(T)TS65MU30-5M/C Area Scan Camera User Manual

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Hefei I-TEK Optoelectronics Co., LTD.

http://www.i-tek.cn/

Revision History

Revision	Date	Description
0.1	2020/06/16	● Initial release
0.2	2021/04/12	● Add the TS65MU30 camera information ● Update the product appearance, power consumption and mechanical dimensions of the TTS65MU30 camera ● Correct schematic diagram of test image
0.3	2021/12/20	● Update the strobe output schematic
0.4	2022/01/10	● Update the name of company
0.5	2022/04/25	● Update the logo of company
0.6	2022/07/13	● Update power consumption of TTS65MU30
0.7	2023/02/11	● Update company address
0.8	2023/10/12	● Update chapter 7 ● Update camera parameter table

Manufacturer Information

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Contents

1 Precautions

- **General**

① Do not drop, damage, disassemble the camera.
② Do not let children touch the camera without supervision.
③ Do not use the camera for other purposes than those specified herein.
④ Should there be any problem with the camera, please contact us in time for technical support.

- **Installation and Maintenance**

① Do not install the camera in an environment with direct sunlight, high humidity or heavy dust.
② Keep the camera away from an environment with strong electromagnetic interference.
③ Keep the camera away from heat sources.
④ Be careful not to let the camera soak in liquid, such as water and drinks.
⑤ Clean dust on the surface of the camera as often as possible to avoid dust entering the camera, otherwise it may cause fault to the camera.
⑥ To clean the dust on the camera surface, do not wash with water. Please use a soft object dipped in a small amount of 70% alcohol to wipe it off.

- **Power Supply**

①The recommended voltage is +12V±10%, TS65MU30 camera current must be 1.5A, TTS65MU30 camera current must be 5.0A.
② Hefei I-TEK Optoelectronics Co., LTD. does not provide power supply with the camera, users may prepare the power supply on their own.

- **Document**

① Hefei I-TEK Optoelectronics Co., LTD. does not warrant that the document is the final version. The document may be updated after product upgrade. Please contact market@i-tek.cn for the latest version, which is provided for the authorized users free of charge.

2 Camera Models

- **Camera Product Model**

Abbreviation	Name	Description
Line Scan Camera:		
PA	Panther	Panther (Single line industrial line scan camera)
PL	Plasma	Plasma (Multi-line industrial line scan camera)
PH	Phoenix	Phoenix (TDI industrial line scan camera)
TPH	TEC-Phoenix	TEC-Phoenix (TEC-TDI industrial line scan camera)
PN	Pneuma	Pneuma (Basic industrial line scan camera)
PR	Prometheus	Prometheus (High resolution industrial line scan camera)
PU	PupMaya	PupMaya (High width industrial line scan camera)
PT	Ptepare	Ptepare (Special custom industrial line scan camera)
PM	Prism	Prism line scan camera
Area Scan Camera:		
TM	Taurus-Prism	Prism area scan camera
HS	Hercules	Hercules (CCD industrial area scan camera)
TS	Taurus	Taurus (CMOS industrial area scan camera)
THS	TEC-Hercules	TEC-Hercules (CCD TEC industrial area scan camera)
TTS	TEC-Taurus	TEC-Taurus (CMOS industrial area scan camera)
XS	XStream	XStream (Super high speed camera)

- **Interface Specification**

Abbreviation	Interface Type
GV	GigE Vision
CL	Camera Link
CXP/CXP10/CXP12	CoaXPress
U30	USB3.0
XGV	10 GigE Vision
PCIe	PCI-Express
SFP	Small Form Pluggable

- **Color Form**

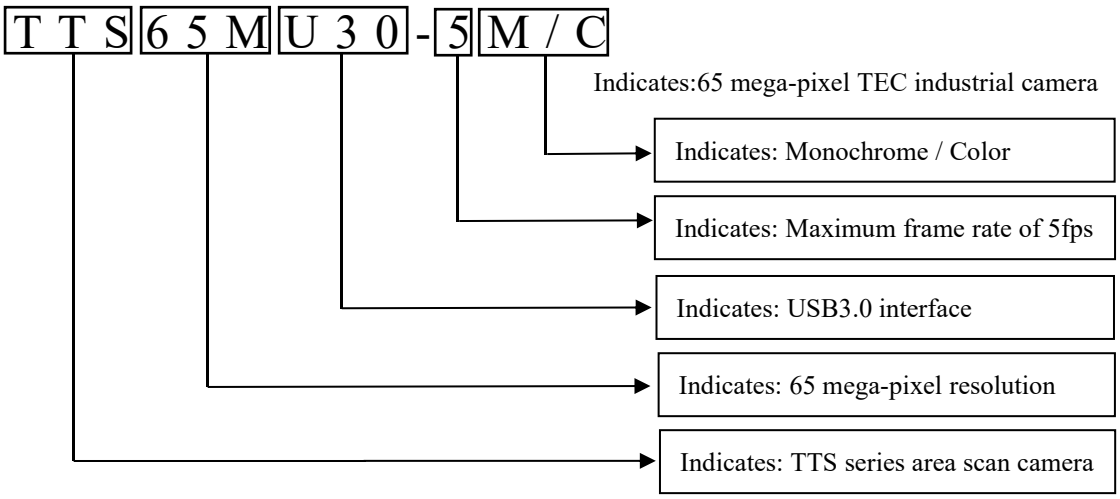
Abbreviation	Image Mode
M	Monochrome
C	Color
F	Full Color
T	Monochrome TDI (Time Delay Integration)
X	Time Division Camera
U	UV (Ultraviolet)
N	NIR (Near Infrared)

S	SWIR (Short Wave Infrared)
W	MWIR (Middle Wave Infrared)
L	LWIR (Long Wave Infrared)

- **Line Rate or Frame Rate**

Camera Type	Description
Line Scan Camera	Maximum line rate, e.g. 30kHz
Area Scan Camera	Maximum frame rate, e.g. 4000fps

e.g.



3 Product Appearance

TS65MU30 camera:

TTS65MU30 camera:

Fig.1 Product Appearance

Note:

① The front and the side of camera provide threaded holes for mounting camera.

② Please refer to “Mechanical Dimensions and Interfaces” below for detailed camera dimensions.

4 Product Specifications

(T)TS65MU30 camera adopts advanced global shutter CMOS image sensor and USB3.0 interface. It is a high-speed area scan camera designed for industrial measurement and detection. It has high reliability and stability, and is suitable for image acquisition with high requirements (high resolution, high speed) occasions, such as surface detection, electronic mount detection.

4.1 Main Features

- Global Shutter CMOS Sensor
- 65 Mega-Pixel Resolution
- Full Frame Rate up to 5fps
- High Sensitivity and Low Noise
- ROI
- Flexible Exposure Mode Control (External Trigger, Free-Run)
- Minimum Exposure Time: 22us, Exposure Time Step: 1us
- Output Pixel Format: 8/12bit
- LUT
- Defect Pixel Correction
- White Balance
- Flat Field Correction
- Strobe
- Analog Gain / Digital Gain / Offset Control
- User-configurable Scanning Direction
- Real-time Temperature Monitor

4.2 Camera Specifications

Table 1 (T)TS65MU30-5M/C Product Specifications

Model	TS65MU30-5M/C	TTS65MU30-5M/C
Product Description	65 mega-pixel industrial camera	65 mega-pixel TEC industrial camera
Resolution	9344 x 7000	
Pixel Size	3.2um x 3.2um	
Sensor Type	Global shutter CMOS	
Image Type	Monochrome / Color	
Sensor Size	37.36mm (diagonal)	
Dynamic Range	≥66dB	
SNR	40dB	
Data Rate	350MB/s	
Lens Mount	M58/F Mount	M42/F Mount
Max. Frame Rate	5.32fps@8bit, 2.55fps@12bit	
Analog Gain	0~64	
Analog Offset	0~4095	

Digital Gain	0.01~8	0.1~8
Digital Offset	-4095~4095	
Trigger Mode	External trigger, Free-Run	
External Trigger	External IO / Software trigger	
Exposure Control	Pulse Width Control, Timed	
Exposure Time	22us~10s (step: 1us)	
Data Format	8/12bit	
Operating Temperature	0~45°C	0~50°C
Data Interface	USB3.0	
Power Supply	DC 12V±10% 1.5A	DC 12V±10% 5.0A
Power Consumption	11.2W	TEC on: 44.2W TEC off: 12.8W
Mechanical	75mm x 75mm x 99.5mm	111mm x 111mm x 124mm
Cooling Method	/	TEC and an external fan

Note: This table is for 0304-900A version of (T)TS65MU30 camera specifications, which may vary slightly from version to version.

