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Basler L100k



USER'S MANUAL

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For customers in the U.S.A.

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to 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 own expense.

You are cautioned that any changes or modifications not expressly approved in this manual could void your authority to operate this equipment.

The shielded interface cable recommended in this manual must be used with this equipment in order to comply with the limits for a computing device pursuant to Subpart J of Part 15 of FCC Rules.

For customers in Canada

This apparatus complies with the Class A limits for radio noise emissions set out in Radio Interference Regulations.

Pour utilisateurs au Canada

Cet appareil est conforme aux normes Classe A pour bruits radioélectriques, spécifiées dans le Règlement sur le brouillage radioélectrique.

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Warranty Note

Do not open the housing of the camera. The warranty becomes void if the housing is opened.

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1 Introduction

L100k series line scan cameras are versatile cameras designed for industrial use. Superb image sensing features are combined with a robust, high precision manufactured housing.

Important features are:

- High sensitivity
- Anti-blooming
- Electronic exposure time control
- High signal-to-noise ratio
- Single or dual video data output
- Programmable via an RS-644 serial port
- Industrial housing manufactured with high planar, parallel and angular precision
- Super compact size
- Complies with the Camera Link standard

1.1 Camera Models

L100k series line scan cameras are available in different versions; the version depends on the pixel clock speed. Each version of the camera is available with a 1024 or a 2048 pixel sensor.

All models are monochrome.

Throughout the manual, the camera will be called the **L100k**. Passages that are only valid for a specific version will be so indicated.

Camera Version	Pixel Clock (single output mode)	Pixel Clock (dual output mode)
L101k	20 MHz	20 MHz
L103k	40 MHz	20 MHz
L104k	62.5 MHz	31.25 MHz

Table 1-1: Versions of the **L100k** Series Camera

1.2 Performance Specifications

Specifications	L101k	L103k	L104k
Sensor	1024 pixel or 2048 pixel linear CCD Thomson TA7813		
Pixel Size	10 µm x 10 µm (10 µm pitch)		
Fill Factor	100 %		
Spectral Response	300 - 1000 nm, peak at 700 nm (see Figure 1-1)		
Anti-blooming	1:100 or better		
Fixed Pattern Noise	± 1 gray value		
Photo Resp. Non-uniformity	± 5 % typical		
Pixel Clock Speed Single Output Modes: Dual Output Modes:	 20 MHz 20 MHz	 40 MHz 20 MHz	 62.5 MHz 31.25 MHz
Maximum Line Rate 1024 Pixel Cameras: 2048 Pixel Cameras:	 18.7 kHz 9.5 kHz	 35.7 kHz 18.7 kHz	 58.5 kHz 29.2 kHz
Minimum Line Rate	1 kHz		
Pixel Depth	Programmable 8 bit or 10 bit		
Video Output Type	Camera Link LVDS (RS-644 LVDS when used with the optional Basler Interface Converter (k-BIC))		
Video Output Formats	Single 8 Bit, Single 10 Bit, Dual 8 Bit, or Dual 10 Bit		
Synchronization	Via external ExSync signal or free-run		
Exposure Time Control	Edge-controlled, level-controlled, or programmable		
Gain and Offset	Programmable via a serial link		
Connectors	One, 26 pin, female MDR connector One, 6 pin, Hirose micro-miniature push-pull receptacle		
Power Requirements	12 VDC ± 10% max. 6.5 W	12 VDC ± 10% max. 8.5 W	12 VDC ± 10% max. 10 W
Lens Adapters	1024 Pixel Cameras: C-mount or F-mount 2048 Pixel Cameras: F-mount		
Housing Size (L x W x H)	without lens adapter: 37.6 mm x 62 mm x 62 mm with C-Mount Adapter: 40.1 mm x 62 mm x 62 mm with F-mount adapter: 69.1 mm x 62 mm x 62 mm		
Weight	without lens adapter: ~ 175 g with C-mount adapter: ~ 220 g with F-mount adapter: ~ 285 g		
Conformity	CE, FCC		

Table 1-2: **L100k** Series Performance Specifications

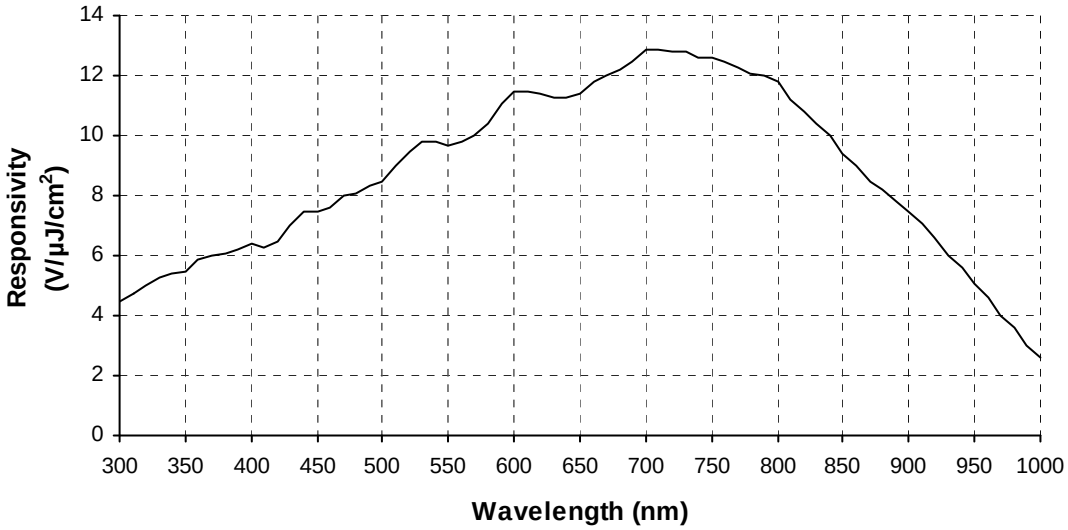


Figure 1-1: Responsivity for **L‌l00k** Series Cameras

1.3 Environmental Requirements

1.3.1 Temperature and Humidity

Housing temperature during operation:	0 °C ... + 50 °C (+ 32 °F ... + 122 °F)
Humidity during operation:	20 % ... 80 %, relative, non-condensing
Housing temperature during storage:	- 20 °C ... + 80 °C (- 4 °F ... + 176 °F)
Humidity during storage:	5 % ... 95 %, relative, non-condensing

1.3.2 Ventilation

Allow sufficient air circulation around the camera to prevent internal heat build-up in your system and to keep the camera housing temperature during operation below 50 °C. Provide additional cooling such as fans or heat sinks if necessary.



Warning!

Without sufficient cooling, the camera can get hot enough during operation to cause burning when touched.

1.4 Precautions

Power



Caution!

Be sure that all power to your system is switched off before you make or break connections to the camera. Making or breaking connections when power is on can result in damage to the camera.



Caution!

The camera has no overvoltage protection. An input voltage higher than 14 VDC will damage the camera.



Caution!

Do not reverse the polarity of the input power to the camera. Reversing the polarity of the input power can severely damage the camera and leave it non-operational.

Do not remove the camera's serial number label

If the label is removed and the serial number can't be read from the camera's registers, the warranty is void.

Read the manual

Read the manual carefully before using the camera.

Keep foreign matter outside of the camera

Do not open the casing. Touching internal components may damage them.

Be careful not to allow liquid, flammable, or metallic material inside the camera housing. If operated with any foreign matter inside, the camera may fail or cause a fire.

Electromagnetic Fields

Do not operate the camera in the vicinity of strong electromagnetic fields. Avoid electrostatic charging.

Transporting

Only transport the camera in its original packaging. Do not discard the packaging.

Cleaning

Avoid cleaning the surface of the CCD sensor if possible. If you must clean it, use a soft, lint free cloth dampened with a small quantity of pure alcohol. Do not use methylated alcohol.
Because electrostatic discharge can damage the CCD sensor, you must use a cloth that will not generate static during cleaning (cotton is a good choice).

To clean the surface of the camera housing, use a soft, dry cloth. To remove severe stains, use a soft cloth dampened with a small quantity of neutral detergent, then wipe dry.

Do not use volatile solvents such as benzine and thinners; they can damage the surface finish.

2 Camera Interface

2.1 Connections

2.1.1 General Description

L100k series cameras are interfaced to external circuitry via two connectors located on the back of the camera:

- a 26 pin, .050” Mini D Ribbon (MDR) female connector used to transmit video data, control data, and configuration data,
- a 6 pin, micro-miniature, push-pull receptacle used to provide power to the camera.

A status LED located on the back of the camera is used to indicate power present and signal integrity. Figure 2-1 shows the connectors and the LED.

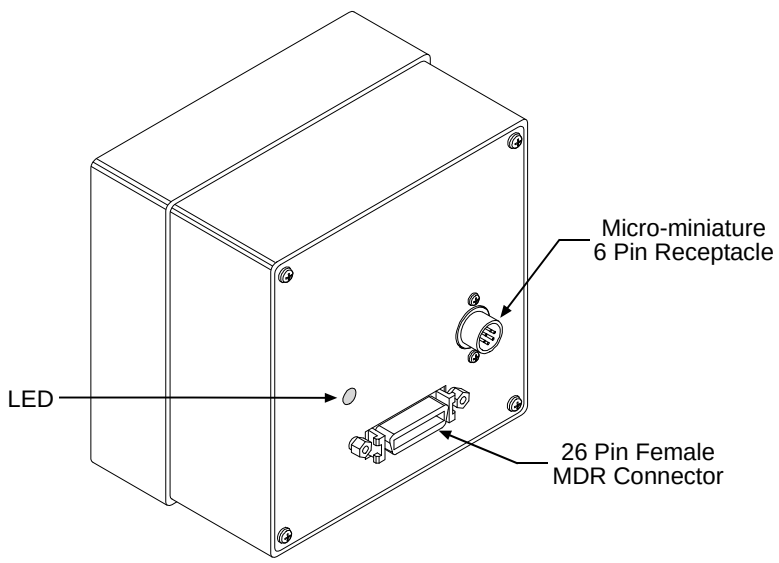


Figure 2-1: **L100k** Connectors and LED

2.1.2 Pin Assignments

26-Pin MDR Connector

The pin assignments for the 26 pin, MDR connector used to transmit video data, control data, and configuration data are shown in Table 2-1.

