User's Manual

Line Scan Camera

Model : NUCLi4KA

CAMERA Link

NIPPON ELECTRO-SENSORY DEVICES CORPORATION

For Customers in U.S.A.

This equipment has been tested and found to comply with the limits for a Class A digital device, in accordance with Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at his or her own expense.

For Customers in the EU

This equipment has been tested and found to comply with the essential requirements of the EMC Directive 2004/108/EC, based on the following specifications applied:
EU Harmonised Standards
EN55011:2009/A1:2010 Class A
EN55032:2015 Class A
EN55032:2012 Class A
EN61000-6-2:2005

Warning
This is a class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

Directive on Waste Electrical and Electronic Equipment (WEEE)

Please return all End of Life NED products to the distributor from whom the product was purchased for adequate recycling and / or disposal. All costs of returning the Product to NED are borne by the shipper.

Introduction

Thank you for purchasing NED's Line Scan Camera. We look forward to your continued custom in the future.

For safety use

- For your protection, please read these safety instructions completely before operating the product and keep this manual for future reference.
- The following symbols appear next to important information regarding safe product handling.

 Warning	If the product is not handled properly, this may result in serious injury or possible death.
 Caution	If the product is not handled properly, this may result in physical injury or cause property damage.

Safety precaution

 Warning

- Never disassemble or modify this product, unless otherwise specified to do so in this manual.
- When hands are wet, avoid handling this product and do not touch any of the connection cable pins or other metallic components.
- Do not operate this product in an environment that is exposed to rain or other severe external elements, hazardous gases or chemicals.
- If the product is not to be used for an extended period of time, as a safety precaution, always unplug the connection cable from the camera unit.
- If the product installation or inspection must be executed in an overhead location, please take the necessary measures to prevent the camera unit and its components from accidentally falling to the ground.
- If smoke, an abnormal odor or strange noise is emitted from the camera unit, first turn off power, then unplug the cable from the camera unit.
- This product is not intended for use in a system configuration built for critical applications.

Instructions before use

- Only operate this product within the recommended environmental temperature range.
- Use only the specified power source and voltage rating.
- Do not drop this product. Avoid exposure to strong impact and vibrations.
- Install the camera unit in a well-ventilated environment, in order to prevent the camera from overheating.
- If the camera must be installed in an environment containing dust or other particles, take required measures to protect the camera unit from dust adhesion.
- Do not unplug the cable while power is being supplied to the camera unit. To prevent product damage, always shut down the power supply before unplugging the power cable.
- When the surface of the camera window becomes dirty due to dust or grime, black smudges appear in the displayed image. Use an air blower to remove the dust particles. Dip a cotton swab into ethanol alcohol and clean the camera window. Be careful not to scratch the glass.
- Use of non-infrared lighting such as a daylight fluorescent lamp is recommended. If halogen lighting is employed, always install an infrared filter into your system configuration.
- Please note that exposure to long wavelength light outside of the sensors visible optical range can affect the image.
- Sensitivity may fluctuate depending on the spectral response level of the light source. In cases like this, changing the light source to one with a different spectral response level may reduce this problem.
- Note that when the CCD is exposed to excessive quantities of light, blooming may occur because this product does not have a special Anti-Blooming function.
- If the CCD is continually exposed to bright light which would exceed the CCD saturation for a long time, the colour filter may become faded. As far as possible, the sensor should be protected from light except when in use.
- For stabilized image capturing, turn ON the power supply and execute aging for ten to twenty minutes before actually using the camera unit.
- Do not share the power supply with motor units or other devices that generate noise interference.
- The signal ground (SG) and the frame ground (FG) are connected inside the camera unit. Design the system configuration so that a loop will not be formed by the ground potential differential.
- Do not disconnect the camera while rewriting the embedded memory.
- When you change the exposure mode that is set at the NED factory, input control signal (CC1) from the capture board.

Product Warranty

Warranty Period

- The product warranty period, as a general rule, is two years from purchase; however, for detailed conditions please contact the sales representative for your region/country.
- However, in some cases due to the usage environment, usage conditions and/or frequency of use, this warranty period may not be applicable.

Warranty Scope

- Product repair will be performed on a Return To Manufacturer basis. On-site maintenance will incur additional charges.
- If defects in material or workmanship occur during the warranty period, the faulty part will be replaced or repaired by us free of charge. Return shipping charges must be paid by the sender. However, the following cases fall outside of the scope of this warranty:
- The expired date of the warranty period on the product repaired or replaced during the warranty period of the original product is the same as the expired date of the warranty period on the original product.

Exclusions from Warranty Coverage

- We will under no circumstances assume responsibility for the following cases: damage caused by fire, earthquake, other acts of a third party, other accidents, negligent or intentional misuse by the user, or other usage under extraordinary circumstances.
- Damages (e.g. Loss of business profits, business interruption, etc.) resulting from use or non-use.
- Damages caused by use other than as described in this document.
- Damages resulting from malfunction due to a connected device.
- Damages resulting from repairs or modifications performed by the customer.

Fault Diagnosis

- As a general rule, in the first instance fault diagnosis should take the form of a telephone call or an email to enable us to assess the circumstances of the malfunction.
- However, depending on the customer’s requests, we, or our agent, may require an additional fee for this service.

Exclusion of Liability for Compensation for Missed Opportunities

- Regardless of whether within the warranty period or not, our warranty does not cover compensation for missed opportunities for our customers, or our customers' customers, caused by a fault of our products, nor for damage to products other than our own, or related business.

Note about Product Usage

- This product has been designed and manufactured as a general-purpose product for general industry. In applications expected to be life-critical or safety-critical, the installer or user is requested to install double or triple failsafe systems.

Repair Service Outline

- The cost of dispatching engineers etc. for repair service is not included in the price of purchased and supplied goods. On request, arrangements can be made separately.

Scope of Repair Service

- The above assumes business dealings and usage to take place in the customer's region / country. In cases of business dealings and/or usage outside the customer's region/country, separate consultation is required.

Table of Contents

1 Product Outline

1.1 Features

- High speed readout（80MHz, 3 taps, 8/10 bits）
- High resolution（4096pixels）
- Easy control of gain / offset / video output with external software.
- Single power source DC12V to 15V for operation
- Flat-field correction - minimizes lens vignetting, non-uniform lighting and sensor FPN and PRNU
- Auto white balance
- Pseudo-exposure control

1.2 Applications

- Inspection of Transparent panels and PCBs
- Visual inspection of color printed materials
- Color identification and inspection of foreign material
- Inspection of sheet film
- Inspection of wood surface

An example of Visual Inspection of PCBs is shown below.

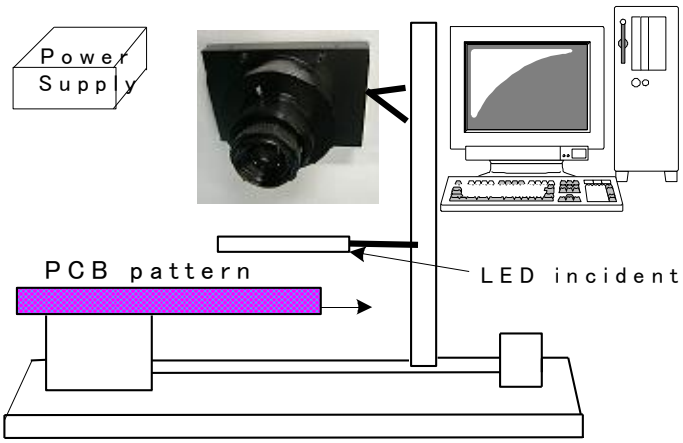


Figure 1-2-1 Visual Inspection of PCBs

Applicable Work

PCB pattern

Performance

1. Maximum board size: 150mm×150mm
2. Resolution: 20μm
3. Inspection time: less than 30 seconds

Unit Configuration

1. Camera: Color line scan camera
2. Controller: Dedicated software for PC system
3. Size: L930 x D500 x H500 (mm)

Applicable Fields

Inspection of patterns on film PCBs

1.3 Image Sensor

The camera uses a CCD sensor with a maximum data rate of 140MHz to acquire high responsivity and superior quality images.

The pixel size is 10μm x 10μm. It outputs 4096pixels data through 80MHz.

1.4 Performance Specifications

The Performance Specifications are shown below. Unless otherwise specified, the data shown is when the camera is operating at the maximum scan rate.

Table 1-4-1 Performance Specifications

Items	Specifications
Number of Pixels	4096 x 3
Pixel Size H x V (μm)	10 x 10
Sensor Length (mm)	40.96
Line pitch (μm)	40 (=4 lines) *R-G G-B distance
Spectral Responsivity (nm)	400 – 700 (Peak:R=610,G=540,B=460) See Figure 1-4-1
Data Rate (MHz)	80
Maximum Scan Rate (kHz) / (μs)	17.7 / 56.4 * In Pseudo-exposure control mode 8.8 / 112.8
Saturation Exposure （lx・s） (typically)	0.0384 [Minimum Gain, Daylight Fluorescent Light]
Responsivity（typically） [Minimum Gain, Daylight Fluorescent Light]	130(V/[lx・s]) Analog 5V Conversion Sensitivity/Visible Area (400～700nm)

Gain Adjustable Range		Recommended： x 1 to x 2.5 * Possible : up to x 5
Offset Adjustable Range * Digital Number(DN)		8 bit：0 to 15 DN (16 Steps) 10 bit：0 to 60 DN (16 Steps)
PRNU (Photo Response Non Uniformity)		Typically 6 % (without correction, at minimum gain) 2 % (with correction, at minimum gain)
Random Noise		Typically 30DN (peak value at minimum gain)
Video output		Camera Link Base Configuration (8 bit 3 tap) Camera Link Medium Configuration (10bit 3tap) See Table 3-3-1
Control Input		CC1: External Trigger Signal, CC2: Encoder input signal CC3, 4: Not in use
Connectors	Data/Controller	3M: MDR26 [Camera Link] x 2
	Power Supply	Hirose: HR10G (6Pin)
Lens Mount		Nikon F Mount
Operating Temperature (˚C) *No Condensation		0 to 50 *1
Power Supply Voltage (V)		DC12 to 15 [+/-5%] 2.5 A
Consumption Current (mA) (typically)		900
Size W x H x D (mm)		150 × 100 × 70.1
Mass (g)		Approx. 900
Additional Functions		1. Auto white balance 2. Pixel correction 3. RGB line delay 4. Line fine adjusting correction setting 5. Pseudo-exposure control mode 6. Programmable Exposure Control 7. Average output mode 8. Gain / Offset Control 9. 8 or 10 bits Video Output 10. Scan Direction Switching 11. Test Pattern Output

*1 : The CCD image sensor used in this camera has high power consumption.
Use the camera in the environment that the temperature of the camera front panel surface is at less than 50℃.

The spectral Responsivity is shown below.

（Ta=25℃）

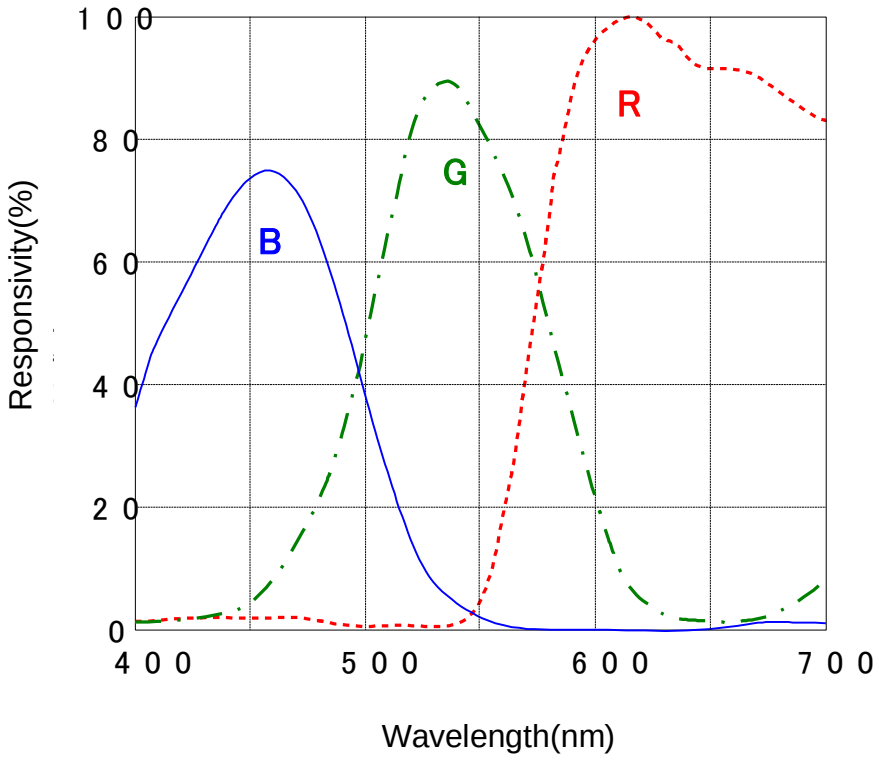


Figure 1-4-1 Spectral Responsivity

2 Camera Setting and Optical Interface

2.1 Setting Camera

The M4 screws on the front panel can be used to set the camera.

Use the camera mounting bracket with excellent heat radiation property to radiate the heat of the camera from camera front panel to the camera mounting bracket.

2.2 Fixing Camera

◆ No X-, Y-axis orientation and tilt adjustment mechanism is available. Please provide an adjustment mechanism yourself as necessary.

2.3 Camera dimension

The dimensions for the cameras are shown below.