4.3 Camera Block Diagram

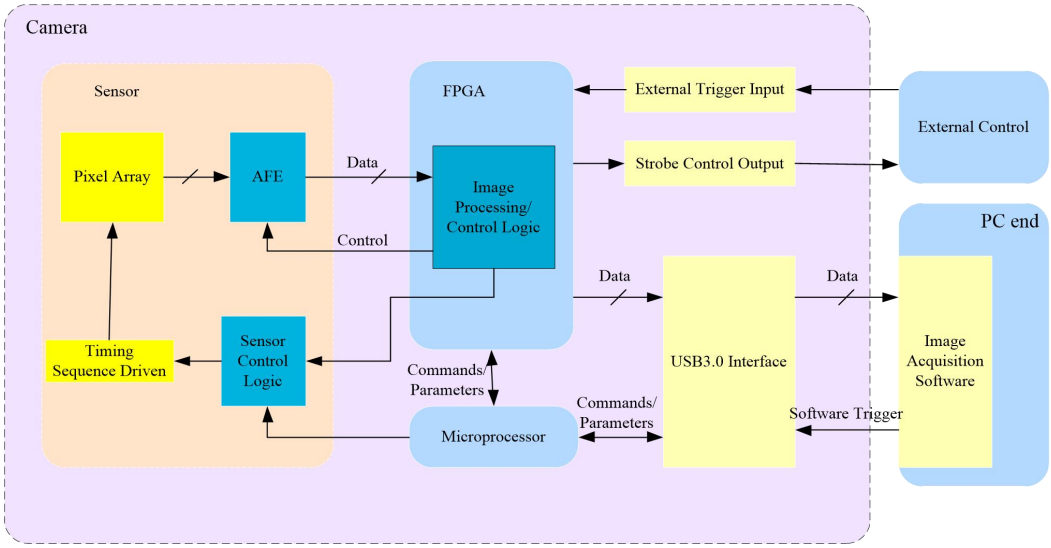


Fig.2 Internal Implementation Structure of Camera

(T)TS65MU30 camera uses a unified architecture to achieve image sensor control, data transmission and embedded algorithm processing with different resolutions. The internal structure of the camera is shown in figure above. The pixel array is uniformly sampled and maintained by the global shutter control system, converted into digital signals by analog front end, processed by FPGA and microprocessor, and transmitted to the PC acquisition software through USB3.0 interface.

(T)TS65MU30 camera can accept external signal trigger acquisition, the source is IO signal or software

trigger signal. At the same time, the camera can also output synchronization signal during exposure, which is convenient for external strobe control.

4.4 Spectral Response

The spectral response diagram of (T)TS65MU30 camera is shown below.

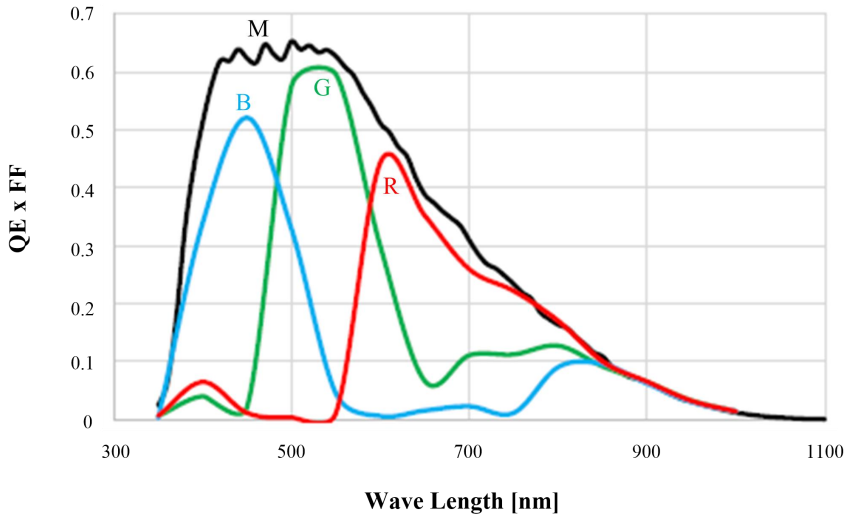


Fig.3 Spectral Response

4.5 Camera Bayer Pattern

(T)TS65MU30 camera supports color mode, Bayer pattern is shown in figure below (HR is horizontal resolution, VR is vertical resolution) :

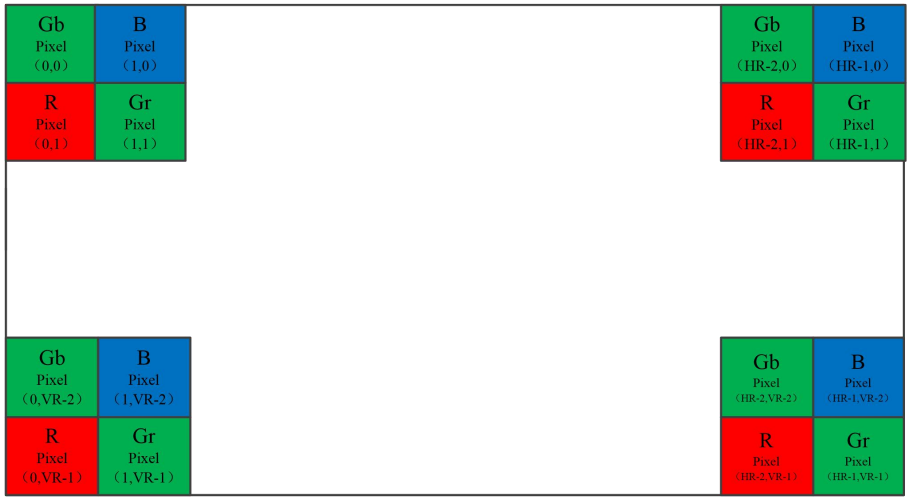


Fig.4 Camera Bayer Pattern

4.6 Environmental Requirements

(1) Operating temperature: TS65MU30 camera: 0℃~45℃, TTS65MU30 camera: 0℃~50℃, humidity: 10%~80%; Storage temperature:-20℃~75℃.

(2) The sensor in the camera has dustproof sealing setting, which can effectively prevent dust from entering the sensor surface. If the lens cap is open, dust may enter. Therefore, tighten the lens cap when the camera is not in use.

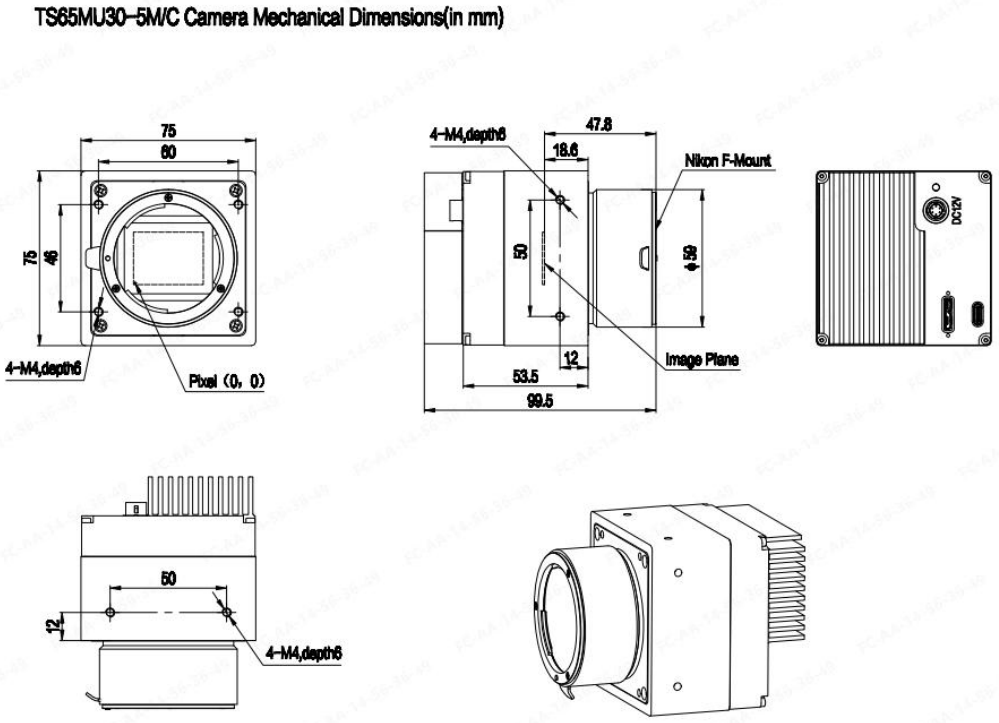
4.7 RoHS Certification

All camera components (including electronic components, PCB, and shell) are RoHS compliant.

5 Mechanical Dimensions and Interfaces

5.1 Mechanical Dimensions

TS65MU30 camera:



TTS65MU30 camera:

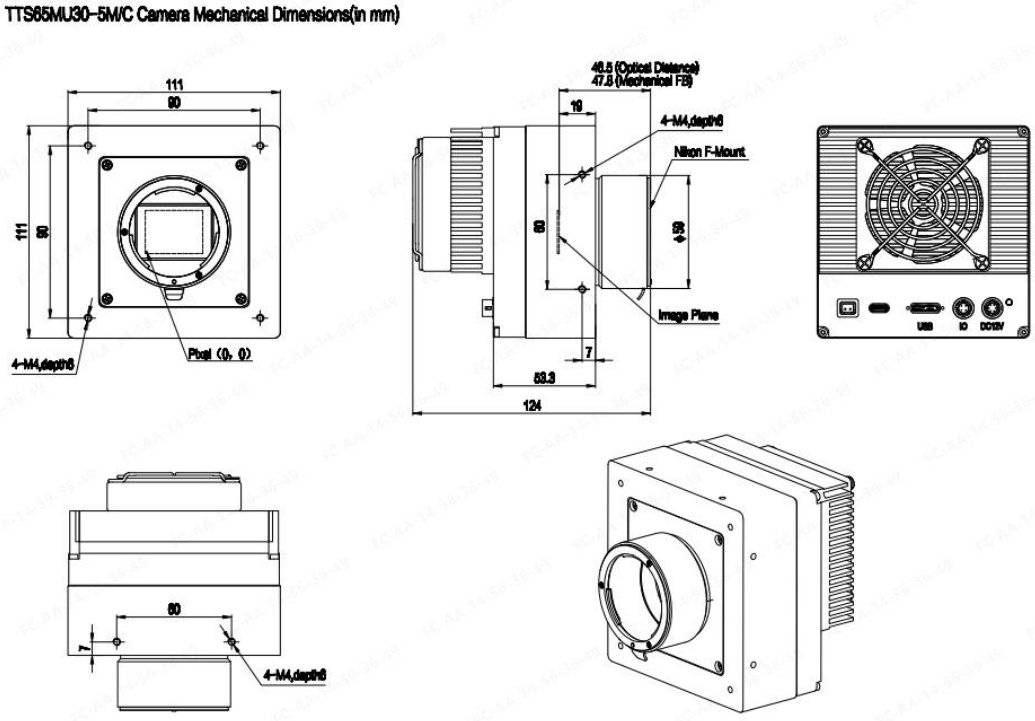


Fig.5 Camera Mechanical Dimensions

5.2 Camera Interface

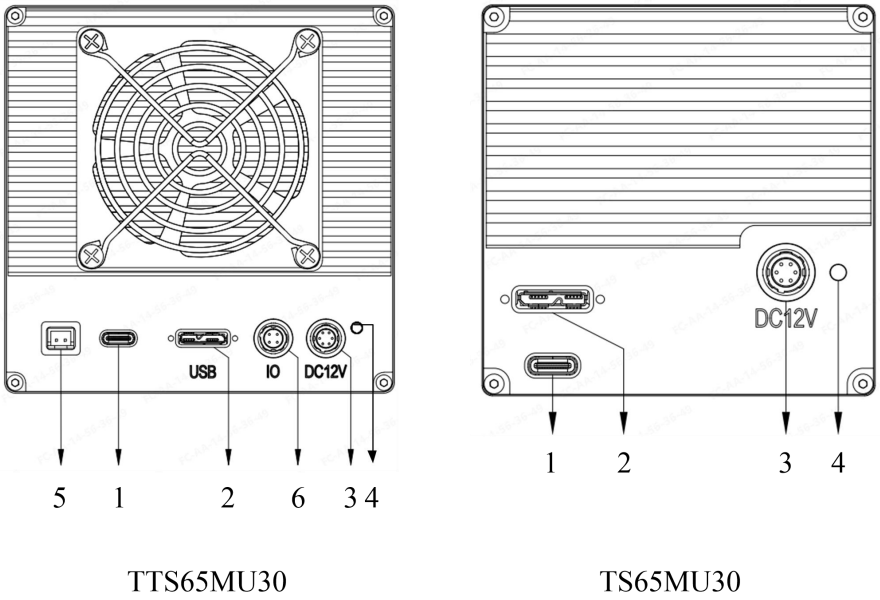


Fig.6 External Interfaces of Camera

① Type-C Interface
② Micro USB 3.0 Interface
③ 6-pin Power Interface
④ Camera Status Indicator
⑤ Fan Power Interface (TTS65MU30 camera)
⑥ 4-pin Control Interface (TTS65MU30 camera)

5.2.1 Camera Status Indicator

Camera status indicator is used to indicate the real-time status of camera, as shown in the table below:

Table 2 Camera Status Indicators

LED Status Indicators	Camera Status
Solid Green	Normal
Blinking Green	No trigger input within three seconds in external trigger mode
Solid Red	Processor is starting
Blinking Red	Camera fatal error (need contact technical support)
Solid Yellow	Camera is initializing or executing command

5.2.2 Power Interface

Power interface adopts 6-pin connector with the model:
Hirose HR10A-7R-6PB(Male).

Corresponding connector on the cable model:
Hirose HR10A-7P-6S(Female).

Power interface on the back of the camera is shown as follows:

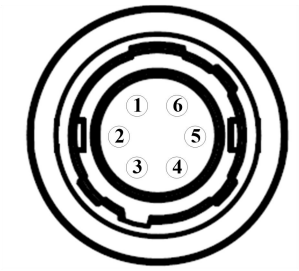


Fig.7 Assignments for Interface

Table 3 Pin Configurations for Interface (TS65MU30)

Signal	Pin	Signal	Pin
Power	1	Trigger in_GND	4
Power	2	GND	5
Trigger in	3	GND	6

Trigger input circuit is as follows:

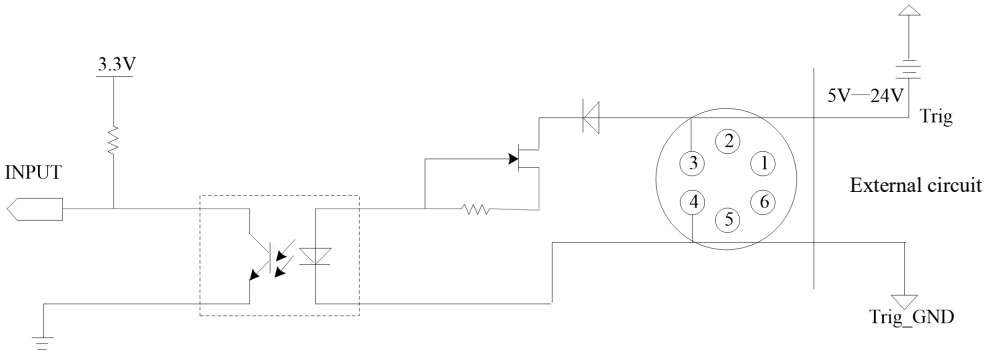


Fig.8 Trigger Input Circuit Schematic

- Trigger voltage range: 5~24V

Table 4 Pin Configurations for Interface (TTS65MU30)

Signal	Pin	Signal	Pin
+12 V	1	GND	4
+12 V	2	GND	5
+12 V	3	GND	6

5.2.3 Control Interface

Control interface adopts 4-pin connector with the model:
Hirose HR10A-7R-4PB(Male).

Corresponding connector on the cable model:

Hirose HR10A-7P-4S(Female).

Control interface on the back of the camera is shown as follows:

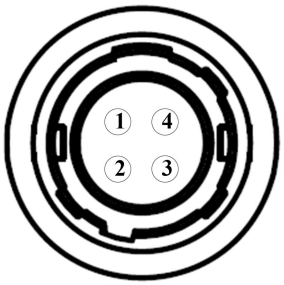


Fig.9 Assignments for Interface

Table 5 Pin Configurations for Interface

Signal	Pin	Signal	Pin
Trigger In +	1	GND	3
Trigger In -	2	Strobe Out	4

The schematic diagram of Trigger input circuit and Strobe output circuit is shown below:

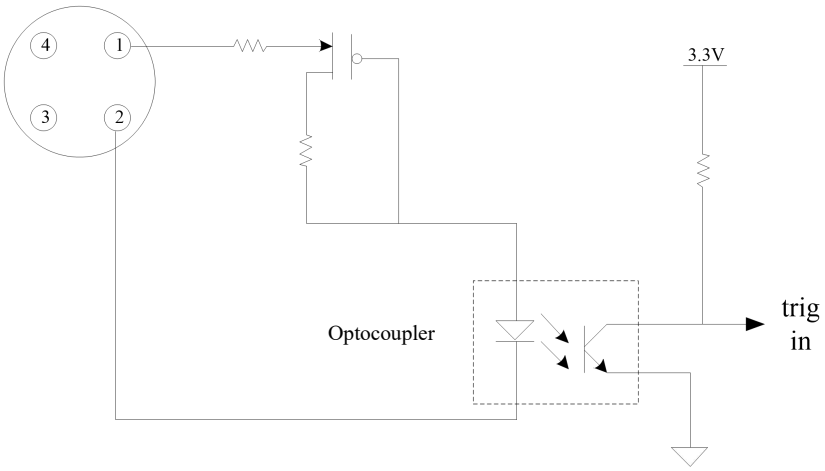


Fig. 10 Trigger Input Circuit Schematic

- Trigger voltage range: 2.5~24V
- Minimum pulse width: 1us

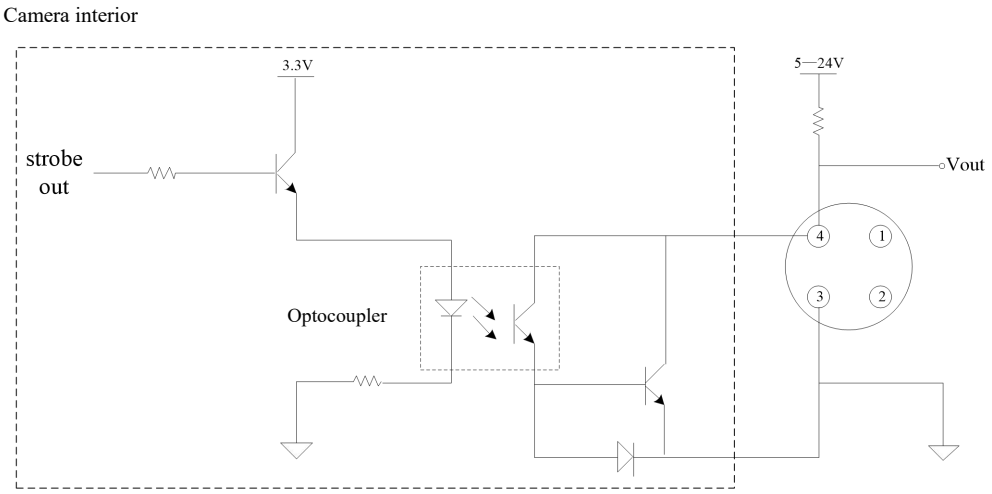
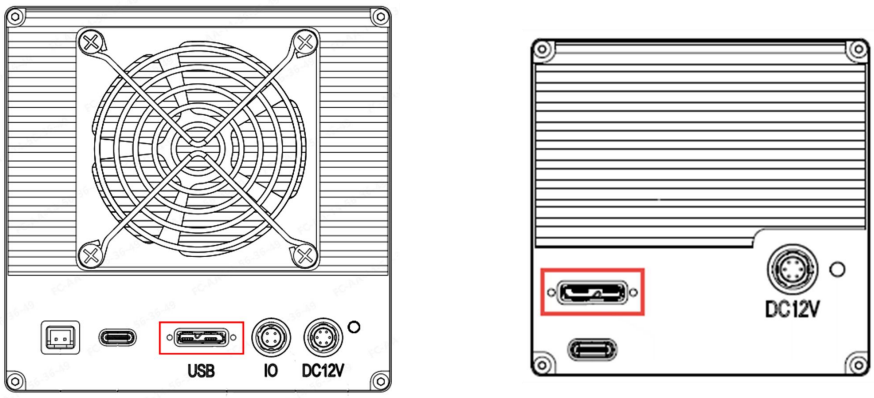