Pin Number	Signal Name	Direction	Level	Function
15	Tx X0+	Output	Camera Link LVDS	Data from Camera Link Transmitter
2	Tx X0-			
16	Tx X1+	Output	Camera Link LVDS	Data from Camera Link Transmitter
3	Tx X1-			
17	Tx X2+	Output	Camera Link LVDS	Data from Camera Link Transmitter
4	Tx X2-			
19	Tx X3+	Output	Camera Link LVDS	Data from Camera Link Transmitter
6	Tx X3-			
18	Tx Clk+	Output	Camera Link LVDS	Transmit Clock from Camera Link Transmitter
5	Tx Clk-			
12	CC4+			Not Connected
25	CC4-			
24	CC3+	Output	RS-644 LVDS	Integrate Enabled
11	CC3-			
10	CC2+	Input	RS-644 LVDS	Not Used
23	CC2-			
22	CC1+	Input	RS-644 LVDS	External Trigger (ExSync)
9	CC1-			
21	SerTFG+	Output	RS-644 LVDS	Serial Communication Data Transmit
8	SerTFG-			
7	SerTC+	Input	RS-644 LVDS	Serial Communication Data Receive
20	SerTC-			
1, 13, 14, 26 [1]	DC Gnd	Input	Ground	DC Ground

[1] Pins 1, 13, 14, and 26 are all tied together inside of the camera.

Table 2-1: **L100k** Pin Assignments for the 26-pin MDR Connector



The camera housing is not grounded and is electrically isolated from the circuit boards inside of the camera.

6-Pin Micro-miniature Receptacle

The pin assignments for the 6 pin, micro-miniature receptacle used to supply power to the camera are shown in Table 2-2.

Pin Number	Signal Name	Direction	Level	Function
1, 2 [1]	12 V In	Input	+12 VDC	Camera Power Input
3				Not Connected
4				Not Connected
5, 6 [2]	DC Gnd	Input	Ground	DC Ground

[1] Pins 1 and 2 are tied together inside of the camera.

[2] Pins 5 and 6 are tied together inside of the camera.

Table 2-2: **L100k** Pin Assignments for the 6-pin Micro-miniature Receptacle

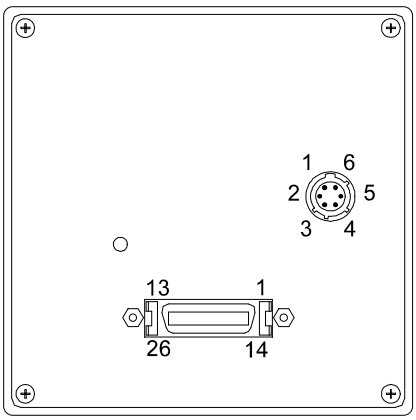


Figure 2-2: **L100k** Pin Numbering

2.1.3 Connector Types

The **26 pin connector** on the camera will be a female .050” MDR connector as called for in the Camera Link Specification.

The **6 pin connector** on the camera is a Hirose micro-miniature locking receptacle (part # HR10A-7R-6PB) or the equivalent. The recommended mating connector is the Hirose micro-miniature locking plug (Part # HR10A-7P-6S). This plug will be shipped with each camera. It should be used to terminate the cable on the power supply for the camera.

2.2 Cable Information

2.2.1 Camera Link Cable

A Camera Link compatible MDR cable assembly is available from Basler as a stock item (part # 1000013041 for a 3 meter cable and part # 1000013042 for a 5 meter cable). Alternatively, you can use the cable assembly manufactured by 3M (part # 14X26-SZLB-XXX-0LC).

The maximum allowed length for the MDR cable used with an **L100k** is 10 meters.

	Note that in order to access the Integrate Enabled signal, you must use the Basler stock cable (see Sect. 2.5.6).

2.2.2 Power Cable

For proper EMI protection, the power supply cable attached to the Hirose plug must be a twin-cored, shielded cable. Also, the housing of the Hirose plug must be connected to the cable shield and the cable must be connected to earth ground at the power supply.

Power requirements are given in Section 2.8.

2.3 Camera Link Implementation in the L100k

The **L100k** uses a National Semiconductor DS90CR287 as a Camera Link transmitter. For a Camera Link receiver, we recommend that you use the National Semiconductor DS90CR288, the National Semiconductor DS90CR288A or an equivalent. Detailed data sheets for these components are available at the National Semiconductor web site (www.national.com). The data sheets contain all of the information that you need to implement Camera Link, including application notes.

	Note that the timing used for sampling the data at the Camera Link receiver in the frame grabber varies from device to device. On some receivers, TTL data must be sampled on the rising edge of the receive clock, and on others, it must be sampled on the falling edge. Also, some devices are available which allow you to select either rising edge or falling edge sampling. Please consult the data sheet for the receiver that you are using for specific timing information.

The **L100k** uses a National Semiconductor DS90LV048A differential line receiver to receive the RS-644 camera control input signals and the serial communication input signal defined in the Camera Link specification. A DS90LV047A differential line transmitter is used to transmit the serial communication output signal defined in the specification. Detailed spec sheets for these devices are available at the National Semiconductor web site (www.national.com).

The schematic in Figure 2-3 shows the interface for **L100k** and a typical implementation for the frame grabber interface.

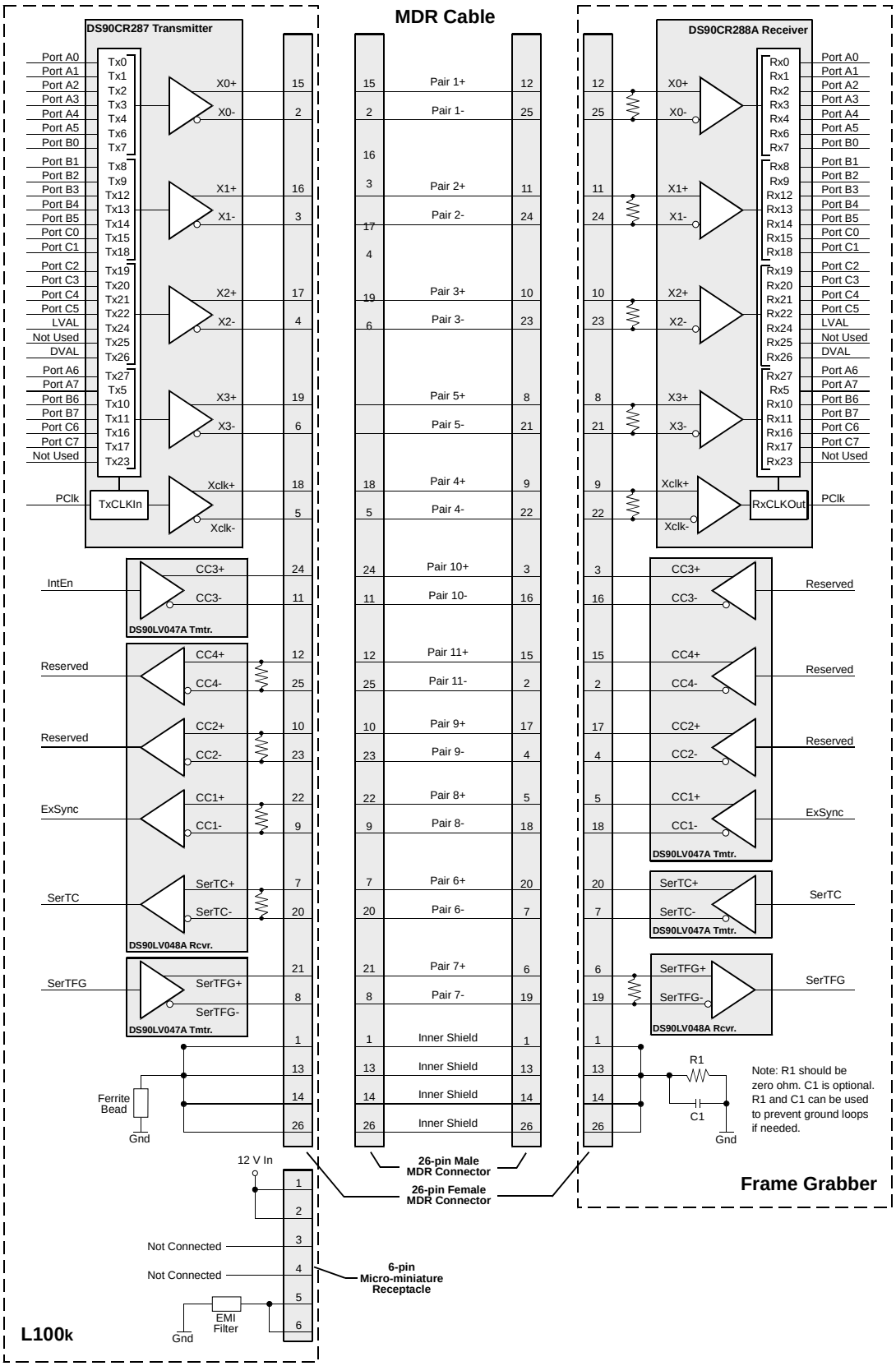


Figure 2-3: Camera / Frame Grabber Interface

2.4 Input Signal

The only control signal that can be input into the **L100k** is an external sync (ExSync) signal. ExSync is an RS-644 LVDS signal as specified in the Camera Link standard. Section 2.4.1 describes the function of the ExSync signal.

2.4.1 ExSync: Controls Line Readout and Exposure Time

The ExSync input signal is used to control exposure time and line read out. When the camera is operating with an ExSync signal, three exposure time control modes are available: edge-controlled, level-controlled and programmable. For more detailed information on the three modes, see Section 3.2.

ExSync can be a periodic or non-periodic function. The frequency of the ExSync signal determines the camera's line rate:

$$\text{Maximum line rate} = \frac{1}{\text{Minimum ExSync signal period}}$$

Note that ExSync is edge sensitive and therefore must toggle.

Minimum high time for the ExSync signal is 0.2 µs.

2.5 Output Signals

The camera's output signals include a pixel clock, video data, and video data qualifiers such as line valid and data valid. Sections 2.5.1 through 2.5.4 describe the output signals.

2.5.1 Pixel Clock

As shown in Figure 2-3 and in Table 2-3, the pixel clock is assigned to the TxClkIn (transmit clock) pin of the Camera Link transmitter. The pixel clock is used to time the sampling and transmission of pixel data as shown in Figures 2-4 through 2-10. The Camera Link transmitter used in **L100k** cameras requires pixel data to be sampled and transmitted on the falling edge of the clock.