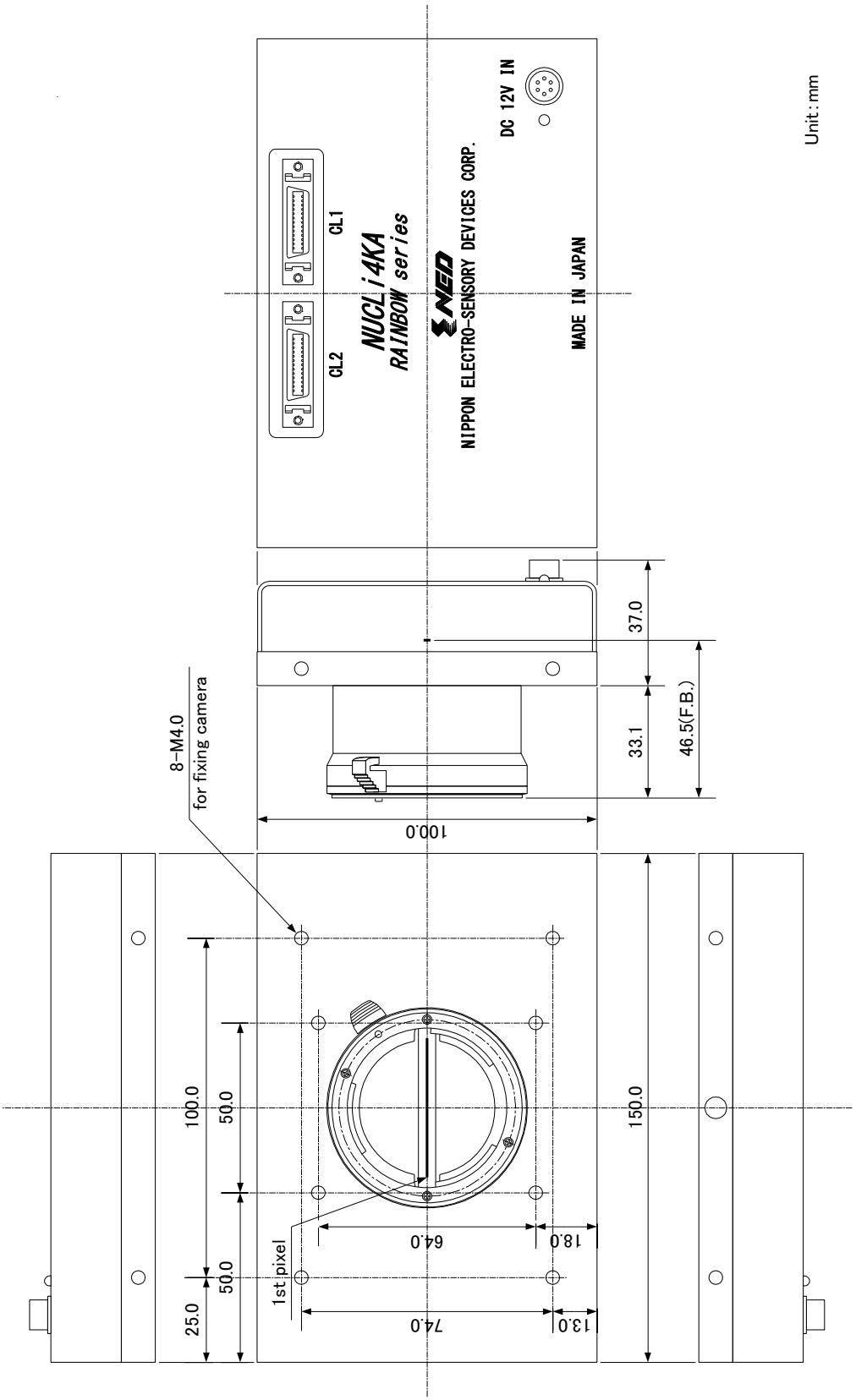


Figure 2-3-1 Dimensions（Nikon F Mount）

2.4 Optical Interface

For the camera Nikon F mount is used.

The amount and wavelengths of light required to capture useful images depend on the intended use. Factors include the property, speed, the object's spectral characteristics, exposure time, the light source characteristics, the specifications of the acquisition system and so on.

The exposure amount (exposure time x light amount) is the most important factor in getting desirable images. Please determine the exposure amount after studying what is most important to your system.

Keep these guidelines in mind when setting up your light source:

- LED light sources are relatively inexpensive, provide a uniform field and longer life span compared to other light sources. However, they also require a camera with excellent sensitivity.
- Halogen light sources generally provide very little blue relative to infrared light (IR).
- Fiber-optic light distribution systems generally transmit very little blue light relative to IR.
- Metal halide light sources are very bright but have a shorter life span compared to other light sources.

Generally speaking, the brighter light sources, the shorter life span.

CCD image sensors are sensitive to infrared (IR). We recommend using daylight color fluorescent lamps that have low IR emissions. If you use a halogen light source, to prevent infrared from distorting the images use an IR cutoff filter that does not transmit IR wavelengths.

3 Hardware

3.1 Camera Connection

(1) Camera Link cables shall be used to connect the camera unit with the frame grabber board.

◆ Use two cables of the same length and the same manufacturer. If you use asymmetric Camera Link cables, connect the camera with the connector labeled as ”Camera side”. But only one cable is required at 8-bit 3-tap output

(2) Connect with a power supply.

Use a power cable to connect the camera with the power source for the camera. Insert the plug end of the cable into the camera. Attach the opposite end (loose wires) to the power unit.

◆ Other than the above, a personal computer, a frame grabber board, a photographic lens, a photographic lens mount, a light source and an encoder are necessary, depending on the situation.

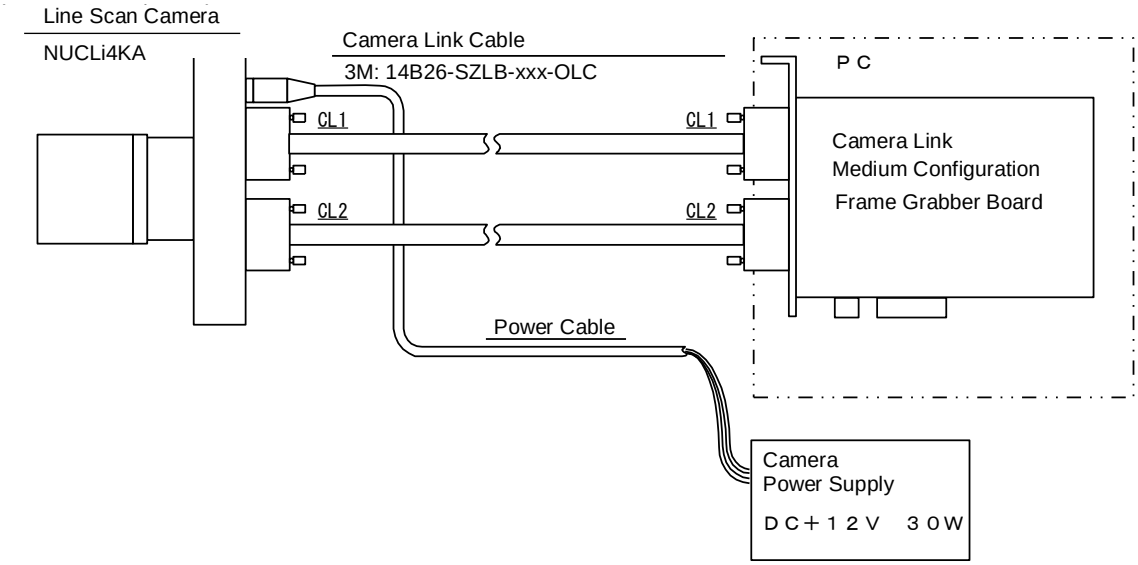


Figure 3-1-1 Connections between Camera and Frame Grabber Board and Power Supply

◆ There are two connectors available for the Camera Link Medium or Full Configuration board. Always check the frame grabber board specifications before making connections.

<Note: Choosing the appropriate Camera Link cable length >

According to the Camera Link Specification, the maximum cable length is 10m. But the maximum cable length to be able to transfer data depends on the type of cable performance and clock speed. The actual maximum transmission distance becomes less than 10m at faster clock speeds, though the transmission distance of 10m is feasible at slower clock speeds.

The following table shows values being calculated in accordance with the Camera Link Specification 2007.Version1.2, using a typical cable (14B26-SZLB-xxx-0LC from 3M) and frame grabber board (Solios from Matrox). Please choose the appropriate Camera Link cable type and length for your application. We recommend you perform a connection test in advance.

Table 3-1-1 calculated value of maximum cable length

Solios model	clock speed（MHz）	maximum cable length (m)
SOL 6M CL E* (20～66MHz)	40	9.8
	66	8.0
SOL 6M FC E* (20～85MHz)	75	7.6
	85	5.8

3.2 Input / Output Connectors and Indicator

The layout of input /output connecters and the indicator lamp are as follows.

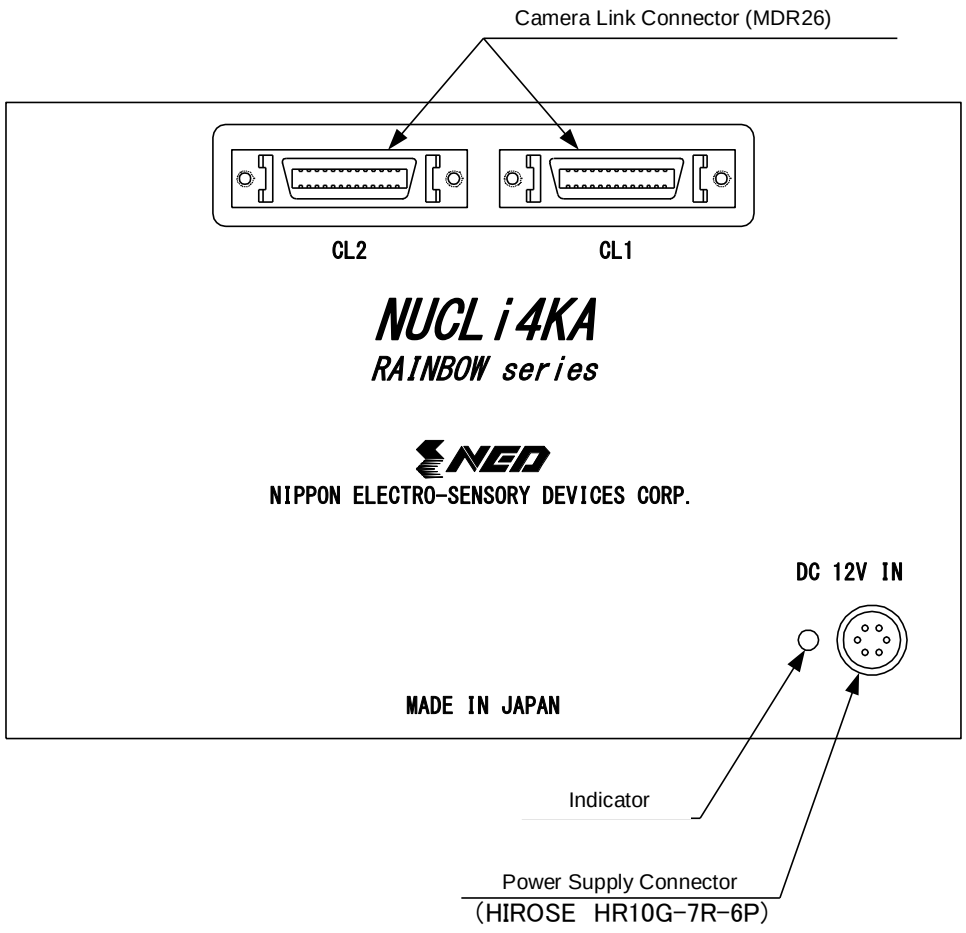


Figure 3-2-1 Input/Output Connectors and Indicator

3.3 Connectors・Pin Assignments・Cables

This camera uses the Base Configuration (8-bit 3-tap output), the Medium Configuration (10-bit 3-tap output) of the Camera Link interface standard. The figure shown below shows the interface for the camera and a typical implementation for the frame grabber interface in the case of Medium Configuration.

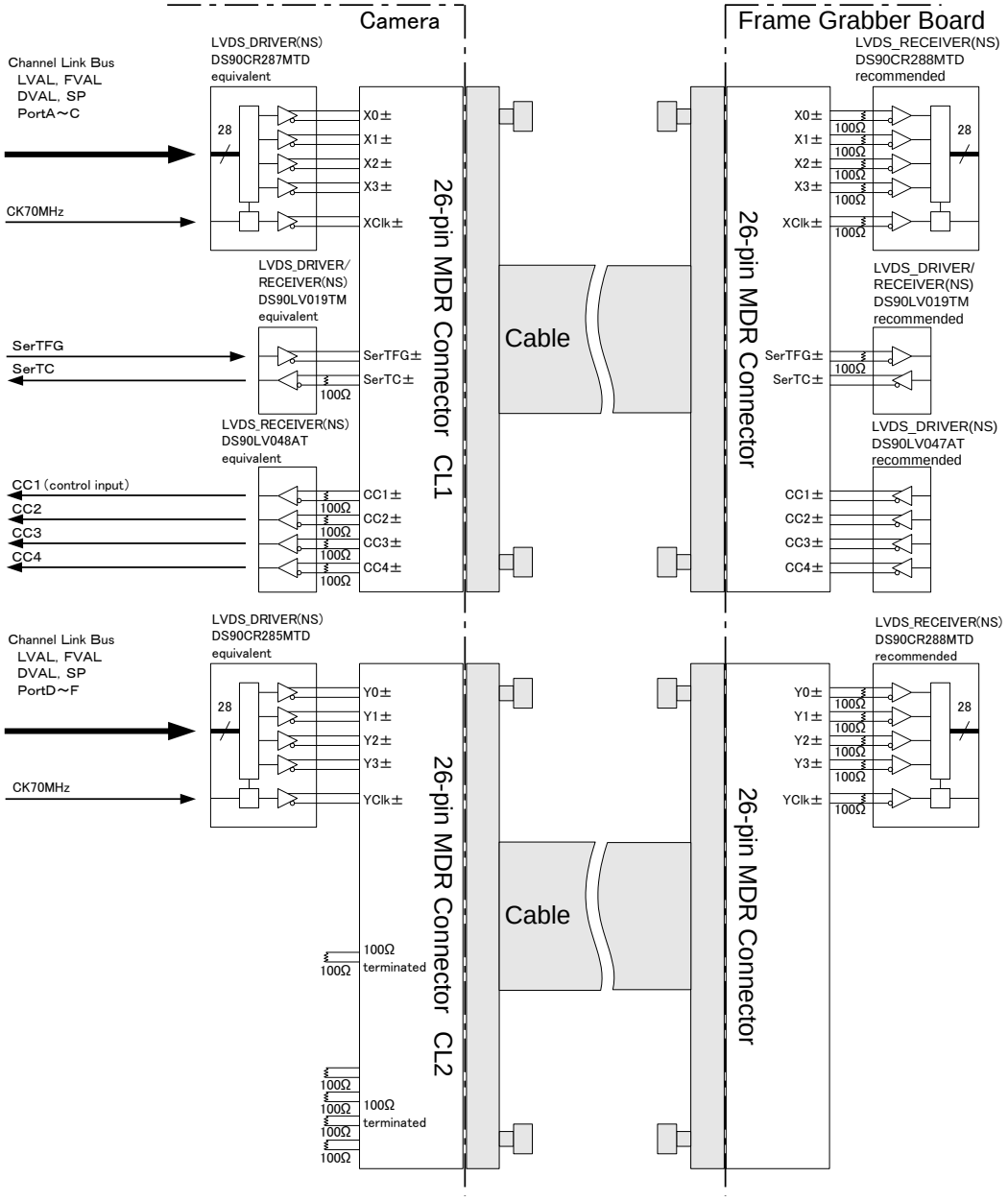


Figure 3-3-1 Camera / Frame Grabber Interface

The table below shows the Camera Link port assignments for 8-bit 3-tap or 10-bit 3-tap output.

