 90%.

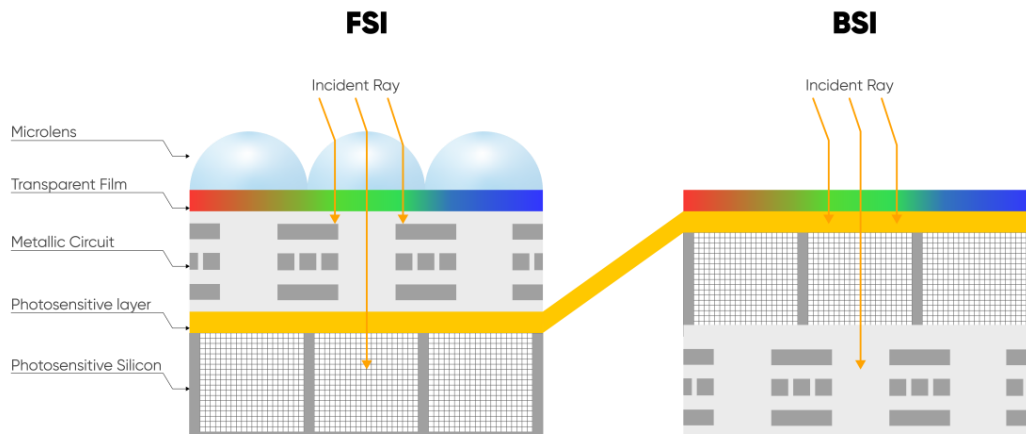


Figure 3-5 Front-Illuminated and Back-Illuminated diagram.

3.5. Readout Noise

Readout noise is the noise introduced by the readout of the signal through the circuit. In CCD camera, since the readout circuit is the same for all pixels, the standard deviation (σ) for each pixel is generally consistent. Therefore, in CCD camera parameter tables, a single value—the root mean square (RMS) of the standard deviation of all pixels—can represent the readout

noise.

However, each pixel in sCMOS corresponds to a different readout circuit, forming a distribution curve, shown in Figure 3-6. To illustrate the characteristics of this curve, sCMOS camera parameter tables typically provide two values—median and RMS. The median is the median of the standard deviations of all pixels, while the RMS is the root mean square of the standard deviations of all pixels. Since there are usually a few pixels with exceptionally high readout noise on the sCMOS camera chip—having less impact on the median than on the RMS—median values are generally lower than RMS values.

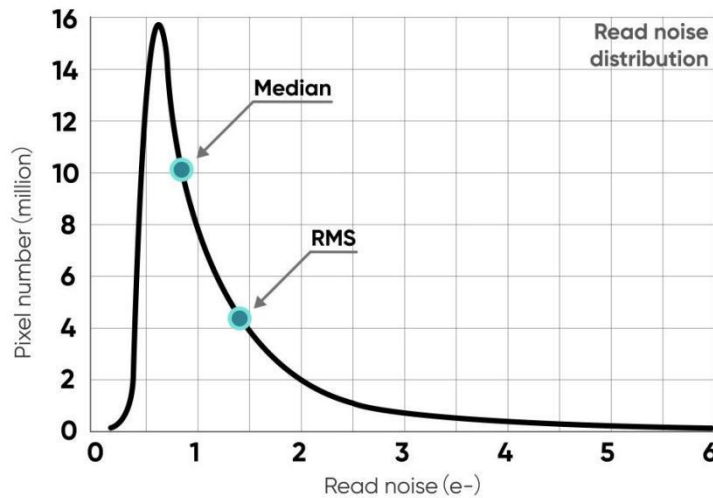


Figure 3-6 Readout noise distribution of a CMOS camera

To measure and calculate readout noise from images, it's necessary to eliminate or minimize the influence of thermal noise and photon shot noise, retaining only the readout noise generated during the circuit readout process. Therefore, when measuring readout noise, it's typically done in an environment without light signals, with the exposure time set to the minimum value (to minimize the accumulation of dark current) to obtain dark-field images (called dark images). By capturing N such images, each pixel obtains N readout values—their standard deviation (σ) reflects the value of the readout noise for the corresponding pixel.

3.6. Defective Pixel Correction (DPC)

There are always a few abnormal values on the sCMOS camera chip. Through the camera's Defective Pixel Correction (DPC) function, these abnormal points can be corrected, removing defective pixels from the image. However, this may cause flickering pixels in some single-molecule imaging applications. It is not recommended to use the DPC function for these applications or to use only the weakest correction level.

The Aries 16 utilizes dynamic bad-point correction, which is applied through a 3 x 3 matrix of pixels. Currently four levels of correction are open, each corresponding to a different

threshold, thus controlling the intensity of the bad dot correction.

3.7. Dark Signal Non-Uniformity (DSNU)

When the camera captures images in complete darkness, ideally, all pixel grayscale values should be close to zero and equal. However, in reality, when the camera captures images in darkness, subtle differences in the performance of each pixel in the sensor will cause some variations in the pixel grayscale values outputted from the camera.

In practical applications, when there are no photons incident on the camera, the obtained image usually does not show a grayscale value of 0 (DN). This is because manufacturers typically set a baseline value, such as 100 grayscale values, to account for the influence of noise on measurements based on this baseline in the absence of light. However, without careful calibration and correction, this fixed offset may also vary between different pixels. This variation is called "fixed pattern noise" and can be measured by DSNU (Dark Signal Non-Uniformity). It represents the standard deviation of pixel offset, measured in charge units.

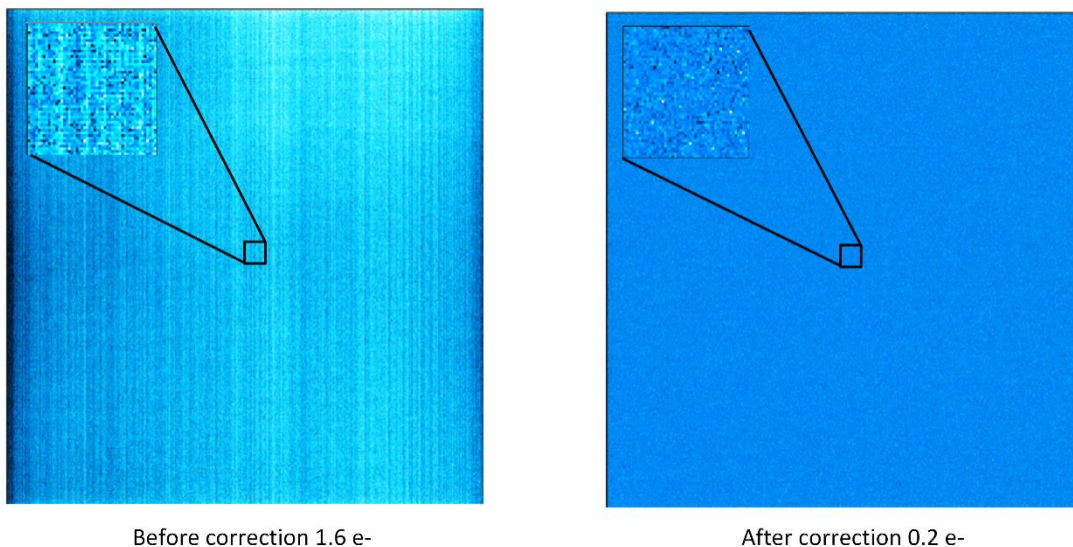


Figure 3-7 DSNU correction comparison before(left) and after(right)

For many low-light imaging cameras, DSNU is typically less than 0.5 e-. This means that in medium or high light level applications (where each pixel can typically capture hundreds or thousands of photons), the influence of this noise can be completely negligible. Moreover, even for low-light applications, if DSNU is lower than the camera's readout noise (typically 1-3 e-), this fixed pattern noise is unlikely to affect image quality.

3.8. Photo Response Non-Uniformity (PRNU)

When a camera captures uniformly illuminated light targets under bright light conditions, ideally, all pixel grayscale values should be close to the maximum grayscale value and equal. However, in reality, there are subtle differences in the performance of camera pixels, causing changes in pixel grayscale values outputted from the camera due to variations in lenses or illumination.

When the camera detects light signals, the number of photoelectrons captured by each pixel during the exposure process is measured and transmitted as digital grayscale values (DN) to the computer. The conversion from electrons to DN follows a certain proportion, called the conversion gain (K), plus a fixed offset (usually 100 DN). These values are determined by both the analog-to-digital converters and amplifiers used for conversion. sCMOS cameras use parallel transmission, with one or more analog-to-digital converters per column of the camera and one amplifier per pixel, resulting in slight variations in pixel gain and offset.

Under dark field or low light conditions, differences in offset can be measured by DSNU as mentioned in Section 3.7. In bright environments, the influence of gain also needs to be considered. Differences in gain and offset changes are measured by Photo Response Non-Uniformity (PRNU), which is the ratio of detected electrons to displayed DN. Given that the intensity values produced will vary depending on the signal size, PRNU is expressed as a percentage.

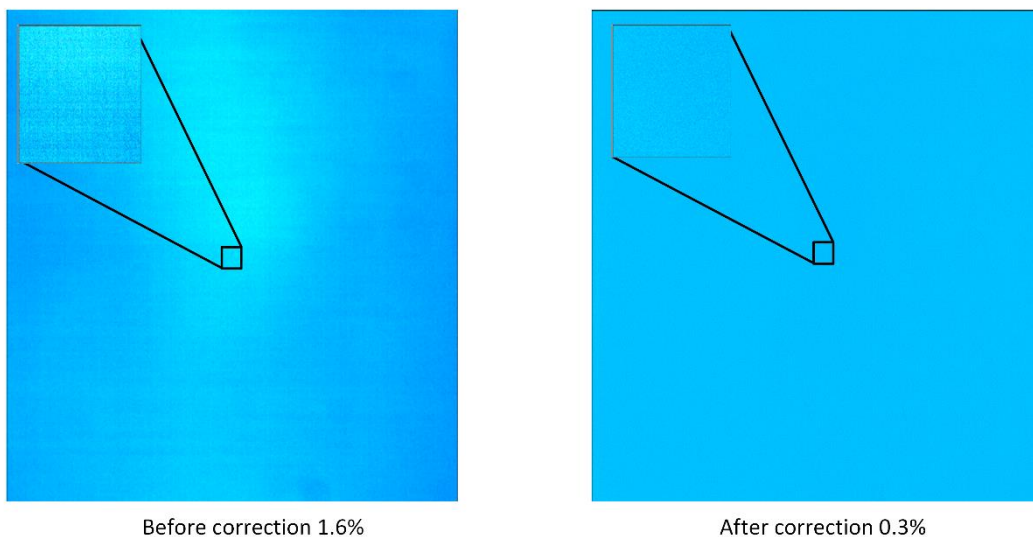


Figure 3-8 PRNU correction comparison before(left) and after(right)

Typical PRNU values are <1%. For all low-light and medium-intensity light source imaging (signals of 1000 e⁻ or less), this variation is negligible compared to readout noise and other sources of noise. Similarly, when imaging at high light levels, this variation is not significant

compared to other noise sources in the image (such as photon shot noise). However, in high light level imaging applications requiring very high measurement accuracy, especially those using frame averaging or frame summation, PRNU values <1% are highly necessary.

3.9. Gain Mode

The Aries 16 camera has four modes of operation, namely High Gain (HG), Low Gain (LG), High Dynamic Range (HDR), and Low Noise (LN), and there are differences in synthesis principle, line time, gain value, and readout noise in different modes. Selecting the appropriate mode based on the actual scenario is essential to obtain high-quality imaging results.

Table 3-1 Typical Gain Parameter Table *

Mode	HDR	High Gain	Low Gain	Low Noise
System gain (DN/e-)	0.85	3.67	0.05	4.3
Full-Well Capacity (e-)	70000	900	73400	900
Readout noise(e-)	1.3(Median) 1.4(RMS)	1.6(Median) 1.7(RMS)	32(Median) 33(RMS)	0.8(Median) 0.85(RMS)

***Note:**

- 1) The values in this table are typical values only and may vary between cameras, please refer to the factory photoelectric report.
- 2) The system gain is also referred to as the conversion gain in the factory optoelectronic report.

3.9.1. High Gain

High Gain (HG) mode has lower readout noise and is suitable for imaging scenarios with weaker signals.

3.9.2. Low Gain

Low Gain (LG) mode has a higher full trap volume and is suitable for imaging scenes with strong signals.

3.9.3. High Dynamic Range

High Dynamic Range (HDR) image mode, whose synthesis schematic is shown in the figure below, the chip outputs both high and low gain data on the same line at the same time.

These two images have exactly the same exposure time, but have different analog gains. Among them, the low gain (Low Gain, LG) mode has a high full-well capacity and high noise, which is suitable for imaging scenes with strong signals; while the high gain (High Gain, HG) mode has a low full-well capacity and low readout noise, which is suitable for imaging scenes with weaker signals. An HDR image can be generated by combining the High Gain and Low Gain images through certain algorithms.