The frequency of the pixel clock varies depending on the camera model and on the output mode of the camera. The available output modes are explained in detail in Section 2.5.5.



Note that the timing used for sampling the data at the Camera Link receiver in the frame grabber varies from device to device. On some receivers, data must be sampled on the rising edge of the pixel clock (receive clock), and on others, it must be sampled on the falling edge. Also, some devices are available which allow you to select either rising edge or falling edge sampling. Please consult the data sheet for the receiver that you are using for specific timing information.

2.5.2 Line Valid Bit

As shown in Figures 2-4 through 2-10, the line valid bit indicates that a valid line is being transmitted. Pixel data is only valid when this bit is high.

2.5.3 Data Valid Bit

The data valid bit is only used with the **L101k** when the **L101k** is operating in Dual 10 Bit or Dual 8 Bit output mode.

In dual output mode, valid pixel data is only transmitted on every other cycle of the pixel clock. On the **L101k**, the data valid bit is used to identify the cycles where valid pixel data is transmitted (see Section 2.5.5). Pixel data is only valid when the line valid bit and the data valid bit are both high.

2.5.4 Video Data

Table 2-3 lists the assignment of pixel data bits to the input ports on the transmitter in the camera and the corresponding output pins on the receiver in the frame grabber. These bit assignments comply with the Camera Link standard. As shown in the table, the bit assignments for pixel data vary depending on the output mode setting of the camera. The available output modes are explained in more detail in Section 2.5.5.

Table 2-3 also shows the assignment for the line valid bit, the data valid bit and the pixel clock. These assignments are constant for all output modes.

Port	Camera	Frame Grabber	Single 10 Bit Output Mode	Single 8 Bit Output Mode	Dual 10 Bit Output Mode	Dual 8 Bit Output Mode
Port A0	TxIN0	RxOUT0	Pixel Bit 0	Pixel Bit 0	Odd Pixel Bit 0	Odd Pixel Bit 0
Port A1	TxIN1	RxOUT1	Pixel Bit 1	Pixel Bit 1	Odd Pixel Bit 1	Odd Pixel Bit 1
Port A2	TxIN2	RxOUT2	Pixel Bit 2	Pixel Bit 2	Odd Pixel Bit 2	Odd Pixel Bit 2
Port A3	TxIN3	RxOUT3	Pixel Bit 3	Pixel Bit 3	Odd Pixel Bit 3	Odd Pixel Bit 3
Port A4	TxIN4	RxOUT4	Pixel Bit 4	Pixel Bit 4	Odd Pixel Bit 4	Odd Pixel Bit 4
Port A5	TxIN6	RxOUT6	Pixel Bit 5	Pixel Bit 5	Odd Pixel Bit 5	Odd Pixel Bit 5
Port A6	TxIN27	RxOUT27	Pixel Bit 6	Pixel Bit 6	Odd Pixel Bit 6	Odd Pixel Bit 6
Port A7	TxIN5	RxOUT5	Pixel Bit 7	Pixel Bit 7 (MSB)	Odd Pixel Bit 7	Odd Pixel Bit 7 (MSB)
Port B0	TxIN7	RxOUT7	Pixel Bit 8	Not Used	Odd Pixel Bit 8	Even Pixel Bit 0
Port B1	TxIN8	RxOUT8	Pixel Bit 9 (MSB)	Not Used	Odd Pixel Bit 9 (MSB)	Even Pixel Bit 1
Port B2	TxIN9	RxOUT9	Not Used	Not Used	Not Used	Even Pixel Bit 2
Port B3	TxIN12	RxOUT12	Not Used	Not Used	Not Used	Even Pixel Bit 3
Port B4	TxIN13	RxOUT13	Not Used	Not Used	Even Pixel Bit 8	Even Pixel Bit 4
Port B5	TxIN14	RxOUT14	Not Used	Not Used	Even Pixel Bit 9 (MSB)	Even Pixel Bit 5
Port B6	TxIN10	RxOUT10	Not Used	Not Used	Not Used	Even Pixel Bit 6
Port B7	TxIN11	RxOUT11	Not Used	Not Used	Not Used	Even Pixel Bit 7 (MSB)
Port C0	TxIN15	RxOUT15	Not Used	Not Used	Even Pixel Bit 0	Not Used
Port C1	TxIN18	RxOUT18	Not Used	Not Used	Even Pixel Bit 1	Not Used
Port C2	TxIN19	RxOUT19	Not Used	Not Used	Even Pixel Bit 2	Not Used
Port C3	TxIN20	RxOUT20	Not Used	Not Used	Even Pixel Bit 3	Not Used
Port C4	TxIN21	RxOUT21	Not Used	Not Used	Even Pixel Bit 4	Not Used
Port C5	TxIN22	RxOUT22	Not Used	Not Used	Even Pixel Bit 5	Not Used
Port C6	TxIN16	RxOUT16	Not Used	Not Used	Even Pixel Bit 6	Not Used
Port C7	TxIN17	RxOUT17	Not Used	Not Used	Even Pixel Bit 7	Not Used
DVAL	TxIN26	RxOUT26	Data Valid	Data Valid	Data Valid	Data Valid
LVAL	TxIN24	RxOUT24	Line Valid	Line Valid	Line Valid	Line Valid
Not Used	TxIN23	RxOUT23	Not Used	Not Used	Not Used	Not Used
Not Used	TxIN25	RxOUT25	Not Used	Not Used	Not Used	Not Used
PClk	TxCLKIn	RxCLKOut	Pixel Clock	Pixel Clock	Pixel Clock	Pixel Clock

Table 2-3: Bit Assignments

2.5.5 Video Data Output Modes

L100k series cameras can operate in Single 10 Bit, Single 8 Bit, Dual 10 Bit, or Dual 8 Bit output mode. These modes are described in detail in this section.

Operation in Single 10 Bit or Single 8 Bit Output Mode (L101k, L103k and L104k)

In Single 10 Bit mode, the pixel clock operates at 20 / 40 / 62.5 MHz for the **L101k** / **L103k** / **L104k** respectively. On each clock cycle, the camera transmits 10 bits of pixel data, a line valid bit and a data valid bit. The assignment of the bits is shown in Table 2-3.

The pixel clock is used to time data sampling and transmission. As shown in Figures 2-4 and 2-6, the camera samples and transmits data on each falling edge of the pixel clock.

The line valid bit indicates that a valid line is being transmitted. Pixel data is only valid when the line valid bit is high. The data valid bit is not used in this mode and should be ignored.

Operation in Single 8 Bit mode is similar to Single 10 Bit mode except that the two least significant bits output from each ADC are dropped and only 8 bits of data per pixel is transmitted.



The data sequence outlined below, along with Figures 2-4 and 2-6, describe what is happening at the inputs to the Camera Link transmitter in the camera.

Note that the timing used for sampling the data at the Camera Link receiver in the frame grabber varies from device to device. On some receivers, data must be sampled on the rising edge of the pixel clock (receive clock), and on others, it must be sampled on the falling edge. Also, some devices are available which allow you to select either rising edge or falling edge sampling. Please consult the data sheet for the receiver that you are using for specific timing information.

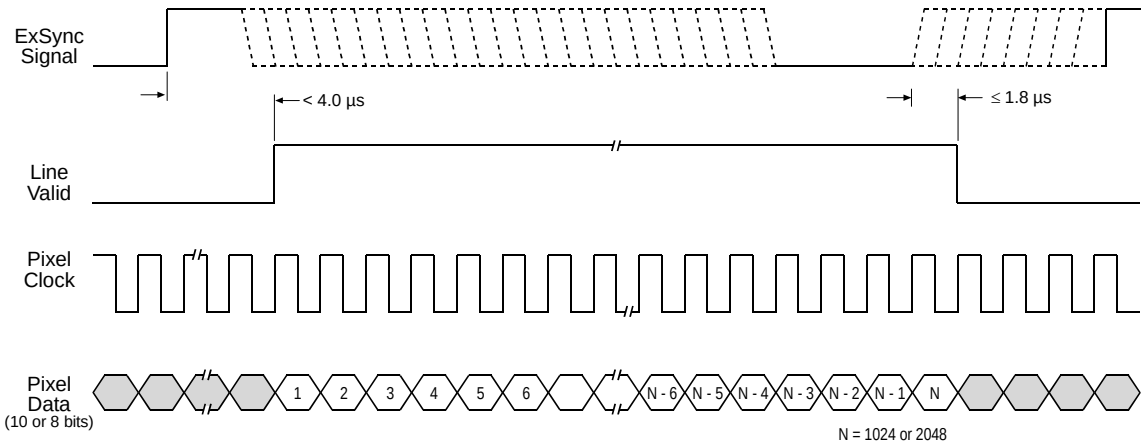
Video Data Sequence[1]

When the camera is not transmitting valid data, the line valid bit sent on each cycle of the pixel clock will be low. Once the camera has completed line acquisition, it will begin to send valid data:

- On the pixel clock cycle where line data transmission begins, the line valid bit will become high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number one.
- On the second cycle of the pixel clock, the line valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number two.
- On the third cycle of the pixel clock, the line valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number three.
- This pattern will continue until all of the pixel data for the line has been transmitted. (A total of 1024 cycles for cameras with a 1K sensor and 2048 cycles for cameras with a 2K sensor.)
- After all of the pixels have been transmitted, the line valid bit will become low indicating that valid line data is no longer being transmitted.

Figures 2-4 and 2-5 show the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode. Figure 2-6 shows the data sequence when the camera is operating in programmable exposure mode.

