TTS101M(2)CL-8M/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	2020/12/11	● Initial version
0.3	2021/06/23	● Update strobe output circuit diagram ● Update product appearance and mechanical dimensions
0.4	2021/12/10	● Update the maximum exposure time ● Update mechanical dimension
0.5	2022/01/10	● Update the name of company
0.6	2022/04/25	● Update the logo of company ● Update legends in section 8
0.7	2023/02/11	● Update company address
0.8	2024/03/05	● Add horizontal flip function ● Add 16bit output mode ● Add sharpen function of color camera ● Update chapter 8

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 If there is 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**

① The recommended voltage is +12V±10%, and the current must be 5.0A.
② Hefei I-TEK Optoelectronics Co., LTD. does not provide external power supply. Users need to connect power supply by themselves.

- **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.

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**

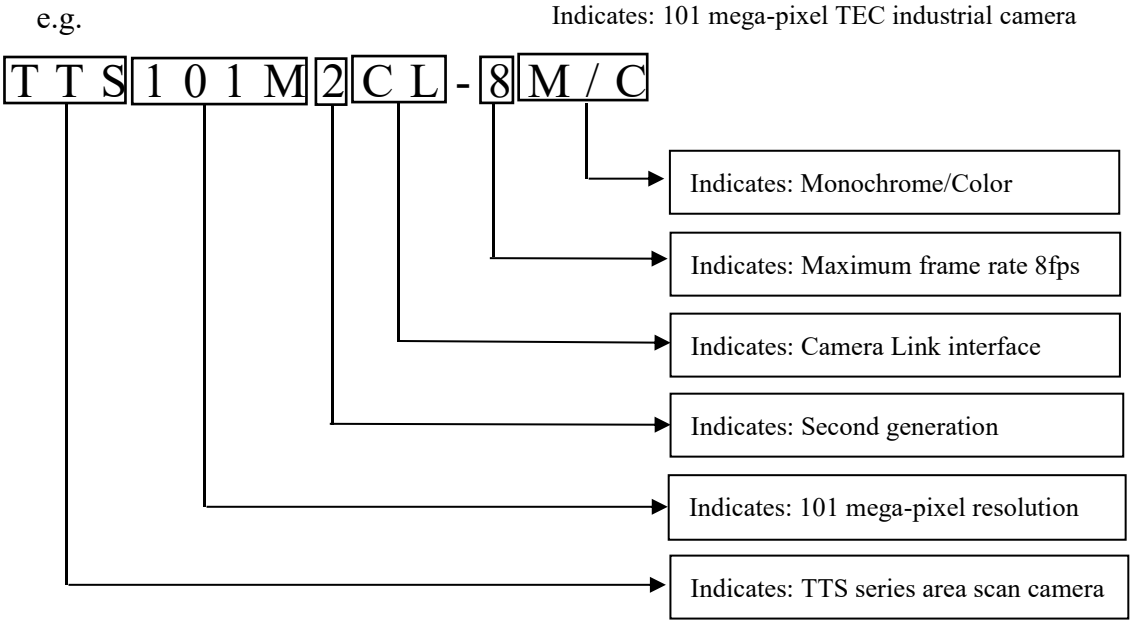
Abbreviation	Image Mode
M	Monochrome
C	Color
F	Full Color
T	Monochrome TDI (Time Delay Integration)
X	Time Division Camera
U	UV (Ultraviolet)
N	NIR (Near Infrared)

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

TTS101MCL camera:

TTS101M2CL camera:

Fig. 1 Product Appearance

Note:

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

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

4 Product Specifications

TTS101M(2)CL camera adopts advanced rolling shutter CMOS image sensor and Camera Link data interface. It is a area scan camera designed for industrial measurement and inspection. It has high reliability and stability, and is suitable for occasions with high requirements (high resolution, high speed) for image acquisition, such as surface inspection, electronic placement inspection, etc.

4.1 Main Features

- Rolling Shutter CMOS Sensor
- 101 Mega-Pixel Resolution
- Maximum Frame Rate at Full Resolution is 8fps
- High Sensitivity and Low Noise
- ROI
- Rich Exposure Control Modes (External Trigger, Free-Run)
- Output Pixel Format: 8/10/12/16bit
- LUT
- Defect Pixel Correction
- Flat Field Correction
- Analog Gain / Digital Gain / Offset Control
- Strobe
- White Balance
- User-configurable Scanning Direction
- Real-time Temperature Monitoring
- Thermal Electric Cooling: 20 ℃ lower than ambient temperature

4.2 Camera Specifications

Table 1 TTS101M(2)CL-8M/C Product Specifications

Model	TTS101MCL-8M/C	TTS101M2CL-8M/C
Product Description	101 mega-pixel TEC industrial camera	
Resolution	11656 x 8742	
Pixel Specifications	3.76um x 3.76um	
Sensor Type	Rolling shutter CMOS	
Image Type	Monochrome/Color	
Sensor Length	54.78mm (diagonal)	
Dynamic Range	≥78dB	
SNR	46dB	
Data Rate	800MB/s	
Lens Mount	M72	
Analog Gain	0~96	
Digital Gain	0.01 ~ 8	
Digital Offset	-4095~4095	

Max. Frame Rate	7.86fps@10Tap, 6.26fps@8Tap, 3.13fps@4Tap	
Trigger Mode	External Pulse, Free-Run	
External Trigger	External IO/Camera Link CC1	
Exposure Control	Timed, Pulse Width Control	
Exposure Time	73us~60s (Step: 1us)	
Data Format	8/10/12/16bit	
Operation Temperature	0~50°C	
Data Interface	Camera Link	
Power Supply	DC 12±10% 5.0A	
Power Consumption	50.0W	
Mechanical	140mm x 110mm x 95.5mm	111mm x 111mm x 104.9mm
Pixel Clock	83MHz	
Cooling Method	TEC and an external fan	
Cooling Performance	Approximately 20 ℃ below ambient temperature	

Note: This table is for 0904-91A version of TTS101M(2)CL camera specifications, which may vary slightly from version to version.

4.3 Camera Block Diagram

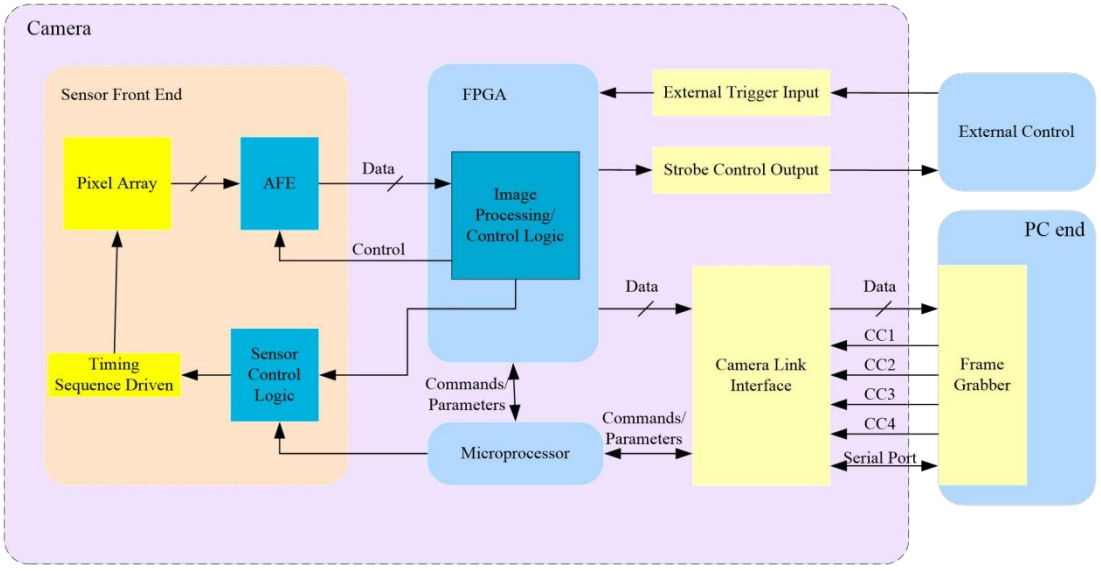


Fig.2 Internal Implementation Structure of Camera

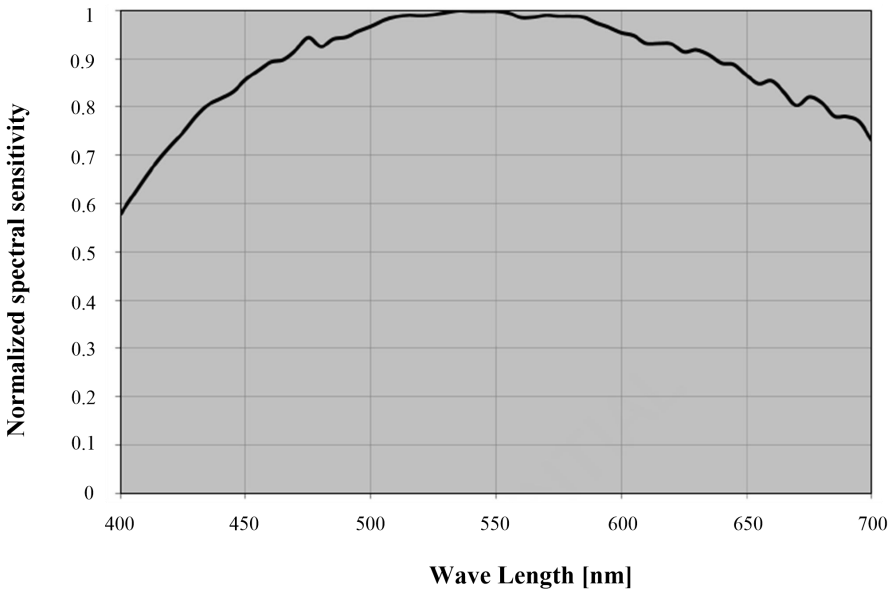
TTS101M(2)CL camera uses a unified architecture to achieve image sensor control, data transmission and embedded algorithm processing with different resolutions. The internal structure of the camera is shown in figure above. The pixel array is uniformly sampled and maintained by the rolling shutter control system, converted into digital signals by analog front end, and then transmitted to PC frame grabber through Camera Link interface after processed by FPGA and microprocessor.

Camera can receive external signal trigger acquisition, from the IO signal or signal of the Camera Link

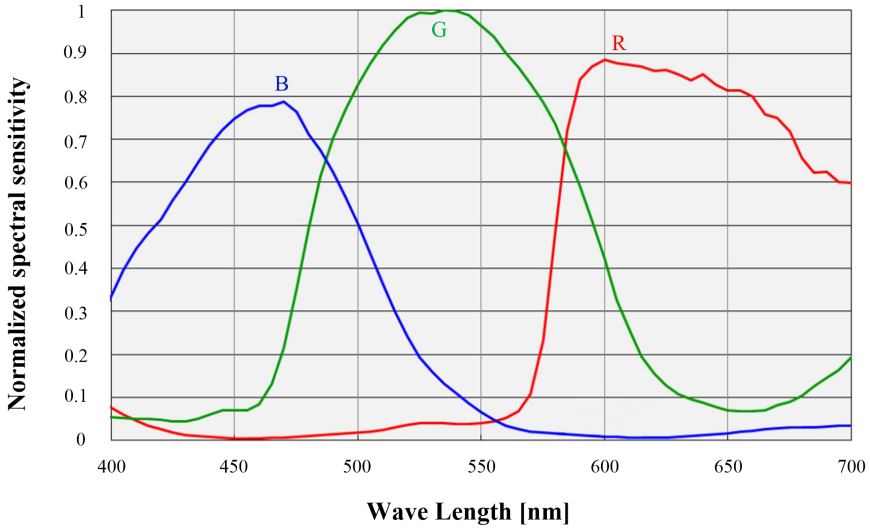
interface.At the same time, camera can also output synchronization signals during exposure, facilitating external strobe control.