Table 3-3-1 Output data bit assignment

	8-bit RGB	10-bit RGB
	Base Configuration	Medium Configuration
Port A0	R0	R0
Port A1	R1	R1
Port A2	R2	R2
Port A3	R3	R3
Port A4	R4	R4
Port A5	R5	R5
Port A6	R6	R6
Port A7	R7	R7
Port B0	G0	R8
Port B1	G1	R9
Port B2	G2	—
Port B3	G3	—
Port B4	G4	B8
Port B5	G5	B9
Port B6	G6	—
Port B7	G7	—
Port C0	B0	B0
Port C1	B1	B1
Port C2	B2	B2
Port C3	B3	B3
Port C4	B4	B4
Port C5	B5	B5
Port C6	B6	B6
Port C7	B7	B7
Port D0	—	—
Port D1	—	—
Port D2	—	—
Port D3	—	—
Port D4	—	—
Port D5	—	—
Port D6	—	—
Port D7	—	—

	8-bit RGB	10-bit RGB
	Base Configuration	Medium Configuration
Port E0	—	G0
Port E1	—	G1
Port E2	—	G2
Port E3	—	G3
Port E4	—	G4
Port E5	—	G5
Port E6	—	G6
Port E7	—	G7
Port F0	—	G8
Port F1	—	G9
Port F2	—	—
Port F3	—	—
Port F4	—	—
Port F5	—	—
Port F6	—	—
Port F7	—	—
Port G0	—	—
Port G1	—	—
Port G2	—	—
Port G3	—	—
Port G4	—	—
Port G5	—	—
Port G6	—	—
Port G7	—	—
Port H0	—	—
Port H1	—	—
Port H2	—	—
Port H3	—	—
Port H4	—	—
Port H5	—	—
Port H6	—	—
Port H7	—	—

- Set the LVDS, Channel Link receiver side to 100-ohm termination.
- With the driver side of LVDS, even if not used, do not make it open but set the logic to H or L.

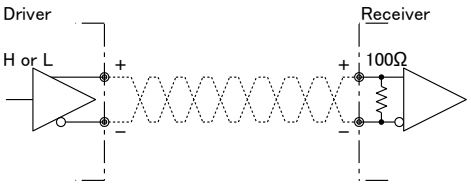


Figure 3-3-2 Circuit of LVDS

The camera has 26-pin MDR connectors for control signals of Camera Link, data signals and serial communications. The camera also has a 6-pin HIROSE connector for power supply.

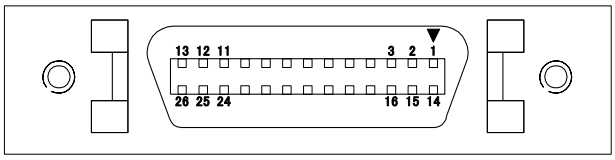


Figure 3-3-3 Camera Link Connector

- Half pitch (miniature half ribbon) shape
- Locking screw (UNC #4-40) type

Table 3-3-2 Camera Link Connector (26-pin MDR Connector) pin assignments

CL1 (Base Configuration)

No	NAME	No	NAME	I/O
1	Inner Shield	14	Inner Shield	
2	X0-	15	X0+	Out
3	X1-	16	X1+	Out
4	X2-	17	X2+	Out
5	Xclk-	18	Xclk+	Out
6	X3-	19	X3+	Out
7	SerTC+	20	SerTC-	In
8	SerTFG-	21	SerTFG+	Out
9	CC1-	22	CC1+	In
10	CC2+	23	CC2-	In
11	CC3-	24	CC3+	In
12	CC4+	25	CC4-	In
13	Inner Shield	26	Inner Shield	

CL2 (Medium or Full Configuration)

No	NAME	No	NAME	I/O
1	Inner Shield	14	Inner Shield	
2	Y0-	15	Y0+	Out
3	Y1-	16	Y1+	Out
4	Y2-	17	Y2+	Out
5	Yclk-	18	Yclk+	Out
6	Y3-	19	Y3+	Out
7	100Ω terminated	20	100Ω terminated	
8	Z0-	21	Z0+	Out
9	Z1-	22	Z1+	Out
10	Z2-	23	Z2+	Out
11	Zclk-	24	Zclk+	Out
12	Z3-	25	Z3+	Out
13	Inner Shield	26	Inner Shield	

- Explanation of Signals

  Inner Shield: Shield cable (GND)
  X0+, X0-…X3+, X3-: Data output (Channel Link)
  Xclk+,Xclk- : Clock output for above data output synchronization (Channel Link)
  Y0+, Y0-…Y3+, Y3-: Data output (Channel Link)
  Yclk+,Yclk- : Clock output for above data output synchronization (Channel Link)
  Z0+, Z0-…Z3+, Z3-: Data output (Channel Link)
  Zclk+, Zclk- : Clock output for above data output synchronization (Channel Link)
  SerTC+, SerTC- : Serial data input (LVDS)
  SerTFG+, SerTFG- : Serial data output (LVDS)
  CC1+,CC1- : External synchronous signal input (LVDS)
  *When External Trigger is used.
  CC2+,CC2- : External encoder signal input(LVDS)
  *When Average output mode is used
  CC3+,CC3- : Not in use (LVDS)
  CC4+,CC4- : Not in use (LVDS)

- Camera Link cable compatibility

  3M：14B26-SZLB-xxx-0LC or equivalent

- To avoid uncoupling of cable connectors during power on, make sure to clamp them with locking screws.
- Do not unplug the cable while power is being supplied to the camera.

The pin assignment of the power supply connector is shown below.

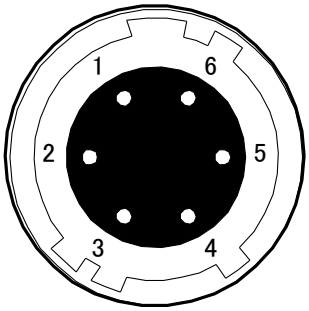


Figure 3-3-4 Power Supply Connector (HIROSE: HR10G -7R- 6P)

- Round shape push-pull lock type

Table 3-3-3 Pin Assignment of Power Supply Connector

No	NAME
1	12 -15V
2	12 -15V
3	12 -15V
4	GND
5	GND
6	GND

3.4 Power Supply

The camera requires a single power supply (DC+12 to +15V).

- ◆ When selecting a power source, choose one with the capacity to allow for inrush current. (30W or more recommended)
- ◆ Insert the cable plug securely until it locks into position. This is to prevent the connector from coming loose during power transmission.

- ● Compatible Cable (Compatible plug): DGPSH -10 (HIROSE: HR10A -7P - 6S)
- ● Power supply voltage: DC+12 -15V (+/-5%)
- ● Consumption Current (rated): DC+12V: 900mA

- ● The LED lamp illuminates when +12V to +15V power is being supplied to the camera.
- ◆ If the lamp fails to illuminate even after power is supplied, turn off power immediately. Inspect wiring. Check the voltage and capacity of the supplied power source.
- ◆ Provide a lightning surge protector on the power supply line for the camera used in in the region where the possibility of thunder becomes high.
- ◆ Do not share the power supply and ground connection with the apparatus such as the inverter controlled motor units or other devices that generate noise interference to avoid the failure and malfunction of the camera. Place the camera far away from the apparatus generating noise. Do not arrange the signal cables and the power supply cable for camera adjacently.

4 Camera Control

The camera can be controlled through serial communication. Two methods can be used to change the camera's parameters. The first approach is to change parameters using NCCtrl(Camera control software). (See "8 NCCtrl".) Or you can also change the parameters directly from your application by using binary read/write commands to set values in the camera register.

The camera can be used without the serial interface after it has been set up correctly.

4.1 Flow of Camera Control

4.1.1 Command Overview

The serial interface uses a simple ASCII-based command.

- Communication begins when the computer sends control commands to the camera.
- The camera receives and interprets the computer commands and then executes control operation accordingly.
- Transmission ends when the camera returns the analyzed results of control commands to the computer.
- ◆ Always allow the previous transmission to end before starting the next transmission. (Only one command can be sent per transmission.)

4.1.2 Command Format (PC to Camera Transmission)

- Format 1 CMD CR
- Format 2 CMD VAL CR

CMD: Control text (1 Byte) Use 1~5 lowercase letters only. No numerals allowed.

CR: Carriage Return (0x0D)

VAL: Setting value (decimal, 1 Byte x maximum 8 digits)

<Example>

r0CR

WBr684CR

4.1.3 Reply Format (Camera to PC Transmission)

- Format 1 >R CR >[SB] CR EOT
- Format 2 (for “l” command) >OK CR >[MEM] CR >l CR EOT

> : Results start text (0×3E)
R: Camera receive command analyzed results
[SB] : Camera receive command send back
[MEM] : Memory data readout value
CR: Separated text (0×0D)
EOT: Send command all text End text (0×04)

<Example>

>OK CR >r 0 CR EOT

Table 4-1-3-1 Error Messages

Camera Response	Meaning
OK	Camera executed command
CMD ERR!	Command is not valid
CMD OVR ERR!	Command text line is too long
VAL ERR!	Parameter accepted was outside of specified
MEM ERR!	Memory error

4.1.4 Camera Control Commands

The table below shows the list of Camera Control Commands.

Table 4-1-4-1 List of Camera Control Commands

Control Item	CMD	VAL	Control Description
Gain	r	90 to 210	Red gain adjustment (all pixels) x1...x2.5
	g	60 to 200	Green gain adjustment (all pixels) x1... x2.5
	b	120 to 220	Blue gain adjustment (all pixels) x1... x2.5
	grfo	90 to 210	Red (front half, odd pixels) gain adjustment x1...x2.5
	grfe	90 to 210	Red (front half, even pixels) gain adjustment x1...x2.5
	grro	90 to 210	Red (rear half, odd pixels) gain adjustment x1...x2.5
	grre	90 to 210	Red (rear half, even pixels) gain adjustment x1...x2.5
	ggfo	60 to 200	Green (front half, odd pixels) gain adjustment x1...x2.5
	ggfe	60 to 200	Green (front half, even pixels) gain adjustment x1...x2.5
	ggro	60 to 200	Green (rear half, odd pixels) gain adjustment x1...x2.5
	ggre	60 to 200	Green (rear half, even pixels) gain adjustment x1...x2.5
	gbfo	120 to 220	Blue (front half, odd pixels) gain adjustment x1...x2.5
	gbfe	120 to 220	Blue (front half, even pixels) gain adjustment x1...x2.5
	gbro	120 to 220	Blue (rear half, odd pixels) gain adjustment x1...x2.5
	gbre	120 to 220	Blue (rear half, even pixels) gain adjustment x1...x2.5
Auto white balance Setting	WBr	128 to 896	Red channel brightness level
	WBg	128 to 896	Green channel brightness level
	WBb	128 to 896	Blue channel brightness level

Run Auto white balance function	WB		Run Auto white balance function
Offset	q	0 to 15	Red offset adjustment (all pixels) 0...15 (1 DN / step at 8 bit) 0...60 (4 DN / step at 10 bit)
	o	0 to 15	Green offset adjustment (all pixels) As above
	p	0 to 15	Blue offset adjustment (all pixels) As above
	orf	0 to 15	Red (front half pixels) offset adjustment As above
	orr	0 to 15	Red (rear half pixels) offset adjustment As above
	ogf	0 to 15	Green (front half pixels) offset adjustment As above
	ogr	0 to 15	Green (rear half pixels) offset adjustment As above
	obf	0 to 15	Blue (front half pixels) offset adjustment As above
	obr	0 to 15	Blue (rear half pixels) offset adjustment As above
Output Signal Setting	v	0 to 1	8-bit / 10-bit
Operation Status Readout	sta		Returns the current camera settings
Memory Initializing	z		Reset to factory settings
Memory Load	l		Readout setup data in memory
Memory Save	w		Store present setup data in memory
Line Delay	d	-5 to 5	Adjust output delay between lines (RGB)
Line Fine Adjusting Correction	ldlys	-5 to 5	Line fine adjusting correction for output datas at each RGB
Pixel Correction Reference Setting	MFr	0 to 1023	Red Channel factory set Pixel Correction Reference Level
	MFg	0 to 1023	Green Channel factory set Pixel Correction Reference Level
	MFb	0 to 1023	Blue Channel factory set Pixel Correction Reference Level
	MUr	0 to 1023	Red Channel User1 Pixel Correction Reference Level

	MUg	0 to 1023	Green Channel User1 Pixel Correction Reference Level
	MUb	0 to 1023	Blue Channel User1 Pixel Correction Reference Level
	MVr	0 to 1023	Red Channel User2 Pixel Correction Reference Level
	MVg	0 to 1023	Green Channel User2 Pixel Correction Reference Level
	MVb	0 to 1023	Blue Channel User2 Pixel Correction Reference Level
Pixel Correction Data Import	W		Acquire user pixel correction data
Pixel Correction Data Save	L		Store the acquired data in the memory
Pixel Correction Mode	C	0 to 3	Off / On (Reset to factory set selection) / On (User1 Pixel Correction selection) / On (User2 Pixel Correction selection)
Exposure Mode	t	0 to 4	Free Run / Edge mode / Pseudo Exposure control (Edge Mode) / Pseudo Exposure control (Level Mode) / Average Output Mode
Programmable Exposure Time	expo	56400 to 32767000	56.4μs～32.767ms
Test Pattern	T	0 to 1	Off / On
Scanning Direction	rev	0 to 1	Forward / Reverse

4.1.5 Memory Setup Values (Factory Settings)

The memory setup values (factory settings) are shown below.