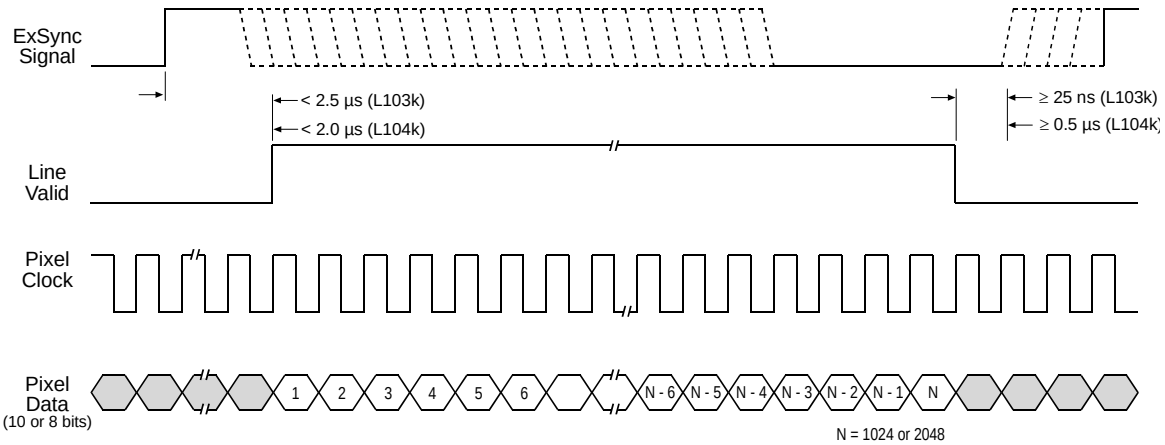
[1] The data sequence assumes that the camera is operating in 10 bit mode. If the camera is operating in 8 bit mode, only 8 bits of data per pixel will be transmitted.



When the ExSync signal triggers an exposure start, the actual exposure start can be slightly delayed (see Section 3.2.1.2).

Timing diagrams are not to scale.

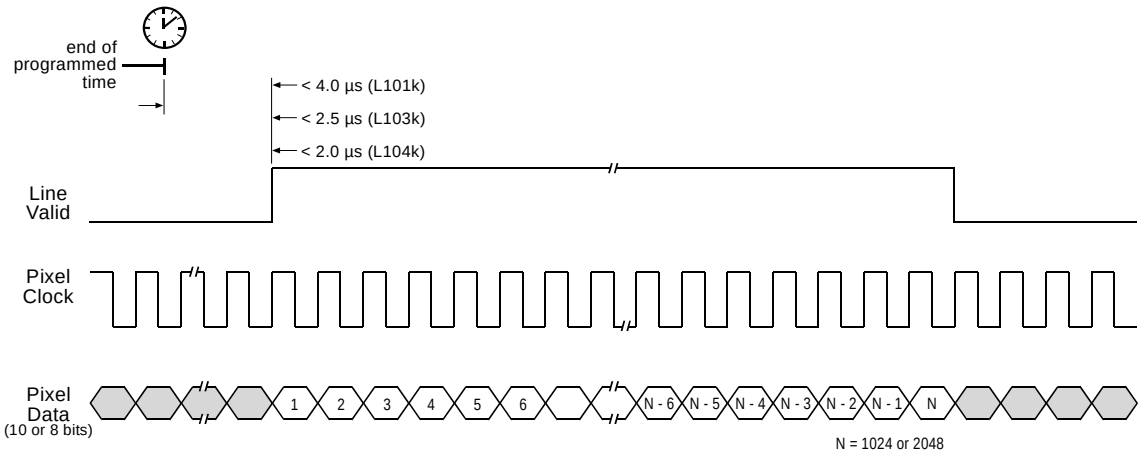
Figure 2-4: L101k Single 10 Bit or Single 8 Bit Output Mode with Edge or Level Controlled Exposure



When the ExSync signal triggers an exposure start, the actual exposure start can be slightly delayed (see Section 3.2.1.2).

Timing diagrams are not to scale.

Figure 2-5: L103k/L104k Single 10 Bit or Single 8 Bit Output Mode with Edge or Level Controlled Exposure



When the ExSync signal triggers an exposure start, the actual exposure start can be slightly delayed (see Section 3.2.1.2). Timing diagrams are not to scale.

Figure 2-6: Single 10 Bit or Single 8 Bit Output Mode with Programmable Exposure

Operation in Dual 10 Bit or Dual 8 Bit Output Mode (L101k only)

In Dual 10 Bit mode, the pixel clock operates at 20 MHz for the **L101k**. On every pixel clock cycle, the camera transmits a line valid bit and a data valid bit. On every other cycle of the pixel clock, the camera transmits 10 bits of data for two pixels. The assignment of the bits is shown in Table 2-3.

The pixel clock is used to time data sampling and transmission. As shown in Figures 2-7 and 2-8, the camera samples and transmits data on each falling edge of the pixel clock.

The line valid bit indicates that a valid line is being transmitted. The data valid bit indicates that valid pixel data is being transmitted. Pixel data is only valid when the line valid and data valid bits are both high.

Operation in Dual 8 Bit mode is similar to Dual 10 Bit mode except that the two least significant bits output from each ADC are dropped and only 8 bits of data per pixel is transmitted.



The data sequence outlined below, along with Figures 2-7 and 2-8, describe what is happening at the inputs to the Camera Link transmitter in the camera.

Note that the timing used for sampling the data at the Camera Link receiver in the frame grabber varies from device to device. On some receivers, data must be sampled on the rising edge of the pixel clock (receive clock), and on others, it must be sampled on the falling edge. Also, some devices are available which allow you to select either rising edge or falling edge sampling. Please consult the data sheet for the receiver that you are using for specific timing information.

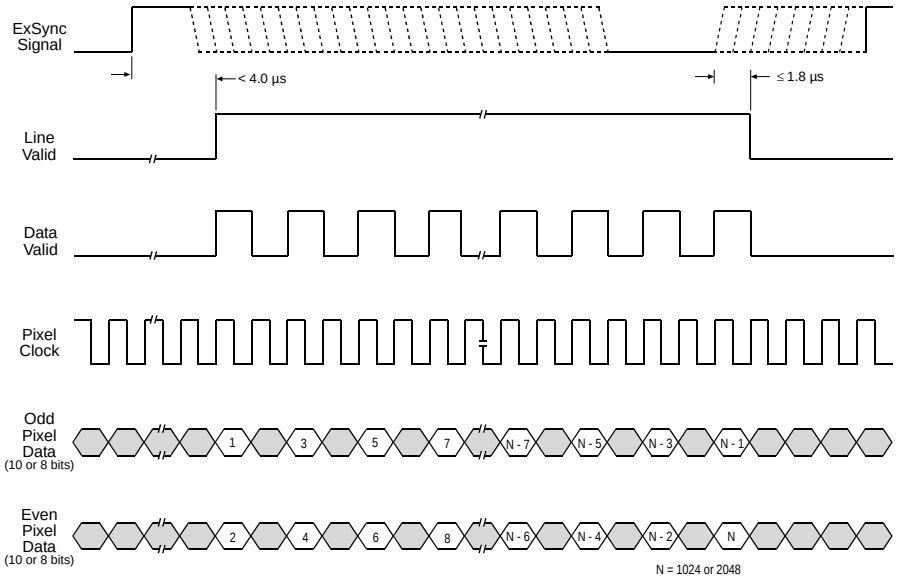
Video Data Sequence[1]

When the camera is not transmitting valid data, the line valid bit and the data valid bit sent on each cycle of the pixel clock will be low. Once the camera has completed line acquisition, it will begin to send valid data:

- On the pixel clock cycle where line data transmission begins, the line valid bit and the data valid bit will become high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number one and ten of the bits will contain data for pixel number two.
- On the second cycle of the pixel clock, the data valid bit will be low. Valid data is not transmitted during this cycle.
- On the third cycle of the pixel clock, the line valid bit and the data valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number three and ten of the bits will contain data for pixel number four.
- On the fourth cycle of the pixel clock, the data valid bit will be low. Valid data is not transmitted during this cycle.
- This pattern will continue until all of the pixel data for the line has been transmitted. (A total of 1024 cycles for cameras with a 1K sensor and 2048 cycles for cameras with a 2K sensor.)
- After all of the pixels have been transmitted, the line valid bit will become low indicating that valid line data is no longer being transmitted.

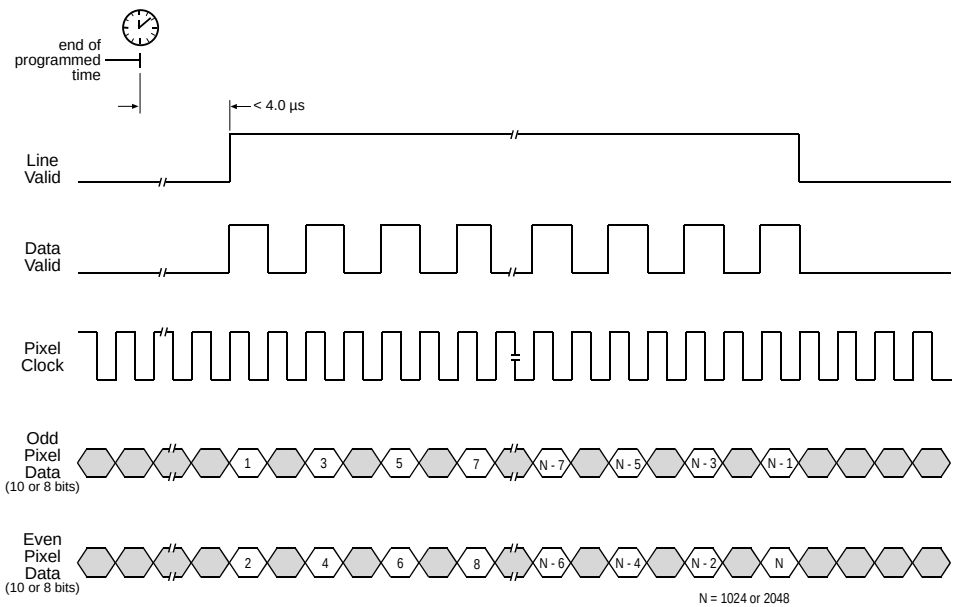
Figure 2-7 shows the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode and Figure 2-8 shows the data sequence when the camera is operating in programmable exposure mode.

[1] The data sequence assumes that the camera is operating in 10 bit mode. If the camera is operating in 8 bit mode, only 8 bits of data per pixel will be transmitted.



When the ExSync signal triggers an exposure start, the actual exposure start can be slightly delayed (see Section 3.2.1.2). Timing diagrams are not to scale.

Figure 2-7: **L101k** Dual 10 or 8 Bit Output Mode with Edge or Level-controlled Exposure



When the ExSync signal triggers an exposure start, the actual exposure start can be slightly delayed (see Section 3.2.1.2). Timing diagrams are not to scale.