4.4 Spectral Response

The spectral response curve of TTS101M(2)CL camera is shown in the following figure.



(a) Monochrome Camera



(b) Color Camera

Fig.3 Spectral Response of Camera

4.5 Camera Bayer Pattern

TTS101M(2)CL camera supports color mode, the 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: 0℃~50℃, humidity: 10% ~ 80%; Storage temperature: -20℃~75℃.

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

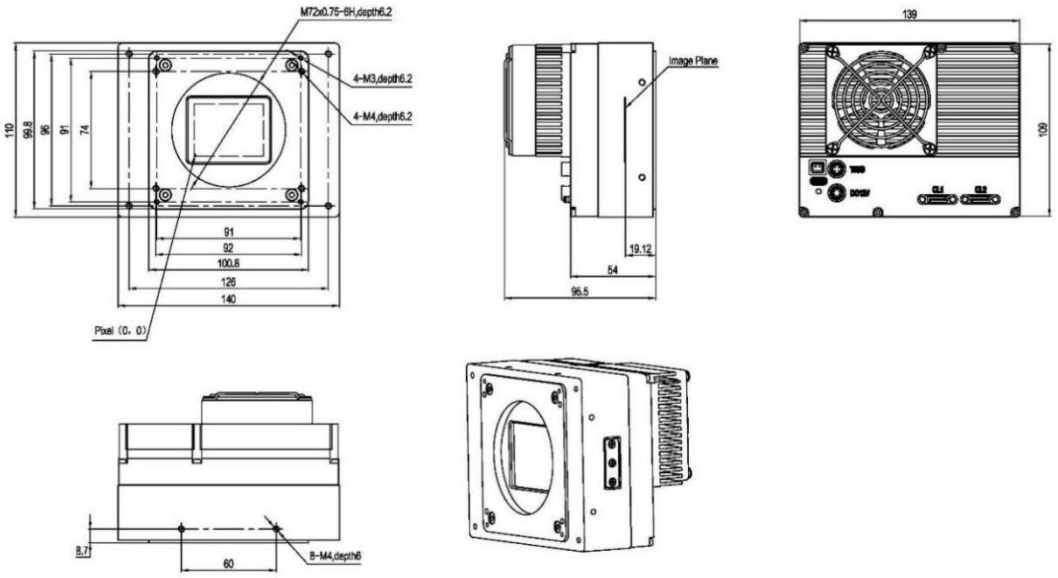
4.7 RoHS Certification

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

5 Mechanical Dimensions and Interfaces

5.1 Mechanical Dimensions

TTS101MCL camera:



TTS101M2CL camera:

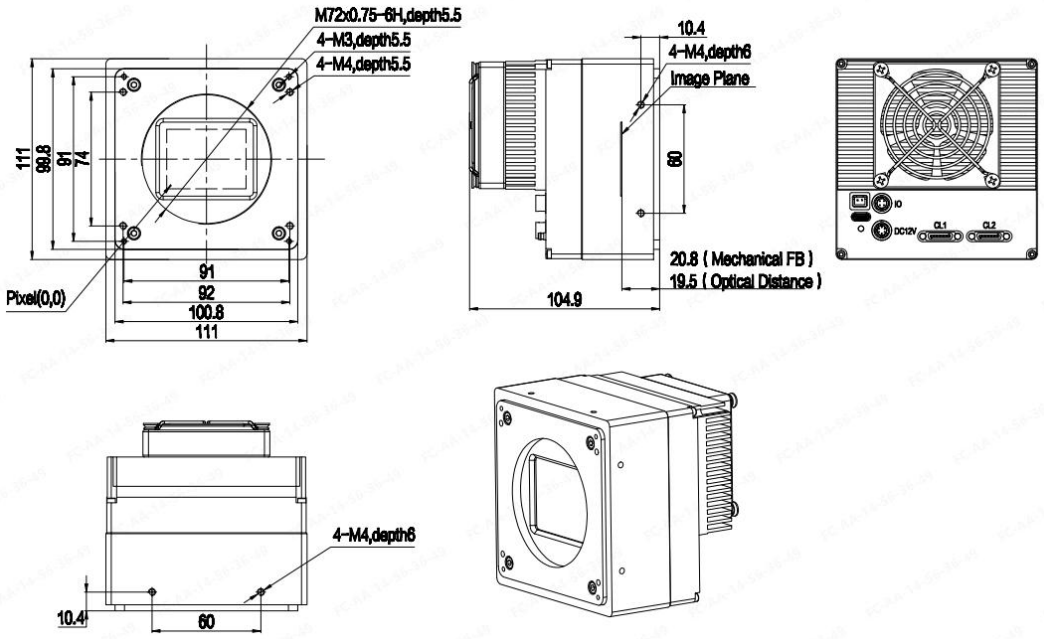


Fig.5 Camera Mechanical Dimensions

5.2 Camera Interface

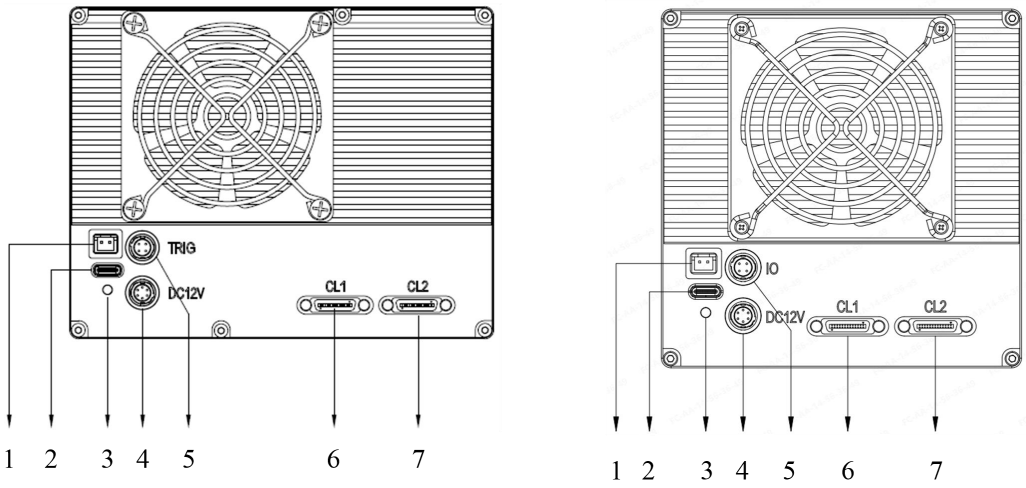


Fig.6 Interfaces of Camera

① Fan Power Socket
② Type-C Interface
③ Camera Status Indicator
④ 6-pin Power Interface
⑤ 4-pin Control Interface
⑥ Camera Link Interface 1 (Base)
⑦ Camera Link Interface 2 (Medium/Full)

5.2.1 Camera Status Indicator

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

Table 2 Camera Status Indicator

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

5.2.2 Power Interface

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

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

The power interface on the back of the camera is shown as follows:

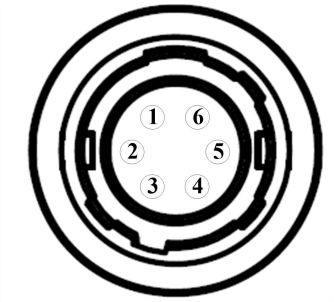


Fig. 7 Pin Assignments for Interface

Table 3 Pin Configurations for Interface

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 is a 4-pin connector with the model:
Hirose HR10A-7R-4PB(Male).

Corresponding connector on the power cable model:
Hirose HR10A-7P-4S(Female).

The control interface on the back of the camera is shown as follows:

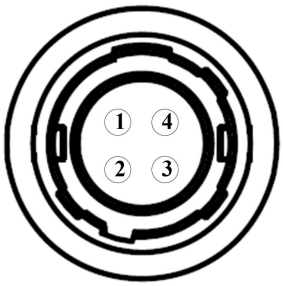


Fig. 8 Control Interface Plugin

Table 4 Control Interface Plugin Pin Definition

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

The external trigger circuit is shown as follows:

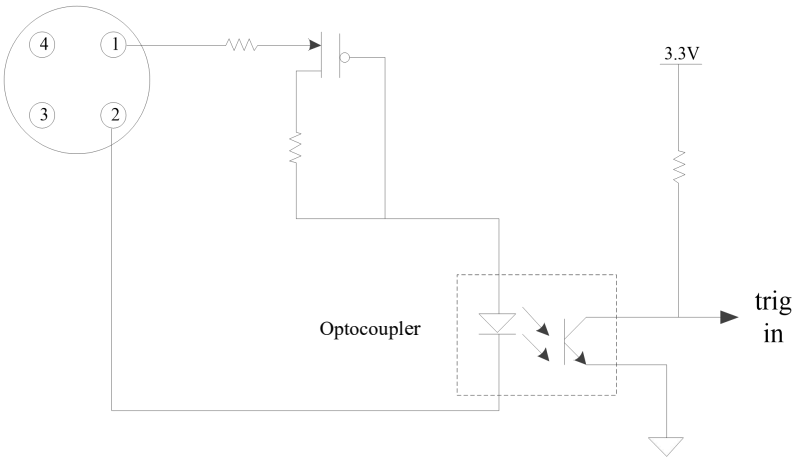


Fig. 9 Trig Input Circuit

- Trigger voltage range: 2.5~12V
- Minimum pulse width: 1us

Strobe output circuit is shown below:

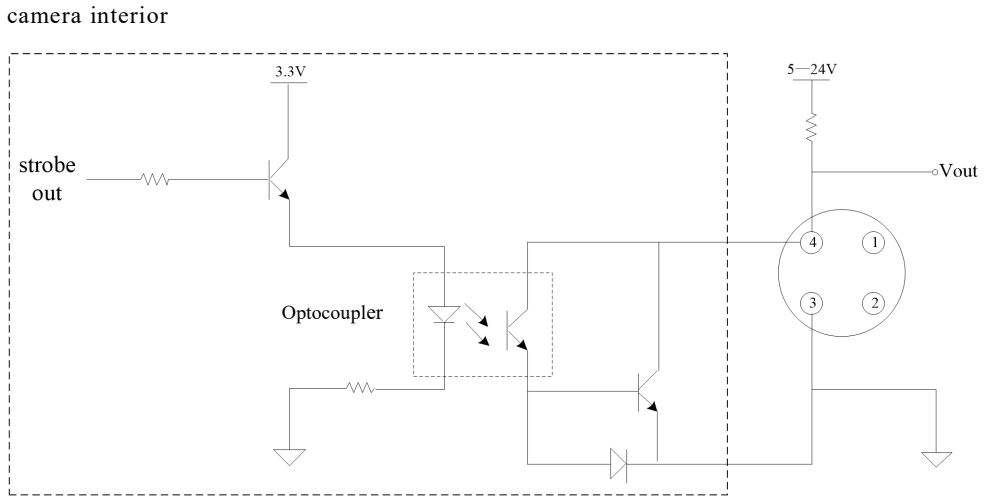


Fig. 10 Strobe Output Circuit

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

5.2.4 Data Interface

TTS101M(2)CL camera uses a Mini Camera Link connector as data output interface. Mini Camera Link connector is an industry standard interface. The signal definition is as follows:

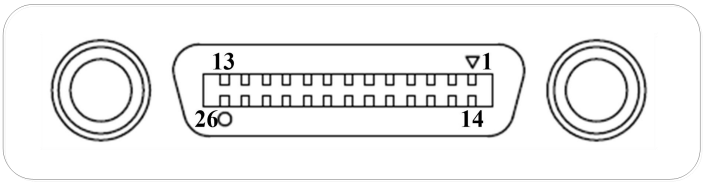


Fig. 11 Mini Camera Link Interface

Table 5 Pin Assignments for Camera Link interface 1

PAIR List	Pin	Signal Name	Type	Description
PAIR 0	1	Ground	Ground	Cable Shield
	14	Ground	Ground	Cable Shield
PAIR 1	2	X0-	LVDS-Out	Camera Link Transmitter
	15	X0+	LVDS-Out	Camera Link Transmitter
PAIR 2	3	X1-	LVDS-Out	Camera Link Transmitter
	16	X1+	LVDS-Out	Camera Link Transmitter
PAIR 3	4	X2-	LVDS-Out	Camera Link Transmitter
	17	X2+	LVDS-Out	Camera Link Transmitter
PAIR 4	5	XCLK-	LVDS-Out	Camera Link Transmitter
	18	XCLK+	LVDS-Out	Camera Link Transmitter
PAIR 5	6	X3-	LVDS-Out	Camera Link Transmitter
	19	X3+	LVDS-Out	Camera Link Transmitter
PAIR 6	7	UART_RX+	LVDS-In	Serial Data Receiver
	20	UART_RX-	LVDS-In	Serial Data Receiver
PAIR 7	8	UART_TX-	LVDS-Out	Serial Data Transmitter
	21	UART_TX+	LVDS-Out	Serial Data Transmitter
PAIR 8	9	CC1-	LVDS-In	Software External Trigger
	22	CC1+	LVDS-In	Software External Trigger
PAIR 9	10	CC2+	LVDS-In	Software External Trigger
	23	CC2-	LVDS-In	Software External Trigger
PAIR 10	11	CC3-	LVDS-In	Software External Trigger
	24	CC3+	LVDS-In	Software External Trigger
PAIR 11	12	CC4+	LVDS-In	Software External Trigger
	25	CC4-	LVDS-In	Software External Trigger
PAIR 12	13	Ground	Ground	Cable Shield
	26	Ground	Ground	Cable Shield

Table 6 Pin Assignments for Camera Link interface 2

PAIR List	Pin	Signal Name	Type	Description
PAIR 0	1	Ground	Ground	Cable Shield
	14	Ground	Ground	Cable Shield
PAIR 1	2	Y0-	LVDS-Out	Camera Link Transmitter
	15	Y0+	LVDS-Out	Camera Link Transmitter
PAIR 2	3	Y1-	LVDS-Out	Camera Link Transmitter
	16	Y1+	LVDS-Out	Camera Link Transmitter
PAIR 3	4	Y2-	LVDS-Out	Camera Link Transmitter
	17	Y2+	LVDS-Out	Camera Link Transmitter
PAIR 4	5	YCLK-	LVDS-Out	Camera Link Transmitter

	18	YCLK+	LVDS-Out	Camera Link Clock Tx
PAIR 5	6	Y3-	LVDS-Out	Camera Link Channel Tx
	19	Y3+	LVDS-Out	Camera Link Channel Tx
PAIR 6	7	-	Not Used	Connected with 100 ohm
	20	-	Not Used	
PAIR 7	8	Z0-	LVDS-Out	Camera Link Transmitter
	21	Z0+	LVDS-Out	Camera Link Transmitter
PAIR 8	9	Z1-	LVDS-Out	Camera Link Transmitter
	22	Z1+	LVDS-Out	Camera Link Transmitter
PAIR 9	10	Z2-	LVDS-Out	Camera Link Transmitter
	23	Z2+	LVDS-Out	Camera Link Transmitter
PAIR 10	11	ZCLK-	LVDS-Out	Camera Link Transmitter
	24	ZCLK+	LVDS-Out	Camera Link Clock Tx
PAIR 11	12	Z3-	LVDS-Out	Camera Link Channel Tx
	25	Z3+	LVDS-Out	Camera Link Channel Tx
PAIR 12	13	Ground	Ground	Cable Shield
	26	Ground	Ground	Cable Shield

Note: The Base interface (CL1) and the Medium/Full interface (CL2) must be correctly connected to their respective interfaces on the frame grabber according to the instructions on the back of camera.

The correspondence between signals and ports in each output mode is shown in the following table:

Table 7 Port Assignments (4tap @ 8/10/12/16bit)

	8bit	10bit	12bit	16bit
	4tap/8bit	4tap/10bit	4tap/12bit	4tap/16bit
Port A0	A0	A0	A0	A0
Port A1	A1	A1	A1	A1
Port A2	A2	A2	A2	A2
Port A3	A3	A3	A3	A3
Port A4	A4	A4	A4	A4
Port A5	A5	A5	A5	A5
Port A6	A6	A6	A6	A6
Port A7	A7	A7	A7	A7
Port B0	B0	A8	A8	A8
Port B1	B1	A9	A9	A9
Port B2	B2	-	A10	A10
Port B3	B3	-	A11	A11
Port B4	B4	B8	B8	A12
Port B5	B5	B9	B9	A13
Port B6	B6	-	B10	A14
Port B7	B7	-	B11	A15
Port C0	C0	B0	B0	B0
Port C1	C1	B1	B1	B1
Port C2	C2	B2	B2	B2
Port C3	C3	B3	B3	B3
Port C4	C4	B4	B4	B4
Port C5	C5	B5	B5	B5
Port C6	C6	B6	B6	B6
Port C7	C7	B7	B7	B7
Port D0	D0	D0	D0	B8
Port D1	D1	D1	D1	B9
Port D2	D2	D2	D2	B10
Port D3	D3	D3	D3	B11
Port D4	D4	D4	D4	B12
Port D5	D5	D5	D5	B13
Port D6	D6	D6	D6	B14
Port D7	D7	D7	D7	B15

	8bit	10bit	12bit	16bit
	4tap/8bit	4tap/10bit	4tap/12bit	4tap/16bit
Port E0	-	C0	C0	C0
Port E1	-	C1	C1	C1
Port E2	-	C2	C2	C2
Port E3	-	C3	C3	C3
Port E4	-	C4	C4	C4
Port E5	-	C5	C5	C5
Port E6	-	C6	C6	C6
Port E7	-	C7	C7	C7
Port F0	-	C8	C8	C8
Port F1	-	C9	C9	C9
Port F2	-	-	C10	C10
Port F3	-	-	C11	C11
Port F4	-	D8	D8	C12
Port F5	-	D9	D9	C13
Port F6	-	-	D10	C14
Port F7	-	-	D11	C15
Port G0	-	-	-	D0
Port G1	-	-	-	D1
Port G2	-	-	-	D2
Port G3	-	-	-	D3
Port G4	-	-	-	D4
Port G5	-	-	-	D5
Port G6	-	-	-	D6
Port G7	-	-	-	D7
Port H0	-	-	-	D8
Port H1	-	-	-	D9
Port H2	-	-	-	D10
Port H3	-	-	-	D11
Port H4	-	-	-	D12
Port H5	-	-	-	D13
Port H6	-	-	-	D14
Port H7	-	-	-	D15

Table 8 Port Assignments (8tap @ 8/10bit)

	8bit	10bit
	8tap/8bit	8tap/10bit
Port A0	A0	A2
Port A1	A1	A3
Port A2	A2	A4
Port A3	A3	A5
Port A4	A4	A6
Port A5	A5	A7
Port A6	A6	A8
Port A7	A7	A9
Port B0	B0	B2
Port B1	B1	B3
Port B2	B2	B4
Port B3	B3	B5
Port B4	B4	B6
Port B5	B5	B7
Port B6	B6	B8
Port B7	B7	B9
Port C0	C0	C2
Port C1	C1	C3
Port C2	C2	C4
Port C3	C3	C5
Port C4	C4	C6
Port C5	C5	C7
Port C6	C6	C8
Port C7	C7	C9
Port D0	D0	D2
Port D1	D1	D3
Port D2	D2	D4
Port D3	D3	D5
Port D4	D4	D6
Port D5	D5	D7
Port D6	D6	D8
Port D7	D7	D9
Port E0	E0	E2
Port E1	E1	E3
Port E2	E2	E4
Port E3	E3	E5
Port E4	E4	E6
Port E5	E5	E7
Port E6	E6	E8
Port E7	E7	E9

	8bit	10bit
	8tap/8bit	8tap/10bit
Port F0	F0	F2
Port F1	F1	F3
Port F2	F2	F4
Port F3	F3	F5
Port F4	F4	F6
Port F5	F5	F7
Port F6	F6	F8
Port F7	F7	F9
Port G0	G0	G2
Port G1	G1	G3
Port G2	G2	G4
Port G3	G3	G5
Port G4	G4	G6
Port G5	G5	G7
Port G6	G6	G8
Port G7	G7	G9
Port H0	H0	H2
Port H1	H1	H3
Port H2	H2	H4
Port H3	H3	H5
Port H4	H4	H6
Port H5	H5	H7
Port H6	H6	H8
Port H7	H7	H9
Port I0	-	A0
Port I1	-	A1
Port I2	-	B0
Port I3	-	B1
Port I4	-	C0
Port I5	-	C1
Port I6	-	D0
Port I7	-	D1
Port J0	-	E0
Port J1	-	E1
Port J2	-	F0
Port J3	-	F1
Port J4	-	G0
Port J5	-	G1
Port J6	-	H0
Port J7	-	H1

Table 9 Port Assignments (10tap @ 8bit)

	8bit
	10tap/8bit
Port A0	A0
Port A1	A1
Port A2	A2
Port A3	A3
Port A4	A4
Port A5	A5
Port A6	A6
Port A7	A7
Port B0	B0
Port B1	B1
Port B2	B2
Port B3	B3
Port B4	B4
Port B5	B5
Port B6	B6
Port B7	B7
Port C0	C0
Port C1	C1
Port C2	C2
Port C3	C3
Port C4	C4
Port C5	C5
Port C6	C6
Port C7	C7
Port D0	D0
Port D1	D1
Port D2	D2
Port D3	D3
Port D4	D4
Port D5	D5
Port D6	D6
Port D7	D7
Port E0	E0
Port E1	E1
Port E2	E2
Port E3	E3
Port E4	E4
Port E5	E5
Port E6	E6
Port E7	E7

	8bit
	10tap/8bit
Port F0	F0
Port F1	F1
Port F2	F2
Port F3	F3
Port F4	F4
Port F5	F5
Port F6	F6
Port F7	F7
Port G0	G0
Port G1	G1
Port G2	G2
Port G3	G3
Port G4	G4
Port G5	G5
Port G6	G6
Port G7	G7
Port H0	H0
Port H1	H1
Port H2	H2
Port H3	H3
Port H4	H4
Port H5	H5
Port H6	H6
Port H7	H7
Port I0	I0
Port I1	I1
Port I2	I2
Port I3	I3
Port I4	I4
Port I5	I5
Port I6	I6
Port I7	I7
Port J0	J0
Port J1	J1
Port J2	J2
Port J3	J3
Port J4	J4
Port J5	J5
Port J6	J6
Port J7	J7

6 Camera Features

This chapter introduces the main features of TTS101M(2)CL camera.