Table 4-1-5-1 Memory Setup Values (Factory Settings)

Control Item	CMD	VAL1	Control Description
Gain	grfo, grfe grro, grre	≒90	Red front and rear half, odd-even pixel gain (x1)
	ggfo, ggfe ggro, ggre	≒60	Green front and rear half, odd-even pixel gain (x1)
	gbfo, gbfe gbro, gbre	≒120	Blue front and rear half, odd-even pixel gain (x1)
Auto white balance setting	WBr,WBg,WBb	684	Red,Green,Blue channel brightness level
Offset	orf, orr	8	Red front and rear half pixel offset (8DN)
	ogf, ogr	8	Green front and rear half pixel offset (8DN)
	obf, obr	8	Blue front and rear half pixel offset (8DN)
Output Signal Setting	v	0	8-bit
Delay Line Setting	d	4	Output delay between lines (RGB)
Line Fine Adjusting Correction	ldlys	0	No fine adjusting correction for output line at each RGB
Pixel Correction Reference Setting	MFr,MFg,MFb	760	Red,Green,Blue channel factory set Pixel Correction Reference Level
	MUr,MUg,MUb	760	Red,Green,Blue channel User1 Pixel Correction Reference Level
	MVr,MVg,MVb	760	Red,Green,Blue channel User2 Pixel Correction Reference Level
Pixel Correction Mode	C	1	On(factory set Pixel Correction)
Programmable Exposure Time	expo	56400	56.4μs
Exposure Mode	t	0	Free Run
Test Pattern	T	0	Off
Scanning Direction	rev	0	Forward

4.2 Details on Commands

4.2.1 Adjusting automatic white balance

Adjusts RGB balance.

- Format 2 CMD VAL CR
- CMD WBr(WBr,WBg,WBb)
- VAL 128～896

<Example>

WBr700CR（Sets R output level before pixel correction to 700DN(10 bit）

>OK

>WBr700

4.2.2 Execute auto white balance function

Execute automatic gain adjustment for the current RGB balance settings.

- Format 1 CMD CR
- CMD WB

<Example>

WBCR

>OK

>WB

4.2.3 Setting Offset

Sets offset from 0 to +15(8 bit: 1DN/Step), or from 0 to +60(10 bit: 4DN/step).

- Format 2 CMD VAL CR
- CMD q(q,o,p)
- VAL 0 ～ 15

<Example>

q5CR （Sets offset 5(8-bit) or 20(10-bit)）

>OK

>q5

4.2.4 Setting Output Signals (Setting Data Format)

Sets the data format of output signals.

- Format 2 CMD VAL CR
- CMD v
- VAL 0,1

<Example>

v0CR （8bit output）

>OK

>v0

4.2.5 Readout the Operation Status

Reads out the current camera settings.

- Format 1 CMD CR
- CMD sta

<Example>

```
sta
>OK
>Type=NUCLi4KA
>Ver.=0.91_0x000a
>r0
>g0
>b0
>grfo92
>grfe93
>grro91
>grre91
>ggfo59
>ggfe62
>ggro57
>ggre59
>gbfo118
>gbfe120
>gbro117
>gbre116
>q8
>o8
>p8
>orf8
>orr8
>ogf8
>ogr8
>obf8
>obr8
>d4
>ldlys0
>v0
>t0
>C1
>MFr760
>MFg760
>MFb760
```

>MUr760
>MUg760
>MUb760
>MVr760
>MVg760
>MVb760
>T0
>rev0
>WBr684
>WBg684
>WBb684
>expo56400
>logmode 1
>sta

4.2.6 Memory Initializing (Initializing Camera Settings)

Reset the flash memory to the factory default.

- Format 1 CMD CR
- CMD z

<Example>

zCR
>OK
>z

4.2.7 Memory Load (Readout the Camera setting from the flash memory)

Reads out the camera settings from the flash memory.

- Format 1 CMD CR
- CMD l

<Example>

l
>OK
>Type=NUCLi4KA
>Ver.=0.91_0x000a
>r0
>g0
>b0
>grfo92
>grfe93
>grro91

>grre91
>ggfo59
>ggfe62
>ggro57
>ggre59
>gbfo118
>gbfe120
>gbro117
>gbre116
>q8
>o8
>p8
>orf8
>orr8
>ogf8
>ogr8
>obf8
>obr8
>d4
>ldlys0
>v0
>t0
>C1
>MFr760
>MFg760
>MFb760
>MUr760
>MUg760
>MUb760
>MVr760
>MVg760
>MVb760
>T0
>rev0
>WBr684
>WBg684
>WBb684
>expo56400
>logmode 1
>l

4.2.8 Memory Save

Stores current camera settings in the flash memory.

- Format 1 CMD CR
- CMD w

<Example>

wCR
>OK
>w

4.2.9 Line Delay

Adjust the delay between lines (RGB).

- Format 2 CMD VAL CR
- CMD d
- VAL -5～5

<Example>

d5CR （Sets delay to 5）
>OK
>d5

4.2.10 Line Fine Adjusting Correction Between Output Datas

Sets the line fine adjusting correction between the output datas at each RGB.

- Format 2 CMD VAL CR
- CMD ldlys
- VAL -5～5

<Example>

ldlys5CR (0.5 line correction in the movement direction)
>OK
>ldlys5

4.2.11 Pixel Correction Data Import

Acquires user pixel correction data.

- Format 1 CMD CR
- CMD W

<Example>

WCR
>OK
>W

4.2.12 Pixel Correction Data Save

Saves and applies acquired correction data in the memory.

- Format 1 CMD CR
- CMD L

<Example>

LCR
>OK
>L

4.2.13 Pixel Correction Reference Setting

Sets pixel correction reference level.

- Format 2 CMD VAL CR
- CMD MUr(MUr,MUg,MUb,MVr,MVg,MVb)
- VAL 0-1023

<Example>

MUr768CR （Sets user1,R pixel correction reference level to 768）
>OK
>MUr768

4.2.14 Pixel Correction Mode

Sets pixel correction mode.

- Format 2 CMD VAL CR
- CMD C
- VAL 0,1,2,3

<Example>

C1CR （factory settings Pixel Correction selection）
>OK
>C1

4.2.15 Exposure Mode

Sets Exposure Mode.

- Format 2 CMD VAL CR
- CMD t
- VAL 0,1,2,3,4

<Example>

t0CR （Free run selection）
>OK
>t0

4.2.16 Programmable Exposure Time Setting

Sets Exposure time.

- Format 2 CMD VAL CR
- CMD expo
- VAL 56400-32767000

<Example>

expo200000CR （Sets Exposure time to 200μs.）

>OK

>expo200000

4.3 Internal Circuit Configuration Block

The Internal Circuit Configuration block is shown below.

After the output signal from the CCD image sensor is converted by the A/D converter, digital data processing is done in the FPGA video is output in the Camera Link Medium configuration(at 10-bit 3-tap output).

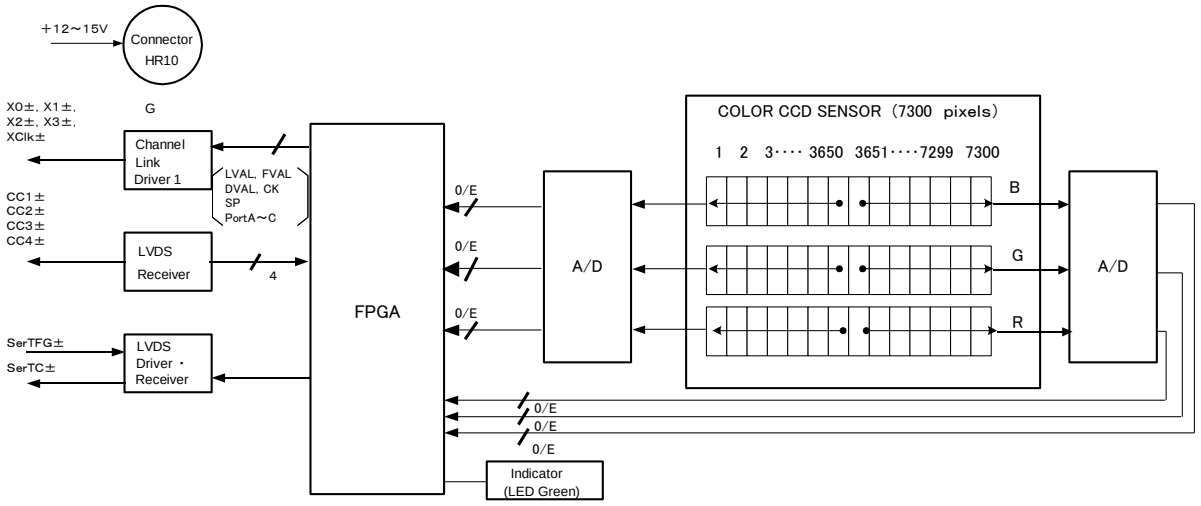


Figure 4-3-1 Internal Circuit Configuration Block

Digital Processing flow in FPGA

The figure below shows the digital processing flow in the FPGA.

Digital Data Processing block diagram

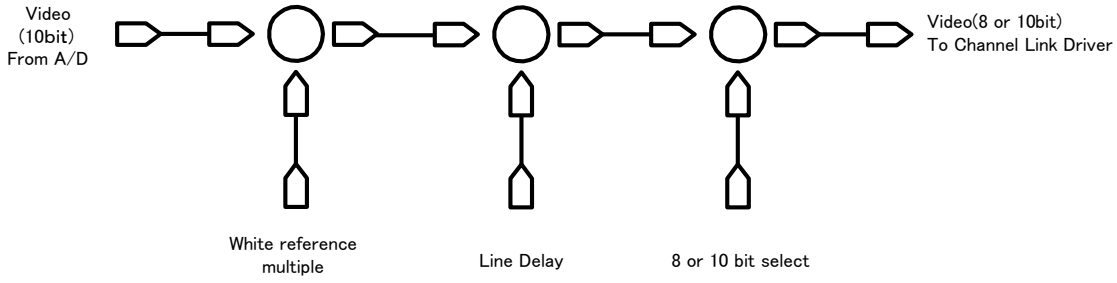


Figure 4-3-2 Digital Processing Block Diagram

4.4 Startup

After turning on, the camera runs a startup procedure before it starts getting images and outputting data. It takes about six seconds.

The startup procedure is as follows.

(1) The camera initializes the hardware.

(2) Reads out the latest camera settings from the flash memory. (User settings if any or factory default settings)

(3) Sets up the camera with the setting values from the flash memory.

After this sequence, the camera is ready to get images and output data.

4.5 Saving and Loading Camera Settings

The camera setting data is saved in the internal memory (flash memory) and is loaded from the memory when turning on the power supply or loading (sending the “I” command).

- The number of times the flash memory can be rewritten will vary depending on actual operational conditions. After turning on the power supply, the camera always checks the memory status. If the data is not within the designated range due to a malfunction or other type of trouble, the memory will be automatically rewritten with the factory settings.

◆ If disconnecting camera power while rewriting the memory, all data saved in the memory will be deleted.

As it takes several seconds to rewrite the memory, do not disconnect the power supply before receiving the response from the camera.

Commands for rewriting the memory are as follows.

- Reset to factory settings（z）
- Store present setup data in memory（w）
- Store pixel correction data in memory (L)

◆ When changing the camera setting, be sure to send the control input signal (CC1) from the frame grabber board. If you do not send CC1 or send control input signals are out of the designated range, you cannot get images and cannot change the settings. See 4.8.2 to 4.8.4.

4.6 Serial Communication Settings

Serial communication is performed through the Camera Link Interface.

The table below shows the serial communication settings.

Table 4-6-1 Serial Communication Settings

Parameter Items	Setup Value
Communication Speed (Baud rate)	9600bps
Data Length	8bit
Parity Bit	None
Stop bit	1bit
Flow Control	None

4.7 Video Output Format

The camera outputs 8-bit or 10-bit digital data through 3taps(R,G,B).