Figure 2-8: **L101k** Dual 10 or 8 Bit Output Mode with Programmable Exposure

Operation in Dual 10 Bit or Dual 8 Bit Output Mode (L103k and L104k only)

In Dual 10 Bit mode, the pixel clock operates at 20 MHz for the **L103k** and 31.25 MHz for the **L104k**. On each clock cycle, the camera transmits a line valid bit, a data valid bit and ten bits of data for two pixels. The assignment of the bits is shown in Table 2-3.

The pixel clock is used to time data sampling and transmission. As shown in Figures 2-9 and 2-10, the camera samples and transmits data on each falling edge of the pixel clock.

The line valid bit indicates that a valid line is being transmitted. Pixel data is only valid when the line valid bit is high. The data valid bit is not used in this mode. It is always high and should be ignored.

Operation in Dual 8 Bit mode is similar to Dual 10 Bit mode except that the two least significant bits output from each ADC are dropped and only 8 bits of data per pixel is transmitted.



The data sequence outlined below, along with Figures 2-9 and 2-10, describe what is happening at the inputs to the Camera Link transmitter in the camera.

Note that the timing used for sampling the data at the Camera Link receiver in the frame grabber varies from device to device. On some receivers, data must be sampled on the rising edge of the pixel clock (receive clock), and on others, it must be sampled on the falling edge. Also, some devices are available which allow you to select either rising edge or falling edge sampling. Please consult the data sheet for the receiver that you are using for specific timing information.

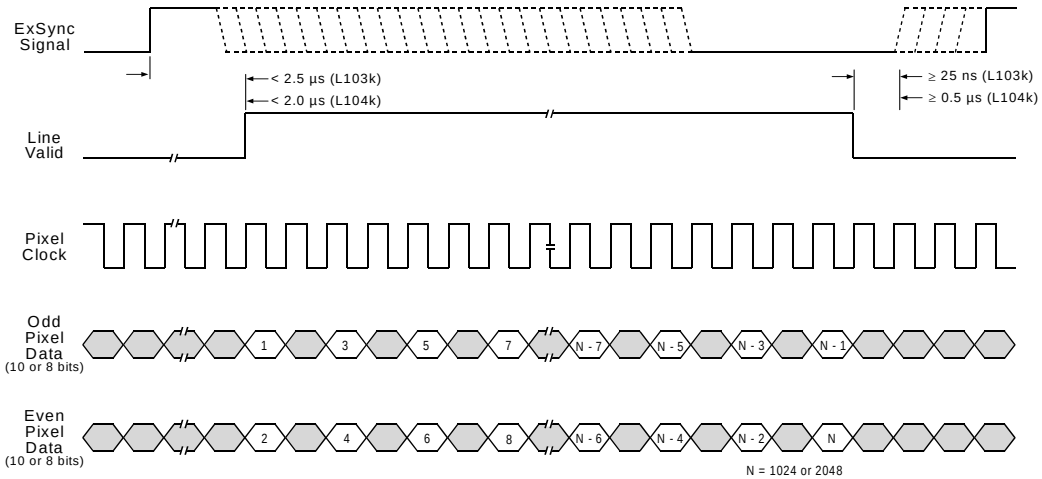
Video Data Sequence[1]

When the camera is not transmitting valid data, the line valid bit sent on each cycle of the pixel clock will be low. Once the camera has completed line acquisition, it will begin to send valid data:

- On the pixel clock cycle where line data transmission begins, the line valid bit will become high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number one and ten of the bits will contain data for pixel number two.
- On the second cycle of the pixel clock, the line valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number three and ten of the bits will contain data for pixel number four.
- This pattern will continue until all of the pixel data for the line has been transmitted. (A total of 512 cycles for cameras with a 1K sensor and 1024 cycles for cameras with a 2K sensor.)
- After all of the pixels have been transmitted, the line valid bit will become low indicating that valid line data is no longer being transmitted.

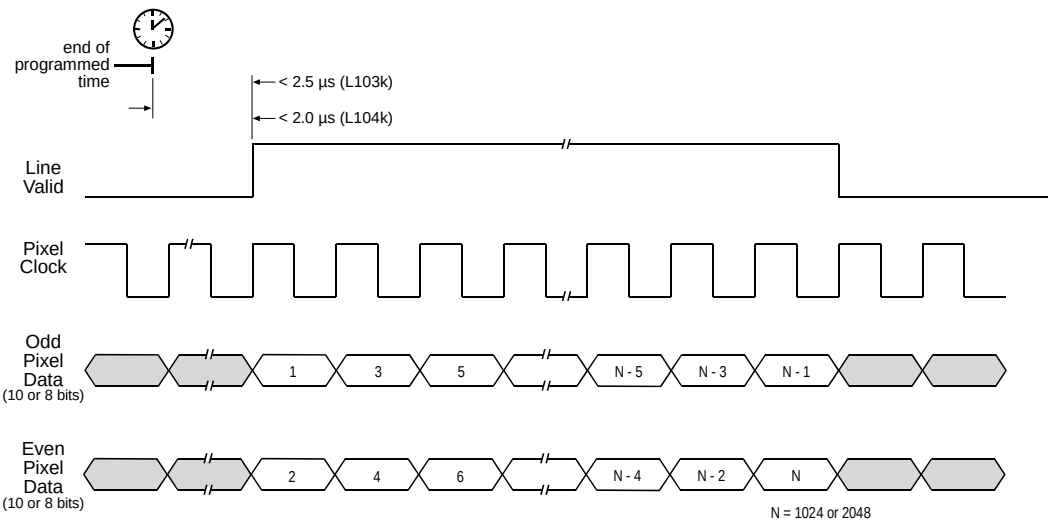
Figure 2-9 shows the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode and Figure 2-10 shows the data sequence when the camera is operating in programmable exposure mode.

[1] The data sequence assumes that the camera is operating in 10 bit mode. If the camera is operating in 8 bit mode, only 8 bits of data per pixel will be transmitted.



When the ExSync signal triggers an exposure start, the actual exposure start can be slightly delayed (see Section 3.2.1.2). Timing diagrams are not to scale.

Figure 2-9: **L103k** or **L104k** Dual 10 or 8 Bit Output Mode with Edge or Level-controlled Exposure



When the ExSync signal triggers an exposure start, the actual exposure start can be slightly delayed (see Section 3.2.1.2). Timing diagrams are not to scale.

Figure 2-10: **L103k** or **L104k** Dual 10 or 8 Bit Output Mode with Programmable Exposure

2.5.6 Integrate Enabled Signal

An RS-644 LVDS output signal called Integrate Enabled (IntEn) is available on **L100k** cameras. The integrate enabled signal indicates that an exposure is taking place. The signal will go high when each exposure begins and go low when the exposure ends. As shown in the schematic in Section 2.3, the IntEn signal is available on pins 24 and 11 of the **L100k**.

The integrate enabled signal can not be easily accessed if a standard Camera Link Cable is used between the camera and the frame grabber. However, a Camera Link cable which allows easy access to this signal is available from Basler as a stock item (part # 100013041 for a 3 meter cable and part # 100013042 for a 5 meter cable).

In the Basler cable, the wires which carry the integrate enabled signal from the camera are not attached to the pins in the frame grabber end of the cable. Instead, the wires are unterminated and are folded back inside of the connector housing on the frame grabber end (see Figure 2-11 below). If you open the connector housing, you can locate the wires and use them to access the integrate enabled signal. As shown below, a blue wire carries the positive signal and a gray wire carries the negative signal. The wires require a 100 Ohm termination.

	If you use a standard Camera Link cable to connect the **L100k** to a Camera Link frame grabber, the RS-644 LVDS transmitter for the integrate enabled signal will be connected to an RS-644 LVDS transmitter in the frame grabber as shown in the schematic in Section 2.3. Because the transmitter in the camera is a low current source and because the opposing transmitter in the frame grabber is typically short circuit protected, this configuration will not cause damage to the camera or the frame grabber.

In edge-controlled mode, the IntEn signal is low during charge transfer.

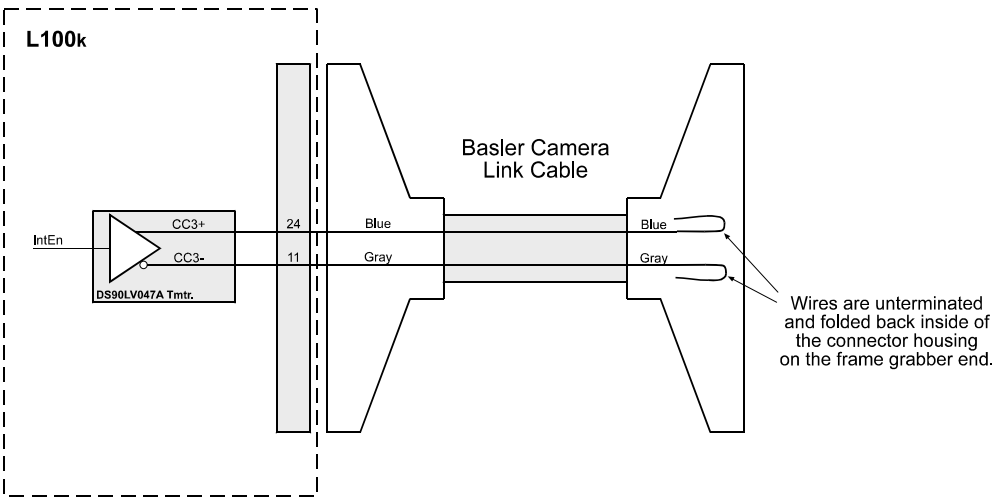


Figure 2-11: Basler Camera Link Cable

2.6 RS-644 Serial Communication

The **L100k** is equipped for RS-644 serial communication via the frame grabber as specified in the Camera Link standard. The RS-644 serial connection in the Camera Link interface is used to issue commands to the camera for changing modes and parameters. The serial link can also be used to query the camera about its current setup.

The Basler Camera Configuration Tool Plus (CCT+) is a convenient, graphical interface that can be used to change camera modes and parameters via the serial connection. The configuration tool is installed as part of the camera installation procedure shown in the CCT+ booklet that is shipped with the camera. Section 4.1 provides some basic information about the configuration tool. Detailed instructions for using the tool are included in the on-line help file that is installed with the tool.