Fig. 11 Strobe Output Circuit Schematic

- Strobe external pull-up voltage range: 5~24V

5.2.4 Data Interface

Camera uses USB3.0 data interface, as shown in the red block diagram below:



TTS65MU30 TS65MU30

Fig.12 Data Interface

USB3.0 is a new generation of USB interface with a very fast transmission rate, the maximum transmission rate can reach 350MB/s.

6 Camera Features

This chapter details the internal features of (T)TS65MU30 camera.

6.1 Trigger Mode

(T)TS65MU30 camera supports three trigger modes: Free-Run mode, External Pulse mode and External PWM mode.

6.1.1 Free-Run Mode

In Free-Run mode, camera generates relevant control sequence internally according to frame period and exposure time parameters configured by users and outputs the image.

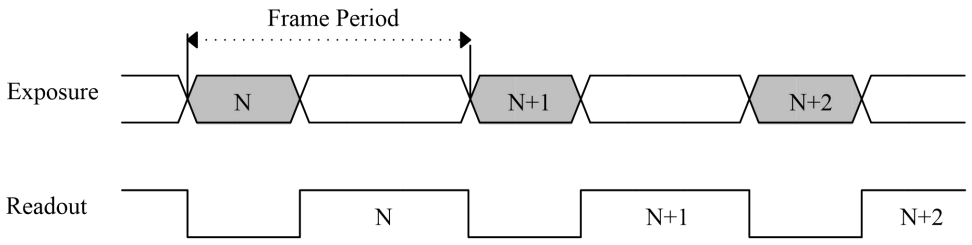


Fig.13 Free-Run Mode

To achieve normal image output, (T)TS65MU30 camera limits the range of frame periods and exposure times. The minimum frame period should be greater than both the exposure time and the readout time of one frame of data.

6.1.2 External Pulse Mode

In External Pulse mode, camera starts to expose at rising edge of external trigger signal, and exposure time length is configured by users commands (consistent with the Free-Run mode). The frame rate of camera output image is determined by interval between rising edge of external trigger pulse.

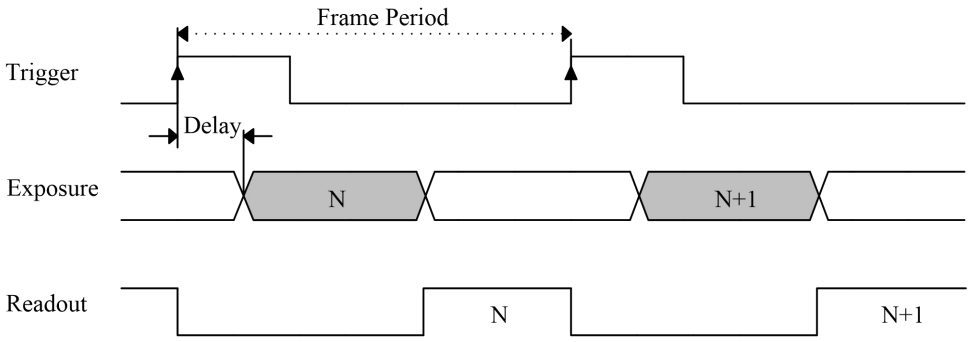


Fig.14 External Pulse Mode

External trigger signal can be selected as input from the external IO interface or software trigger input, and the input source is selected by the user through instructions. In order to achieve a higher frame rate, a new trigger pulse can be initiated while the camera reads data after the previous frame exposure ends. In this fast mode, since it is necessary to ensure that the reading stages of the two frames before and

after do not conflict, external triggers with intervals less than 1 frame of reading time will be automatically ignored by the camera, as shown in the following figure.

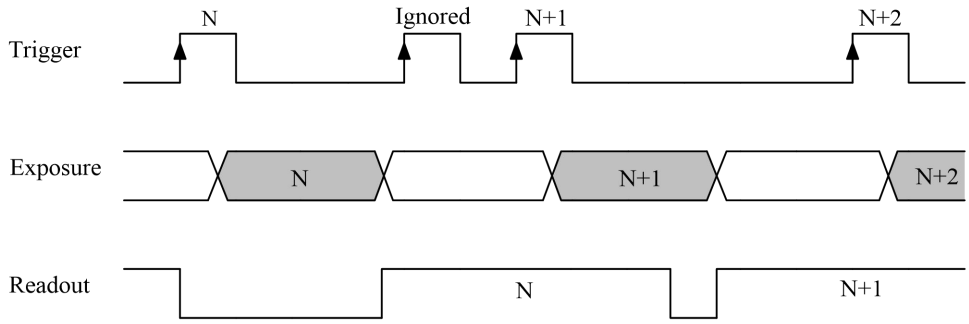


Fig.15 External Trigger Interval is too short

6.1.3 External PWM Mode

In External PWM mode, camera starts to count high level length at the rising edge of external trigger signal, and exposure begins at the falling edge of external trigger signal. The actual exposure time is equal to high level duration of external trigger signal, and frame period is equal to pulse interval.

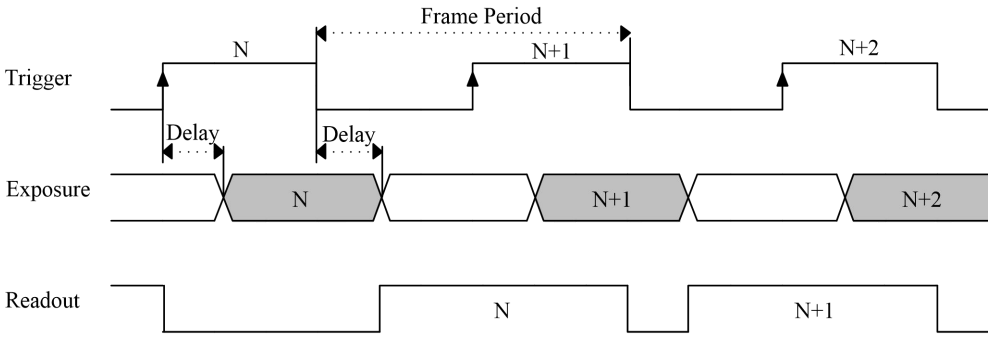


Fig.16 External PWM Mode

Please note that in this mode, the width of external trigger high level should be greater than minimum exposure time. In fact, for pulses less than minimum exposure time, camera will always process them according to minimum exposure time.

If the external trigger interval is too short, it will cause a conflict in the readout time of the two frames before and after the camera. At this time, the camera will ignore the pulses that do not meet the requirements internally, allowing the camera to maintain normal operation. Therefore, in this mode, it should be ensured that the distance between the falling edges of adjacent external triggers is greater than the readout time of one frame.

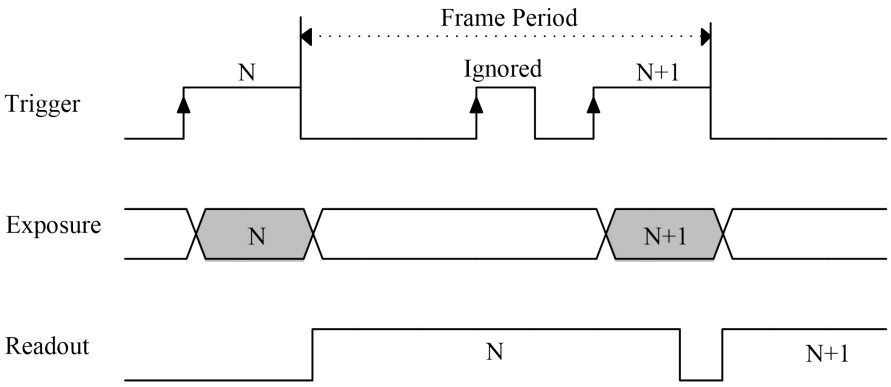


Fig.17 External Trigger Interval is too short

6.2 ROI

Region of interest (ROI) is part of a specified sensor array. Users can obtain frame data from a specified part of the sensor array with the same frame quality as from the entire sensor array. When the starting point and the number of pixel lines are specified in both horizontal and vertical directions, the ROI is determined to be an overlap of the two regions, as shown in the figure below.