6.1 Trigger Mode

TTS101M(2)CL camera supports three trigger modes: Free-Run mode, External Pulse mode, External PWM mode.

6.1.1 Free-Run Mode

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

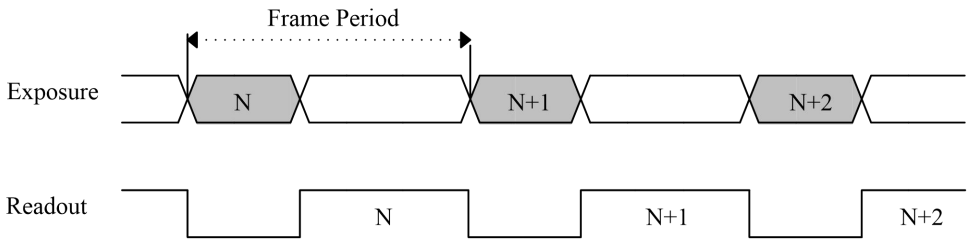


Fig. 12 Free-Run Mode

To achieve normal image output, TTS101M(2)CL camera limits the range of frame periods and exposure time. Minimum frame period should be longer than both exposure time and readout time of a frame data. The operation sequence of the camera is shown in the figure above.

6.1.2 External Pulse Mode

In the External Pulse mode, camera starts exposure at the rising edge of the external trigger signal, while the exposure time is set by users command (consistent with the Free-Run mode). The frame rate of the camera is determined by the frame period between the rising edges of the external trigger pulse, as shown in the figure below.

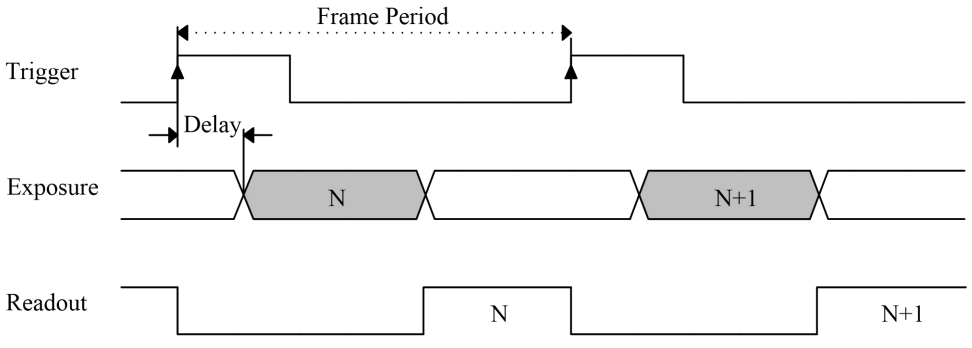


Fig. 13 External Pulse Mode

The external trigger signal can be input from CC1 interface of Camera Link or 4-pin control interface, and the input source could be selected by users. To get a higher frame rate, a new trigger pulse can be fired at the same time the camera reads the data after the last frame exposure. In this fast mode, since it

is necessary to ensure that the readout stages of two frames do not conflict, the external trigger with an interval less than 1 frame readout time will be automatically ignored by the camera, as shown in the figure below.

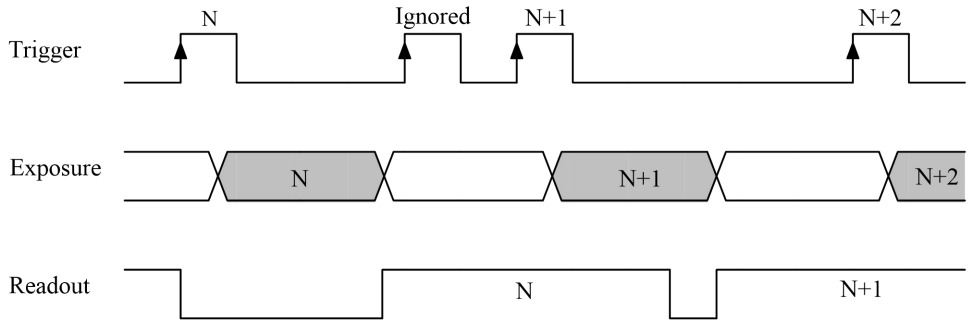


Fig. 14 External Trigger Interval is Too Short

6.1.3 External PWM Mode

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

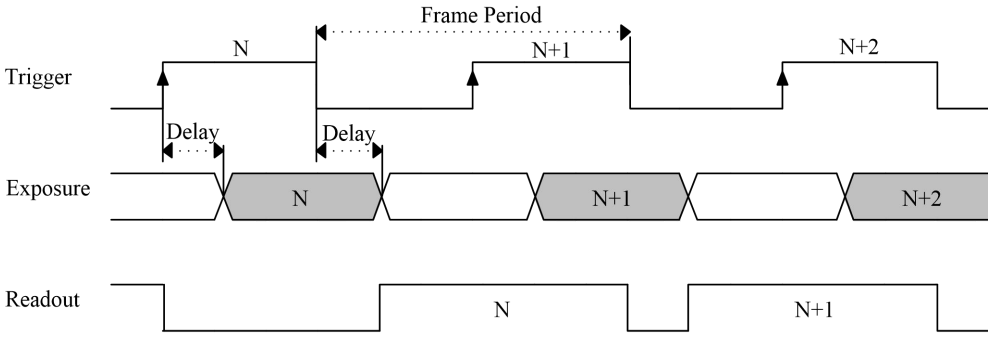


Fig. 15 High Level Mode

Please note that in this model, external trigger signal 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.

Too short frame period of external trigger will lead to the conflict between the data readout of the previous and current frames of the camera. The pulses that do not meet the requirements will be ignored inside the camera, so that the device can maintain its normal operation. Therefore, in this mode, it should be ensured that the frame period between the falling edges of adjacent external triggers is greater than one-frame readout time.

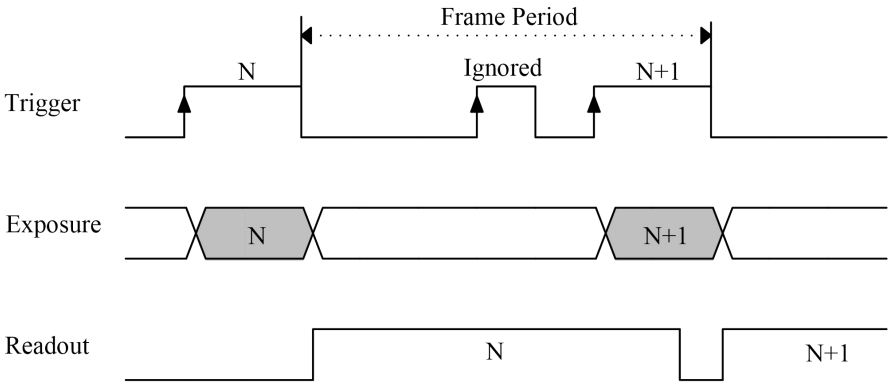


Fig. 16 External Trigger Interval is Too Short

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.

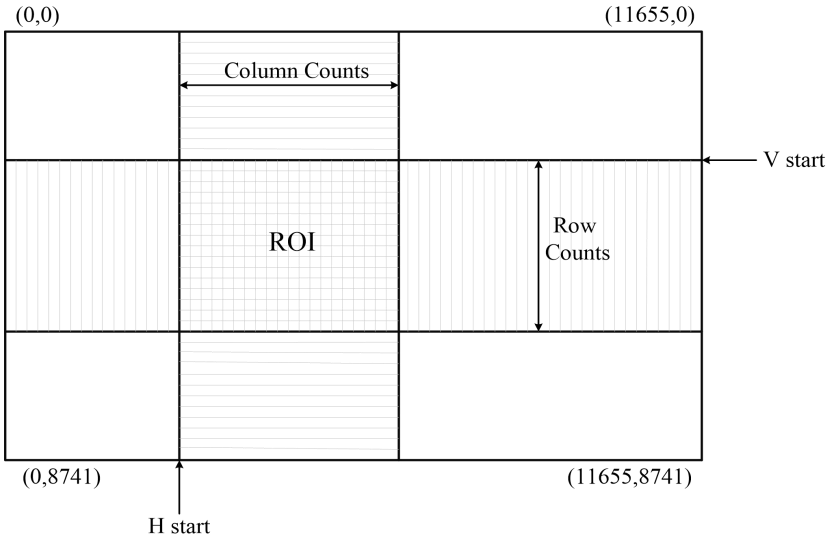


Fig. 17 ROI

Table 10 Maximum Frame Rate Depending on ROI Values

ROI Size H	ROI Size V	4Tap	8Tap	10Tap
11656	8742	3.13fps	6.26fps	7.86fps
10000	8742	3.13fps	6.26fps	7.86fps
8000	8742	3.13fps	6.26fps	7.86fps
6000	8742	3.13fps	6.26fps	7.86fps
4000	8742	3.13fps	6.26fps	7.86fps
2000	8742	3.13fps	6.26fps	7.86fps
11656	8000	3.41fps	6.83fps	8.58fps

11656	6000	4.53fps	9.07fps	11.38fps
11656	4000	6.74fps	13.48fps	16.92fps
11656	2000	13.12fps	26.24fps	32.95fps

6.3 LUT

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

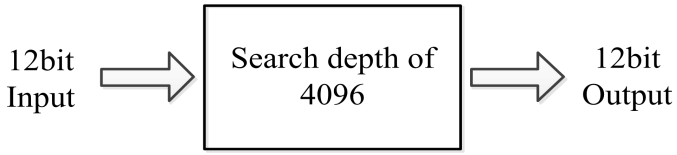


Fig.18 LUT Structure

The LUT mapping curve for Gamma=0.5 is shown below:

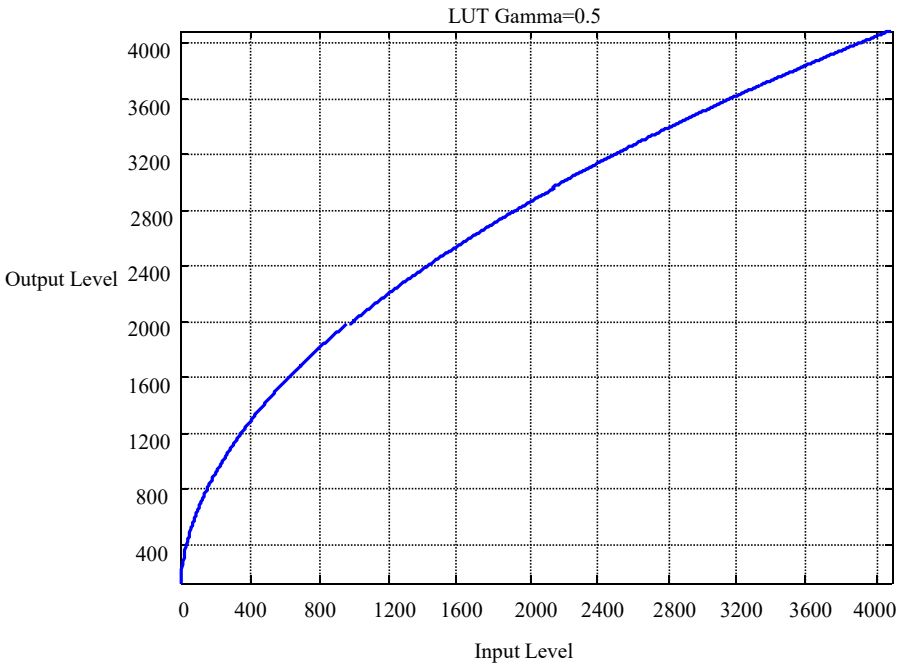
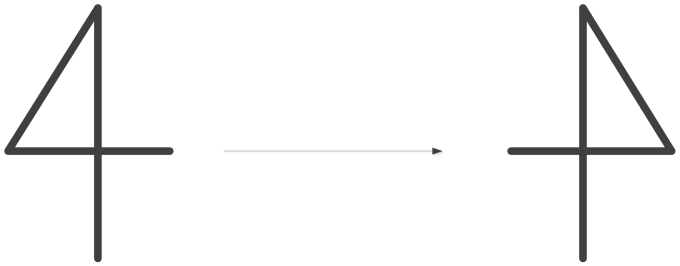


Fig.19 LUT Gamma = 0.5

6.4 Camera Scanning Direction

TTS101M (2) CL camera scanning direction is horizontal scanning direction, supporting left to right and right to left scanning.



Left to Right Right to Left

Fig.20 Horizontal Scan 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. TTS101M(2)CL 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 defect 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, the defect pixel values are replaced by adjacent pixel values.
- For color camera, the defect pixel values are replaced by separated pixel values.

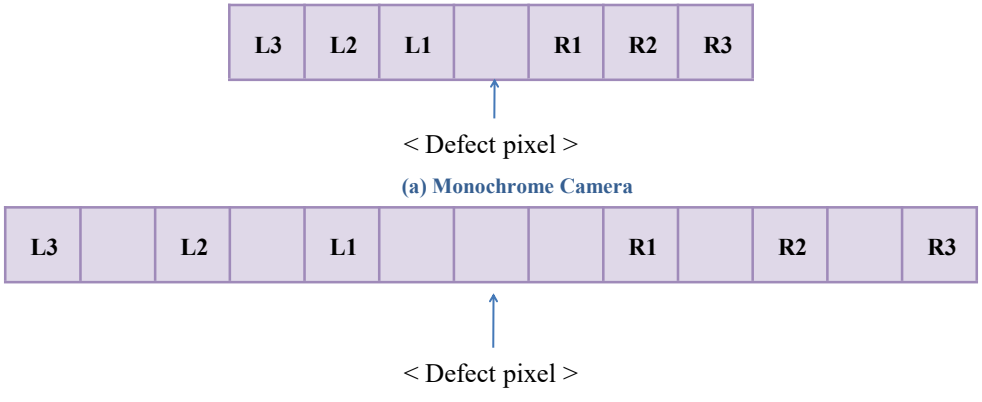


Fig. 21 Defect Pixel Correction Methods for Different Cameras

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 11 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. TTS101M(2)CL camera is a rolling shutter camera type, which requires camera or target to be stationary during exposure, otherwise there may be dragging phenomenon. Strobe signal can serve as a basis for determining whether exposure has ended or not.

TTS101M(2)CL camera offers two strobe signal modes: Wide Strobe and Narrow Strobe. Under Wide Strobe, strobe signal transitions to a high level at the beginning of exposure in the first line of the image, and to a low level at the end of the last line of image. Under Narrow Strobe, strobe signal transitions to a high level at the beginning of exposure on the last line of the image, and to a low level at the end of exposure on the first line of the image. Strobe signal of Narrow Strobe mode is only effective when the exposure time is greater than the reading time.

TTS101M(2)CL camera supports setting the polarity of the strobe output signal, with the option of High or Low. High is high level available, the strobe signal default to low levels, and transitions to high levels at the beginning of exposure; Low is low level available, the strobe signal defaults to high levels, and transitions to low levels at the beginning of exposure.

Taking High polarity as an example, the timing of the TTS101M(2)CL camera strobe signal will be explained below. Where Texp represents exposure time, Tout represents readout time

- **External Pulse Mode**

When exposure time is less than readout time, the pulse width of the strobe signal in Wide mode is equal to the sum of the exposure time and readout time. In Narrow mode, there is no signal, and the timing is shown in the following figure.

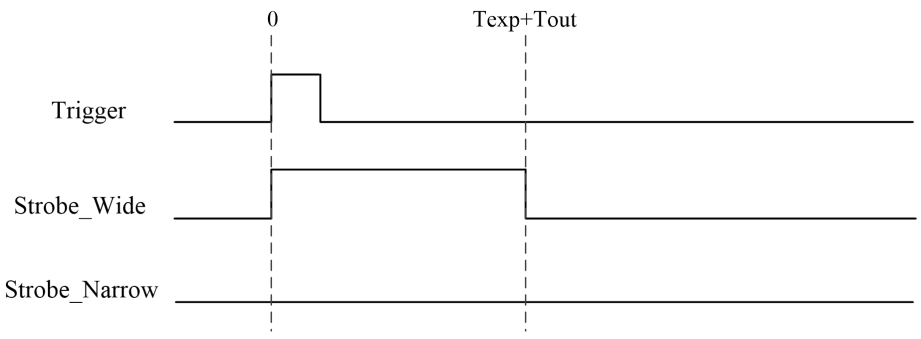


Fig. 22 Exposure Time is less than Readout Time

When exposure time is greater than readout time, the pulse width of the strobe signal in Wide mode is equal to the sum of the exposure time and readout time, while in Narrow mode, the pulse width of the strobe signal is equal to the difference between the exposure time and readout time.

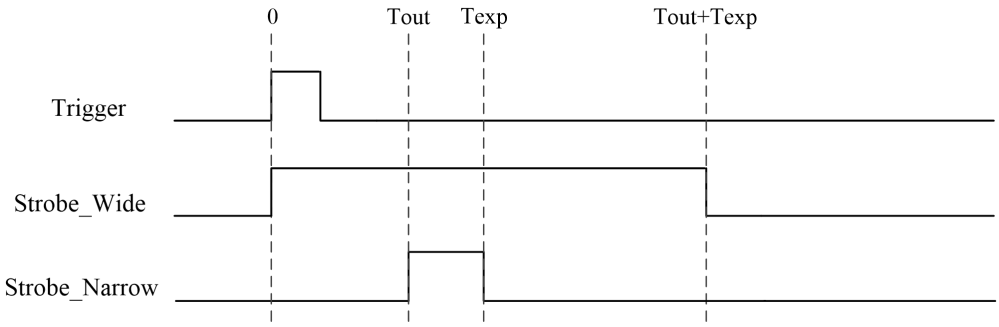


Fig. 23 Exposure Time is greater than Readout Time

- **External PWM mode**

When exposure time is less than readout time, the pulse width of the strobe signal in Wide mode is equal to the sum of the exposure time and readout time. In Narrow mode, there is no signal, and the timing is shown in the following figure.

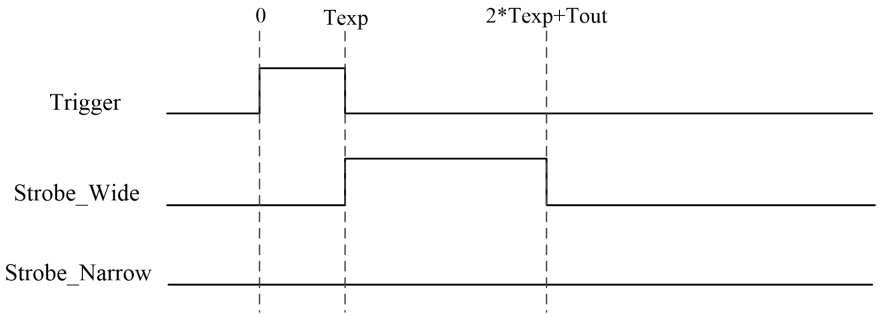


Fig. 24 Exposure Time is less than Readout Time

When exposure time is greater than readout time, the pulse width of the strobe signal in Wide mode is equal to the sum of the exposure time and readout time, while in Narrow mode, the pulse width of the strobe signal is equal to the difference between the exposure time and readout time.

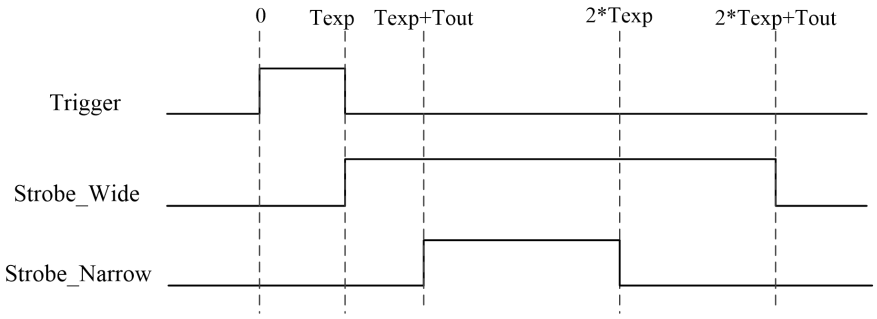


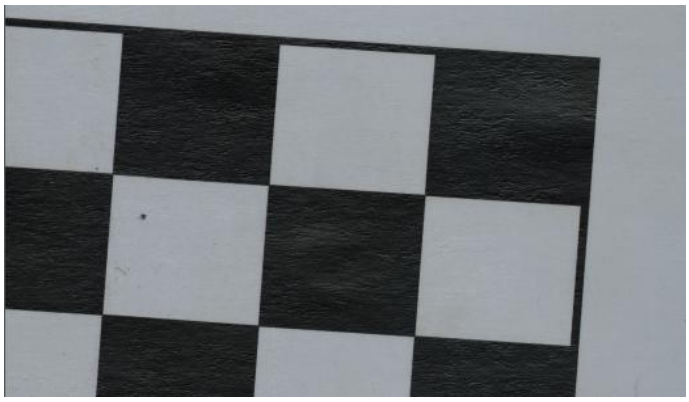
Fig. 25 Exposure Time is greater than Readout Time

6.7 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.