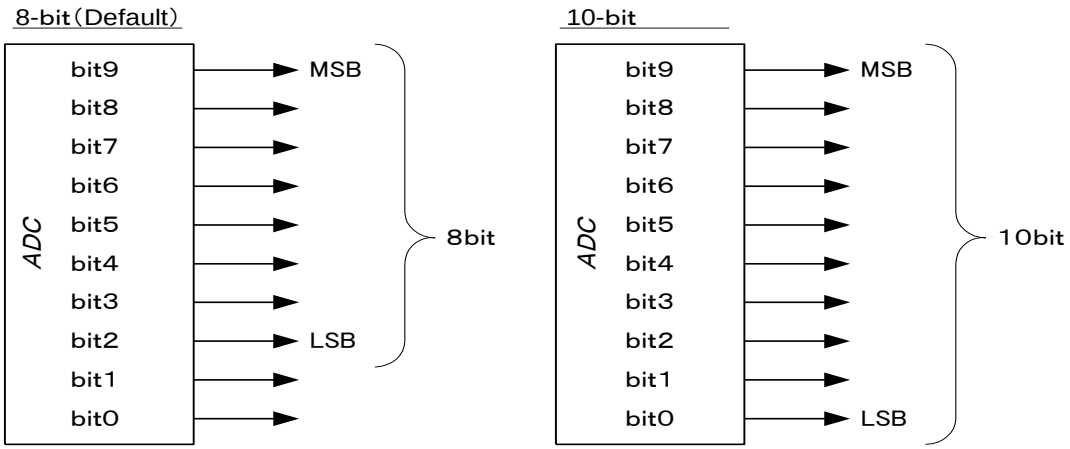


Figure 4-7-1 Pin Assignments of Digital Data

- The A/D converter of the camera has a 10-bit resolution. For 8-bit output, the upper 8-bit signal can be output as a video data.
- In R, G, B 8-bit 3-tap output mode, output is Camera Link Base Configuration.
- In R, G, B 10-bit 3-tap output mode, output is Camera Link Medium Configuration.

The video output phase is shown below.

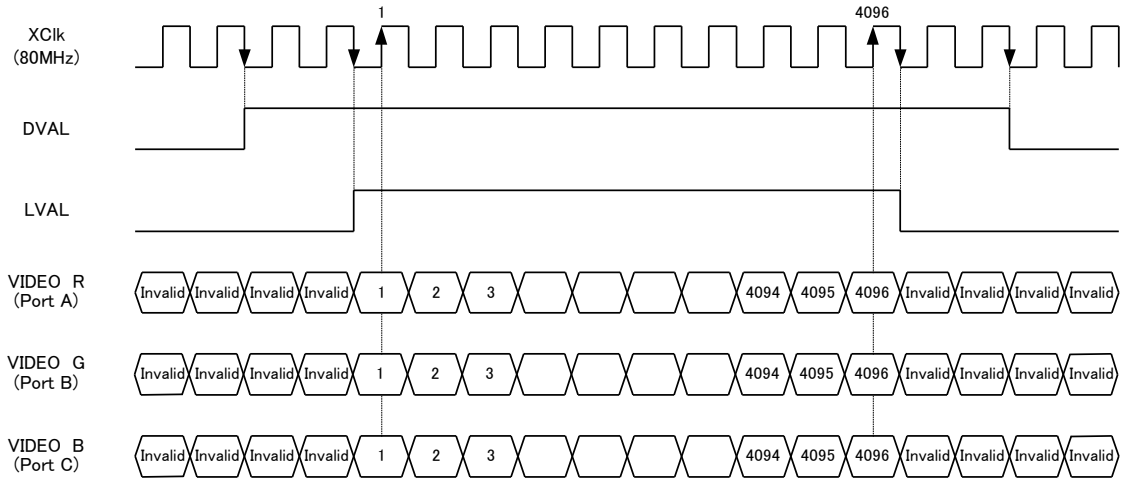


Figure 4-7-2 Video Output Phase at 3-tap Output

4.8 Exposure Mode and Timing Chart

The camera has four exposure modes. The overview of each mode and the timing are as follows.

4.8.1 Free Run Exposure Mode

In free-run exposure mode, the camera generates its own internal control signal based on two programmable parameters, exposure time and readout time. The range of programmable exposure time and the timing chart of the exposure and the readout are shown below.

Table 4-8-1-1 Free Run Exposure Time

e	Programmable exposure time	56.4 ~ 32767
r	Readout time (LVAL)	51.2

(unit : μs)

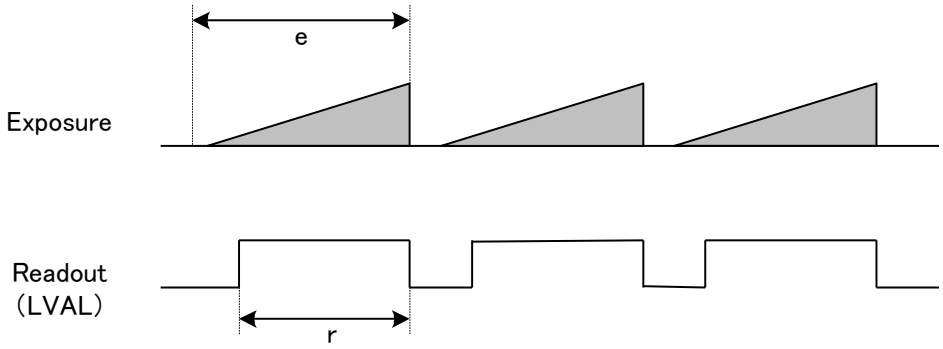


Figure 4-8-1-1 Free Run Exposure Mode

4.8.2 External Trigger Exposure Mode

In external trigger exposure mode, the exposure time is determined by the setting made through the external trigger pulse (CC1) cycle. Each exposure starts with the rising edge and the line period is determined by the time from rising edge to rising edge of the trigger pulse. The range of programmable exposure time and the timing chart of the exposure and the readout are shown below.

Table 4-8-2-1 External Trigger Exposure Time

h	Trigger pulse High time	≧0.1
t	Trigger pulse cycle	≧56.4
r	Readout time (LVAL)	51.2

(unit : μs)

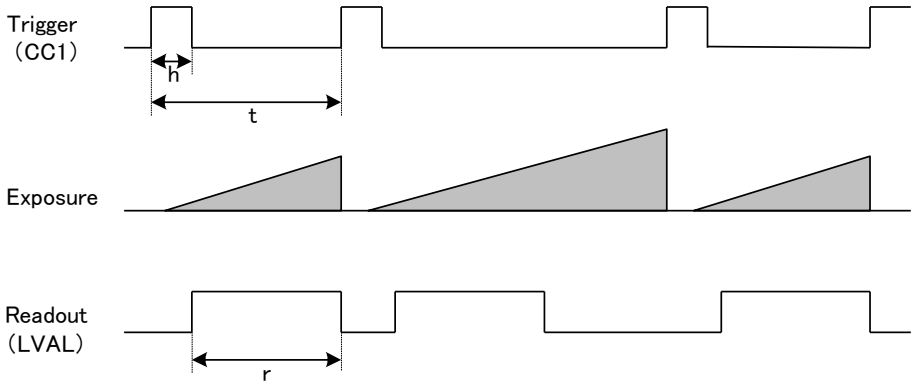


Figure 4-8-2-1 External Trigger Exposure Mode

4.8.3 Pseudo-exposure control mode (Edge)

In Pseudo-exposure control mode (Edge), the exposure time is determined by sending a camera command. Each exposure starts with the rising edge and the line period is determined by the time from rising edge to rising edge of trigger pulse. The range of programmable exposure time, the timing chart of the exposure and the readout are shown below.

Table 4-8-3-1 Pseudo-exposure control mode (Edge)

h	Trigger pulse High time	≧0.1
t	Trigger pulse cycle	≧e+56.4
e	Programmable exposure time	56.4 ~ 32767
r	Readout time (LVAL)	51.2

(unit:μs)

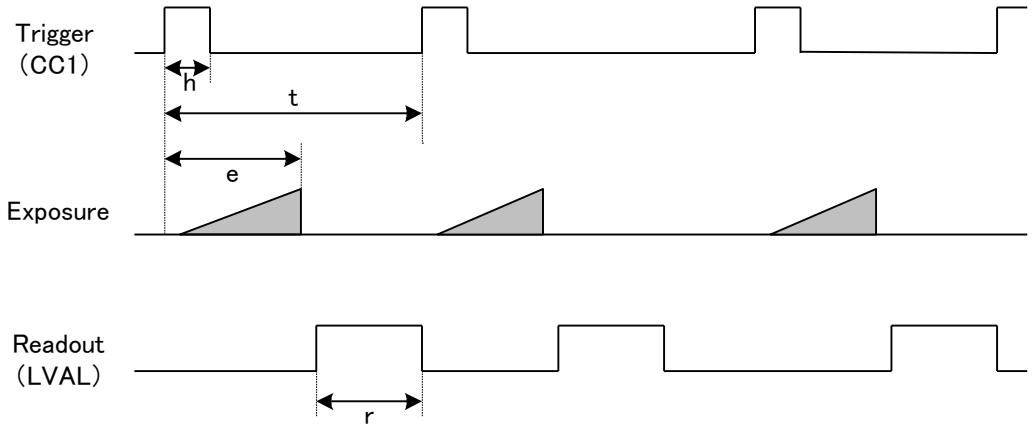


Figure 4-8-3-1 Pseudo-exposure control mode (Edge)

4.8.4 Pseudo-exposure control mode (Level)

In Pseudo-exposure control mode (Level), the exposure time is determined by the High time of the trigger pulse. Each exposure starts with the rising edge and the line period is determined by the time from rising edge to rising edge of trigger pulse. The range of programmable exposure time, the timing chart of the exposure and the readout are shown below.

Table 4-8-4-1 Pseudo-exposure control mode (Level)

h	Trigger pulse High time	≧56.4
l	Trigger pulse Low time	≧56.4
r	Readout time (LVAL)	112.8

(unit : μs)

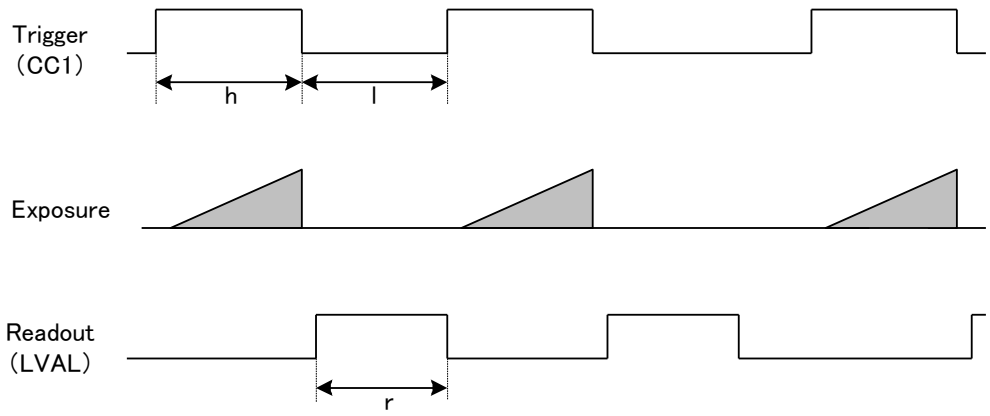


Figure 4-8-4-1 Pseudo-exposure control mode (Level)

4.8.5 Average output mode

In the average output mode, the exposure time is determined by the setting made through the external trigger pulse (CC1) cycle.

The line period is determined by the time from rising edge to rising edge of the external encoder pulse(CC2).

Each exposure output by the external trigger signal (CC1) in the line period of the external encoder cycle is added and averaged.

The range of programmable exposure time, the timing chart of the exposure and the readout are shown below.

Table 4-8-5-1 Average output mode

h	Trigger pulse High time	≧0.1
t	Trigger pulse cycle	≧56.4
hE	Encoder pulse High time	≧0.1
tE	Encoder pulse cycle	≧56.4
r	Readout time (LVAL)	51.2

(unit : μs)

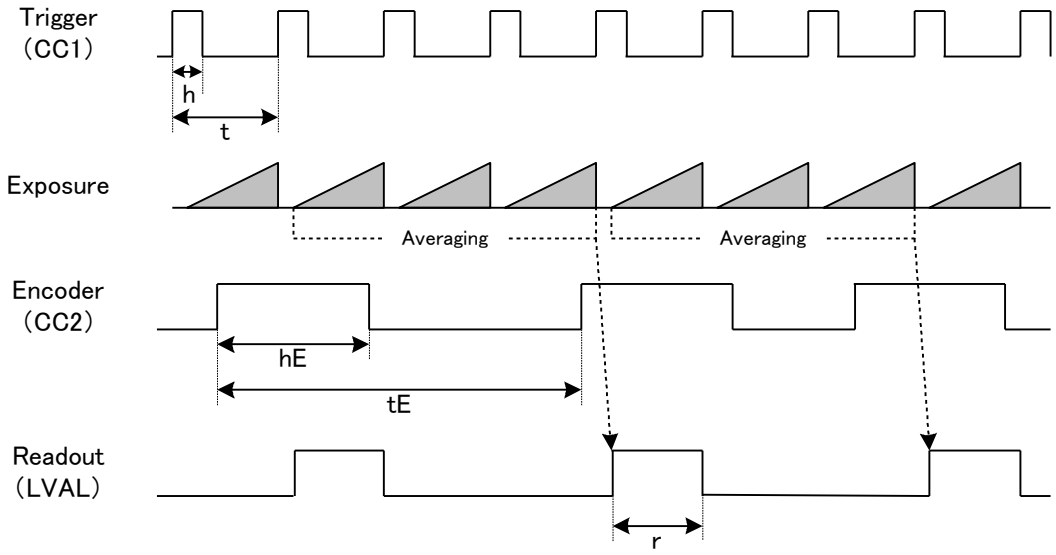


Figure 4-8-5-1 Average output mode

Reference: The difference between the pseudo-exposure control mode (level) and the average mode is shown in the following charts.

In the pseudo-exposure control mode (level) there is the non-exposure period as shown in the chart. The non-exposure period is the non-inspected period.

However, in the average mode the exposure is consecutively performed by the setting made through the external trigger pulse (CC1) cycle. When the external encoder signal (CC2) becomes Hi, each exposure from the next external trigger signal (CC1) is added and averaged in the line period of the external encoder cycle. The exposure can be output as the line data without the non-inspected period.