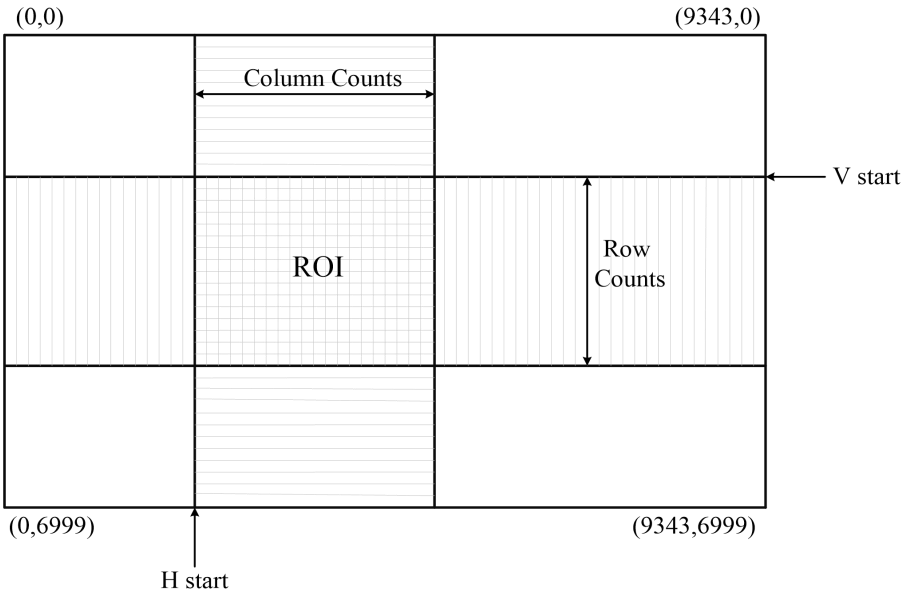


Fig.18 Region of Interest

Table 6 Maximum Frame Rate Depending on ROI Values

ROI Size H	ROI Size V	8bit	12bit
9344	7000	5.32fps	2.55fps
8960	7000	5.38fps	2.60fps
7936	7000	5.47fps	2.84fps
6912	7000	6.76fps	3.35fps
5888	7000	7.11fps	3.94fps
4992	7000	7.11fps	4.70fps

3968	7000	7.11fps	5.93fps
2944	7000	7.11fps	7.11fps
1920	7000	7.11fps	7.11fps
896	7000	7.11fps	7.11fps
9344	6000	6.05fps	3.00fps
9344	5000	7.29fps	3.53fps
9344	4000	9.16fps	4.41fps
9344	3000	11.88fps	5.97fps
9344	2000	18.99fps	9.76fps
9344	1000	35.82fps	18.60fps

6.3 LUT

The LUT uses a 12bit input and 12bit output look-up table to map and convert the values of the original image. Users can use this function to implement gamma correction.

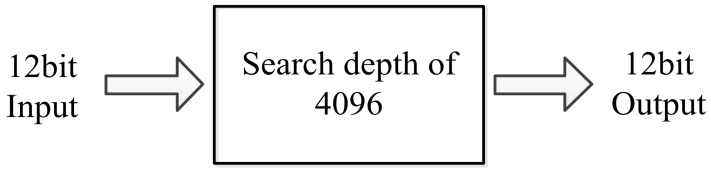


Fig.19 LUT Structure

The following figure is the LUT mapping curve with Gamma=0.5:

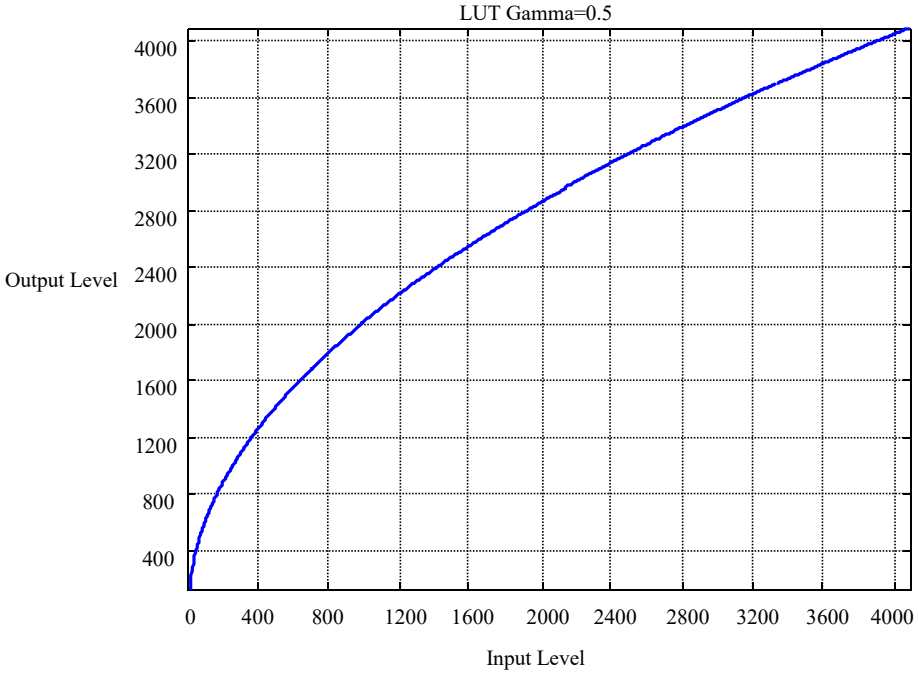


Fig.20 LUT: Gamma = 0.5

6.4 Image Flipping

(T)TS65MU30 camera can make the image flip along the X/Y direction, or both can be used in combination. Users can use this feature to change the camera scan direction, as shown below:

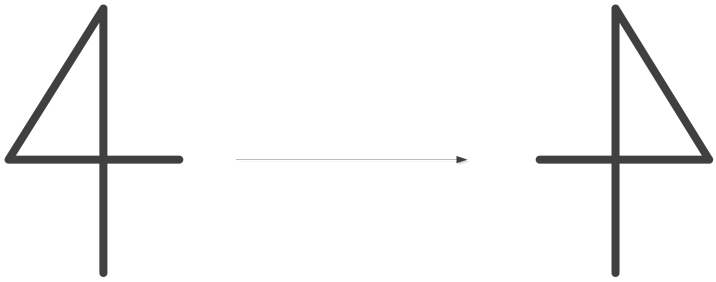


Fig.21 Flip in X Direction

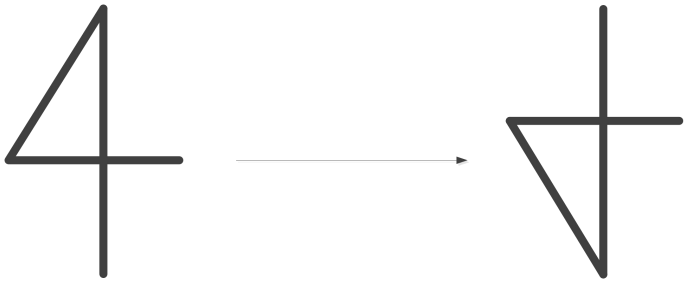


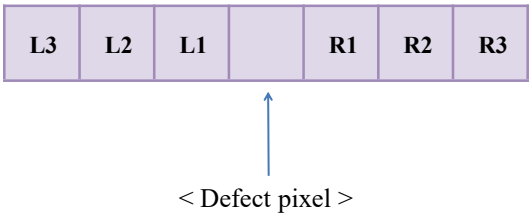
Fig.22 Flip in Y Direction

6.5 Defect Pixel Correction

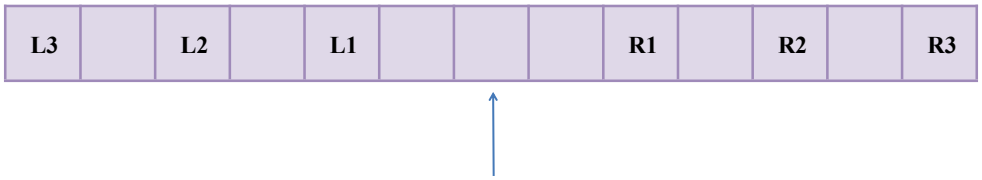
Due to the defects of the material itself and the issue with the process flow of semiconductor production, there are usually a certain number of pixels in area scan imaging sensors that cannot properly response to the input light, which we call defect pixels. (T)TS65MU30 camera provides with defect pixel automatic correction feature. The defect pixel information of the imaging sensor is written into the camera before the camera is delivered out of the factory. Users can control whether to enable the defect pixel correction, add new defect pixels and read out the current defect pixel list from the camera.

The correction method of defective pixels is based on calculation and output of adjacent valid pixel values in the same line. The correction methods of monochrome and color cameras are different:

- For monochrome camera, replace defect pixel values with adjacent pixel values.
- For color camera, replace defect pixel values with row and column separated pixel values.



(a) Monochrome Camera



(b) Color Camera

Fig.23 Defect Pixel Correction Methods for Different Cameras

In the figure above, the modified value of defect pixels will be calculated according to whether the surrounding pixels are defect pixels, as the rules shown in the following table.

Table 7 Calculation Defect Pixel Correction Value

Adjacent Defect Pixel(s)	Correction value of Current Pixel
None	L1
L1	R1
R1	L1
L1,R1	L2
L1,R1,L2	R2
L1,R1,L2,R2	L3
L1,R1,L2,R2,L3	R3

6.6 Strobe

Strobe signal is used to synchronize external light sources with the camera. The timing of the strobe signal is exactly the same as the camera exposure timing. When the camera exposure starts, the strobe signal will be pulled down/up; camera exposure ends, the strobe signal will return to its initial level.