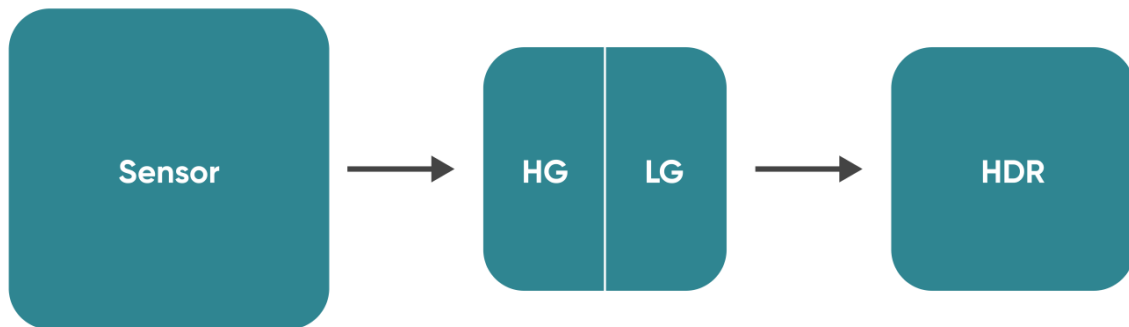


Figure 3-9 Schematic diagram of HDR mode

3.9.4. Low Noise

This mode reduces the frequency of sensor usage, while also shutting down unnecessary backend circuits to decrease chip power consumption and heat generation during frequency reduction, thereby reducing readout noise.

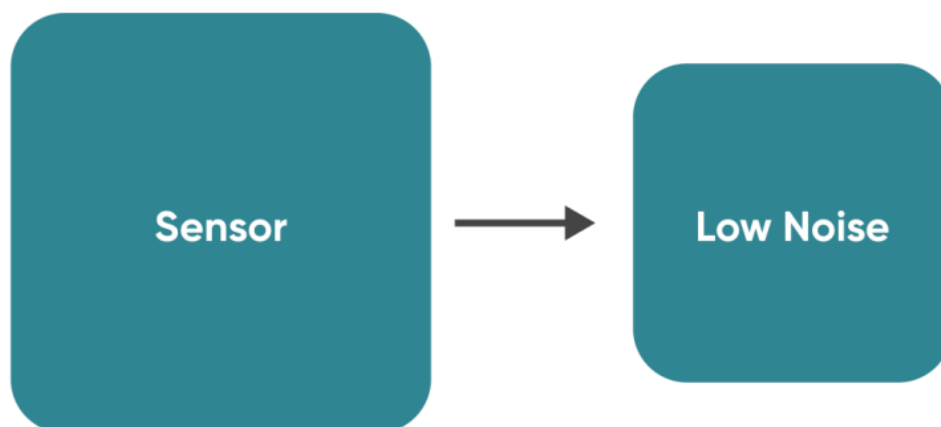


Figure 3-10 Low Noise Mode Diagram

3.10. Region of Interest (ROI) Readout

In imaging applications, ROI (Region of Interest) defines a subregion of interest within the camera sensor's resolution range, and selecting an ROI allows only the images within this subregion to be read out. Rolling shutter cameras can increase the camera's readout speed

by reducing the number of rows. The software sets preset subregions and also supports manual settings, where the row window must be a multiple of 4, and the column window must be a multiple of 8.

The measured frame rates (fps) of the typical ROI areas of the Aries 16 camera under CameraLink are shown in the table below:

Table 3-2 Typical ROI area measured frame rates for Aries 16 camera under CameraLink

Column(Pixel)	Row(Pixel)	Rolling		Global Reset	
		HDR/HG/LG	Low Noise	HDR/HG/LG	Low Noise
800	600	60	25	60	25
800	300	117	50	119	50
800	152	218	93	225	95
800	76	391	165	417	175
800	36	669	283	744	315
800	32	720	305	818	344
800	16	1041	441	1241	526
800	8	1339	567	1709	717
48	8	1339	567	1710	722

The measured frame rates (fps) of the typical ROI areas of the Aries 16 camera under USB3.0 are shown in the table below:

Table 3-3 Typical ROI area measured frame rates for Aries 16 camera under USB3.0

Column(Pixel)	Row(Pixel)	Rolling		Global Reset	
		HDR/HG/LG	Low Noise	HDR/HG/LG	Low Noise
800	600	60	25	60	25
800	300	117	50	119	50
800	152	218	93	225	95
800	76	390	165	416	176
800	36	669	283	749	317
800	32	720	305	814	344
800	16	1041	441	1248	529
800	8	1339	567	1704	721
48	8	1338	567	1703	721

Note:

- 1) *The minimum supported ROI for Aries 16 on Mosaic V3 is: 48 (columns) × 8 (rows).*
- 2) *Frame rate is affected by computer system configuration. It is recommended to use a computer with an i5 processor or above and a 64-bit operating system.*
- 3) *For high-speed image acquisition, it is recommended to uncheck automatic levels and disable the Image Adjustment module.*
- 4) *The values in the table above are the measured maximum under the shortest exposure time in live mode. For hardware trigger mode, refer to section 3.13 for frame rates.*

3.11. Binning Readout

Binning is a readout mode that recombines camera pixels, which can improve sensitivity but may also reduce resolution. For example, 2 x 2 binning combines every 4 pixels (2 rows 2 columns) into one "large pixel", and the camera outputs one pixel intensity value.

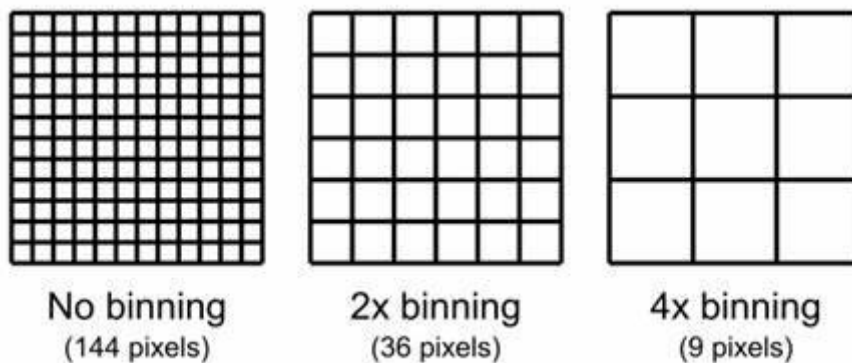


Figure 3-11 Schematic diagram of binning

Binning can be performed by the camera's FPGA or by the camera operating software. Combining signals in this way can improve the signal-to-noise ratio, enabling the detection of weaker signals, improving image quality, or shortening exposure times. However, the effective pixel size of the camera also increases, which may reduce the camera's resolution of target details.

Binning data processing can be divided into Sum Binning and Average Binning. In 2 x 2 Binning, for example, Sum Binning adds the grayscale values of four pixels, while Average Binning adds the grayscale values of four pixels and then divides by 4 to obtain the average grayscale value.

The software Binning selection on Mosaic V3 is shown below:

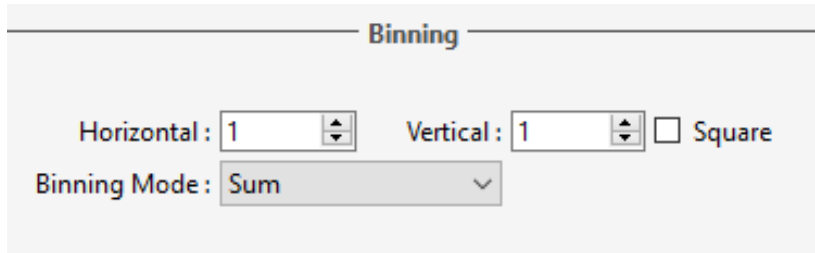


Figure 3-12

3.12. Timestamp

The camera accurately reads the start time of each frame with 1μs time accuracy. In Mosaic V3 version software, use [.sen] format to save the picture, the timestamp information will be displayed in the picture information, support exporting the picture information to [.csv] format file.

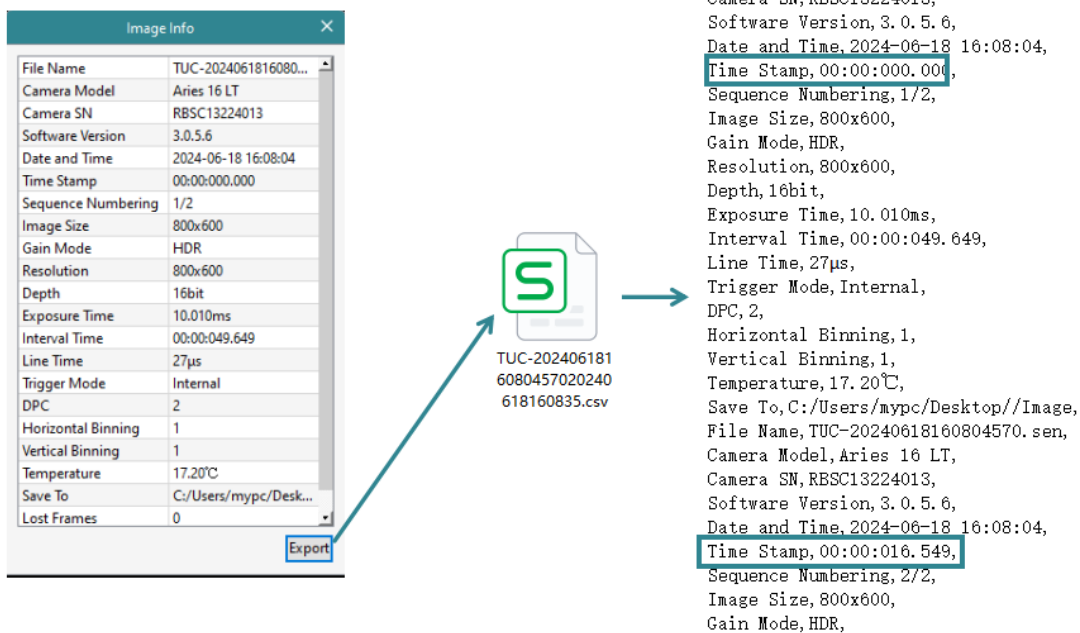


Figure 3-13 Timestamp Export Schematic

Note:

In general, applications that require timestamp functionality have relatively high demands for time accuracy, and it is recommended to use the To RAM image storage mode.

3.13. Frame Rate Calculation

The frame rate of the camera is influenced by the readout time and exposure time. The theoretical frame rate can be calculated with reference to Tables 3-5, 3-6, and 3-7.

Rolling shutter: Readout time= $T_{line}*(Vn+20)$

Global reset: Readout time = $T_{line}*(Vn+14)$

Table 3-4 Calculation of readout time

Gain mode	Line Time (T_{line})	Readout Time ($T_{readout}$) (Rolling)	Readout Time ($T_{readout}$) (Global Reset)
High Gain Low Gain High Dynamic Range	26.694 μ s	$(600+20)*26.694 \mu$ s=16.55 ms	$(600+14)*26.694 \mu$ s=16.39ms
Low Noise	63.03 μ s	$(600+20)*63.03 \mu$ s=39.078 ms	$(600+14)*63.03 \mu$ s=38.70ms

Calculation of typical frame rates for CameraLink and USB3.0 (Rolling):

Hn: The number of rows selected in the horizontal direction;Vn: The number of rows selected in vertical direction; T_{line} : Line time; T_{exp} : Exposure time.

Table 3-5 Calculation of Rolling Frame Rates (Live Mode)

Gain mode	Line Time (T_{line})	Calculation formula	Horizontal (Hn)	Vertical (Vn)	Frame rate (fps)
High Gain Low Gain High Dynamic Range	26.694 μ s	$1/((Vn+20)*T_{line})$	800	600	60.42
				300	117.07
				152	217.80
				76	390.23
				36	668.96
				32	720.42
				16	1040.60
Low Noise	63.03 μ s	$1/((Vn+20)*T_{line})$	800	600	25.59
				300	49.58
				152	92.24
				76	165.27
				36	283.31
				32	305.11
				16	440.71
			8	566.62	

Table 3-6 Rolling Frame Rate Calculation (Hardware Trigger Mode)

Gain mode	Line Time (T _{line})	Calculation formula	Horizontal (Hn)	Vertical (Vn)	Frame rate (fps)	
High Gain Low Gain High Dynamic Range	26.694μs	$1/(2*(Vn+20)*T_{line})$	800	600	30.21	
				300	58.53	
				152	108.90	
				76	195.11	
				36	334.48	
				32	360.21	
				16	520.30	
8	668.96					
Low Noise	63.03μs		$1/(2*(Vn+20)*T_{line})$	800	600	12.79
					300	24.79
					152	46.12
					76	82.63
					36	141.66
					32	152.55
		16			220.35	
8	283.31					

Typical Frame Rate Calculation for CameraLink and USB3.0 (Global Reset)

Table 3-7 Global Reset Frame Rate Calculation (Live Mode, Hardware Trigger Mode)

Gain mode	Line Time (T _{line})	Calculation formula	Horizontal (Hn)	Vertical (Vn)	Frame rate (fps)	
High Gain Low Gain High Dynamic Range	26.694μs	$1/((Vn+14)*T_{line})+T_{exp}$	800	600	61.01	
				300	119.30	
				152	225.67	
				76	416.24	
				36	749.23	
				32	814.38	
				16	1248.72	
8	1702.80					
Low Noise	63.03μs		$1/((Vn+14)*T_{line})+T_{exp}$	800	600	25.84
					300	50.53
					152	95.58
					76	176.28
					36	317.31
					32	344.90
		16			528.85	
8	721.16					

Note:

- 1) The frame rates in the above table are calculated values under the minimum exposure time. When the exposure time is greater than the readout time in Rolling mode: Live mode frame rate = $1/T_{exp}(s)$; Hardware trigger mode frame rate = $1/(T_{exp}+T_{readout})(s)$
- 2) Frame rate is affected by factors such as actual transmission bandwidth and computer system configuration. To prevent frame dropping, additional interval time in units of line time is added during actual transmission, which increases the readout time correspondingly. This may result in calculated frame rates being higher than actual frame rates.