Basler has also developed a binary command protocol that can be used to change camera modes and parameters directly from your own application via the serial connection using either the API delivered with the frame grabber or the Basler CPA driver. See Section 4.2 for details on the binary command format.

2.6.1 Making the Serial Connection

Frame grabbers compliant with the Camera Link specification are equipped with a serial port integrated into the Camera Link interface that can be used for RS-644 serial communication. The characteristics of the serial port can vary from manufacturer to manufacturer.

If you are using the Basler Camera Configuration Tool Plus to configure the camera, the tool will detect the characteristics of the serial port on the frame grabber and will determine the appropriate settings so that the tool can open and use the port.

	In order for the Camera Configuration Tool Plus to detect and use the port, the characteristics of the port must comply with the Camera Link standard and the DLL called for in the standard must be present.

If you are configuring the camera using binary commands from within your application software, your software must be able to access the frame grabber serial port and to determine the appropriate settings so that it can open and use the port. Please consult your frame grabber's documentation to determine the port access method and the port characteristics.

2.7 Converting Camera Link Output to RS-644 with a k-BIC

On the **L100k**, video data is output from the camera in Camera Link LVDS format and parameter change commands are issued to the camera using RS-644 serial communication via the frame grabber. On older cameras, video data was output using an RS-644 LVDS format and commands were issued using RS-232 serial communication via the host PC. The output from **L100k** cameras can be converted to the older style of output by using a Basler Interface Converter for k-series cameras (k-BIC). The k-BIC is a small device which attaches to the **L100k** with a Camera Link compatible cable. For complete information on the k-BIC, refer to the k-BIC Users Manual and the k-BIC installation guide.

2.8 DC Power

The **L100k** requires 12 VDC (± 10%) power. The maximum power consumption is approximately 6.5 W / 8.5 W / 10 W for the **L101k** / **L103k** / **L104k** respectively.



Caution!

The camera has no overvoltage protection. An input voltage higher than 14 VDC will damage the camera



Caution!

Do not reverse the polarity of the input power to the camera. Reversing the polarity of the input power can severely damage the camera and leave it non-operational.

Also, note the information about the 6-pin connector in Section 2.1.3 and on the power cable in Section 2.2.2.

2.9 Status LED

The **L100k** has a status LED on the back of the camera. The LED is used to indicate that power is present and to indicate an error condition if one is detected. See Section 6.3 for details.

3 Basic Operation and Features

3.1 Functional Description

BASLER L100k line scan cameras employ a CCD-sensor chip which provides features such as electronic exposure time control and anti-blooming. Exposure time is normally controlled via an external trigger (ExSync) signal. The ExSync signal facilitates periodic or non-periodic pixel readout.

When exposure is controlled by an ExSync signal, exposure time can be either edge-controlled, level-controlled, or programmable. In edge-controlled mode, charge is accumulated over the entire period of the ExSync signal and a rising edge of ExSync triggers the readout of accumulated charges from the sensor elements to the CCD shift registers. In level-controlled mode, charge is accumulated when the ExSync signal is low and a rising edge of ExSync triggers the readout. In programmable mode, exposure time can be programmed to a predetermined time period. In this case, exposure begins on the rising edge of ExSync and accumulated charges are read out when the programmed exposure time ends.

A free-run mode that allows the camera to operate without an ExSync signal is also available. In free-run mode, the camera generates its own internal control signal and the internal signal is used to control exposure and charge read out. When operating in free-run, the camera outputs lines continuously.

At readout, accumulated charges are transported from the light-sensitive sensor elements (pixels) to the CCD shift registers. The charges from the odd pixels and the charges from the even pixels are handled by separate shift registers as shown in Figure 3-1. As charges move out of the shift registers, they are converted to voltages proportional to the size of each charge. Shifting is clocked according to the camera's internal data rate.

The voltages moving out of each shift register are amplified by a Variable Gain Control (VGC) and then digitized by a ten bit, Analog to Digital converter (ADC). The digitized video data is transmitted from the camera to the frame grabber using a format compatible with the Camera Link standard (see Section 2.3 for details). The camera can transmit video at a ten bit or an eight bit depth and as a single pixel or a dual pixel stream.

For optimal digitization, gain and offset are programmable via a serial port.

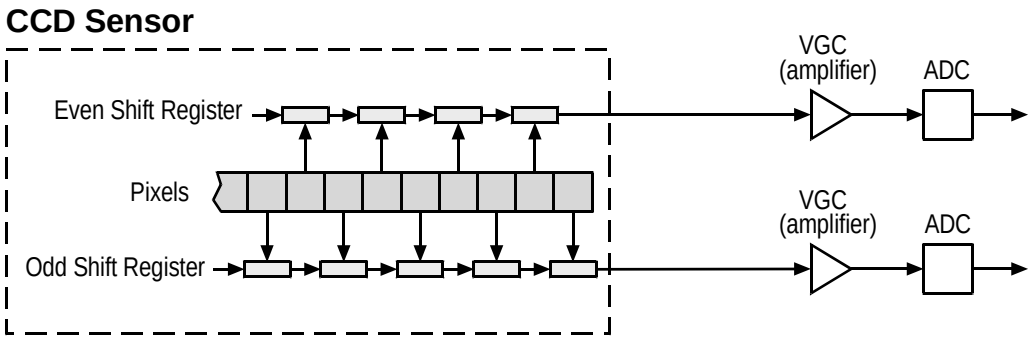


Figure 3-1: **L100k** Sensor Architecture

3.2 Exposure Time Control Modes

L100k series cameras can operate under the control of an external trigger signal (ExSync) or can operate in “free-run.” In free-run, the camera generates its own internal control signal and does not require an ExSync signal.

3.2.1 ExSync Controlled Operation

3.2.1.1 Basics of ExSync Controlled Operation

In ExSync operation, the camera’s line rate and exposure time are controlled by an externally generated (ExSync) signal. The ExSync signal is typically supplied to the camera by a frame grabber board. You should refer to the manual supplied with your frame grabber board to determine how to set up the ExSync signal that is being supplied to the camera.

When the camera is operating under the control of an ExSync signal, the length of the ExSync signal period determines the camera’s line rate. (Line Rate = 1/ExSync Signal Period.) ExSync can be periodic or non-periodic.

When the camera is operating with an ExSync signal, it has three modes of exposure time control available: edge-controlled mode, level-controlled mode, and programmable mode.

- In **ExSync**, **edge-controlled** mode, the pixels are exposed and charge is accumulated over the full period of the ExSync signal (rising edge to rising edge). The falling edge of the ExSync signal is irrelevant. The line is read out and transferred on the rising edge of ExSync (see Figure 3-2).

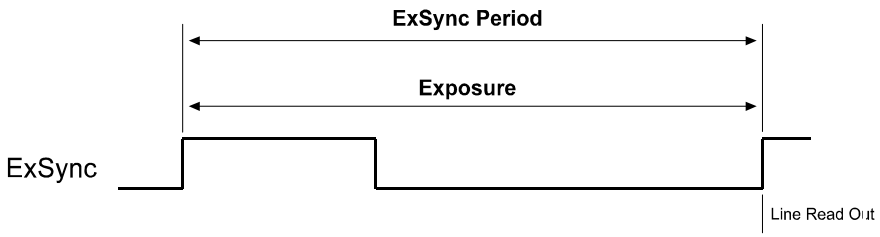


Figure 3-2: ExSync, Edge-Controlled Mode

- In **ExSync**, **level-controlled** mode, the exposure time is determined by the time between the falling edge of ExSync and the next rising edge. The pixels are exposed and charge is accumulated only when ExSync is low. The line is read out and transferred on the rising edge of the ExSync signal (see Figure 3-3).

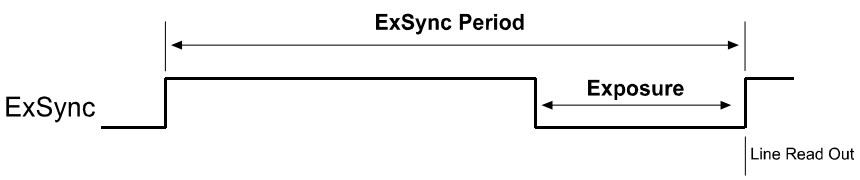


Figure 3-3: ExSync, Level-controlled Mode

- In **ExSync**, **programmable** mode, the rising edge of ExSync triggers exposure and charge accumulation for a pre-programmed period of time. The line is read out and transferred at the end of the pre-programmed period. The falling edge of ExSync is irrelevant (see Figure 3-4).

  A parameter called “Timer 1” is used to set the length of the pre-programmed exposure period.

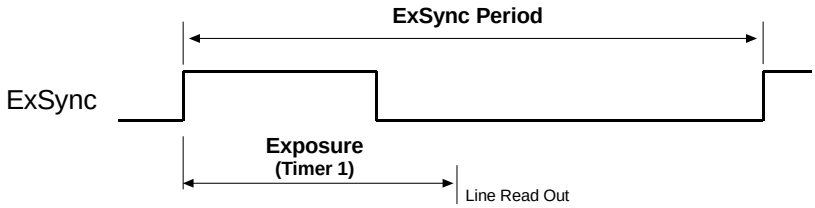


Figure 3-4: ExSync, Programmable Mode

You can set the camera to operate in one of the ExSync controlled exposure modes using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the Exposure Time Control Mode setting in the Exposure parameter group to set the camera for ExSync operation and to select the edge-controlled, level controlled or programmable exposure time control mode. If you select the programmable mode, you must also enter an exposure time. When you enter an exposure time, the configuration tool will automatically set the “Timer 1” parameter to the correct value.

With binary commands, you must use the Exposure Time Control Mode command to select ExSync edge-controlled, ExSync level-controlled or ExSync programmable mode (see Section 4.2.4.2). If you choose the programmable mode, you must also use the Timer 1 command to set the exposure time.

3.2.1.2 Recommendations When Using ExSync

When using an ExSync signal to control operation, several general guidelines must be followed:

- ExSync must toggle.
- The ExSync signal period must not be lower than a defined minimum. The minimum ExSync period for each camera version is shown in Table 3-1.

	L101k	L103k	L104k
1024 Pixel CCD	53.4 µs	28.0 µs	17.1 µs
2048 Pixel CCD	105.0 µs	53.3 µs	34.2 µs

Table 3-1: Minimum ExSync Signal Period

- The ExSync signal must remain high for at least 0.2 µs.
- The minimum exposure time is 1 µs. That means that:

  In ExSync level-controlled mode, the ExSync signal must remain low for at least 1 µs.