TTS101M(2)CL 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. 26 White Balance

6.8 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. TTS101M(2)CL camera provides a flat field correction function to correct this problem. Actually, users can achieve flat field effect by 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:

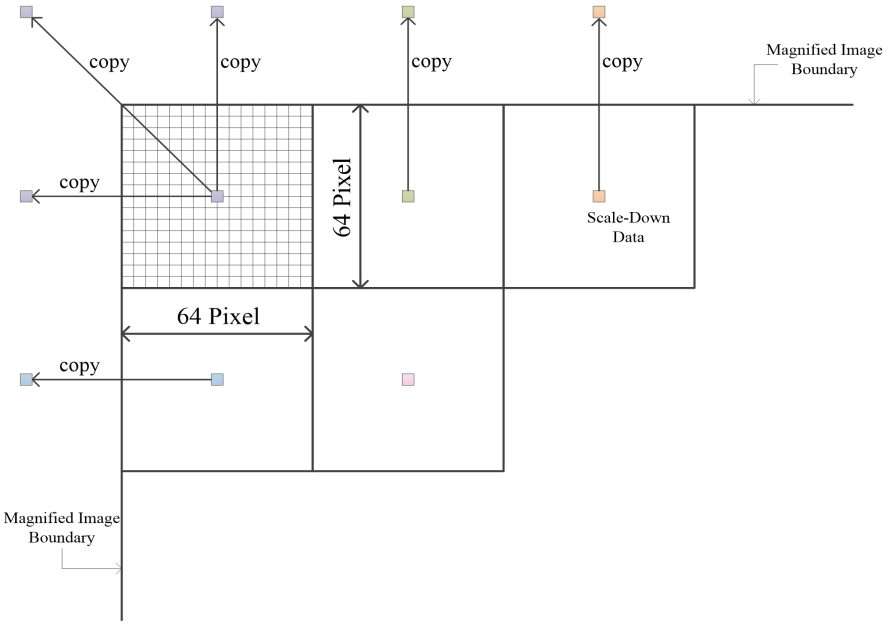


Fig. 27 Flat Field Correction Effect

6.9 Test Image

Camera provides 3 test images. Different from the collected images whose data comes from sensors, the test images are fixed patterns that are pre-edited and stored inside the camera, independent of the scene shot by the camera, and can be used to test whether the data link works normal.

- Test image 1: fixed image with horizontal gray gradient.
- Test image 2: scroll image with vertical gray gradient.
- Test image 3:fixed image with consistent grayscale across all pixels

Fig. 28 Test Image 1

Fig. 29 Test Image 2

Fig. 30 Test Image 3

6.10 Data Format

TTS101M(2)CL camera processes data in 16bit data format, but provides 8bit, 10bit, 12bit and 16bit output. When camera outputs 8bit data, the lowest 8bit data will be deleted. When the camera outputs 10bit of data, the lowest 6bit will be deleted. When the camera outputs 12bit of data, the lowest 4bit will be deleted.

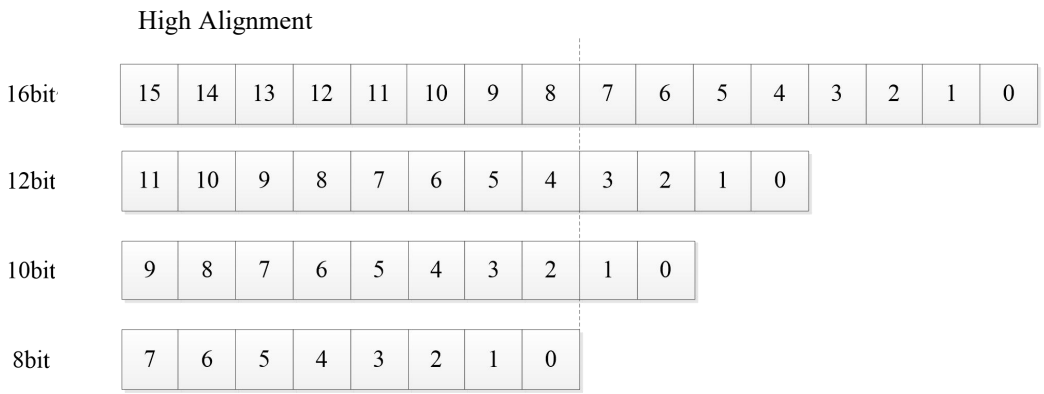


Fig. 31 Data Format

6.11 Gain & Offset

Camera gain is divided into the analog gain and digital gain.

Analog gain acts on analog signal. By increasing analog gain, a stronger response can be generally obtained under weak illumination, thus realizing a higher signal-to-noise ratio.

Digital gain amplifies or reduces data after photoelectric conversion signal passes through AD. It is usually used to increase dynamic range of output image. Digital gain can also be used to adjust brightness of image. Digital offset is often used to adjust overall background brightness of 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 image data is 8bit or 10bit, actual digital offset is divided by 16 or 4.

6.12 Camera Temperature

TTS101M(2)CL camera supports real-time acquisition of camera temperature, and users can monitor the working status of front-end sensor by reading camera temperature value.

The recommended ambient temperature range of the camera is from 0~50℃. If the user detects an abnormal temperature (such as over 55℃), it is recommended to stop the camera immediately and contact our technical support.

6.13 Load / Save Configuration

TTS101M(2)CL camera provides multi 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 multi 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

TTS101M(2)CL camera supports users to send control commands to the camera through the serial channel of the Camera Link interface, and configure the camera working mode.

7.1 Serial Port Parameters

Table 12 Serial Port Parameters

Serial Port Parameters	Value
Baud Rate	115200
Data Bit	8
Parity Bit	N/A
Stop Bit	1
Flow Control	N/A

7.2 Command Format

The commands received by camera have the following two formats depending on whether the command has parameter:

- **Pure command**
  [CMD][CR]
- **Data configuration command**
  [CMD]=[VAL][CR]

After receiving the command, camera will return message in two formats:

- **Format 1**

After receiving the general command, the camera will execute the command and return > OK
For example, input: load=0[CR]
Output: >Ok[CR]

- **Format 2**

After receiving the command to read the internal message, camera will output the corresponding message before >Ok
For example, input: list[CR]
Output: >[MEM][CR]>Ok[CR]

- **Format 3**

After receiving the command to read the internal message, camera will output the corresponding message before >Ok
For example, input: clnk[CR]
Output: [VAL][CR]>Ok[CR]

Note:
[CMD] command, 4byte

[VAL] data, no more than 4 decimal digits
[MEM] memory data
[CR] 0x0D, enter

If the input command is in wrong format, an error code will be returned in stead of Ok, as shown in the table below:

Table 13 Error Codes Returned upon Failure of Command Execution

Return Code	Description
Ok	Correct
0	Correct, Equivalent to Ok
128	Command does not exist.
130	Conflict with other parameters.
131	Parameter value is out of range or does not meet requirements.
132	Command is not allowed to be executed in the current status.
133	Input command syntax error.

7.3 Command List

The list of serial commands supported by TTS101M(2)CL camera is as follows. After connecting the camera through serial port, you can input relevant commands to configure the camera.

Table 14 Camera Instruction List

Command	Description
help	Show this information
list	Show Current Configurations
load	Load Configuration From Flash 0/1/2: Factory/User1/User2
save	Save Current Configuration To Flash 1/2: User1/User2
temp	Get Current Camera Temperature
hmdt	Get Current Camera Humidity
fsyn	Set Frame Sync Mode (0/1/2: Internal Free Run/External Pulse/External PWM)
angn	Set Camera Analog Gain (0~96)
clnk	Set Camera Link Mode (0/1/2/3/4/5/6: 4tap@8/10/12bit,8tap@8/10bit,10tap@8bit,4tap@16bit)
texp	Set Exposure Time in microsecond (73us to 60s)
dmod	Set Data Mode (0/1/2/3/4: Original/Corrected/Pattern_1/Pattern_2/Pattern_3)
dign	Set Digital Gain x0.01~x8.0
dios	Set Digital Offset (-4095 to +4095)
sroi	Set ROI (0/1: Disable/Enable ROI)
rics	Set ROI Window Start Column Address (0~11648) (multiples of 8)
ricc	Set ROI Window Column Count (256~11656) (multiples of 8)
rirs	Set ROI Window Start Row Address (0~8740) (multiples of 2)
rirc	Set ROI Window Row Count (2~8742) (multiples of 2)

bpcr	Bad Pixel Correction (0/1: Disable/Enable)
bplt	List Bad Pixel Array
adbp	Add A New Bad Pixel into Camera (column,row)
rmbp	Remove A Bad Pixel from Camera (column,row)
wbcr	White Balance Correction (0/1: Disable/Enable)
wbpr	Set White Balance Red Parameter (1024 to 16383)
wbpg	Set White Balance Green Parameter (1024 to 16383)
wbpb	Set White Balance Blue Parameter (1024 to 16383)
wbcl	White Balance Correction Calibration (0/1: Init/Calibrate)
ffcr	Flat Field Correction (0/1: Disable/Enable)
ffcl	Flat Field Correction Calibration (0/1: Init/Calibrate)
rffp	Readout Flat Field Correction Data
wffp	Write Flat Field Correction Data (addr,data)
enlt	Look up Table (0/1 Disable/Enable)
slut	Select Look up Table (0/1)
rlut	Readout Current Look up Table
wlut	Write Current Look up Table Data (addr,data)
gama	Set Gamma Correction Parameter Directly (0.01~127)
ftsc	Select Frame Trigger Source (0/1: CC1/IO0)
ftpr	Set Trigger Input Polarity (0/1: rising/falling edge)
sotp	Set Strobe Output Type (0/1: wide/narrow)
sopr	Set Strobe Output Polarity (0/1: high/low)
tftd	Set Frame Trigger Delay in microsecond (0~10ms)
envt	TEC Cooler Control (0/1: Disable/Enable)
tset	Set Sensor Temperature (-10~55C)
efan	Set Fan Speed (0~127)
baud	Set Camera Link Serial Port Baudrate (4800~460800bps)

8 Camera Configuration

Hefei I-TEK Optoelectronics Co., LTD. has implemented a library IKapC.lib for camera configuration based on Gen<i>Cam standard, which allows users to use all Hefei I-TEK Optoelectronics Co., LTD. cameras based on IKapC.lib without re-writing codes for each camera. For more information about IKapC.lib, please refer to IKapC user manual.

Hefei I-TEK Optoelectronics Co., LTD. provides visual camera feature configuration tool IKapCViewer.exe. The following shows how to configure the supported camera features. For more information about IKapCViewer.exe, please refer to IKapCViewer user manual.

8.1 Device Control Category

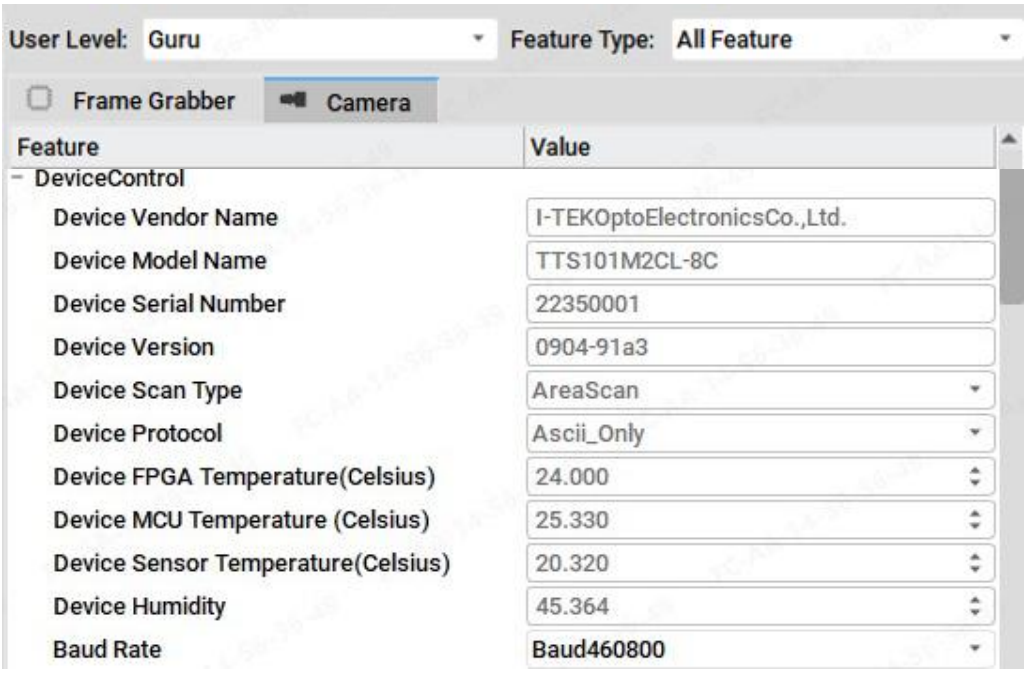


Fig.32 Device Control Category

- **DeviceVendorName**
  Device vendor name.