3.14. Frame Rate Adjustment

Each frame image readout has a fixed blanking time, and frame rate adjustment is achieved by changing the blanking time ($T_{blinking}$) to control the frame rate.

For example, if the exposure time < readout time, considering a frame rate of 60.42 fps, setting the frame rate to 40 fps adds 8.45 ms of blanking time during image output.

Similarly, if the exposure time > readout time, considering an exposure time of 100 ms, setting the frame rate to 5 fps adds 100 ms of blanking time during image output.

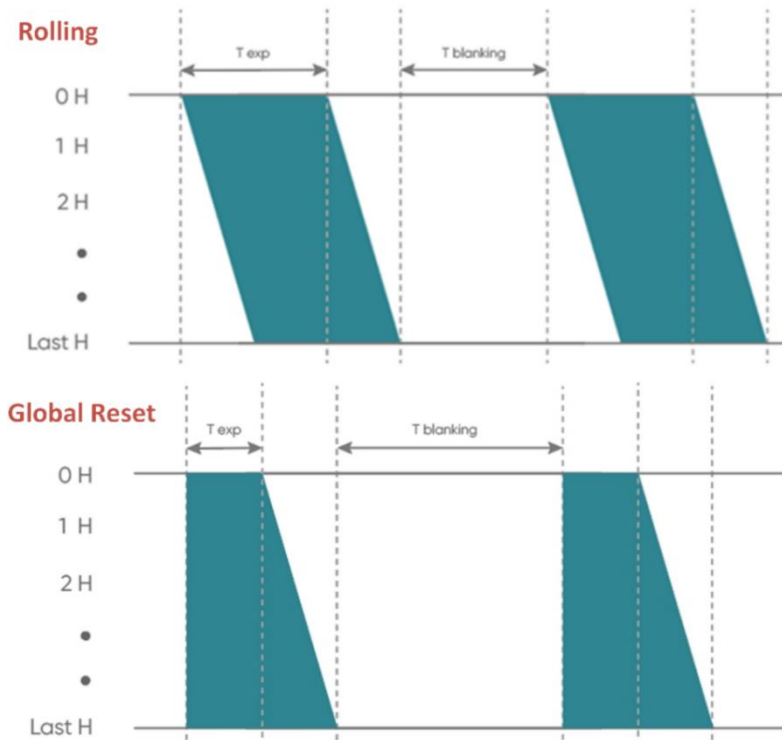


Figure 3-14 Frame rate adjustment timing diagram

3.15. Incident Photon Calculation

Scientific camera imaging involves the conversion process from photons to electrons, voltage, and grayscale values. Therefore, it is possible to deduce the incident photon count from grayscale values using the following formula:

$$P = \frac{(DN - Offset)/K}{Q(\lambda)}$$

Where: P represents the incident number of photons. DN is the grayscale value of the light signal. K is the system gain (refer to Table 3-1), with units of (DN/e-), Q(λ) corresponds to the quantum efficiency at the wavelength. Offset is the camera's background value in DN.

3.16. Acquisition Mode

3.16.1. Live Mode

Live mode is suitable for real-time preview, providing data stream output. Images are continuously output like a flowing stream. In this mode, users can freely modify settings such as exposure time, gain mode, region of interest, etc., for real-time preview and image capture operations.

After successfully installing the Mosaic V3 software and drivers, the hardware trigger mode defaults to "internal trigger" (live mode), the user can click Preview/Stop to control the opening and closing of the camera live mode, and click Capture to obtain the image.

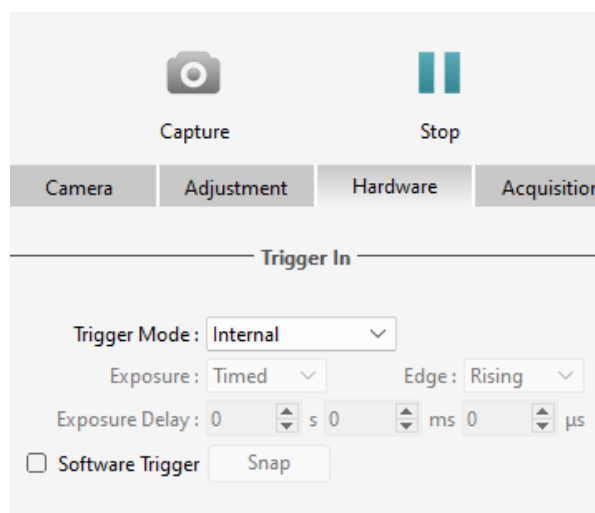


Figure 3-15

Users can set the exposure time, working mode and other camera parameters, and preview them in real time through the preview window to get a suitable image.

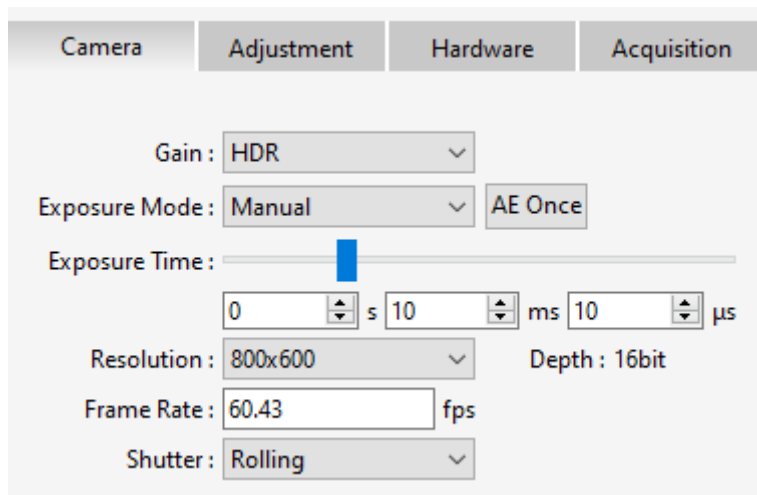


Figure 3-16

In the acquisition module, users can set the save path, file name, total number of frames and other information, and the image can be taken after the setting is completed.

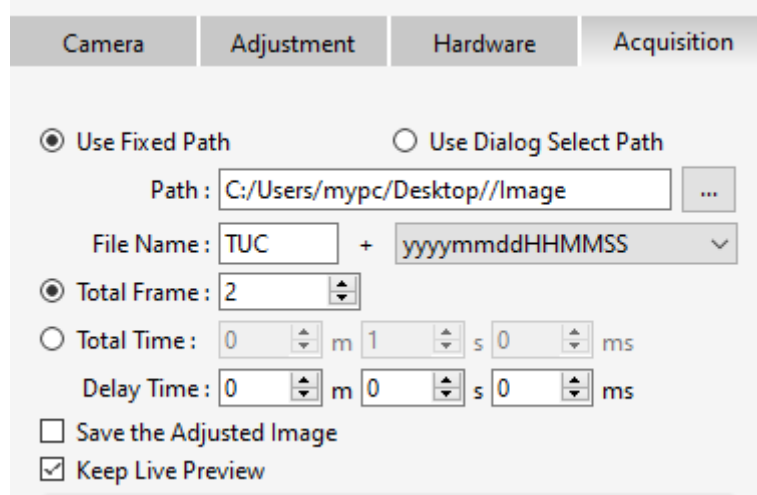


Figure 3-17

3.16.2. Software Trigger Mode

When the camera is in Software trigger mode, the software gives the camera a command to take a picture, and when the camera receives the signal, it starts the exposure and outputs the image.

Mosaic V3 software trigger mode, after checking the software trigger, if you need to save a picture, click on the Capture to enter the waiting trigger state, and then click on the **Snap** after the camera began to expose, and at the end of the exposure of the output of a frame, each time you click on the **Snap** of the output of only one picture.

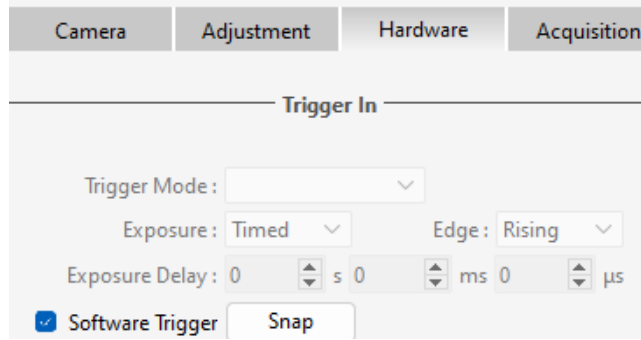


Figure 3-18

3.16.3. Hardware Trigger Mode

Hardware trigger is a mode where the camera waits for an external trigger signal to initiate exposure and image capture.

In Mosaic V3, after entering hardware trigger mode, the settings include several configurations such as mode, edge, exposure delay, and others.

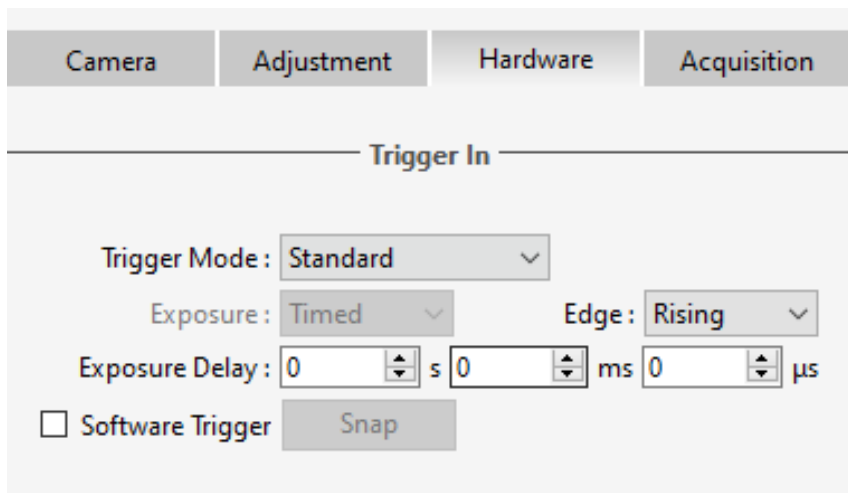


Figure 3-19

3.16.3.1. Hardware Trigger input circuit

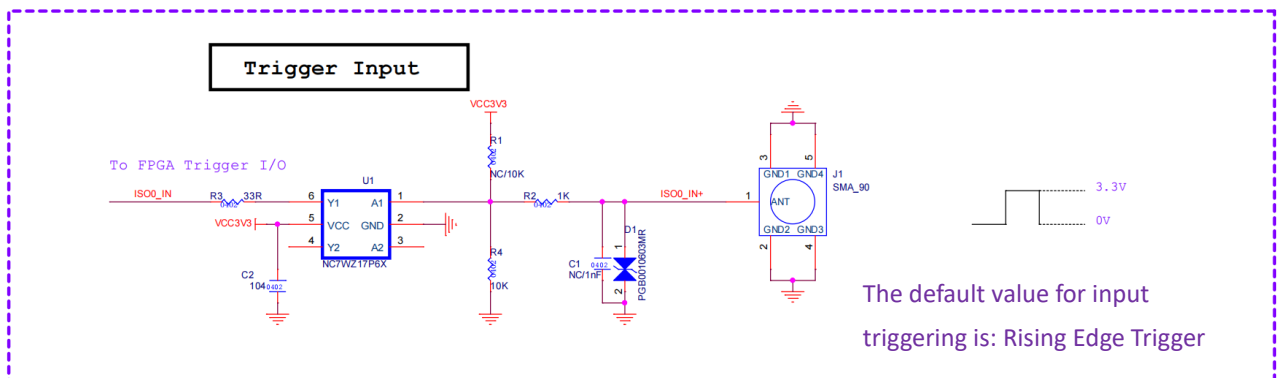


Figure 3-20 Hardware trigger input circuit

Note:

- 1) The valid external trigger signal that the camera can recognize must be a voltage signal between 3.3V to 5V. Exceeding the maximum specified voltage may result in permanent damage.
- 2) The recognizable voltage signal pulse width needs to be greater than 1 μ s.

3.16.3.2. Trigger Delay and Jitter

The triggering delay and jitter for Rolling shutter type are shown in the diagram below. When an external trigger voltage signal arrives, it first undergoes a nanosecond-level delay T_{iso} through the hardware circuitry. After this hardware delay, the voltage signal inputted into the camera undergoes a conversion with a certain jitter delay T_{logic} , ranging from 0 to 1 unit of the minimum exposure time T_{line} .