  In ExSync programmabe mode, the programmed exposure time must be at least 1 µs.

- In the ExSync Programmable mode:

  Maximum allowed programmed exposure time = ExSync signal period - 1 µs.

- In ExSync edge-controlled and ExSync level-controlled modes, the relationship between the the fall of the line valid signal and the rise of the ExSync signal must meet the minimum requirements shown in Figures 2-4, 2-5, 2-7, and 2-9.
- When an exposure is triggered by the ExSync signal, the actual start of exposure can be delayed by up to 1.3 µs. (This is commonly referred to as an exposure start delay.) The maximum delay depends on the camera model and the exposure mode that you are using. Table 3-2 shows the maximum delay for each camera model and exposure mode.

  The actual length of the exposure time will be equal to the exposure time triggered by the ExSync signal minus the delay. Actual exposure can be monitored using the Integrate Enabled signal (see Section 3.4).

Exposure Mode	L101k	L103k	L104k
Edge-controlled	1.3 µs	1.1 µs	0.55 µs
Level-controlled	0.15 µs	0.15 µs	0.15 µs
Programmable	0.45 µs	0.45 µs	0.45 µs

Table 3-2: Maximum Exposure Start Delays

3.2.2 Free Run

3.2.2.1 Basics of Free-run Controlled Operation

In **free-run**, no ExSync signal is required. The camera generates a continuous internal control signal based on two programmable parameters: “Timer 1” and “Timer 2”. Timer 1 determines how long the internal signal will remain low and Timer 2 determines how long the signal will remain high.

When the camera is operating in free-run, the length of the control signal period determines the camera’s line rate. The control signal period is equal to Timer 1 plus Timer 2:

$$\text{Timer 1} + \text{Timer 2} = \text{Control signal period} = \frac{1}{\text{Line rate}}$$

When the camera is operating in free-run, it exposes and outputs lines continuously.

In free-run, two modes of operation are available: edge-controlled and programmable.

- In **free-run**, **edge-controlled mode**, the pixels are exposed and charge is accumulated over the full period of the internal control signal (rising edge to rising edge). The falling edge of the control signal is irrelevant. The line is read out and transferred on the rising edge of the internal control signal (see Figure 3-5).

  In this mode, the exposure time is the sum of Timer 1 plus Timer 2:

$$\text{Timer 1} + \text{Timer 2} = \text{Exposure} = \frac{1}{\text{Line rate}}$$

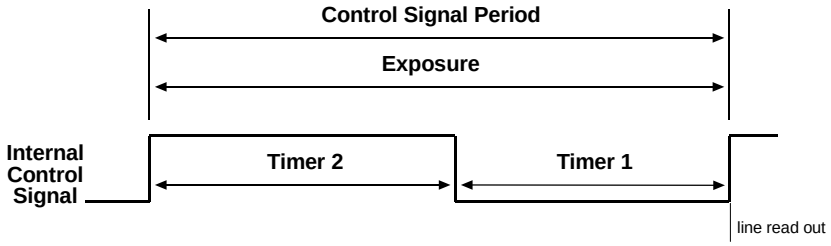


Figure 3-5: Free-run, Edge-controlled Mode

- In **free-run**, **programmable mode**, the pixels are exposed and charge is accumulated when the internal control signal is low. The line is read out and transferred on the rising edge of the internal control signal (see Figure 3-6).

  In this mode, the Timer 1 setting determines the length of exposure:

  Timer 1 = Exposure

  Timer 2 = Rest of the control signal period

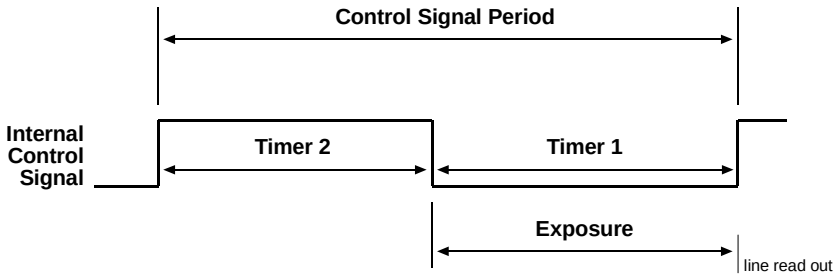


Figure 3-6: Free-run, Programmable Mode

You can set the camera to operate in free-run using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the Exposure Time Control Mode Setting in the Exposure parameter group to set the camera for free-run and to select the edge-controlled or programmable exposure time control mode. If you choose to operate the camera in free-run, the configuration tool will require you to enter a line rate; if you are using the programmable mode, you must also enter an exposure time. The configuration tool will automatically set the Timer 1 and Timer 2 parameters based on the values that you enter in the Exposure parameter group.

With binary commands you must use the Exposure Time Control Mode command to select the free-run, edge-controlled or free-run, programmable mode (see Section 4.2.4.2). You must also use the Timer 1 command to set Timer 1 and the Timer 2 command to set Timer 2.

3.2.2.2 Recommendations When Using Free-run

When using free-run mode to control operation, several general guidelines must be followed:

- In the free-run mode, the period of the internal control signal is equal to the sum of Timer 1 plus Timer 2. This sum must not be lower than the minimum shown in Table 3-3.

	L101k	L103k	L104k
1024 Pixel CCD	53.3 µs	28.0 µs	17.1 µs
2048 Pixel CCD	104.3 µs	53.3 µs	34.2 µs

Table 3-3: Minimum Control Signal Periods

- The minimum recommended exposure time is 1 µs.

3.3 Video Data Output Modes

L100k series cameras can output video data using four different modes: Single 10 Bit mode, Single 8 Bit mode, Dual 10 Bit mode and Dual 8 Bit mode. These modes of operation are described in detail in Section 2.5.5.

You can select the video data output mode using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the Video Data Output Mode setting in the Output parameter group.

With binary commands, you use the Video Data Output Mode command (see Section 4.2.4.1).

3.4 Integrate Enabled Signal

An output signal called Integrate Enabled (IntEn) is available on **L100k** cameras. The integrate enabled signal indicates that an exposure is taking place. The signal will go high when each exposure begins and go low when the exposure ends. The characteristics of the signal are described in more detail in Section 2.5.6.

In cases where flash exposure is required, the integrate enabled signal is useful as a flash trigger.

3.5 Gain and Offset

The pixels in the CCD sensor output voltage signals when they are exposed to light. These voltages are amplified by VGCs and transferred to ADCs where they are converted to digital output signals (see Figure 3-1).

Two parameters, gain and offset are associated with each ADC. As shown in Figures 3-7 and 3-8, increasing or decreasing the gain increases or decreases the amplitude of the signal that is input to the ADC. Increasing or decreasing the offset moves the signal up or down the measurement scale but does not change the signal amplitude.

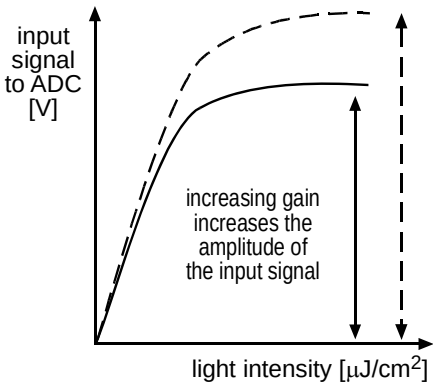


Figure 3-7: Gain

For most applications, black should have a gray value of 1 and white should have a gray value of 254 (in 8 bit output mode) or 1022 (in 10 bit output mode). Attempt to achieve this by varying exposure and illumination rather than changing the camera's gain. The default gain is the optimal operating point (low noise, good odd/even channel match) and should be used if possible.

Internally, the camera processes odd and even pixels separately in two different data channels (see Figure 3-1). Consequently, gain must be adjusted separately for the odd pixels and for the even pixels. Due to variations in the camera's electronics, a gain setting on the odd channel may produce a different output than the same gain setting on the even channel. Gain balance between the odd and even channels is important to maintain uniform output data with minimal gray value differences between odd and even pixels. See Section 3.5.1 for more detailed information on balancing the gain.

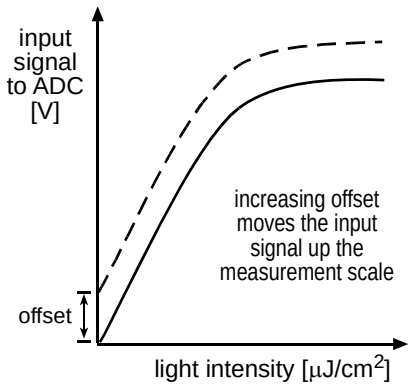


Figure 3-8: Offset

	Because increasing gain increases both signal and noise, the signal to noise ratio does not change significantly when gain is increased.

Since the black level is very stable, you do not need to adjust the offset when you change the gain. The offset is also set separately for the odd and the even channel, but the offset on the channels does not need to be balanced. An odd and even offset of, for example, 0 both produce the same output.

You can set the gain and offset using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the Gain setting and the Offset setting in the Gain and Offset parameter group to set the gain and offset.

With binary commands, you must use the Odd Pixel Gain and Even Pixel Gain commands to set the gain and the Odd Pixel Offset and Even Pixel Offset commands to set the offset (see Sections 4.2.4.11, 4.2.4.13, 4.2.4.12, and 4.2.4.14).

3.5.1 Balancing the Gain on Odd and Even Pixels

As described on the previous page, gain alignment between the channels is important to maintain uniform output data with minimal gray value differences between odd and even pixels.

In some applications, multiple cameras are used, for example, when several line scan cameras are used next to each other to form one large image. Another example is that a camera in an existing application is replaced. In these cases, it is also necessary to balance the gain between cameras.

To meet the goals of balanced channels and comparable camera output, each Basler camera is calibrated before it leaves the factory. This calibration procedure has the following effects:

- The factory gain settings for the odd and even channels are aligned so that they equally amplify the signal and a uniform output is achieved on both channels. In addition, they are set to a low gain value to obtain an optimal operating point (low noise, good odd/even channel match)
- There are reference gain values which can be used to calculate higher or lower odd and even gain settings so that the channels remain balanced.
- All cameras have default gain settings and reference gain values which match the output of a factory master camera of the same type. This output is referred to as 0 dB. So if a camera's gain is set to 2 dB, this means 2 dB more than the gain of the master camera.