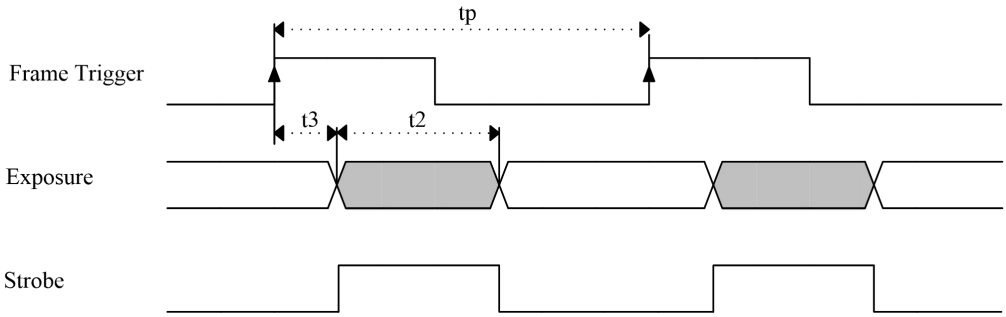


Fig.24 Strobe

6.7 Test Image

Test images are generally used to test whether the data link is unobstructed, making it easier for users to perform various debugging tasks. This camera provides test images as shown in the following figure:

- Test image1: fixed image with horizontal gray gradient.

- Test image2: scroll image with vertical gray gradient.
- Test image3: fixed image with the same gray scale for all pixels.

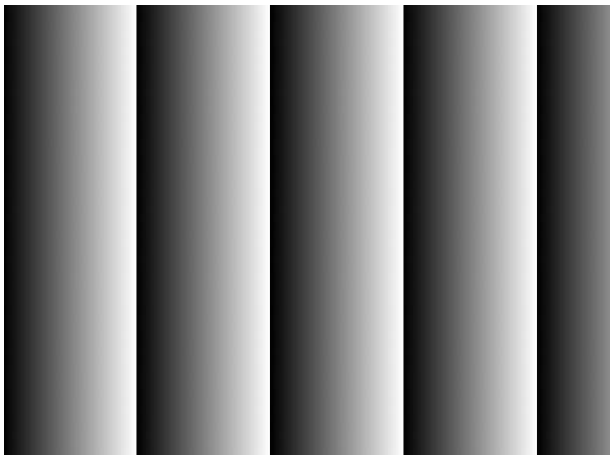


Fig.25 Test Image1

Fig.26 Horizontal Test Image

Fig.27 Uniform Test Image

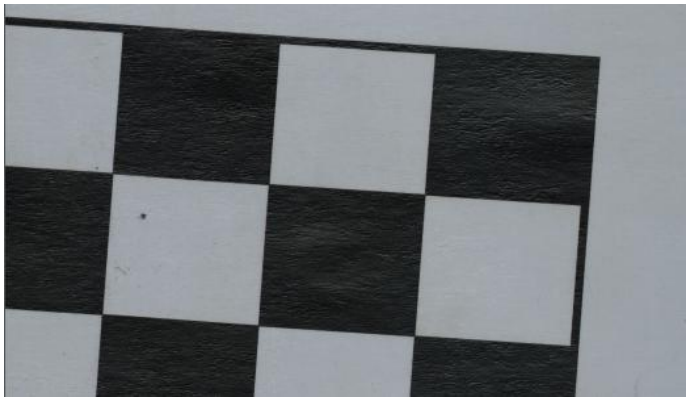
6.8 White Balance

White balance is an important parameter of color industrial camera, it directly affects the color effect of the reproduced image, when the white balance of the industrial camera is not set properly, color

reproduction will occur when the image is reproduced.

(T)TS65MU30 color camera provides white balance function, which balances the output value of each channel of the sensor. Automatic white balance calculates the white balance coefficient by sampling local pixels in the sensor, then adjust each component of the image according to the coefficient to make the red, green and blue components of the output image have the same value. Its function diagram is as follows:

(a) Before White Balance



(b) After White Balance

Fig.28 White Balance

6.9 Flat Field Correction

Generally, in the application process of area scan cameras, due to the vignetting effect of the lens and the inconsistency of illumination, there is a certain difference between the image output by the camera and the actual signal, that is, the output data of the camera is different for the signal with the same brightness. (T)TS65MU30 camera provides a flat field correction function to correct this problem. Actually, users can achieve the flat field effect by flat field correction.

Taking into account the pixel array scale and vignetting effect of area scan cameras, this camera uses 64 x 64 pixel block data, combined with image algorithms to achieve real-time flat field correction algorithms. The fundamental is shown in the figure below:

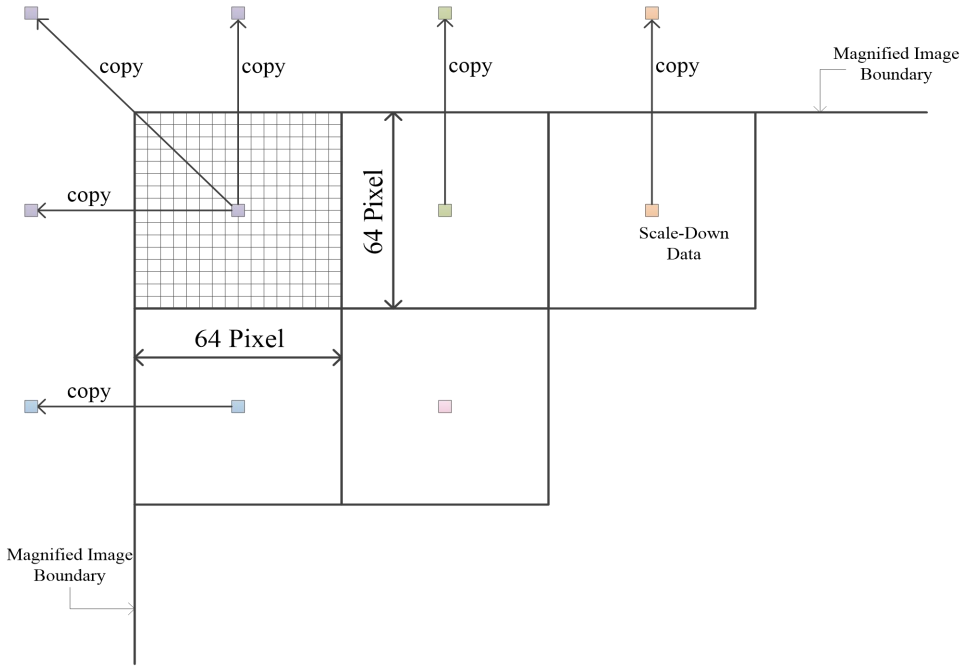


Fig.29 Flat Field Correction Schematic

6.10 Data Format

(T)TS65MU30 camera provides two types of pixel data bit widths: 8bit and 12bit. If the bit width is 8bit, it is equivalent to truncating the top 8bit of 12bit.

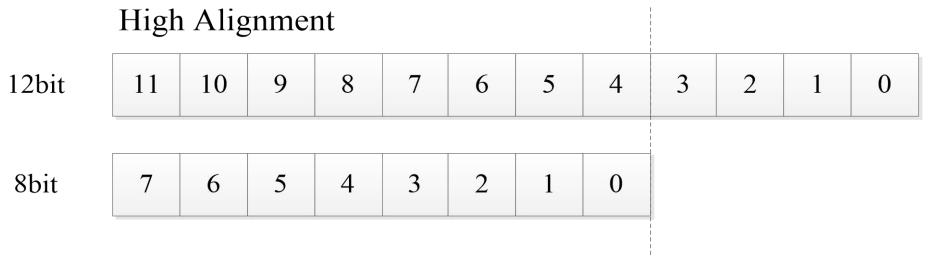


Fig.30 Data Format

6.11 Gain and Offset

The camera gain is divided into analog gain and digital gain.

Analog gain acts on the analog signal. By increasing analog gain, a stronger response can be generally obtained under weak illumination, thus realizing a higher SNR. Users can configure camera's analog gain. Similarly, the analog offset is commonly used to adjust the black level position of the front-end sensor.

Digital gain amplifies or reduces the data of the photoelectric conversion signal after AD, which is usually used to increase the dynamic range of the output image. Digital gain can also be used to adjust the brightness of the image. Digital offset is commonly used to adjust the overall background brightness of an image.

The effect of digital gain can be summarized by the following equation:

Data value (Output) = Data value (digital gain=1 & digital offset=0) x Digital gain value

The effect of digital offset can be summarized by the following equation (Data values less than 0 will be output as 0):

Data value (Output) = Data value (digital offset=0) + Digital offset value

Digital offset is set for 12bit data. If the image data is 8bit, the actual digital offset will be divided by 16.

6.12 Camera Temperature

(T)TS65MU30 supports real-time acquisition of camera temperature. Users can read the camera temperature value to monitor the current temperature value of the sensor or make some responses according to the temperature value.

The operating environment temperature of the camera is recommended to be 0~50°C. If users detect abnormal internal temperature (such as over 60°C), it is recommended to stop the camera immediately to avoid component damage. Power off and contact our technical support in time.