When the external trigger voltage signal arrives, after a delay period T_{delay} , exposure begins. Therefore, the total delay time from external trigger input to the start of exposure is $T_{delay} = T_{iso} + T_{logic} + M * T_{line} + SHS_LINE$, where $M = 8$. If the exposure time is less than the readout time, $SHS_LINE = \text{readout time} - \text{exposure time}$; if the exposure time is greater than the readout time, $SHS_LINE = 0$.

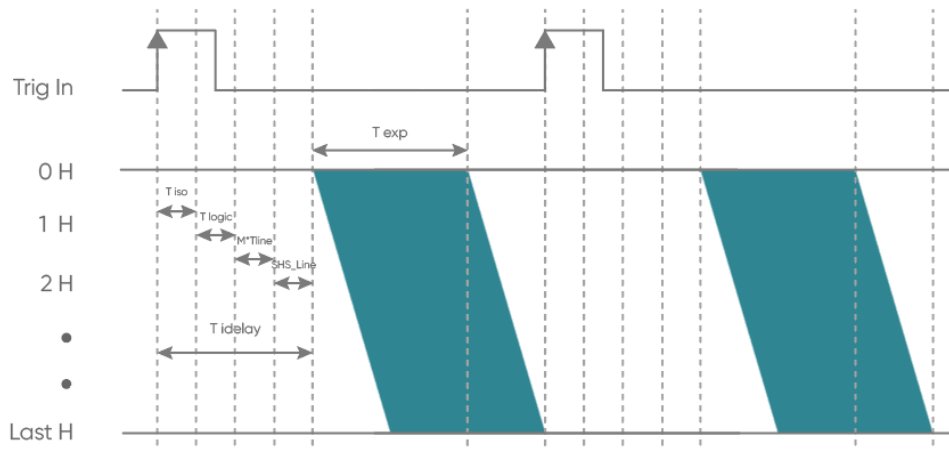


Figure 3-21 Rolling Mode Trigger Delay Schematic

The delay and jitter for Global Reset mode are 600 ns, as shown in the timing diagram below:

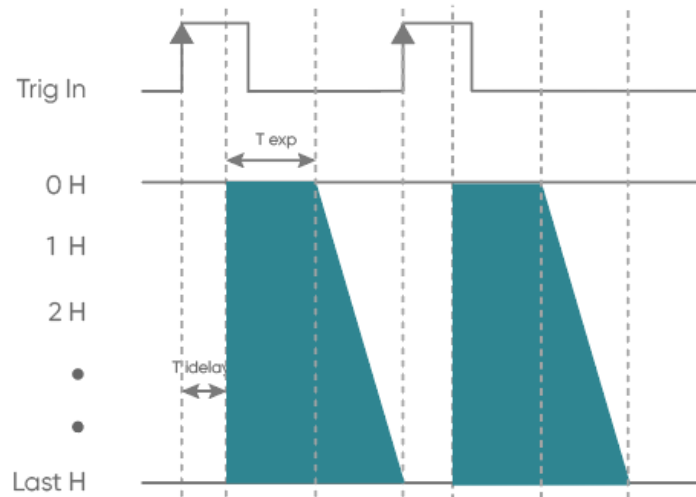


Figure 3-22 Global Reset Mode Trigger Delay Diagram

T_{exp} : exposure time; T_{delay} : total delay time; 1H: one T_{line}

3.16.3.3. Standard Trigger Mode

Standard trigger mode: When the camera is in live mode, it responds to external trigger signals only after the image has been read out.

Edge triggering is used, and the exposure time is directly set in the software interface. When using it, it's important to ensure that the duration of each pulse cycle of the trigger signal (pulse width + pulse interval) is greater than or equal to the total time used for outputting each frame of the image (i.e., the reciprocal of the frame rate), to ensure that each frame of the image is complete and error-free.

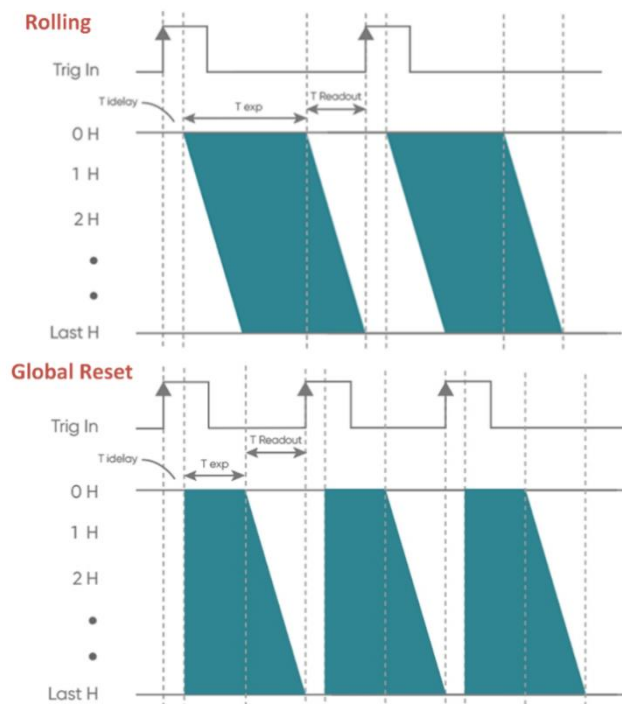


Figure 3-23 Standard Trigger Timing Sequence

3.17. Trigger Output

3.17.1. Hardware Trigger output circuit

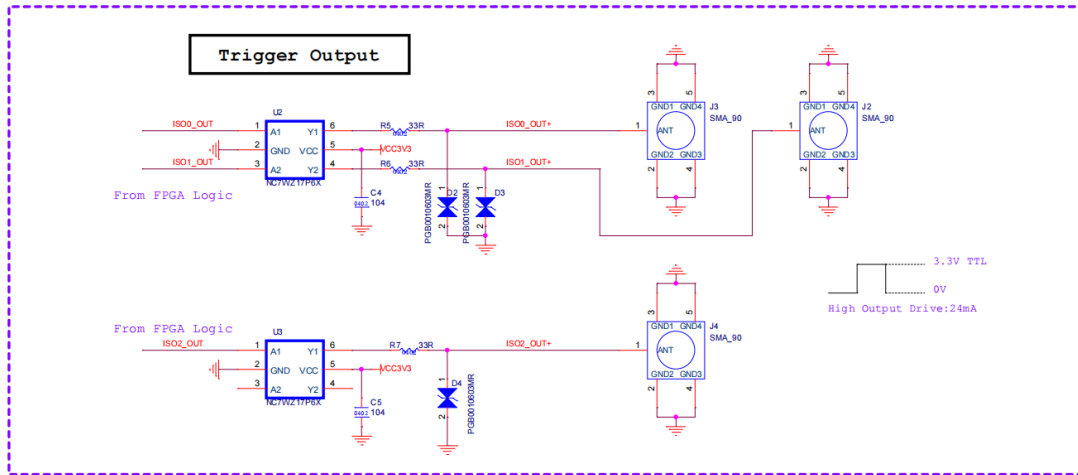


Figure 3-24

3.17.2. Trigger Output Sequence Diagram

The camera has three external trigger output interfaces, each independent of the others, capable of outputting the following five types of timing signals. These output signals do not interfere with each other and can be independently configured on the three output ports. Additionally, they can simultaneously output to different devices.

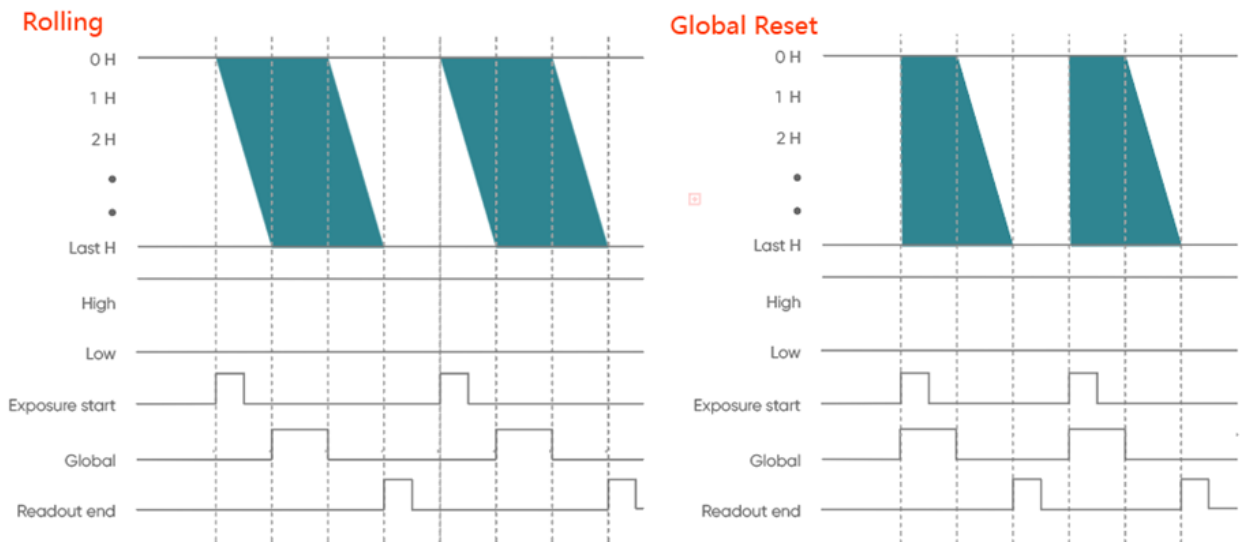


Figure 3-25 Trigger output sequence diagram

- **High:** Always output high level;
- **Low:** Always output low level;

- **Exposure Start:** output starting from the first line of exposure, the default pulse width is 5ms, which is customizable. And the output is in the TRIG.OUT3 interface by default.
- **Readout End:** output starting from the last line of exposure end, the default pulse width is 5ms, which is customizable. And the output is in the TRIG.OUT1 interface by default.
- **Global:** output from the beginning of the last line of exposure to the end of the first line of exposure end (valid when the exposure time is larger than the readout time), the default pulse width is 5ms, which is customizable. And the output is in the TRIG.OUT2 interface by default.

3.18. Cooling

The camera's cooling system effectively reduces "dark current noise" and the impact of hot pixels. The camera utilizes semiconductor cooling, leveraging the Peltier effect, where a pair of thermoelectric elements composed of N-type and P-type materials generate heating and cooling at the junction when a direct current passes through them. The cold side is placed close to the chip to lower its temperature and reduce dark current, while the hot side is connected to a metal heat sink to dissipate generated heat effectively.

Air cooling and water cooling are two common cooling methods. In air cooling, a fan uses airflow to exchange excess heat with the surrounding air. In water cooling, a liquid circulation system transfers excess heat away. The Aries 16 camera supports both air cooling and water cooling methods, allowing users to choose the appropriate cooling method based on their operational environment. In air cooling mode, the inlet and outlet ports are marked as shown in the diagram below:



Figure 3-26 Schematic diagram of Aries 16 air inlet and outlet

Under air cooling, the camera achieves a cooling effect that can maintain a temperature difference of over 50°C from the ambient temperature. Water cooling, on the other hand, can achieve a cooling effect with a temperature difference of over 60°C from the ambient temperature. The camera's fan supports variable speed control typically offering High, Medium, and Low settings. Higher fan speeds enhance heat dissipation performance, while lower speeds reduce vibration transmission. For achieving minimal vibration performance, the fan of the Aries 16 camera can be completely shut off via software control. Additionally, the camera provides a water cooling port (for water cooling installation, refer to section 4.3).

4. Installation

4.1. Recommended computer configurations

Camera Interface	USB3.0	CameraLink
CPU	I5 and above performance, with a main frequency of 2.6GHz and above	
Operating system	Windows 10/11 64 bit PC	
Memory	8GB and above	
PCIe specifications	/	PCIe3.0*16

Note:

In CameraLink, sufficient bandwidth is required. If you see obvious image scrolling when opening the camera software, it is recommended to first confirm whether the bandwidth of the acquisition card is sufficient.