- **DeviceModelName**
  Device model name.

- **DeviceSerialNumber**
  Device serial number.

- **DeviceVersion**
  Device version.

- **DeviceScanType**
  Device scan type.

- **DeviceProtocol**
  Device protocol.

- **DeviceFPGATemperature**
  Device FPGA temperature.

- **DeviceMCUTemperature**
  Device MCUT temperature.

- **DeviceSensorTemperature**
  Sensor temperature.

- **DeviceHumidity**
  Device humidity.

- **DeviceSerialPortBaudRate**
  Device serial port rate. The enumeration names as follows:
  - Baud9600
  - Baud19200
  - Baud38400
  - Baud57600
  - Baud115200
  - Baud230400
  - Baud460800

8.2 Image Format Control Category

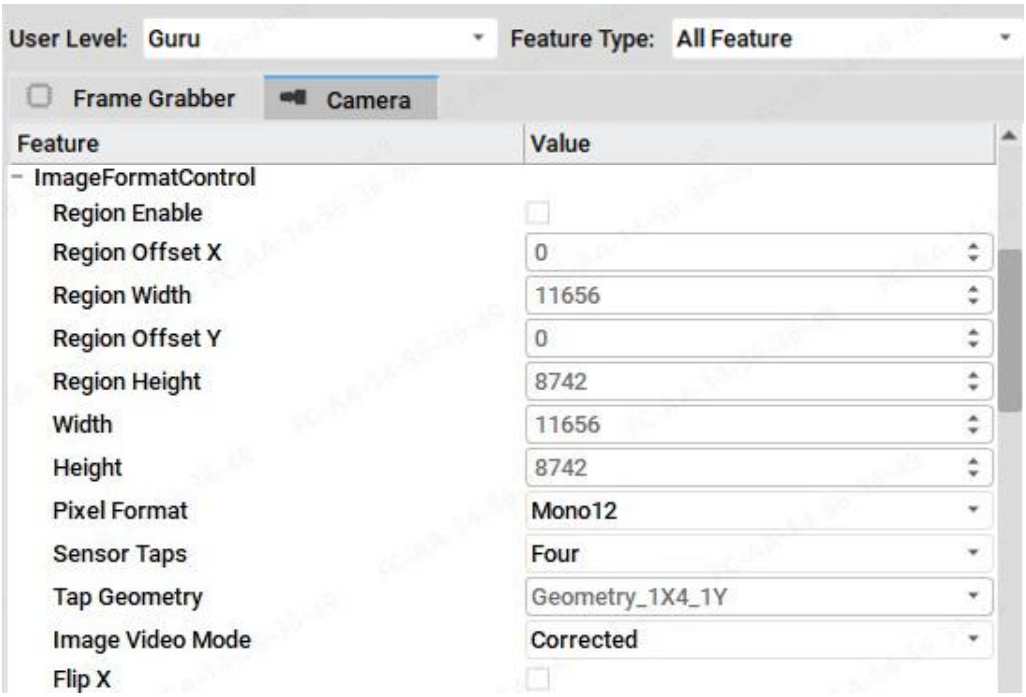


Fig.33 Image Format Control Category

- **RegionEnable**
  Enable ROI.

- **RegionWidth**
  ROI width.

- **RegionOffsetX**
  ROI horizontal offset.

- **RegionHeight**
  ROI height.

- **RegionOffsetY**
  ROI vertical offset.

- **Width**
  Actual width of output image.

- **Height**
  Actual height of output image.

- **PixelFormat**
  Pixel format. The enumeration names as follows:
  - Mono8: Monochrome 8bit
  - Mono10: Monochrome10bit

- Mono12: Monochrome12bit
- Mono16: Monochrome16bit

- **SensorTaps**

  Sensor Tap count. The enumeration names as follows:
  - Four: 4Tap
  - Eight: 8Tap
  - Ten: 10Tap

- **DeviceTapGeometry**

  Tap arrangement.

- **VideoMode**

  Output mode. The enumeration names as follows:
  - Original: Original image
  - Corrected: Corrected image
  - TestPattern1: Test image1
  - TestPattern2: Test image2
  - TestPattern3: Test image3

- **FlipX**

  Horizontal flipping of image.

8.3 Acquisition Control Category

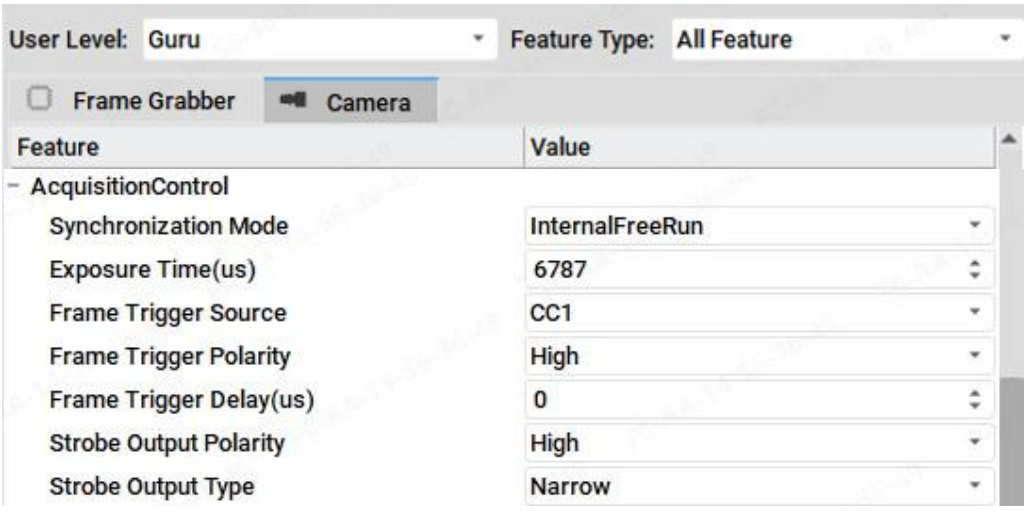


Fig.34 Acquisition Control Category

- **SynchronizationMode**

  Synchronization mode. The enumeration names as follows:
  - InternalFreeRun: Free-Run
  - ExternalPulse: External pulse

- ExternalPWM: External PWM

- **ExposureTime**

  Exposure time, unit is us.

- **FrameTriggerSource**

  Frame trigger signal source. The enumeration names as follows:
  - CC1: Camera Link CC1signal
  - IO0: External IO signal

- **FrameTriggerPolarity**

  Frame trigger signal polarity. The enumeration names as follows:
  - High: Frame trigger signal high-level acquisition
  - Low: Frame trigger signal low-level acquisition

- **FrameTriggerDelay**

  Frame trigger delay time.

- **StrobeOutputPolarity**

  Strobe signal polarity. The enumeration names as follows:
  - High: Default low level, pull-up level when generating strobe signal
  - Low: Default high level, pull-down level when generating strobe signal

- **StrobeOutputType**

  Strobe signal type. The enumeration names as follows:
  - Narrow: Narrow mode
  - Wide: Wide mode

8.4 Analog Control Category

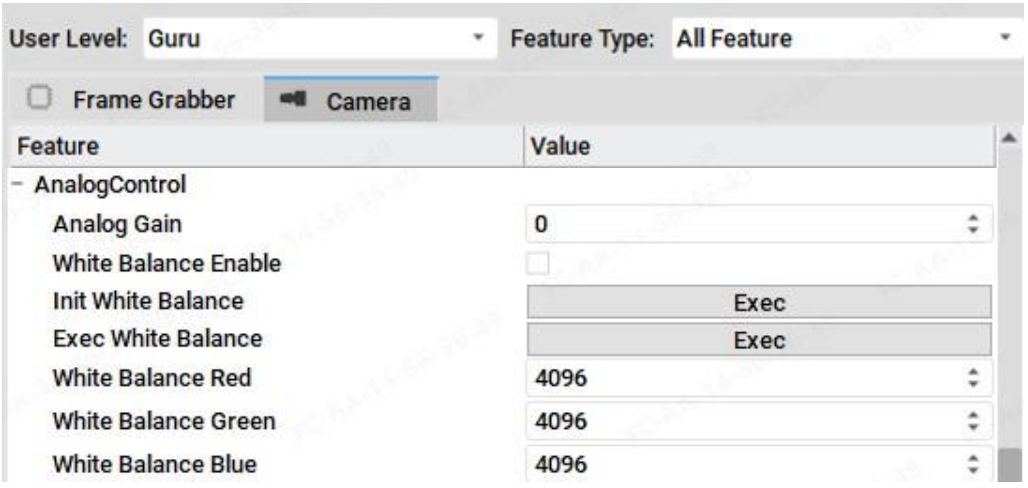


Fig.35 Analog Control Category

- **AnalogGain**
  Analog gain.

- **WhiteBalanceEnable**
  Enable white balance, only allowed for color cameras to set this option.

- **WhiteBalanceInit**
  White balance calibration initialization can restore the white balance parameters to their factory settings. Only allowed for color cameras to set this option.

- **WhiteBalanceExec**
  Perform white balance correction allows for the white balance correction function under current conditions. Only allowed for color cameras to set this option.

- **WhiteBalanceR**
  White balanced R channel gain, only allowed for color cameras to set this option.

- **WhiteBalanceG**
  White balanced G channel gain, only allowed for color cameras to set this option.

- **WhiteBalanceB**
  White balanced B channel gain, only allowed for color cameras to set this option.

8.5 Digital Control Category

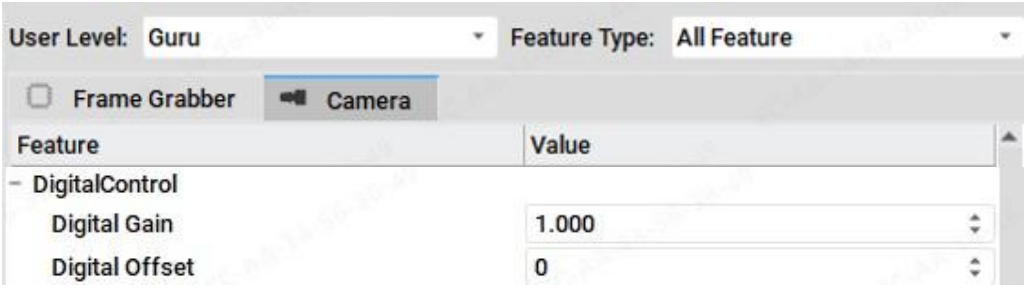


Fig.36 Digital Control Category

- **DigitalGain**
  Digital gain.