6.13 Load / Save Configuration

(T)TS65MU30 camera provides three working parameter sets to meet the use demand in most scenarios. Among them, the factory parameter set has already been optimized and cannot be modified by users. The camera is provided with two user operating parameter sets, among which the internal parameters can be modified and saved by users. The saved operating parameter set will be automatically loaded upon power-on next time.

If the camera is found abnormal after modification of the parameters, users can restore the camera to the factory parameter set.

7 Camera Control

7.1 GenICam Standard

GenICam standard, promulgated by European Machine Vision Association (EMVA), provides a unified programming interface for all types of industrial cameras. The programming interface (API) is the same regardless of which transmission protocol the camera uses or which functions it implements. It mainly contains the following three modules:

- GenAPI: Responsible for parsing XML files and solving problem of how to configure camera
- GenTL: Transport layer, for device enumeration, attribute control, and image acquisition
- SFNC: Standard for naming camera features

Camera XML description file is stored locally on the PC, and collection software will select the most appropriate XML file according to camera model. Application and camera communicate with each other through SFNC, GenAPI, and GigEVision, as shown in the figure below.

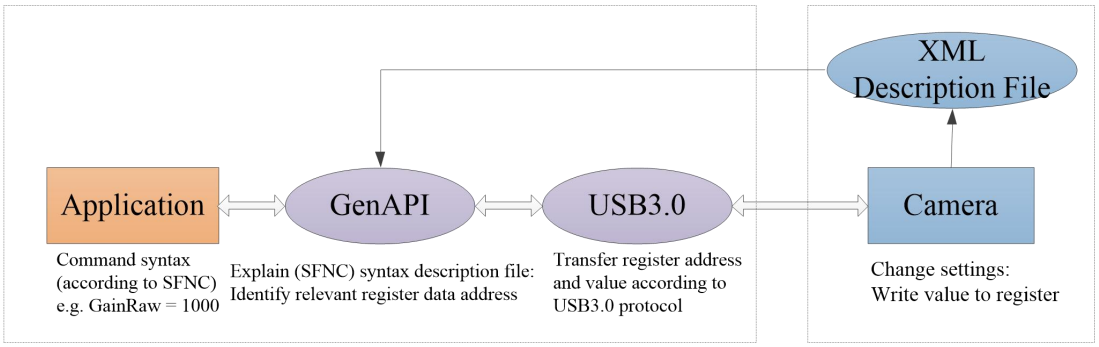


Fig.31 Communication Principle Diagram Between Application and Camera

In fact, if users want to change camera settings, such as gain, GenICam (SFNC) specifies a standardized syntax:

```
if( IsAvailable(Camera.GainRaw) )
    Camera.GainRaw = 1000;
```

GenAPI can parse these commands through the description file. For example, in order to set the gain to 1000, the value of 0x3E8 (HEX) must be written to the register at address 0x0815 (HEX). Other tasks involved may be to check whether the camera has gain characteristics in advance and check whether the new value is consistent with the allowable gain range. This register message is transmitted and parsed via the USB3.0 protocol, and is used in the camera.

7.2 GenAPI Parameter Attribute

The actual method of controlling the camera is closely related to the software implementation of the frame grabber and SDK. Most of the frame grabber software provides a graphical user interface (GUI) that is automatically generated from an XML file. The focus of this manual is on the functions of the camera. It describes in detail the specific commands and their effects on camera operations. It lists the name, interface, access, description, range and default value of each GenAPI parameter.

(1) Register name

Each parameter is identified by a unique name. Most names are part of SFNC, and custom names are used for non-standard parameters.

(2) Register address

This parameter represents the address value of the register (hexadecimal format).

(3) Register size

This parameter represents the size of the register value (in byte).

(4) Register interface

The parameter interface represents the type of parameter, which is mainly used for the GUI of the frame grabber to assign a display type to the parameter.

Table 8 Overview of Parameter Interface

Interface	Interface Name	Description
Integer	I	Integer with value, minimum, maximum, and increment
Float	F	Float with value, minimum, maximum, and physical unit
String	S	String
Enumeration	E	Enumerate type
Command	C	Execute the command
Boolean	B	Boolean type

(5) Parameter access

This parameter represents whether the user can read (RO), write (WO) or read/write (RW) parameters.

(6) Default parameter value and range

When setting the parameter, it will check whether the input value is within the valid range of the parameter.

7.3 Register Classification

7.3.1 Device Control Registers

Table 9 Device Control Register

Name	Address	Size	Interface	Access	Visibility
DeviceVendorName	0x2000	32	S	RO	Beginner
DeviceModelName	0x2020	32	S	RO	Beginner
DeviceVersion	0x2070	32	S	RO	Beginner
DeviceSerialNumber	0x20b0	16	S	RO	Beginner
MCUTemperature	0x6118	4	F	RO	Expert

SensorTemperature	0x6038	4	F	RO	Expert
BoardTemperature	0x6114	4	F	RO	Expert
Humidity	0x615c	4	F	RO	Expert

- **DeviceVendorName**
  Device vendor name.

- **DeviceModelName**
  Device model name.

- **DeviceVersion**
  Device version.

- **DeviceSerialNumber**
  Device serial number.

- **MCUTemperature**
  MCU temperature.

- **SensorTemperature**
  Sensor temperature.

- **BoardTemperature**
  Board temperature.

- **Humidity**
  Humidity, only TTS65MU30 camera supports this parameter.

7.3.2 Image Format Control Registers

Table 10 Image Format Control Registers

Name	Address	Size	Interface	Access	Visibility
Width	0x6000	4	I	RW	Beginner
Height	0x6004	4	I	RW	Beginner
PixelFormat	0x6020	4	E	RW	Beginner
OffsetX	0x6010	4	I	RW	Beginner
OffsetY	0x6014	4	I	RW	Beginner
VideoMode	0x602c	4	E	RW	Beginner
ReverseX	0x613c	4	B	RW	Beginner
ReverseY	0x6140	4	B	RW	Beginner

- **Width**
  Actual camera output width.The parameter range is as follows:

- Maximum: 9408
- Minimum: 128 (TS65MU30 camera), 256 (TTS65MU30 camera)
- Increment: 128

- **Height**

  Actual camera output height. The parameter range is as follows:
  - Maximum: 7008
  - Minimum: 20 (TS65MU30 camera), 60 (TTS65MU30 camera)
  - Increment: 20

- **PixelFormat**

  Pixel format. The enumeration names and values are as follows:
  - Mono8 (17301505): Monochrome 8bit
  - Mono12 (17825797): Monochrome 12bit
  - BayerBG8 (17301515): Bayer BGGR 8bit
  - BayerBG12 (0x01100013): Bayer BGGR 12bit
  - BayerGB8 (17301514): Bayer GBRG 8bit
  - BayerGB12 (0x01100012): Bayer GBRG 12bit
  - BayerGR8 (17301512): Bayer GRBG 8bit
  - BayerGR12 (0x01100010): Bayer GRBG 12bit
  - BayerRG8 (17301513): Bayer RGGB 8bit
  - BayerRG12 (0x01100011): Bayer RGGB 12bit

- **OffsetX**

  Horizontal offset. The parameter range is as follows:
  - Maximum: 9344
  - Minimum: 0
  - Increment: 16

- **OffsetY**

  Vertical offset. The parameter range is as follows:
  - Maximum: 7000
  - Minimum: 0
  - Increment: 2

- **VideoMode**

  Output image mode. The enumeration names and values are as follows:
  - Original (0): Original image
  - Corrected (1): Corrected image
  - VerticalPattern(2): Vertical test image
  - HorizontalPattern(3): Horizontal test image
  - Uniform (4): Uniform test image

- **ReverseX**

Horizontal image flip.

- **ReverseY**
  Vertical image flip.

7.3.3 Acquisition Control Registers

Table 11 Acquisition Control Registers

Name	Address	Size	Interface	Access	Visibility
AcquisitionMode	0x603c	4	E	RW	Beginner
AcquisitionStart	0x6040	4	C	RW	Beginner
AcquisitionStop	0x6040	4	C	RW	Beginner
TriggerSoftware	0x611c	4	C	WO	Expert
TriggerSource	0x6050	4	E	RW	Beginner
TriggerActivation	0x6054	4	E	RW	Beginner
TriggerDelayTime	0x6058	4	I	RW	Beginner
ExposureMode	0x605c	4	E	RW	Beginner
ExposureTime	0x6060	4	I	RW	Beginner
TransferBurstSize	0x6120	4	I	RO	Guru

- **AcquisitionMode**
  Acquisition mode, usually default to continuous acquisition. The enumeration names and values are as follows:
  - Continuous (0): Continuous acquisition

- **AcquisitionStart**
  Start acquisition.

- **AcquisitionStop**
  Stop acquisition.

- **TriggerSoftware**
  Software trigger, clicking on this parameter will generate a software trigger signal.

- **TriggerSource**
  Trigger source selection. The enumeration names and values are as follows:
  - Software (0): Software trigger signal
  - IO0 (1): Control interface signal

- **TriggerActivation**
  Trigger polarity. The enumeration names and values are as follows:
  - FallingEdge (1): Trigger acquisition at the falling edge of the signal
  - RisingEdge (0): Trigger acquisition at the rising edge of the signal

- **TriggerDelayTime**

  Trigger delay time. The parameter range is as follows:

  - Minimum: 0
  - Increment: 1

- **ExposureMode**

  Exposure mode. Please refer to Section 6.1 for specific descriptions. The enumeration names and values are as follows:

  - Timed (0): Free-Run mode
  - TriggerPulse (1): External Pulse mode
  - TriggerWidth (2): External PWM mode

- **ExposureTime**

  Exposure time, the unit is us.