4.2. Camera installation

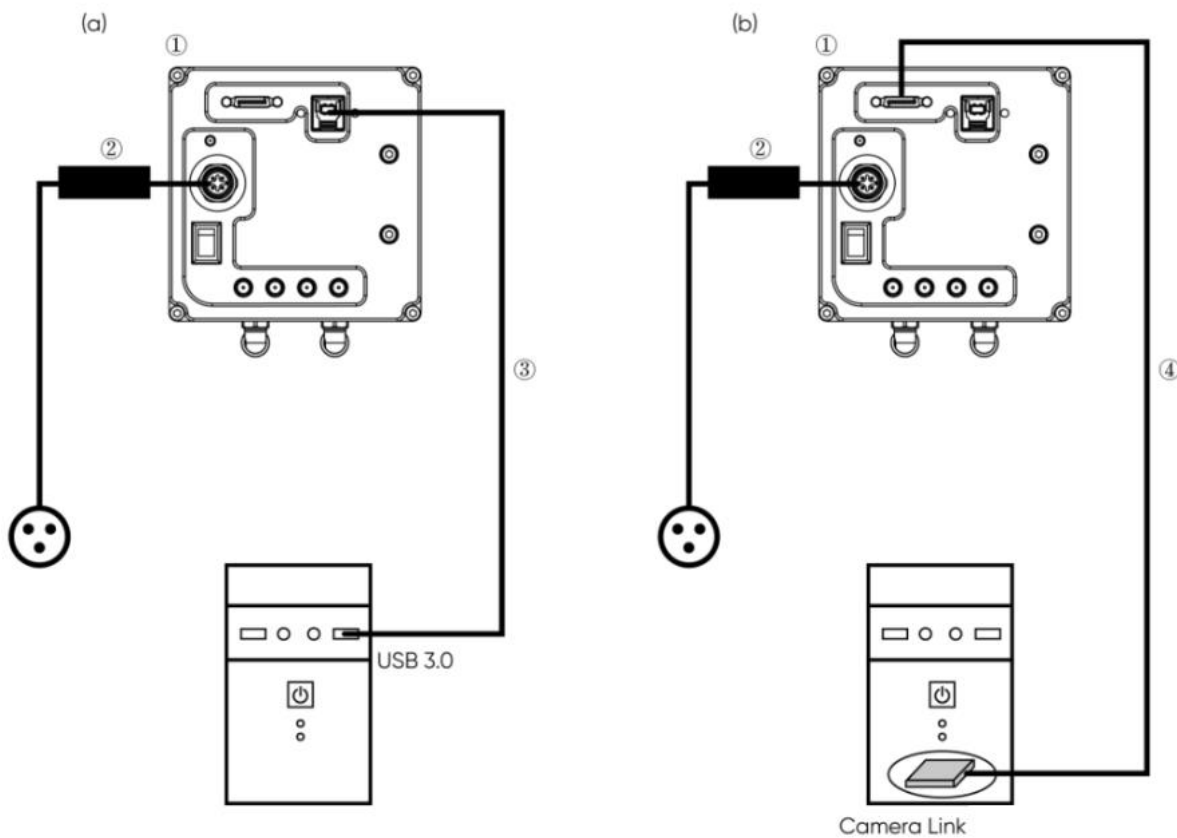


Figure 4-1 Aries 16 Camera Connection Diagram

- ① Aries 16 Camera
- ② Power adapter
- ③ USB 3.0 data cable
- ④ CameraLink cable

Connect one end of the USB 3.0 data cable or CameraLink data cable to the PC. For USB, connect it to a USB 3.0 port at the rear of the host computer. Connect the other end to the sCMOS camera. Secure the connection with screws if necessary. Plug in the power cord to the camera. Turn on the power switch. You should see the indicator light illuminate, typically in red.

Note:

- 1) *To prevent internal overheating of the camera, do not wrap the camera in cloth or any other material, and do not obstruct the camera's ventilation ports in any way.*
- 2) *If operating the camera in a closed environment, ensure there is at least a 10 cm gap between the intake and exhaust vents of the camera during installation. If placing the camera on a desk or platform, ensure that the camera's vents are not facing downward.*
- 3) *The depth of a C-mount is 7 mm. Overtightening the base may scratch the glass surface.*
- 4) *Before connecting or disconnecting cables, ensure to power off the camera and any peripheral devices.*

4.3. Water cooling pipe installation

4.3.1. Connect the water cooling pipe

Operation steps:

- (1) Place the camera on a stable workbench;
- (2) Connect the water cooling pipe to the water pipe joint on the camera and make sure it is inserted in place, as shown in Figure 4-2 below;



Figure 4-2

- (3) Insert the water pipe onto the water nozzle of the cooling water circulation machine and secure it with a hose clamp.
- (4) The water pipe from the cooling water circulation machine connects to the camera's water pipe via a connecting valve.

4.3.2. Software Fan Status

- (1) After installing the water cooling pipe, it is necessary to switch the cooling mode on the software. The default cooling method for the camera is air cooling, which can be switched to water cooling by adjusting the fan gear;

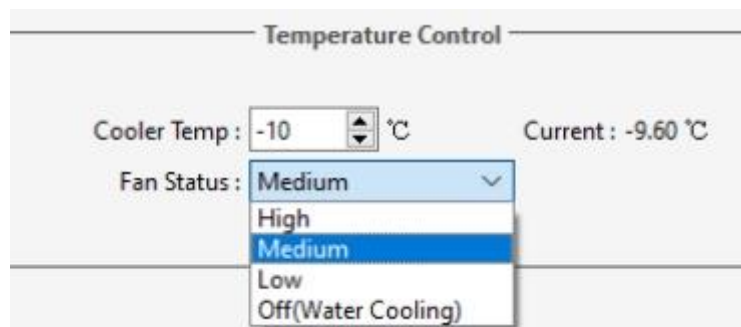


Figure 4-3

- (2) If you choose to turn off the fan, the software will prompt you as follows. Click "Yes" to turn off the fan. Please ensure that the water cooling system is functioning properly before proceeding with this operation.



Figure 4-4

4.3.3. Disconnect the water cooling pipe

- (1) Power off all devices including the camera and any other equipment such as the cooling water circulation machine.
- (2) Following the instructions for the cooling water circulation machine, disconnect the water pipe from the top of the machine and drain the water inside.
- (3) Press the sleeve of the connecting valve and remove the water pipe from the cooling water circulation machine, ensuring all water is drained out.
- (4) Press the water joint and detach the camera's water pipe from the hose connector. Position the side with the installed water valve towards the side (**not upwards**) during removal, ensuring the valve opening faces downwards. Use absorbent towels or tissues to protect against water spills into the camera.



Figure 4-5 Remove the water cooling tube.

Note:

- 1) *Choice of Cooling Water: Deionized water is recommended.*
- 2) *Water Temperature: Generally, a water temperature of 20°C is recommended. Improper environmental conditions can lead to condensation in the water valve and pipes, posing*

a risk of equipment damage. To ensure normal operation, it is advised not to let the water temperature fall below the dew point. Refer to the dew point table in the appendix for the dew point temperature.

- 3) *Pressure: The maximum water pressure entering the camera should not exceed 2 bar.*
- 4) *Cooling Water Circulation Machine: Follow the instructions provided with the cooling water circulation machine for correct usage and refrigeration.*
- 5) *Proper Installation of Water Cooling Lines: Ensure there is no leakage at the interface between the camera end and the cooling water circulation machine end.*
- 6) *Before operating the camera, verify correct installation of the water valve between the cooling water circulation machine and the camera, ensuring a water flow rate of at least 1 L/min. After operation, power off the camera and related equipment, drain water from the circulation machine and the camera.*
- 7) *After operation, power off the camera and related equipment including the circulation machine, and drain the water from both the circulation machine and the camera.*

Warning:

- 1) ***During the operation of the camera, do not turn off the cooling water circulation machine and stop cooling. Otherwise, it may cause damage to the chip during continuous high-temperature operation;***
- 2) ***During the operation of the camera, both the water cooling and fan can be turned on at the same time, but they cannot be turned off at the same time. At least one cooling method is required to operate normally, otherwise it may cause the chip to be damaged due to continuous high temperature.***

4.4. Frame grabber installation

Turn off the computer and open the cover of the computer host, as shown in Figure 4-6. Choose a PCIe slot with a transmission bandwidth greater than 850MB/s, insert the Frame grabber, secure it with screws, and then restart the computer. Connect the interface between the camera and the computer Frame grabber through a data transmission cable.

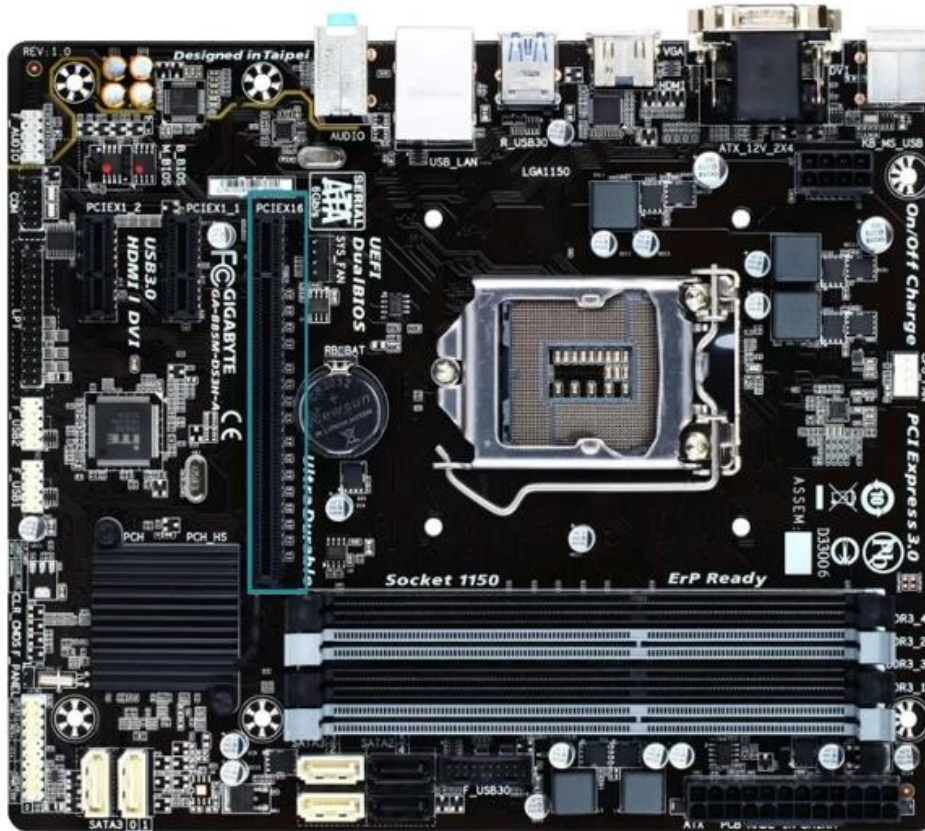


Figure 4-6 Computer motherboard diagram

Table 4-1 Maximum transfer rate corresponding to different PCIe slots

PCIe	X1	X4	X8	X16
1.0	250MB/s	1GB/s	2GB/s	4GB/s
2.0	500MB/s	2GB/s	4GB/s	8GB/s
3.0	985MB/s	3.9GB/s	7.8GB/s	15.7GB/s

Note:

- 1) When installing or removing the acquisition card, always ensure that the power is disconnected.
- 2) When connecting CameraLink cables, operate with the camera powered off, and avoid hot-plugging.

4.5. Driver installation and uninstallation

This section will cover the installation and uninstallation of the camera's USB driver and the acquisition card driver.

4.5.1. Camera USB driver installation

Operation steps:

- (1) Connect the camera to the computer and open the matching USB drive;
- (2) Double click to run the driver installation package;
- (3) Follow the prompts to click [Next] for default installation;

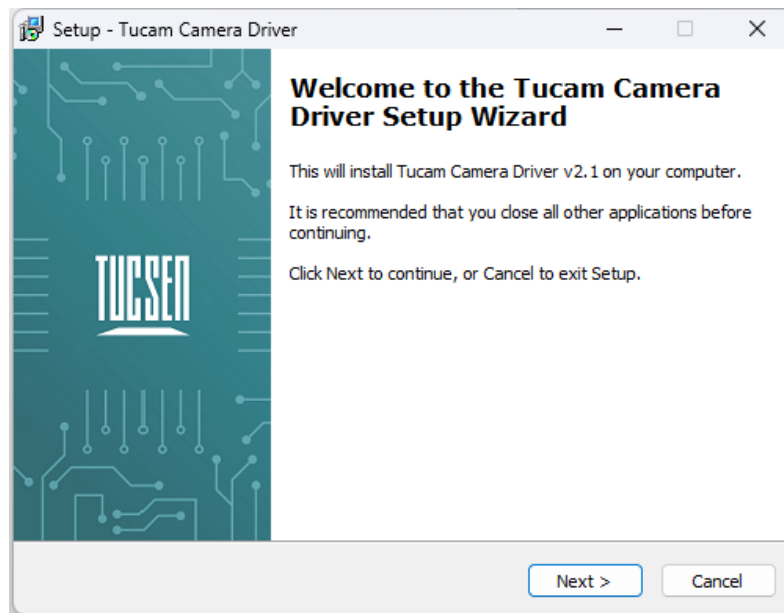


Figure 4-7

- (4) When selecting installation components, it is recommended to leave the default options checked for installing Microsoft runtime libraries vcredist_2008 and vcredist_2013. Unchecking these options may cause software or third-party plugins to malfunction;

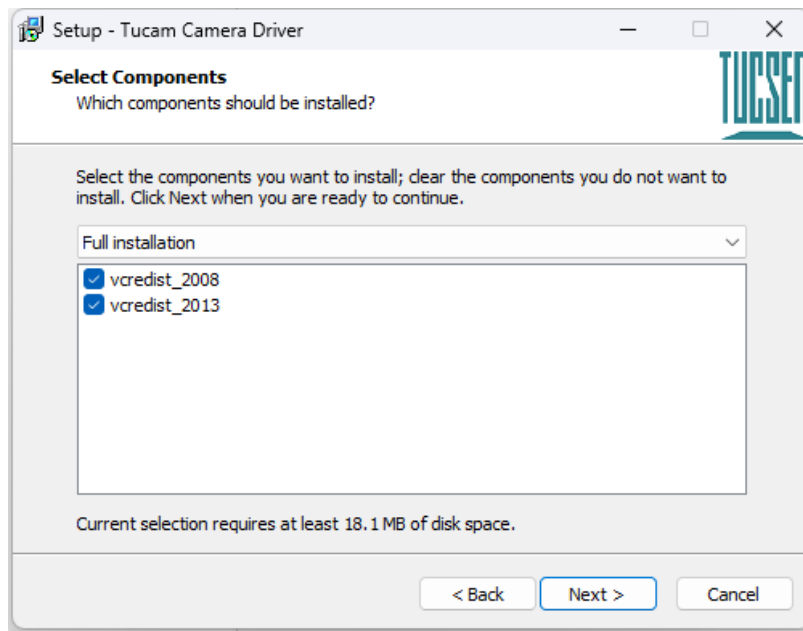


Figure 4-8

(5) Waiting for the driver installation to be completed;