- **DigitalOffset**
  Digital offset.

8.6 LUT Control Category

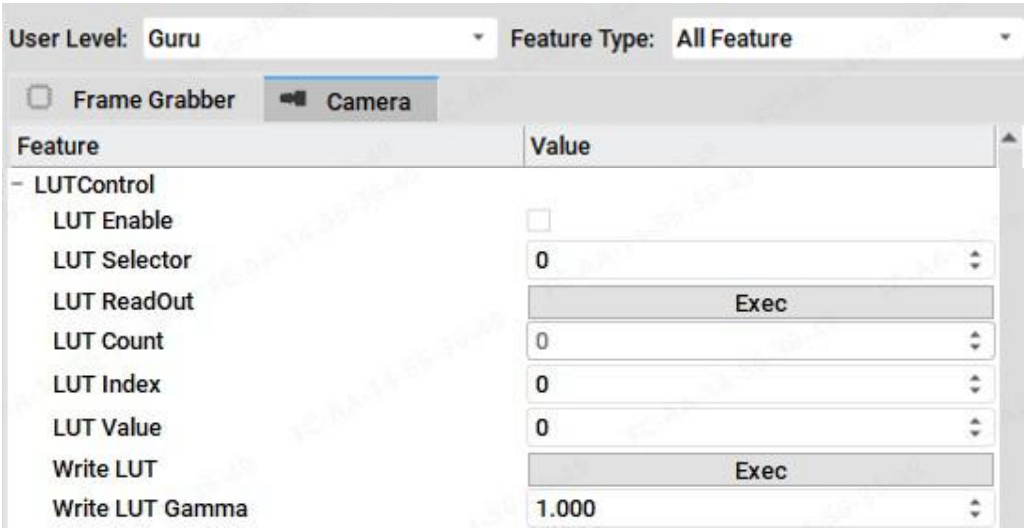


Fig.37 LUT Control Category

- **LUTEnable**
  Enable LUT function.

- **LUTSelector**
  LUT selection.

- **LUTReadOut**
  Read out LUT data.

- **LUTCount**
  The number of LUT.

- **LUTIndex**
  LUT data index, that is, the gray value of image before mapping LUT.

- **LUTValue**
  LUT data value, that is, the gray value of image after mapping LUT.

- **LUTWrite**
  Write into LUT data.

- **LUTGamma**
  Gamma correction coefficient.

8.7 Defect Pixel Control Category

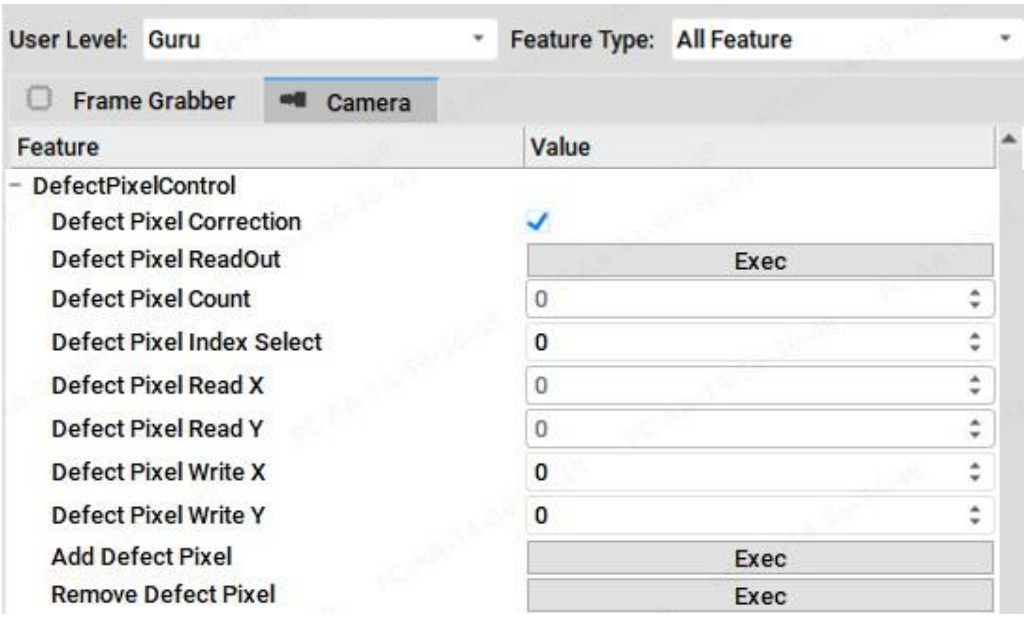


Fig.38 Defect Pixel Control Category

- **DefectPixelCorrectionEnable**
  Enable defect pixel correction.

- **DefectPixelReadOut**
  Read defect pixel.

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

- **DefectPixelSelect**
  Defect pixel index selection.

- **DefectPixelReadX**
  Read the horizontal axis of the current index defect pixel.

- **DefectPixelReadY**
  Read the vertical axis of the current index defect pixel.

- **DefectPixelWriteX**
  Set the horizontal axis of the defect pixel to be written.

- **DefectPixelWriteY**
  Set the vertical axis of the defect pixel to be written.

- **DefectPixelAdd**
  Add defect pixel.

- **DefectPixelRemove**
  Remove current index defect pixel.

8.8 Flat Field Correction Category

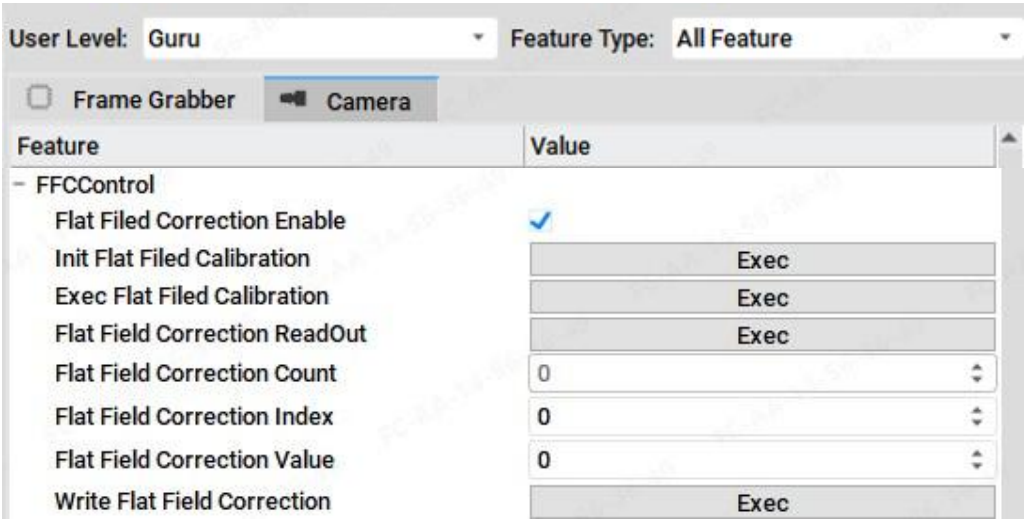


Fig.39 Flat Field Correction Category

- **FFCEnable**
  Enable flat field correction.

- **FFCInit**
  Initialize flat field correction.

- **FFCExec**
  Execute flat field correction.

- **FFCReadOut**
  Read flat field correction data.

- **FFCCount**
  Number of flat field correction parameter sets.

- **FFCIndex**
  Index of flat field correction parameter set.

- **FFCValue**
  Flat field correction data.

- **FFCWrite**
  Write flat field correction data.

8.9 Cooler Control Category

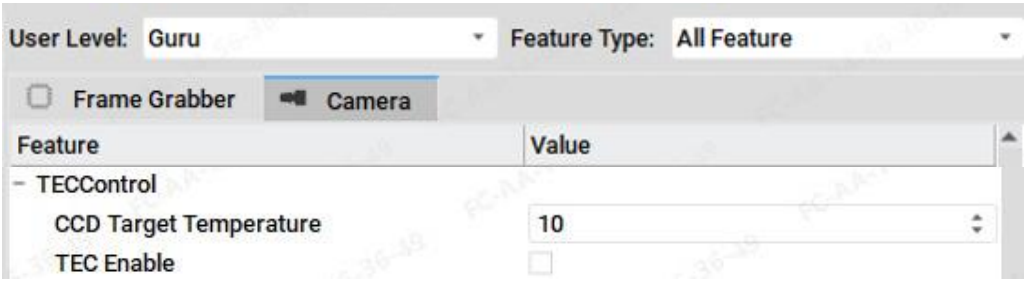


Fig.40 Cooler Control Category

- **CCDTargetTemperature**
  Set TEC cooling target temperature.

- **TECEnable**
  Enable TEC cooling.

8.10 User Set Control Category

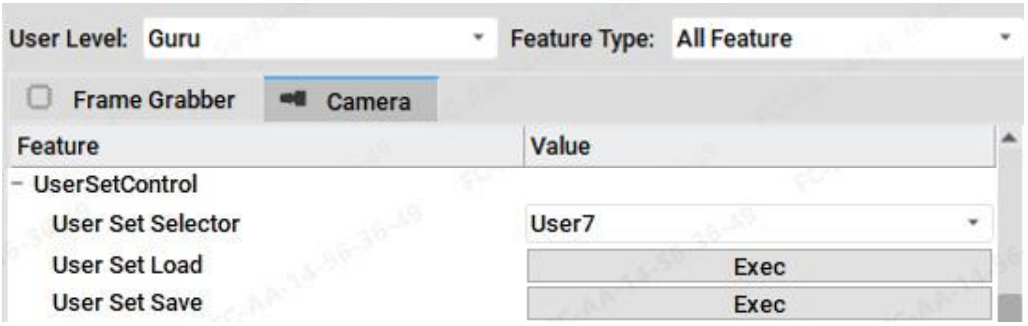


Fig.41 User Set Control Category

- **UserSetSelector**
  User configuration selector. The enumeration names as follows:
  - Factory: Factory configuration
  - User1: User configuration 1
  - User2: User configuration 2
  - User3: User configuration 3
  - User4: User configuration 4
  - User5: User configuration 5
  - User6: User configuration 6
  - User7: User configuration 7

- **UserSetLoad**
  Load selected camera configuration.

- **UserSetSave**

Save selected camera configuration.

9 FAQ

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

① Ensure that the Camera Link interface cable is OK.

② Ensure that the serial port channel parameters in the Camera Link interface are set correctly.

- **If the Camera Link interface cannot receive camera clock signal,**

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

② If a third-party frame grabber is used to acquire images, ensure that the frame grabber and supporting software are operating properly, which can be checked by restarting the computer.

③ Ensure that the Camera Link interface cable is OK.

- **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 Camera Link interface signal is used as the trigger input signal, ensure that the frame grabber is configured correctly.

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

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

② If the case is hot or the camera is smoking, cut off the power immediately and stop using the camera. 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 and offset 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 Camera Link 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 you 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.