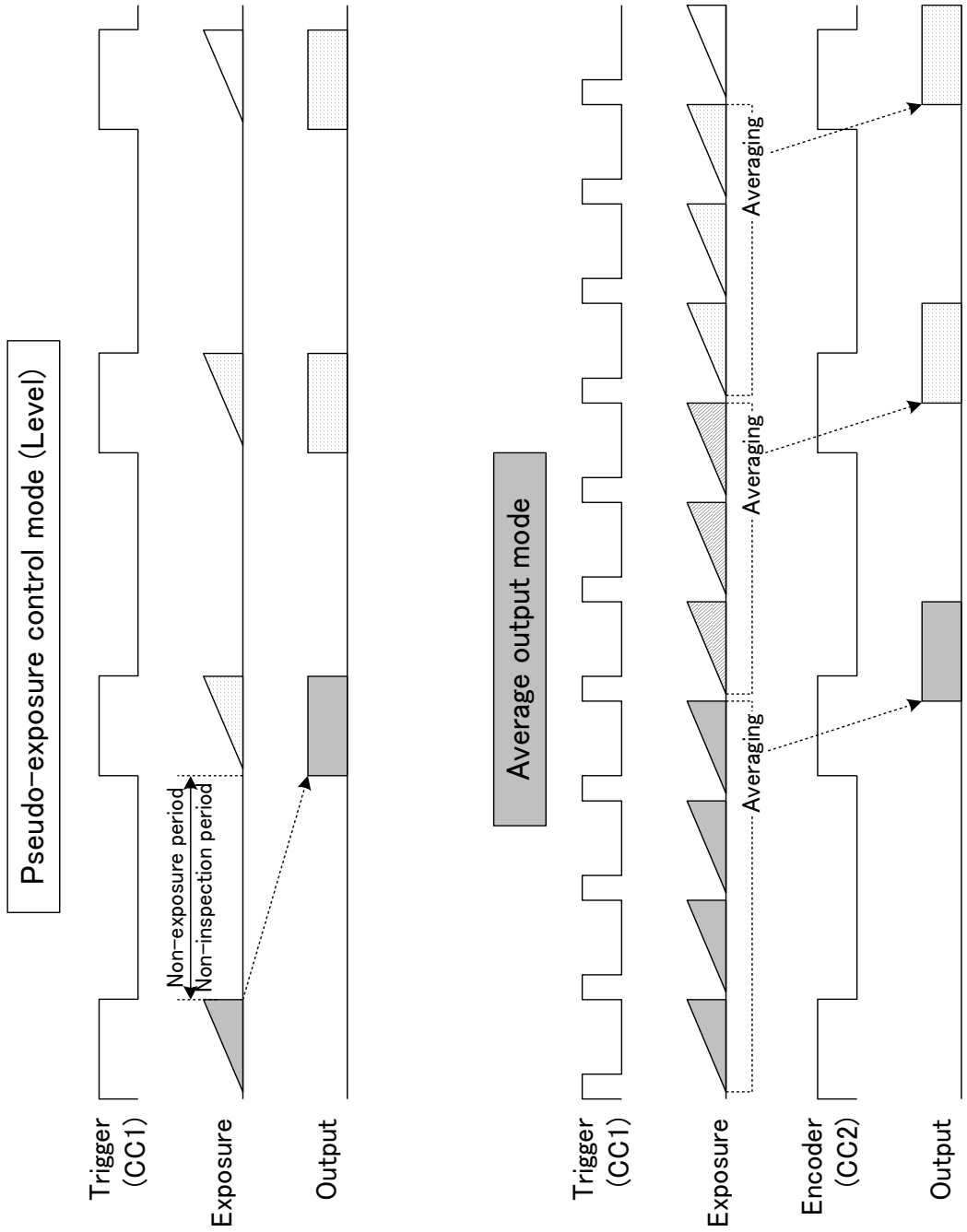


Figure 4-8-5-1 The difference between the pseudo-exposure control mode and the average mode

4.9 Setting Offset

In the figure below, the horizontal axis indicates the amount of incident light and the vertical axis indicates the output.

Fs shows the output at saturation. Dd shows the output at darkness. (Both Fs and Dd are digital.) Se shows the saturation current, or the amount of exposure when the output saturates.

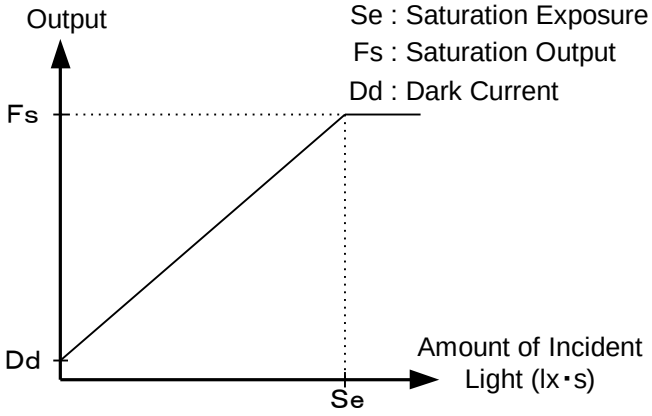


Figure 4-9-1 Saturation Exposure and Dark Current Output

By setting the offset, you can set the Y-intercept arbitrarily. DF shows the digital offset value. The gradient of the line does not change.

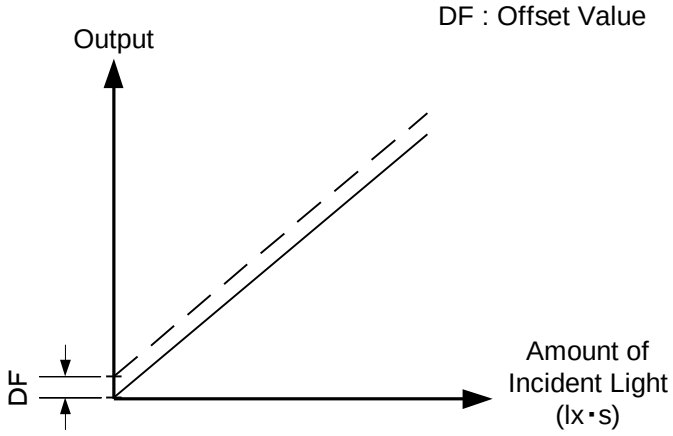


Figure 4-9-2 Offset Adjustment

◆ Adjust amount of offset in accordance with the requirements of your camera system.

4.10 Setting Gain

The camera can adjust the gain (x1 to x 2.5). As shown in the figure below, increasing the gain setting increases the gradient of the camera's response curve and results in a higher camera output for a given amount of light.

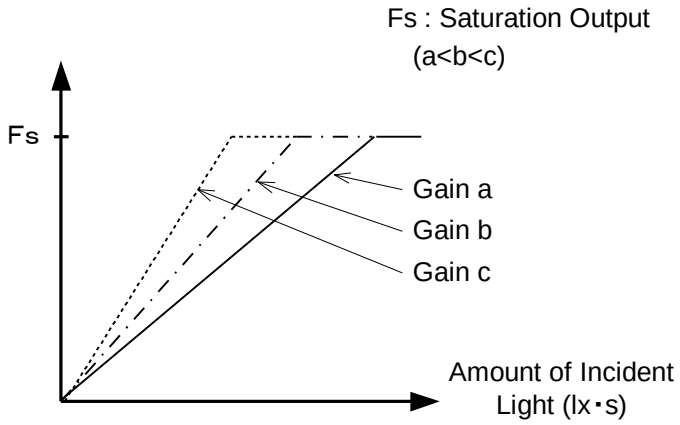


Figure 4-10-1 PGA Gain Adjustment

- ◆ Gain and noise values are proportionally related.
- ◆ Adjust the amount of gain in accordance with the requirements of your camera system.

The relations with VAL(Gain set value) and Gain(magnification) are as following formulas.

Gain initial set value : initVAL

Gain = (283 - initVAL) / (283 - VAL)

VAL = 283 - {(283 - initVAL) / Gain}

For example;

When "initVAL" of Gain initial set value at red channel is 91 and you want to get VAL for two times (x 2.00) of Gain, the VAL is as follows.

VAL＝283－{(283－91)／2}

＝187

Gain set commend: r187

4.11 Auto white balance

The NUCLi4KA has a simple function for balancing the output levels of each channel of the sensor. This section describes how to adjust the RGB signal to the desired level.

As an example, the procedure below describes how to adjust the RGB level to 190DN (in 8bit mode) in the factory set pixel correction mode.

4.11.1 Note about optical adjustment

The Auto white balance adjustment function adjusts front and rear half of the CCD's pixels by sampling the center 128 pixels of the sensor. Please adjust the lighting such that this center area is targeted. If the lighting is off-center, it may result in a difference in level across these center pixels.

4.11.2 Setting the optical adjustment conditions

① Send the command "C1" to set pixel correction to Factory Set Pixel Correction Mode.

② Depending on the exposure time and light source, try to get the level as close to the desired level as possible (in this case, 190DN, shown in the figure below)

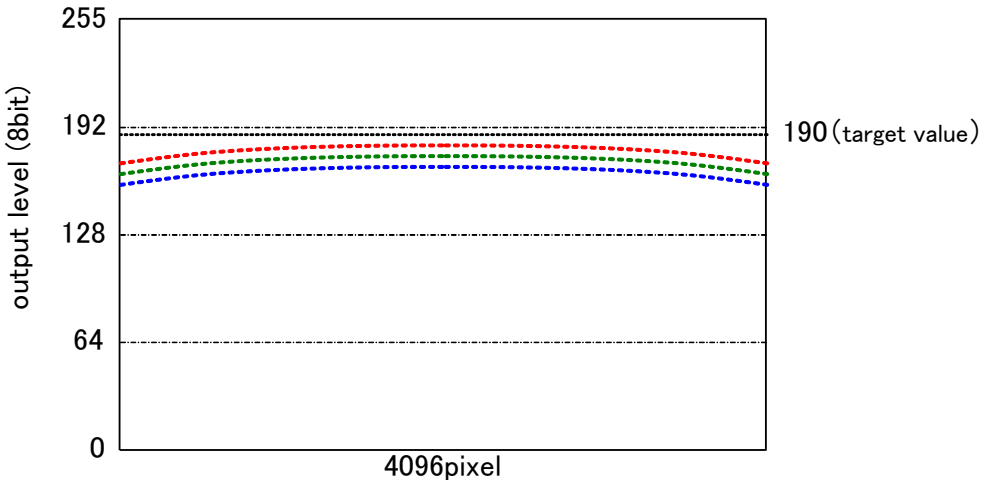


Figure 4-11-2-1 output profile before auto white balance is executed

4.11.3 Auto white balance adjustment

1.Set the target value by sending commands-, e.g. “WBr684”, “WBg684”,” WBb684”. The value sent in the command should be 0.9 x the target value (in factory set mode). Auto white balance adjusts the uncorrected data, so here, it necessary to divide by 1/0.9 (correction output level/no correction output level), the factory correction ratio. In this case, 760(10-bit value of the target 190DN) x 0.9 = 684 (the value to be sent by command)

2. Send the “WB” command. The data level in the center becomes 190DN, as shown below.

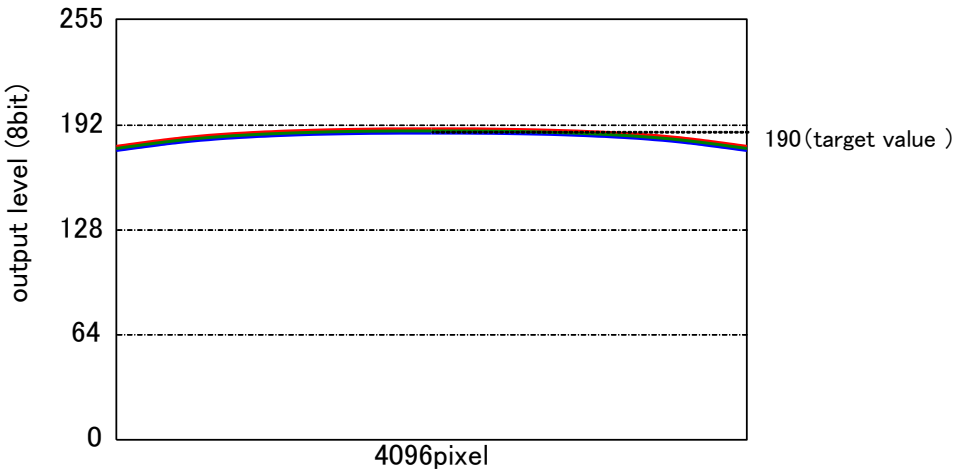


Figure 4-11-3-1 output profile after executing auto white balance

[Supplementary note]

- It is possible to set the target value of each RGB channel.
- The value sent by command should be divided by the correction ratio at the time.
- When using User Pixel Correction, it is recommended first to perform Auto white balancing with pixel correction turned off (Command “C0”), then to obtain the pixel correction data.
- It is possible to read out the gain setting value of each channel with the command “sta” after auto white balance adjustment, and to adjust gain for each channel manually through commands.

```
sta
>OK
>Type=NUCLi4KA
>Ver.=0.91_0x000a
>r0
>g0
>b0
>grfo92←present Red front half odd pixels channel gain set value
```

>grfe93←present Red front half even pixels channel gain set value
>grro91←present Red rear half odd pixels channel gain set value
>grre91←present Red rear half even pixels channel gain set value
>ggfo59←present Green front half odd pixels channel gain set value
>ggfe62←present Green front half even pixels channel gain set value
>ggro57←present Green rear half odd pixels channel gain set value
>ggre59←present Green rear half even pixels channel gain set value
>gbfo118←present Blue front half odd pixels channel gain set value
>gbfe120←present Blue front half even pixels channel gain set value
>gbro117←present Blue rear half odd pixels channel gain set value
>gbre116←present Blue rear half even pixels channel gain set value
.
.
.
>sta

4.12 Pixel Correction

As a rule, image sensors (CCD, CMOS and so on) have fixed pattern noise and photo response non-uniformity. Lens shading and light sources can also cause non-uniformity. The camera is set to the optimal correction before shipping in order to provide images of the highest grade.