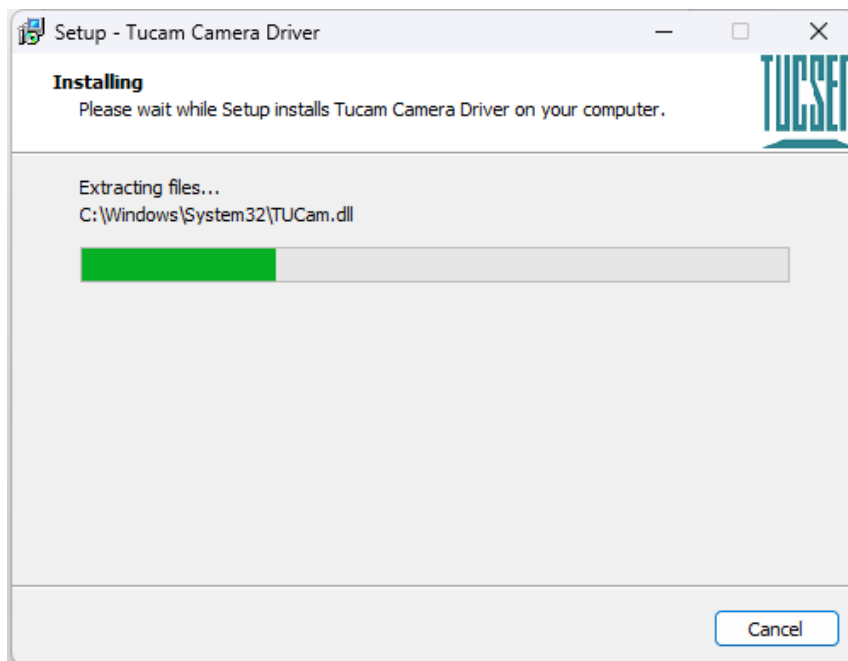


Figure 4-9

(6) Click "Finish" to complete the driver installation;

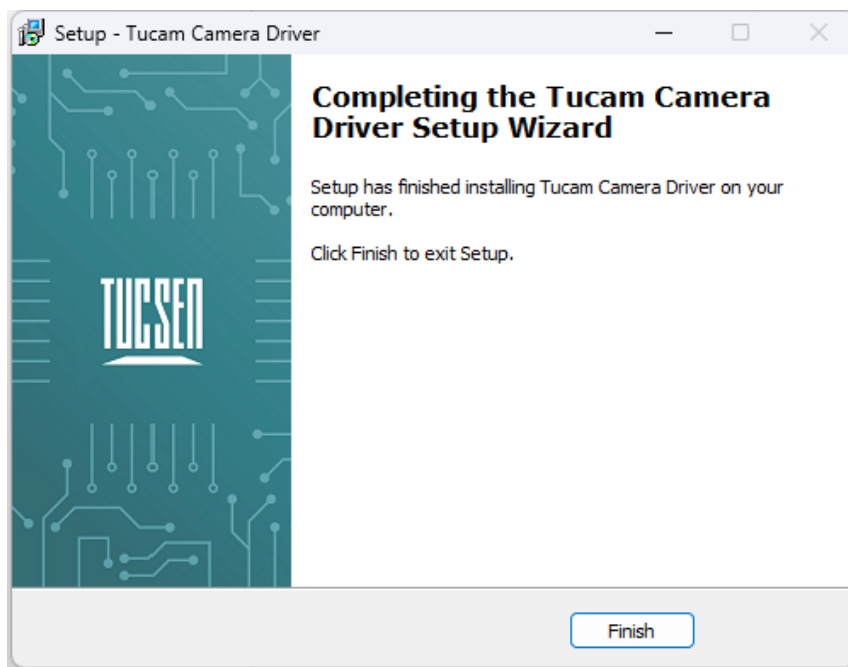


Figure 4-10

After installing the USB 3.0 camera driver, open the Device Manager on your computer. When the driver installation is successful, the camera will appear under Imaging Devices without any yellow exclamation marks, as shown in the diagram. If you see a yellow exclamation mark, it indicates that you need to reinstall the driver.

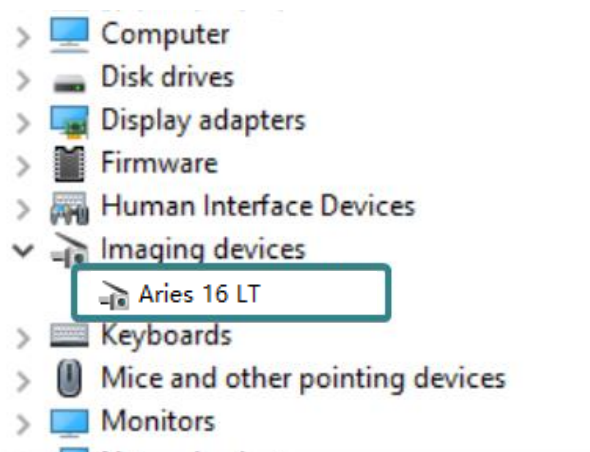


Figure 4-11 Device Manager Display

4.5.2. CameraLink driver installation

Installation steps:

- (1) Connect the camera to the CameraLink interface (CameraLink1) of the installed acquisition card on the computer host using a CameraLink cable.
- (2) Open the accompanying USB drive. Locate the installation package for the acquisition

card driver.

- (3) Double-click to run the CameraLink acquisition card driver setup. Follow the prompts, click [Next] for default installation, and finally click [Finish]. After restarting the computer host, the driver installation will be complete.
- (4) After installing the driver, please restart your computer.

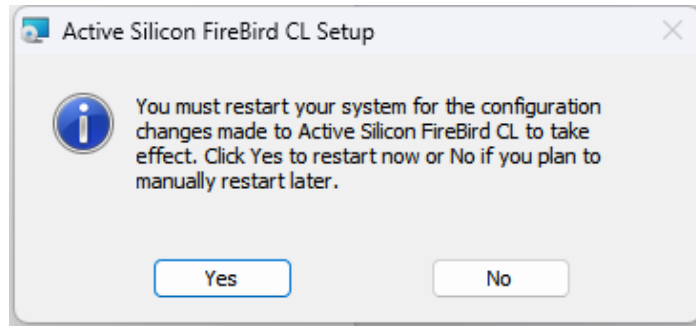


Figure 4-12

After installing the CameraLink driver, open the Device Manager on your computer. When the driver installation is successful, the CameraLink acquisition card will appear in the Device Manager under "FireBird Baseboard." When a camera is connected, it may occupy a COM port, as shown in the diagram.

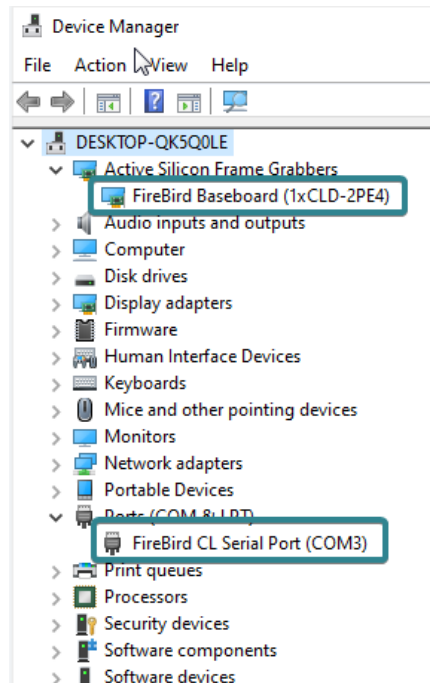


Figure 4-13

4.5.3. CameraLink driver uninstallation

In Windows 11, go to Settings, then click on Apps > Installed apps. Find Active Silicon FireBird CL in the list of installed applications. Click on the three dots icon on the right, choose

Uninstall, and follow the prompts to complete the uninstallation.

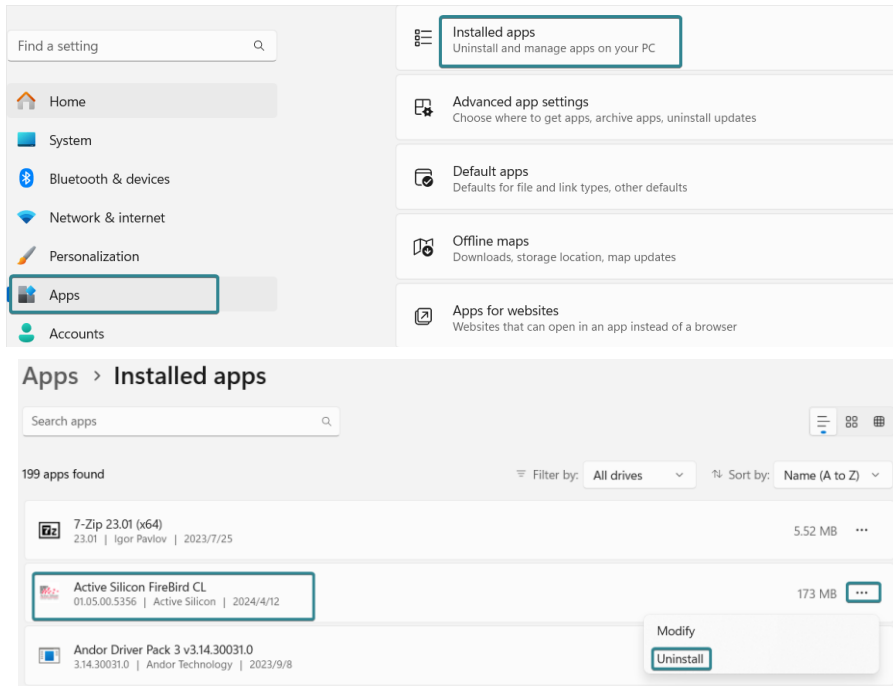


Figure 4-14

4.6. Software installation and uninstallation

4.6.1. Installation

Operation steps:

- (1) Open the supporting USB drive, double-click to run Mosaic V3 software;
- (2) Select the installation path, default to C drive, users can customize the installation path according to their needs;

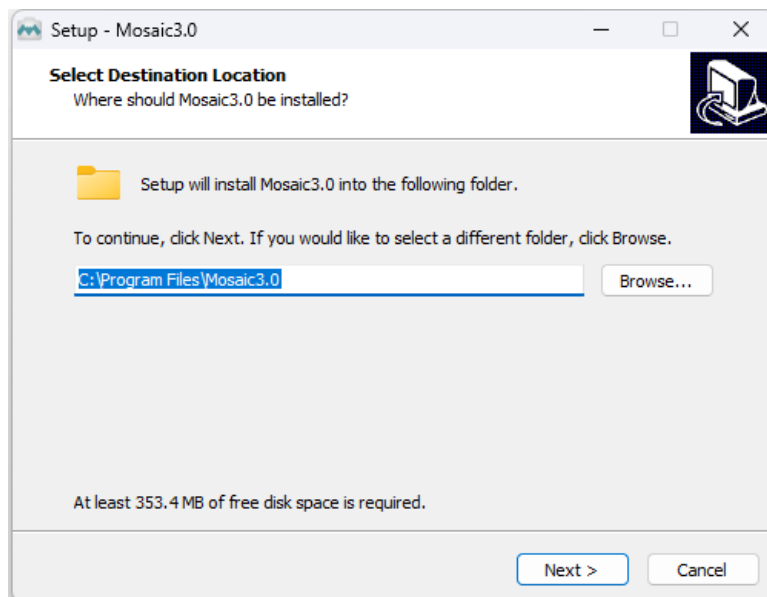


Figure 4-15

- (3) Select installation components: by default, check the boxes for installing the driver and Microsoft runtime library vc_redist_2015. Unchecking these options may result in the camera not being recognized by the software;

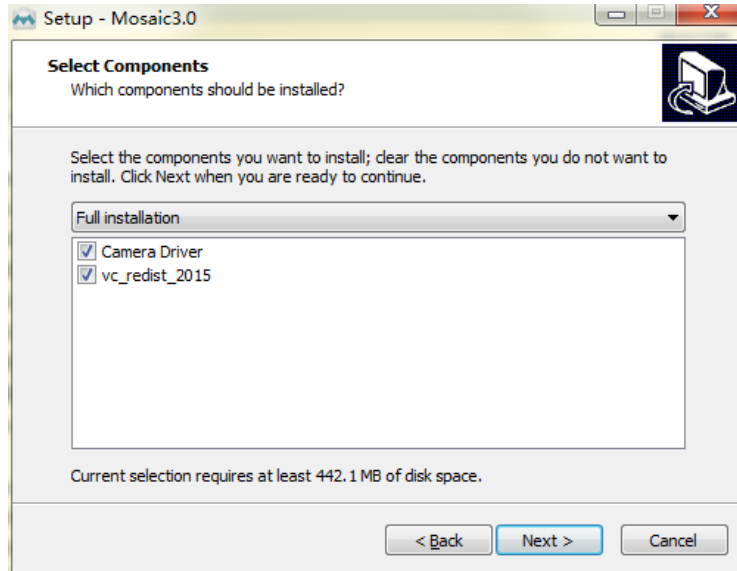


Figure 4-16

- (4) Configure installation parameters and select whether to generate desktop shortcuts;