- **TransferBurstSize**

  The amount of data transmitted by camera each time.

7.3.4 Counter and Timer Control Register

Table 12 Acquisition Control Registers

Name	Address	Size	Interface	Access	Visibility
FlashStrobeActivation	0x6064	4	E	RW	Beginner

- **FlashStrobeActivation**

  Strobe signal polarity. The enumeration names and values are as follows:

  - FallingEdge (1): High level, pull-down level when generating strobe signal
  - RisingEdge (0): Low level, pull-up level when generating strobe signal

7.3.5 Digital Control Registers

Table 13 Digital Control Registers

Name	Address	Size	Interface	Access	Visibility
Gain	0x6068	4	F	RW	Beginner
Offset	0x606c	4	I	RW	Beginner
WhiteBalanceRedGain	0x6070	4	I	RW	Expert
WhiteBalanceGreenGain	0x6074	4	I	RW	Expert
WhiteBalanceBlueGain	0x607c	4	I	RW	Expert
WhiteBalanceEnable	0x608c	4	B	RW	Expert
WhiteBalanceInitialize	0x6080	4	C	WO	Expert
WhiteBalanceCalibrate	0x6080	4	C	WO	Expert
BlackLevel	0x6168	4	I	RW	Guru

- **Gain**

  Digital gain. The parameter range is as follows:

  - Maximum: 8
  - Minimum: 0.1

- **Offset**

  Digital offset. The parameter range is as follows:

  - Maximum: 4095
  - Minimum: -4095
  - Increment: 1

- **WhiteBalanceRedGain**

  White balance R channel gain, only color camera can set this parameter. The parameter range is as follows:

  - Maximum: 16383
  - Minimum: 1024
  - Increment: 1

- **WhiteBalanceGreenGain**

  White balance G channel gain, only color camera can set this parameter. The parameter range is as follows:

  - Maximum: 16383
  - Minimum: 1024
  - Increment: 1

- **WhiteBalanceBlueGain**

  White balance B channel gain, only color camera can set this parameter. The parameter range is as follows:

  - Maximum: 16383
  - Minimum: 1024
  - Increment: 1

- **WhiteBalanceEnable**

  Enable white balance function, only color camera can set this parameter.

- **WhiteBalanceInitialize**

  Initialize white balance correction, which can reset white balance parameters to default setting. Only color camera can set this parameter.

- **WhiteBalanceCalibrate**

  Execute white balance correction, that is, execute white balance correction in current condition. Only color camera can set this parameter.

- **BlackLevel**

Black level, used to adjust the bottom value of camera output in dark field condition. The smaller black level is, the smaller gray value of image in dark field condition is. The parameter range is as follows:

- Maximum: 4095
- Minimum: -4095
- Increment: 1

7.3.6 Sensor Registers

Table 14 Sensor registers

Name	Address	Size	Interface	Access	Visibility
AnalogGain	0x6088	4	I	RW	Beginner
AnalogOffset	0x6130	4	I	RW	Beginner

- **AnalogGain**

  Analog gain. The parameter range is as follows:
  - Maximum: 64
  - Minimum: 0
  - Increment: 1

- **AnalogOffset**

  Analog offset. The parameter range is as follows:
  - Maximum: 4095
  - Minimum: 0
  - Increment: 1

7.3.7 Defect Pixel Registers

Table 15 Defect Pixel Registers

Name	Address	Size	Interface	Access	Visibility
DefectPixelCorrectionEnable	0x60d0	4	B	RW	Guru
DefectPixelTotal	0x60d8	4	I	RO	Expert
DefectPixelSelect	0x60dc	4	I	RW	Expert
DefectPixelReadX	0x60e0	4	I	RO	Expert
DefectPixelReadY	0x60e4	4	I	RO	Expert
DefectPixelWriteX	0x60e8	4	I	RW	Expert
DefectPixelWriteY	0x60ec	4	I	RW	Expert
DefectPixelAdd	0x60f0	4	C	WO	Expert
DefectPixelRemove	0x60f4	4	C	WO	Expert
DefectPixelClearAll	0x60f8	4	C	WO	Expert
DefectPixelSave	0x60fc	4	C	WO	Expert

- **DefectPixelCorrectionEnable**

Enable defect pixel correction function.

- **DefectPixelTotal**
  Total number of defect pixel.

- **DefectPixelSelect**
  Select index of defect pixel. The parameter range is as follows:
  - Maximum: 16383
  - Minimum: 0
  - Increment: 1

- **DefectPixelReadX**
  Read the X coordinate of current defect pixel.

- **DefectPixelReadY**
  Read the Y coordinate of current defect pixel.

- **DefectPixelWriteX**
  Write the X coordinate of defect pixel. The parameter range is as follows:
  - Maximum: 9344
  - Minimum: 0
  - Increment: 1

- **DefectPixelWriteY**
  Write the Y coordinate of defect pixel. The parameter range is as follows:
  - Maximum: 7000
  - Minimum: 0
  - Increment: 1

- **DefectPixelAdd**
  Add defect pixel.

- **DefectPixelRemove**
  Remove current defect pixels.

- **DefectPixelClearAll**
  Remove all defect pixels.

- **DefectPixelSave**
  Save defect pixels.

7.3.8 LUT Control Registers

Table 16 LUT Control Registers

Name	Address	Size	Interface	Access	Visibility
LUTEnable	0x60c0	4	B	RW	Beginner
LUTSelector	0x6134	4	I	RW	Expert
LUTIndex	0x60c4	4	I	RW	Expert
LUTValue	0x60c8	4	I	RW	Expert
Gamma	0x6138	4	F	RW	Beginner

- **LUTEnable**

  Enable LUT function.

- **LUTSelector**

  Select LUT. The parameter range is as follows:

  - Maximum: 3
  - Minimum: 0
  - Increment: 1

- **LUTIndex**

  Look up table data index, that is, the gray value of image before mapping lookup table. The parameter range is as follows:

  - Maximum: 4095
  - Minimum: 0
  - Increment: 1

- **LUTValue**

  Look up table data value, that is, the gray value of image after mapping lookup table. The parameter range is as follows:

  - Maximum: 4095
  - Minimum: 0
  - Increment: 1

- **Gamma**

  Gamma correction value. The parameter range is as follows:

  - Maximum: 127
  - Minimum: 0.01

7.3.9 Flat Field Correction Registers

Table 17 Flat Field Correction Registers

Name	Address	Size	Interface	Access	Visibility
FF_Enable	0x6100	4	B	RW	Beginner
FF_Calibrate	0x6104	4	C	WO	Beginner
FF_RestoreFactory	0x6104	4	C	WO	Beginner

- **FF_Enable**
  Enable flat field correction.

- **FF_Calibrate**
  Execute flat field correction.

- **FF_RestoreFactory**
  Restore factory settings for flat field correction.

7.3.10 Cooler Control Register

Table 18 Cooler Control Registers

Name	Address	Size	Interface	Access	Visibility
TECCoolerEnable	0x6124	4	B	RW	Expert
TECTemperature	0x6128	4	I	RW	Guru

- **TECCoolerEnable**
  Enable TEC cooling function, only TTS65MU30 camera supports this parameter.

- **TECTemperature**
  Set TEC cooling target temperature, only TTS65MU30 camera supports this parameter. The parameter range is as follows:
  - Maximum: 40
  - Minimum: -10
  - Increment: 1

7.3.11 User Set Control Registers

Table 19 User Set Control Registers

Name	Address	Size	Interface	Access	Visibility
UserSetSelector	0x6108	4	E	RW	Beginner
UserSetLoad	0x610c	4	C	WO	Beginner
UserSetSave	0x6110	4	C	WO	Beginner

- **UserSetSelector**
  User configuration selector. The enumeration names and values are as follows:
  - Default (0): Factory configuration
  - UserSet1(1): User configuration 1
  - UserSet2(2): User configuration 2

- **UserSetLoad**
  Load selected camera configuration.

- **UserSetSave**
  Save selected camera configuration.

8 FAQ

- **If the camera cannot be connected to computer,**

① Ensure that the USB3.0 interface cable is OK.

② Remove and plug the USB port on the camera and PC.

- **If the USB3.0 interface cannot receive data,**

① Ensure that the camera has been turned on properly (i.e. the status indicator should be normally green).

② Ensure that the USB3.0 interface is properly and securely connected.

- **If the camera has no image output in External Pulse mode,**

① Ensure that the external input pulse is normal.

② Ensure that the camera has received the trigger pulse correctly (it can be confirmed by the status indicator display).

③ If the USB3.0 interface signal is used as the trigger input signal, ensure that the software sends a software trigger signal.

- **If temperature of camera casing is abnormal,**

① Ensure that the voltage range of external connected power supply is normal.

② If the casing is hot or the camera emits smoke, immediately cut off the power and stop using the camera, then contact us for technical support.

- **If images are dark,**

① Ensure that the sensor aperture on the casing is not blocked.

② Ensure that the exposure time is set properly.

- **If the images are not clear,**

① Ensure that the sensor glass is clean.

② Ensure that the camera status indicator is normal.

- **If the camera cannot output images,**

① Check whether the USB3.0 interface is normal by the test image.

② Check whether the power supply is normal by the camera indicator status.

③ Check whether the external pulse input is normal in the External Pulse mode by the camera indicator.

If users have any problems during the use of the camera, please contact our technical support in time, we will provide you with the service as soon as possible.