The camera also has a user white correction function to cope with lens shading and non-uniform illumination, or to be able to completely clear the uneven brightness generated by changing the spectral response level of the light source. Cal_wh: Output data of each pixel in uniform illumination (digital)

Target_Val : Target value for correction (10bit digital)

Vin: Input data (digital)

Vout: Output data (digital) The corrected data is expressed in the following equation.

Vout=(Vin x Target_val) / Cal_wh

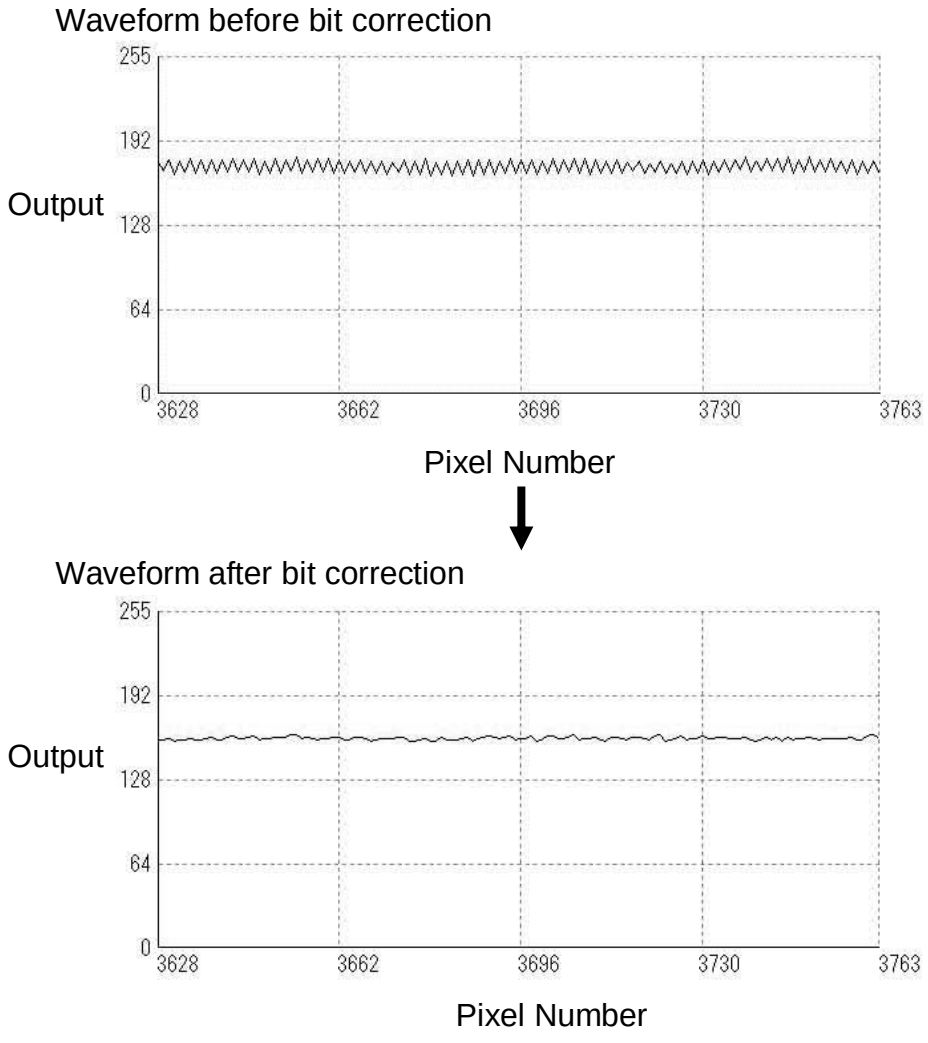


Figure 4-12-1 Waveform before and after bit correction

4.12.1 Command Settings

Set the correction on or off; acquire user white correction data by sending commands through serial communication.

Examples of command settings

C0: No correction
C1: Factory white correction
C2: User white correction(User 1)
C3: User white correction(User 2)
W: Acquisition of user white correction data
L: Save of user white correction data

4.12.2 How to correct

(1) Send the “C2 CR” command through serial communication. Set C2 or C3 Pixel Correction Mode

(2) Remove the lens cap and place a white object. Then you can acquire user white correction data. With a lens, the shading by both the lens and the light source will be simultaneously corrected. At this time, please defocus a little to avoid being affected by the non-uniformity of the object.

(3) Sending “W CR” commands through serial communication.

(4) Confirm that the camera returns “>OK” and “>W”.

(5) Confirm that the image data is correct. If it is okay, save the correct data through command “L CR”

(6) Confirm that the camera returns “>OK” and “>L”.
Send the “shc 2 VAL2 CR” command through serial communication. Then the user white correction will be on and set the correction level as “VAL2”.

5 Sensor Handling Instructions

5.1 Electrostatic Discharge and the Sensor

CCD sensors are susceptible to damage from electrostatic discharge and can deteriorate as a result. Take care when handing the sensor.

5.2 Protecting Against Dust, Oil and Scratches

The CCD sensor window is part of the optical path and should be handled like other optical components with care. If you use the camera in a dusty area, prepare a dust-proof enclosure. Dust can obscure pixels, producing dark lines on the image.

5.3 Cleaning the Sensor Window

Dust: Can usually be removed by blowing the window surface using a compressed air blower.

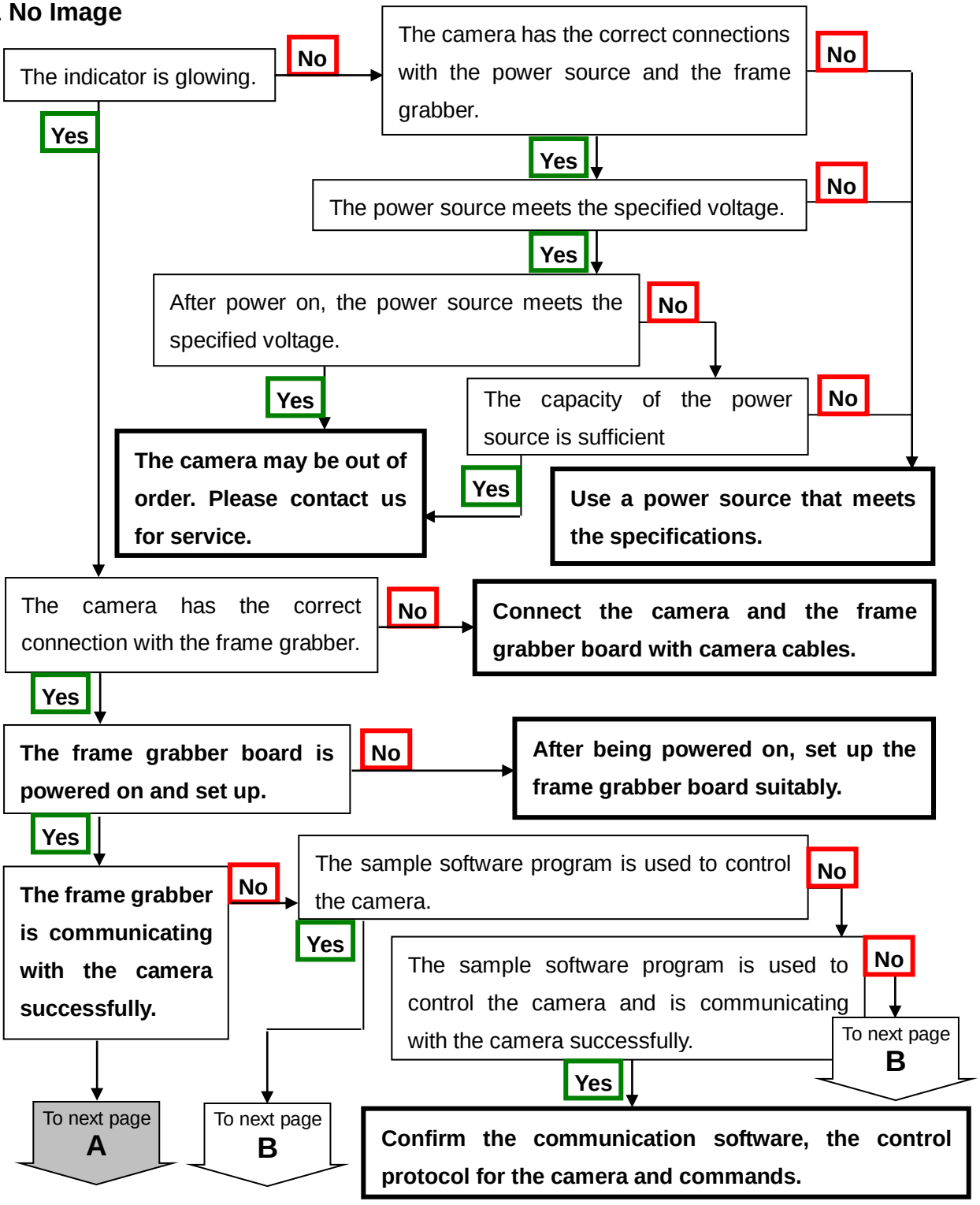
Oil: Wipe the window with a lint-free cloth wiper moistened with ethyl alcohol carefully and slowly.

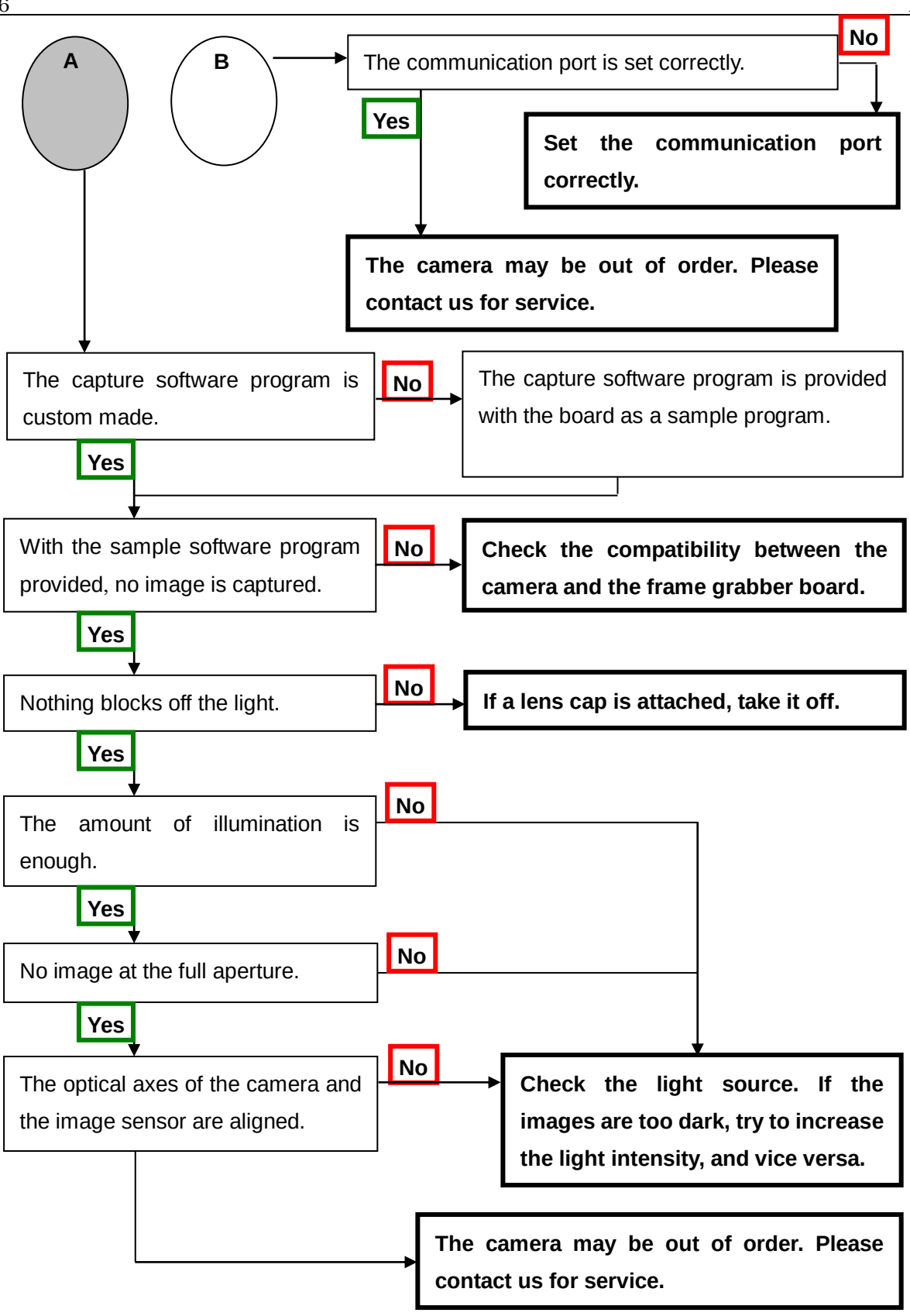
When there is dust or smudges on the sensor window, it appears in the same way as noise on the image. Please remove it appropriately.