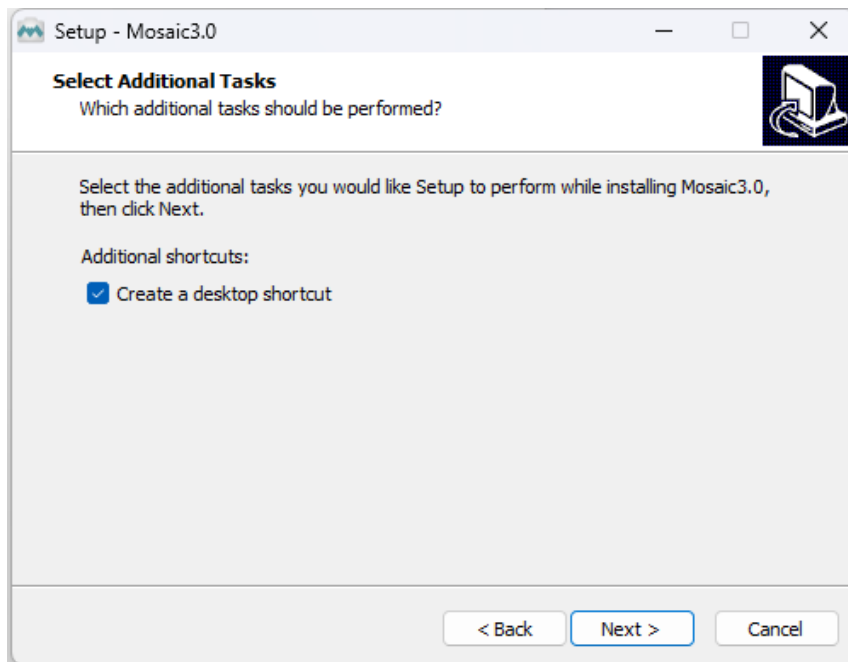


Figure 4-17

- (5) After confirming all installation parameters, click "Install" to start executing the installation action;

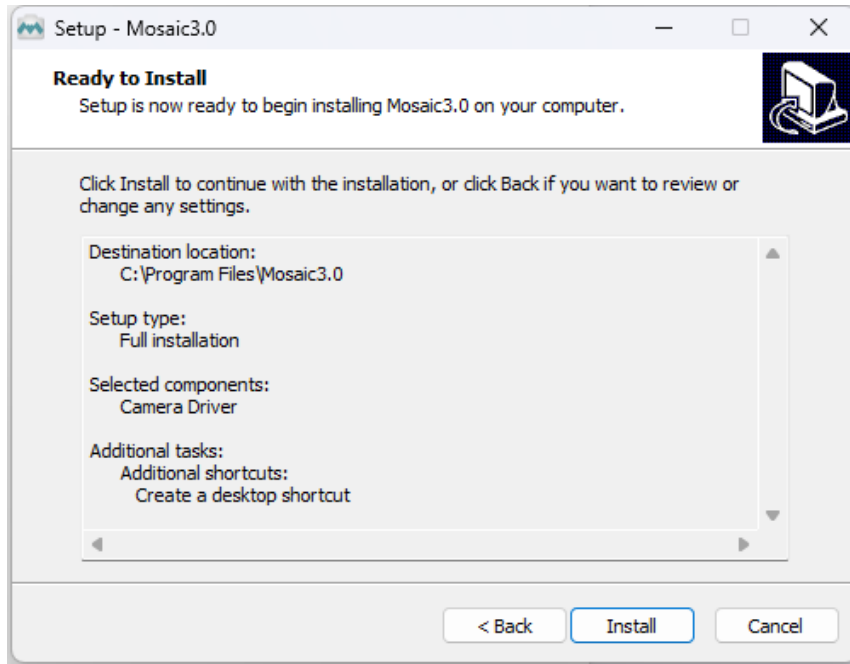


Figure 4-18

(6) Waiting for installation to complete;

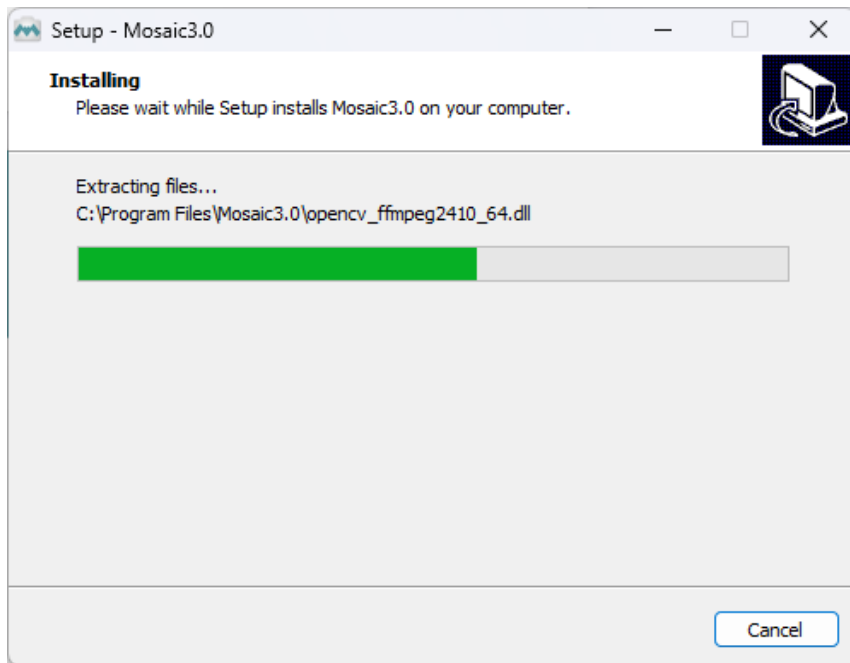


Figure 4-19

4.6.2. Uninstallation

There are three ways to uninstall Mosaic software:

- (1) By uninstalling through the installation package, the existing version on the computer will be uninstalled when the installation package runs, and the default C drive path will take effect;

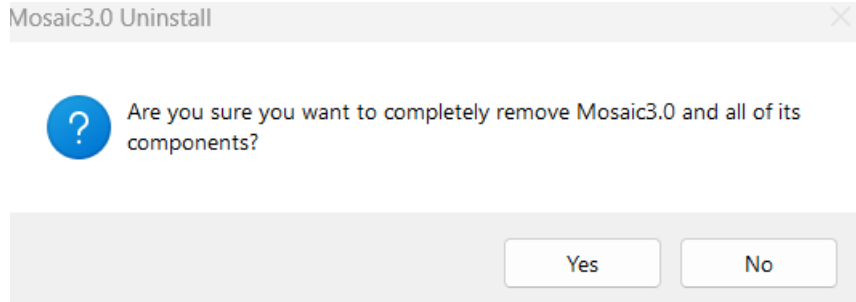


Figure 4-20 Uninstallation via installer

(2) Under the installation path, find unis000.exe to uninstall, double-click uninstall;

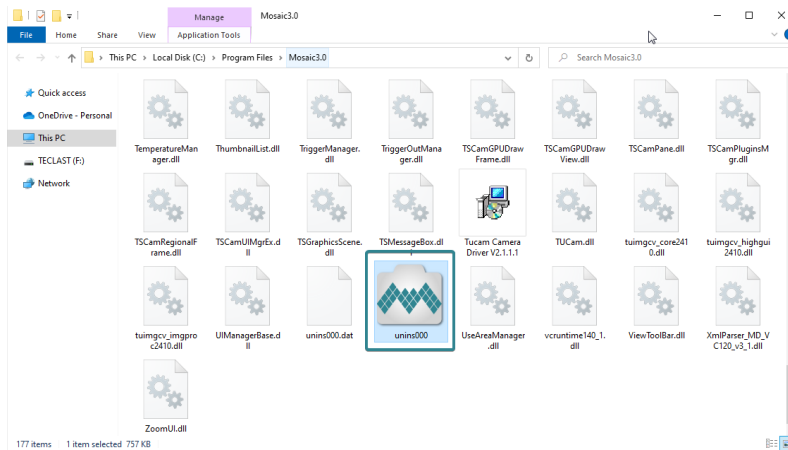


Figure 4-21

(3) Uninstall from the computer program management interface;

Note:

After uninstalling and reinstalling the software, all software configuration information and calibration table data will be deleted.

4.7. Connecting dual cameras to the acquisition card

Operation steps:

(1) Install the FireBird acquisition card on your computer and open the acquisition card software ActiveCapture.

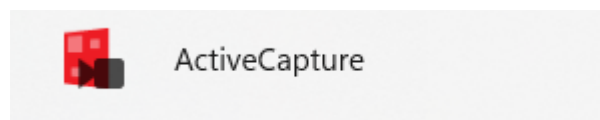


Figure 4-22

(2) Select Tools -> Flash Programming.

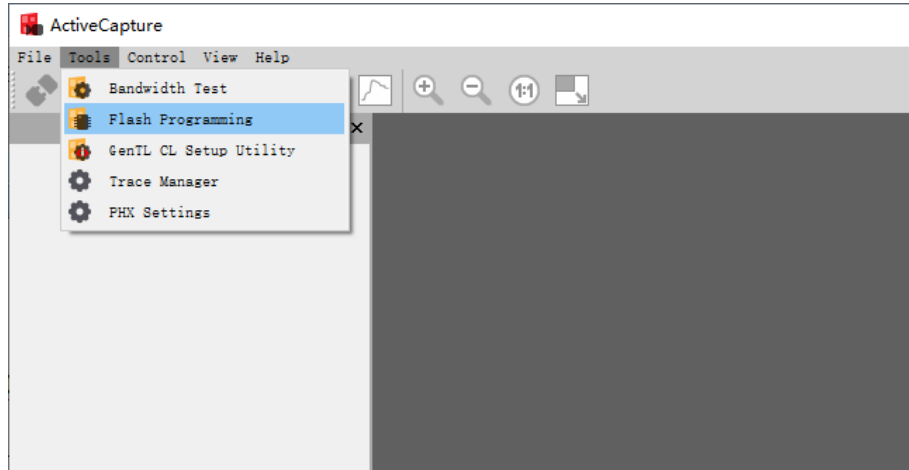


Figure 4-23

- (3) Change the Design from Default to Dual Base mode, click on Program Board(s) to apply the configuration, wait for the computer to restart. After the restart, repeat steps 1 to 3 to verify that the Design mode shows Dual Base, confirming the successful modification.

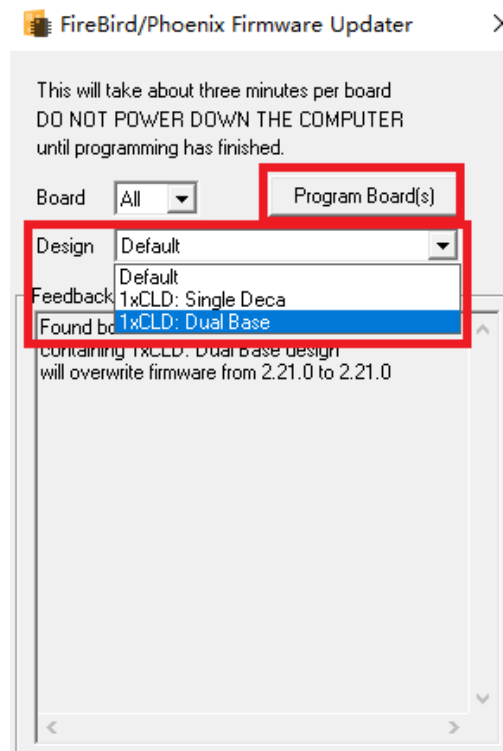


Figure 4-24

- (4) Power on both Aries 16 LT cameras, and connect them respectively to CameraLink-1 and CameraLink-2 ports on the FireBird acquisition card.
- (5) Open the Mosaic V3 software. The software should correctly recognize both cameras.

5. Maintenance

Damage caused by unauthorized maintenance or procedures will void the warranty.

5.1. Regular inspections

The product status should be regularly checked, especially the integrity of the external power supply and main cable, as well as the integrity of the power cord. Do not use damaged equipment.

5.2. Electrical safety inspection

- It is recommended to check the insulation and protective grounding integrity of the AC/DC converter every year
- Do not use damaged equipment

5.3. Cooling hoses and connectors

Users should regularly inspect all coolant hoses and connections for signs of leaks, damage, or wear. All seals must be intact before operating the camera system. Any worn or damaged parts must be replaced immediately.

5.4. Basic usage

- 1) Avoid opening the lens dust cap in a dusty environment;
- 2) Open the lens dust cap and mount the lens with the camera port facing downward to avoid dust falling on the surface of the windowpane;
- 3) If not used for a long time, please install the dust cover..