6 Troubleshooting

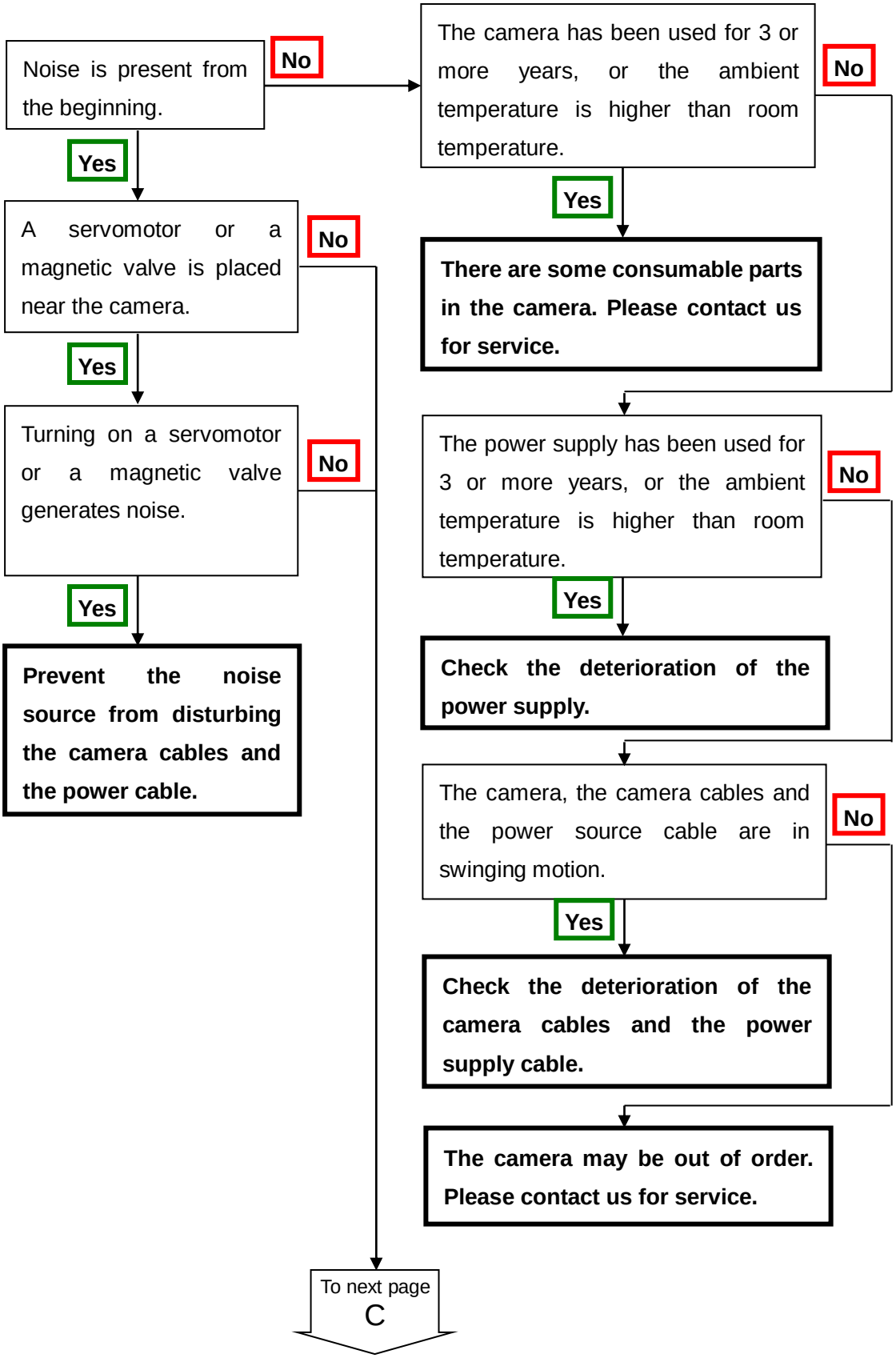
The following pages contain several troubleshooting charts that can help you find the cause of problems users sometimes encounter.

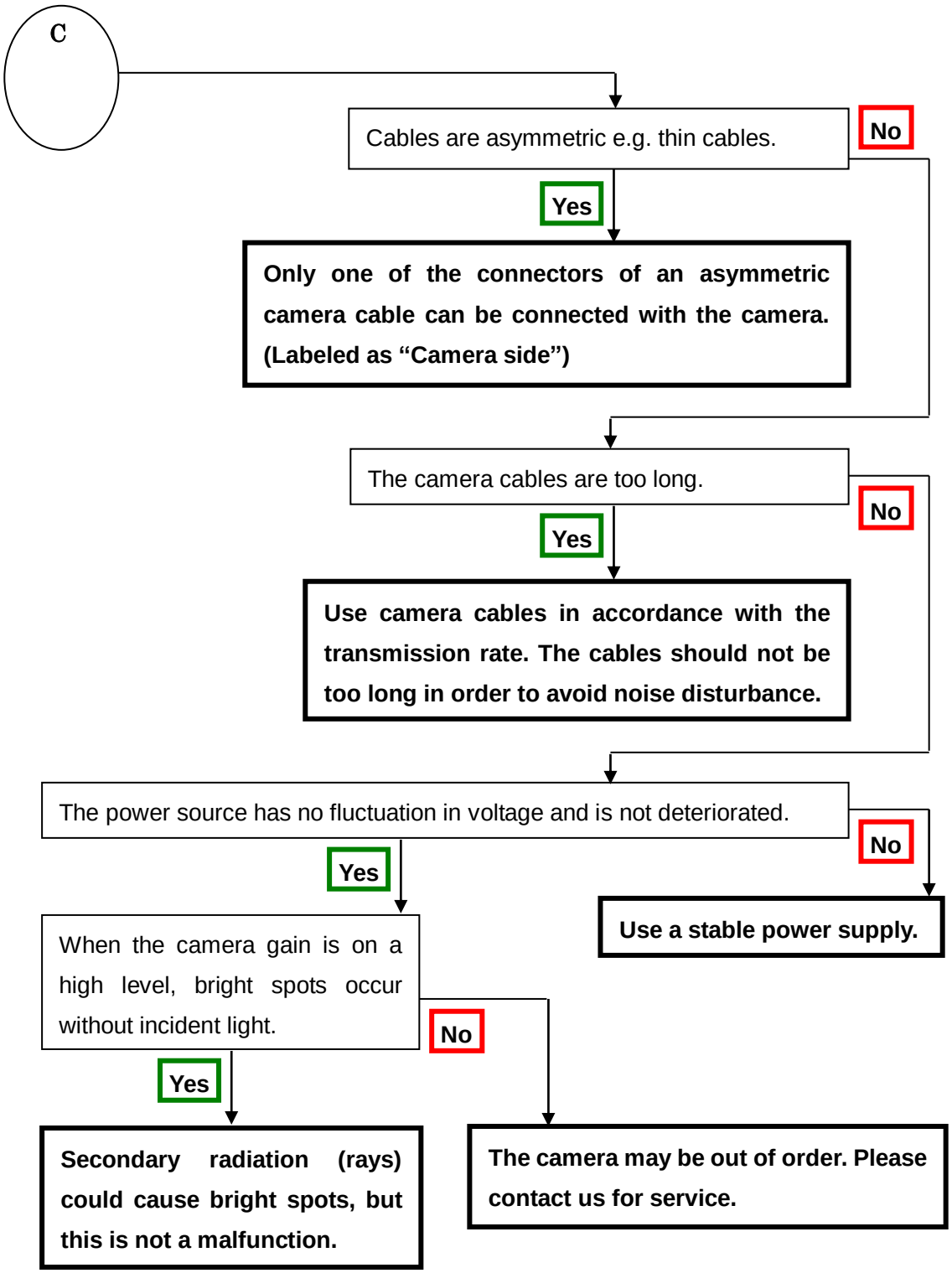
6.1 No Image



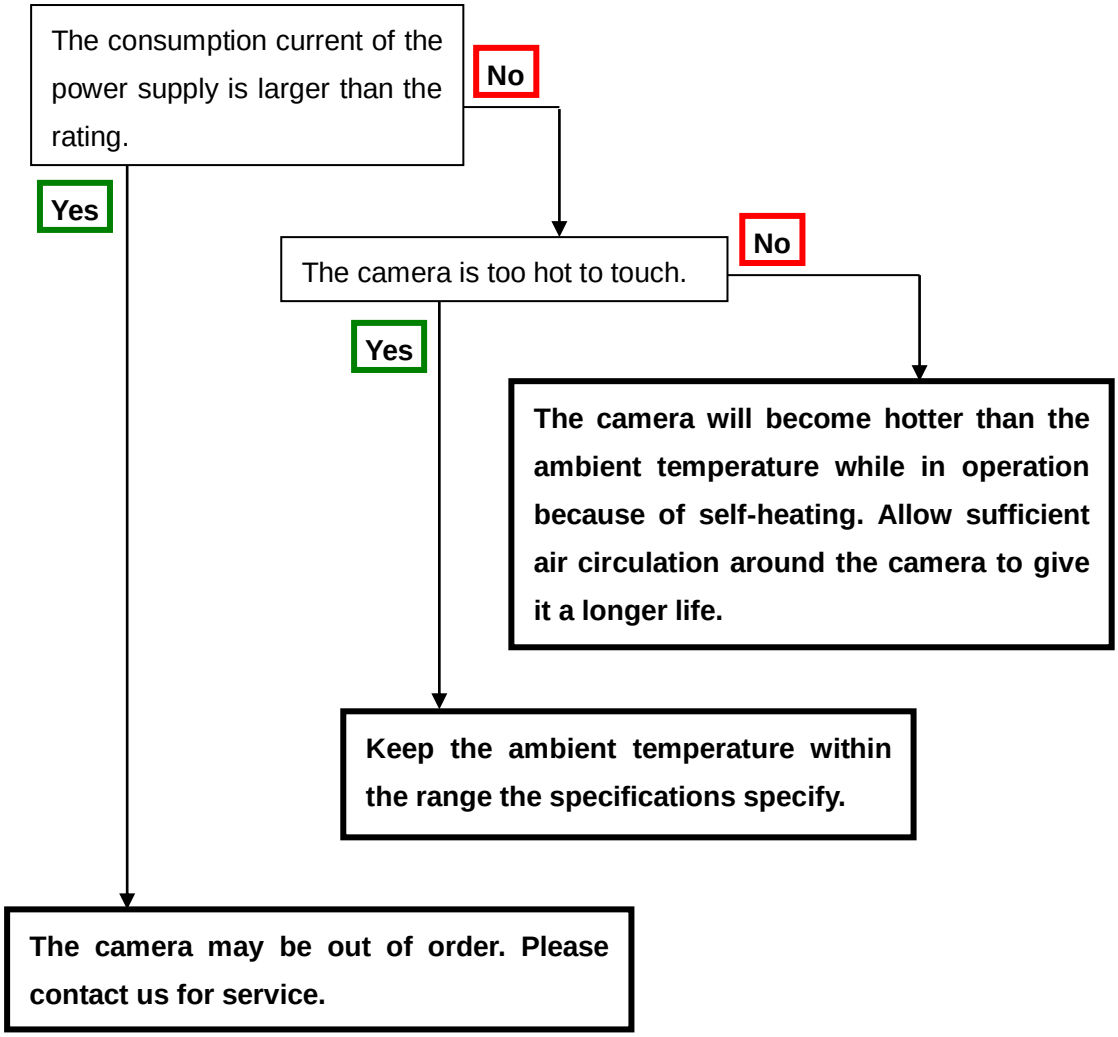

A
B
The communication port is set correctly.
No
Yes
Set the communication port correctly.
The camera may be out of order. Please contact us for service.
The capture software program is custom made.
No
The capture software program is provided with the board as a sample program.
Yes
With the sample software program provided, no image is captured.
No
Check the compatibility between the camera and the frame grabber board.
Yes
Nothing blocks off the light.
No
If a lens cap is attached, take it off.
Yes
The amount of illumination is enough.
No
Yes
No image at the full aperture.
No
Yes
The optical axes of the camera and the image sensor are aligned.
No
Check the light source. If the images are too dark, try to increase the light intensity, and vice versa.
The camera may be out of order. Please contact us for service.

6.2 Noise on Image




C
Cables are asymmetric e.g. thin cables.
No
Yes
Only one of the connectors of an asymmetric camera cable can be connected with the camera. (Labeled as “Camera side”)
The camera cables are too long.
No
Yes
Use camera cables in accordance with the transmission rate. The cables should not be too long in order to avoid noise disturbance.
The power source has no fluctuation in voltage and is not deteriorated.
No
Yes
Use a stable power supply.
When the camera gain is on a high level, bright spots occur without incident light.
No
Yes
Secondary radiation (rays) could cause bright spots, but this is not a malfunction.
The camera may be out of order. Please contact us for service.

6.3 Camera becomes hot



7 Others

7.1 Notice

- No part of this document may be reproduced in any form, in whole or in part, without the expressed written consent of NED.
- Contents of this document are subject to change without prior notice.
- Every care has been taken in the preparation of this User's Manual. If you should discover any errors or omissions, please notify your nearest NED representative.

7.2 Contact for support

Nippon Electro-Sensory Devices Corporation

Head Office
2-5-12, Itachibori, Nishi-ku, Osaka 550-0012, Japan
Phone +81-6-6534-5300
Fax +81-6-6534-6080

Tokyo Branch
Gibraltar Oi Bldg, 4F
1-45-2, Oi, Shinagawa-ku, Tokyo 140-0014, Japan
Phone +81-3-5718-3181
Fax +81-3-5718-0331

West Japan Branch
1-8-28 Enokida, Hakata-ku, Fukuoka 812-0004, Japan
Phone +81-92-451-9333
Fax +81-92-451-9335

URL
http://ned-sensor.co.jp/en

E-Mail
sales@ned-sensor.com

7.3 Product Support

If there is still a problem with your camera after checking it in accordance with the troubleshooting guide, turn off the power and call your NED representative.

In such case, please inform us of the status of the camera. You can get the status by executing the “sta” command.

The example of the camera status.

```
sta
>OK
>Type=NUCLi4KA
>Ver.=0.91_0x000a
>r0
>g0
>b0
>grfo92
>grfe93
>grro91
>grre91
>ggfo59
>ggfe62
>ggro57
>ggre59
>gbfo118
>gbfe120
>gbro117
>gbre116
>q8
>o8
>p8
>orf8
>orr8
>ogf8
>ogr8
>obf8
>obr8
>d4
>ldlys0
>v0
```

```
>t0
>C1
>MFr760
>MFg760
>MFb760
>MUr760
>MUg760
>MUb760
>MVr760
>MVg760
>MVb760
>T0
>rev0
>WBr684
>WBg684
>WBb684
>expo56400
>logmode 1
>sta
```

Revision History

Revision Number	Date	Changes
01	01 March 2019	Initial release