5.5. Window cleaning

If you notice stains or dirt spots in the images captured by the camera, first check whether the lens/objective at the camera interface or the microscope lens is dirty.

If neither of these is the cause and the issue is with the camera itself, you can clean the window as follows:

- 1) Start by using a blower to remove general dust. Use an ear syringe or blower to blow away common dust, and use a brush to remove most of the dust.
- 2) For stubborn oily dust, prepare dust-free cotton swabs (or specialized lens cleaning paper, non-woven fabric, etc.) and tools such as anhydrous ethanol.

- 3) Dip a dust-free cotton swab in an appropriate amount of anhydrous ethanol and gently wipe along the surface of the window. Avoid applying too much pressure during wiping, and always wipe in one direction to prevent back-and-forth wiping.
- 4) After wiping, use a blower or similar item to allow the alcohol on the window surface to completely evaporate before further use.

Note:

- 1) *If you cannot ensure independent completion of the cleaning steps or lack the necessary items, please contact us.*
- 2) *If after following the above steps the dirt remains, you can attempt to repeat the process. If the issue persists, it may be internal dirt on the sensor. In this case, please contact us immediately.*



6.

7. Troubleshooting

7.1. The computer cannot recognize the camera

- 1) Ensure the camera is powered on and functioning properly.
 - ① Confirm the camera is correctly connected to the computer.
 - ② For CameraLink, verify the cable connection at both ends.
- 2) For USB connection, use the USB 3.0 port at the rear of the desktop.
- 3) Verify that the drivers are functioning correctly by checking in the computer's Device Manager to see if the imaging device recognizes the camera.

7.2. Software pauses or freezes

- 1) The computer may be in power-saving mode, causing the CPU performance to decrease, which can lead to software issues such as dropped frames or freezing. Ensure the computer is set to high-performance mode.
- 2) Running too many applications on the computer can cause high CPU usage, resulting in low CPU utilization by the software and preventing it from functioning properly. Close unnecessary applications.
- 3) An abnormal connection of the data cable, such as a loose connection or using an excessively long or extended adapter, can cause software connection issues and prevent normal operation.

7.3. The camera cannot reach the target cooling temperature

- 1) Verify the ambient temperature. The camera's maximum cooling differential is -60°C (for water cooling).
- 2) Check if the exhaust vent is blocked.
- 3) Ensure the fan is operating properly.
- 4) If using water cooling, confirm that the liquid cooling system is functioning correctly.

7.4. The frame rate cannot reach the nominal level

- (1) Verify if exposure time affects frame rate. You can set the minimum exposure time to confirm the frame rate.
- (2) The frame rates in the table are measured under ideal bandwidth conditions. Actual frame rates in real-world scenarios may be affected by data transmission, depending on

the data interface type and cable length.

- (3) Confirm if the correct data transmission interface is used. USB requires a USB 3.0 interface; using a non-3.0 interface may result in frame rates not reaching nominal values.
- (4) If you are using a USB 3.0 interface but have connected through HUB/extension/expansion operations, it may also prevent achieving nominal frame rates.
- (5) For users who require high-speed image storage, if the frame rate cannot reach the nominal value using the CameraLink interface, it is necessary to check whether the bandwidth of the grabber card is limited/whether the recommended grabber card interface is used;
- (6) For users who require high-speed image storage, if the frame rate cannot reach the nominal value using the CameraLink interface, it is necessary to check whether the bandwidth of the acquisition card is limited/whether the recommended acquisition card interface is used.

8. FAQs

8.1. Why is the brightness of the captured image different from the preview window?

When using the camera for the first time and the target is dark, the software preview may show an all-black image. It is recommended to check Auto Left Scale (Auto Min) and Auto Right Scale (Auto Max) in the Histogram setting area, in which case the software preview will show the most suitable brightness and contrast. However, when you save the image, the default image saved by the software will not save the effect of auto colour gradation, resulting in inconsistency between the preview image and the captured image.

You can try the following solutions:

- 1) Disable the automatic color range adjustment in the software settings. This will ensure that the preview image matches the saved image.
- 2) Use a professional image viewing tool such as ImageJ to open the TIFF images and adjust the color range as needed.
- 3) When using Mosaic V3 software for image capture, you can select "Save adjusted image" in the capture section (useful when original image data values are not required).

8.2. Stripe like flicker appears in the camera preview image

May be caused by an external light source that is not synchronized. There may be a strobe light source in the environment, which can be judged by extending the exposure time. If it is an ambient light source, turning off the illumination source is sufficient. If from an irradiated sample light source, a regulated light source is required for illumination.

9. After-sales Support

- 1) Obtain software-related information and technical support information from the official website [support] -> [FAQs].

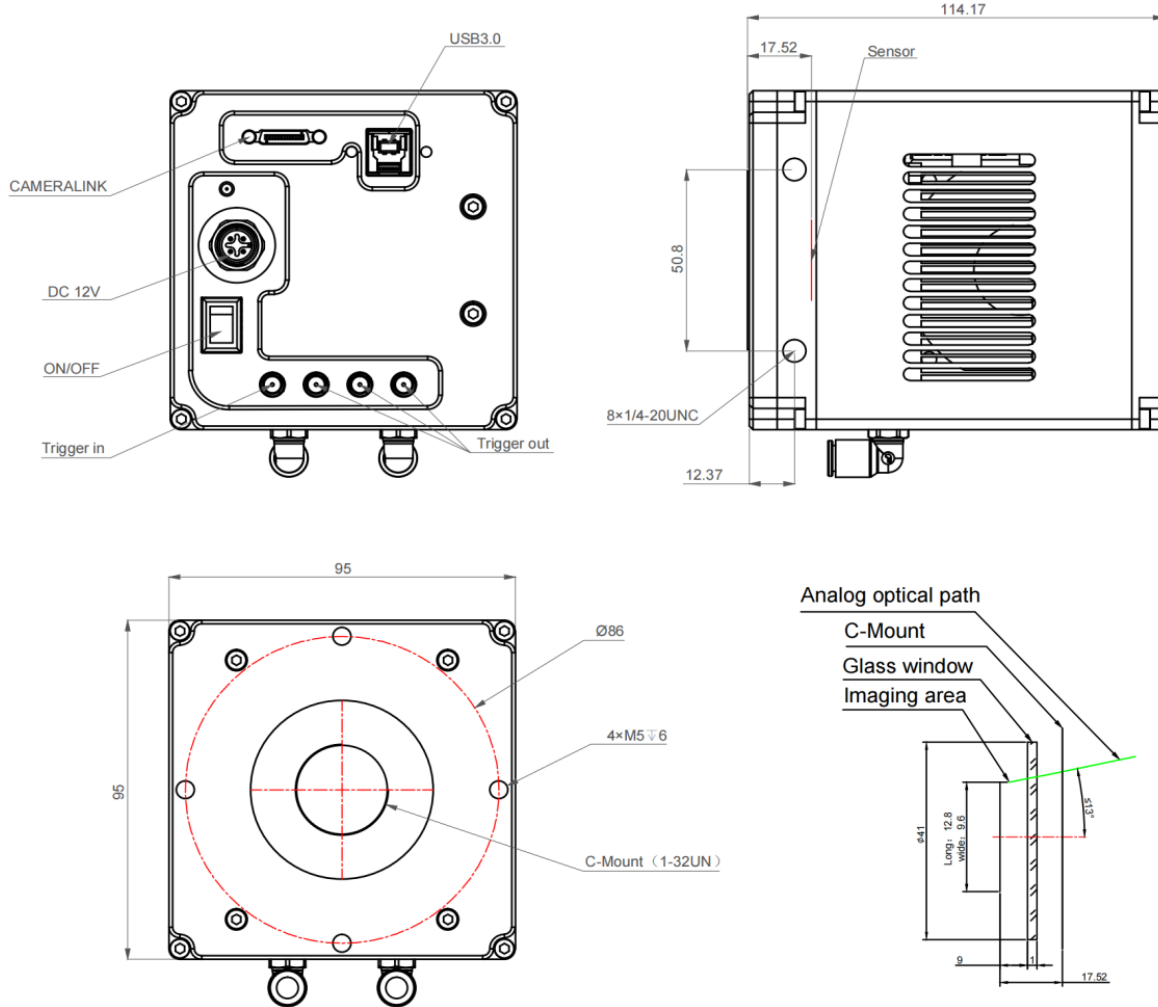
- 2) Warranty:
 - The quality assurance period starts from the date of shipment and lasts for a total of 24 months. During this period, any damage that meets the warranty requirements will be repaired free of charge;
 - The warranty scope is limited to defects in product materials and manufacturing. Damage caused by self disassembly, water ingress, littering, or natural disasters is not covered by the warranty.

- 3) Contact technical support:
 - TEL: +86-591-28055080-818
 - Email: service@tucsen.com
 - Or landing the official website to leave a message: <http://www.tucsen.com>.

- 4) Please have the following information prepared:
 - Camera model and S/N (product serial number);
 - Software version number and PC system information;
 - Description of the problem and any images related to the problem.

Appendix 1:Dimensions

Unit: mm, Diameter: ϕ .



Appendix 2: Specifications

Model	Aries 16
Sensor Type	BSI sCMOS
Sensor Model	SONY IMX571BLR-J
Peak QE	90.7% @ 550 nm
Color / Mono	Mono
Array Diagonal	16mm
Effective Area	12.8 mm x 9.6 mm
Resolution	800(H) x 600 (V)
Pixel Size	16 μm x 16 μm
Full-Well Capacity	Typ.:73 ke-
Dynamic Range	Typ.: Dynamic Range
Frame Rate	60fps @ HDR mode, 25fps @ Low noise mode
Readout Noise	Typ.: 1.6 e- @ HDR mode, 0.9 e- @ Low noise mode
Shutter Type	Rolling, Global Reset
Exposure Time	26.694 μs ~ 60 scc
DSNU	0.3 e-
PRNU	0.3 %
Cooling Method	Air , Liquid
Max. Cooling	50°C below ambient (Air), 60°C below ambient (Liquid)
Dark Current	0.2e-/pixel/s
Binning	2x2, 4x4, Any bin
ROI	Support
Timestamp Accuracy	1 μs
Trigger Mode	Hardware , Software
Output Trigger Signals	Exposure start, Global, Readout end, High level, Low level
Trigger Interface	SMA
Data Interface	USB 3.0, CameraLink
Bit Depth	12 bit, 16 bit
Optical Interface	C-mount
Power Supply	12 V / 8 A
Power Consumption	~38 W
Dimensions	95 mm x 95 mm x 114.17 mm
Weight	1500 g
Software	Mosaic, SamplePro , LabVIEW , MATLAB , Micro-Manager2.0

SDK	C, C++, C#,Python
Operating System	Windows, Linux
Operating Environment	Temperature 0~40°C, Humidity 10~85%

Frame grabber

Brand	Active Silicon
Model	AS-FBD-1XCLD-2PE4-M
Operating System	Windows、Linux
Bus	PCIe 2x4, supports 2GB/s transfer from motherboard to computer
Transmission Speed	1.7 GB/s
Format	Half length PCI Express

Note: The parameters in this table are typical values and are subject to change without notice.



Appendix 3:Third party software applications

Provide plugins for third-party software (LabVIEW, Matlab, Micro-Manager, etc.). Please click the link to download the configuration:[Tucsen camera software download - Tucsen](#)

Appendix 4: Dew Point Table

		Humidity							
		20%	30%	40%	50%	60%	70%	80%	90%
Temperature	5							1.8	3.5
	6							2.8	4.5
	7						1.9	3.8	5.5
	8						2.9	4.8	6.5
	9					1.6	3.8	5.7	7.4
	10					2.6	4.8	6.7	8.4
	11					3.5	5.7	7.7	9.4
	12				1.9	4.5	6.7	8.7	10.4
	13				2.8	5.4	7.7	9.6	11.4
	14				3.7	6.4	8.6	10.6	12.4
	15			1.5	4.7	7.3	9.6	11.6	13.4
	16			2.4	5.6	8.2	10.5	12.6	14.4
	17			3.3	6.5	9.2	11.5	13.5	15.3
	18			4.2	7.4	10.1	12.4	14.5	16.3
	19		1.0	5.1	8.4	11.1	13.4	16.4	18.3
	20		1.9	6.0	9.3	12.0	14.4	16.4	18.3
	21		2.8	6.9	10.2	12.9	15.3	17.4	19.3
	22		3.6	7.8	11.0	13.9	16.3	18.4	20.3
	23		4.5	8.7	12.0	14.8	17.2	19.4	21.3
	24		5.4	9.6	12.9	15.8	18.2	20.3	22.3
25	0.5	6.2	10.5	13.9	16.7	19.1	21.3	23.2	
26	1.3	7.1	11.4	14.8	17.6	20.1	22.3	24.2	
27	2.1	8.0	12.3	15.7	18.6	21.1	23.3	25.2	
28	3.0	8.8	13.2	16.6	19.5	22.0	24.2	26.2	
29	3.8	9.7	14.0	17.5	20.4	23.0	25.2	27.2	



Appendix 5: Update log

Version	Date	Modify Content
V1.0.0	2024-5-31	Create documents