The reference gain values can be used to calculate higher or lower gain settings that will keep the odd and even channels in balance and comparable to other cameras of the same type.

If you use the Gain setting in the Camera Configuration Tool Plus (see Section 4.1) to set the gain on your camera, an "auto-balance" feature will automatically use the stored reference values to keep the channels in balance. If you want to set the camera so that the channels are not balanced, you can use the Gain Balance setting to change the gain on the even pixels only.

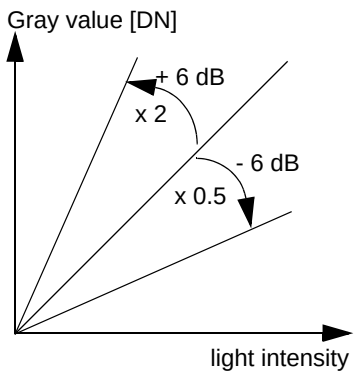
If you use binary commands (see Section 4.2) to set the gain, you can use the reference values to calculate gain settings that will keep the channels in balance. To do this, you must select a desired gain in dB to achieve and then use the reference values along with the formulas shown on pages 3-12 through 3-15 to calculate the required settings for the odd pixel gain and for the even pixel gain. You can then enter the calculated settings into the camera using the appropriate commands.

3.5.1.1 Refresher on dB

A value given in dB is basically a factor. The general formula to calculate a gain factor in dB is as follows:

$$dB = 20 \times \log\left(\frac{\text{camera output}}{\text{reference camera output}}\right)$$

Or, in other words, an increase by 6 dB corresponds to a factor of 2. A decrease by 6 dB corresponds to a factor of 0.5.



3.5.1.2 Calculating Gain Settings on the L101k and L103k with Binary Commands

Gain is adjustable and can be programmed on a decimal scale. The gain register ranges from 0 to 1023 (0x0000 to 0x03FF).

- Do not use gain settings below 91. Only the gain range from 91 to 1023 has tested and guaranteed accuracy.
- The gain can be adjusted in steps of 0.0354 dB.
- The default gain settings and the reference gain result in an amplification referred to as 0 dB.
- A gain of 0 dB to 34 dB can be programmed.

Sample Calculation

Assume that you are working with an **L103k**, that you want to keep the odd pixels and the even pixels balanced, and that you want to set the gain to 2 dB.

1. To read the values that were stored during the camera's calibration procedure, use the "Read reference gain values" command (see section 4.2.7.6). For our example, we will assume that the camera returned the following reference values:

Byte 1 Low byte odd pixel reference gain after decimal point	*0x00*
Byte 2 High byte odd pixel reference gain after decimal point	*0x00*
Byte 3 Low byte odd pixel reference gain before decimal point	*0x6D*
Byte 4 High byte odd pixel reference gain before decimal point	*0x00*
Byte 5 Low byte even pixel reference gain after decimal point	*0x33*
Byte 6 High byte even pixel reference gain after decimal point	*0x66*
Byte 7 Low byte even pixel reference gain before decimal point	*0x6F*
Byte 8 High byte even pixel reference gain before decimal point	*0x00*

2. The reference values are hexadecimal. Convert them to decimal:

Byte 1 = 0	*Byte 2 = 0*	*Byte 3 = 109*	*Byte 4 = 0,*
Byte 5 = 51	*Byte 6 = 102*	*Byte 7 = 111*	*Byte 8 = 0*

3. Use the decimal values of Byte 4 to Byte 1 to determine the odd pixel reference gain RGo:

$$RGo = (Byte\ 4 \times 256) + Byte\ 3 + \frac{Byte\ 2}{256} + \frac{Byte\ 1}{65536}$$

$$RGo = (0 \times 256) + 109 + 0 + 0$$

$$RGo = 109.00$$

4. Enter the decimal odd pixel reference gain RGo and the desired gain G into the following formula:

$$Xo = 20 \log_{10}\left[\frac{658 + RGo}{658 - RGo}\right] + G \qquad G = \text{Desired Gain in dB. Max. } G = 0.0354 * (1024 - RGo)$$

For our example, enter RGo = 109 and G = 2:

$$Xo = 20 \log_{10}\left[\frac{658 + 109}{658 - 109}\right] + 2\ dB = 4.9$$

5. Calculate the values RGe and Xe for the even channel using the same method as in steps 1, 2, 3, and 4. Use the decimal values of Byte 8 to Byte 5 to determine the even pixel reference gain RGe. RGe is 111.40 in this example, the value for Xe is 4.97.
6. Convert the results to decimal using the appropriate formula a) or b):

a) $$\text{Odd pixel gain setting} = \frac{\left(658 \times 10^{\frac{Xo}{20}}\right) - 658}{1 + 10^{\frac{Xo}{20}}} \qquad \text{Where } Xo < 0.0354 * (512 - RGo)$$

b) $$\text{Odd pixel gain setting} = \frac{Xo}{0.0354} \qquad \text{Where } Xo \geq 0.0354 * (512 - RGo)$$

Since Xo is 4.9 and thus definitely less than 14.27, we need formula a):

a) $$\text{Odd pixel gain setting} = \frac{\left(658 \times 10^{\frac{4.9}{20}}\right) - 658}{1 + 10^{\frac{4.9}{20}}}$$

Odd pixel gain setting = 180.8. Round to 181.

7. Calculate the even gain setting in the same way. It is 183 in this example.
8. Convert the results to hexadecimal:

Odd pixel gain setting of 181 decimal = 0x00B5

Even pixel gain setting of 183 decimal = 0x00B7

9. Use the odd pixel gain and even pixel gain binary commands to set the odd and even gain to the calculated values.

After you use the commands to enter the calculated values, the camera will be operating at 2 dB with respect to the master camera. The odd and even pixels will be balanced.

	You may get a better odd/even match by increasing or decreasing either the odd or the even gain by one.

	Since the black level is very stable, you do not need to adjust the offset when you change the gain.

3.5.1.3 Calculating Gain Settings on the L104k with Binary Commands

Gain is adjustable and can be programmed on a decimal scale that ranges from 0 to 319 (0x0000 to 013F). The full scale can be used.

- The default gain settings and the reference gain result in an amplification referred to as 0 dB.
- A gain of 0 dB to 30 dB can be programmed.
- The gain can be adjusted in steps of 0.09 dB. The change in dB settings is linear.

Sample Calculation

Assume that you are working with an **L104k**, that you want to keep the odd pixels and the even pixels balanced, and that you want to set the gain to 2 dB.

1. To read the values that were stored during the camera's calibration procedure, use the "Read reference gain values" command. For our example, we will assume that the camera returned the following reference values:

Byte 1 Low byte odd pixel reference gain after decimal point	*0x00*
Byte 2 High byte odd pixel reference gain after decimal point	*0x00*
Byte 3 Low byte odd pixel reference gain before decimal point	*0x14*
Byte 4 High byte odd pixel reference gain before decimal point	*0x00*
Byte 5 Low byte even pixel reference gain after decimal point	*0x13*
Byte 6 High byte even pixel reference gain after decimal point	*0x64*
Byte 7 Low byte even pixel reference gain before decimal point	*0x15*
Byte 8 High byte even pixel reference gain before decimal point	*0x00*

2. The reference values are hexadecimal. Convert them to decimal:

Byte 1 = 0	*Byte 2 = 0*	*Byte 3 = 20*	*Byte 4 = 0,*
Byte 5 = 19	*Byte 6 = 100*	*Byte 7 = 21*	*Byte 8 = 0*

3. Use the decimal values of Byte 4 to Byte 1 to determine the odd pixel reference gain RGo:

$$RGo = (Byte\ 4 \times 256) + Byte\ 3 + \frac{Byte\ 2}{256} + \frac{Byte\ 1}{65536}$$

$$RGo = (0 \times 256) + 20 + 0 + 0$$

$$RGo = 20$$

4. Enter the decimal odd pixel reference gain RGo and the desired gain G into the following formula:

$$Xo = (0.094 \times RGo) + G$$

G = Desired gain in dB, Max G = 0.094* (1024 - RGo)

$$Xo = (0.094 \times 20) + 2$$

$$Xo = 3.88$$

5. Calculate the values RGe and Xe for the even channel using the same method as in steps 3 and 4. Use the decimal values of Byte 8 to Byte 5 to determine the even pixel reference gain RGe:

$$RGe = (Byte\ 8 \times 256) + Byte\ 7 + \frac{Byte\ 6}{256} + \frac{Byte\ 5}{65536}$$

   RGe is 21.39 in this example, the value for Xe is 4.01.

6. Convert the results to decimal:

$$Odd\ pixel\ gain\ setting = \frac{Xo}{0.094}$$

$$Odd\ pixel\ gain\ setting = \frac{3.88}{0.094}$$

$$Odd\ pixel\ gain\ setting = 41.28$$

   Round to 41.

7. Calculate the even gain setting in the same way. It is 43 in this example.

8. Convert the results to hexadecimal:

   Odd pixel gain setting of 41 decimal = 0x0029

   Even pixel gain setting of 43 decimal = 0x002B

9. Use the odd pixel gain and even pixel gain binary commands to set the odd and even gain to the calculated values.

After you use the commands to enter the calculated values, the camera will be operating at 2 dB with respect to the reference camera. The odd and even pixels will be balanced.

	You may get a better odd/even match by increasing or decreasing either the odd or the even gain by one.

	Since the black level is very stable, you do not need to adjust the offset when you change the gain.

3.5.2 Setting the Offset

You can use the Offset setting in the Camera Configuration Tool Plus (see Section 4.1) to set the offst on your camera. When you change the Offset setting, the CCT+ will automatically change the offset on the odd pixels and on the even pixels by the same amount. If you want to set the camera so that the offset on each channel is different, you can use the Offset Balance setting to change the offset on the even pixels only.

You can also use the Odd Pixel Offset binary command to set the offset for the odd pixels and the Even Pixel Offset binary command to set the offset for the even pixels (see Sections 4.2.4.12 and 4.2.4.14). The odd pixel and even pixel offset settings can be programmed on a decimal scale that ranges from 0 to 255 (0x0000 to 0x00FF).

If the camera is operating in 10 bit output mode, an increase of 4 (decimal) in the odd pixel setting will result in a positive offset of 1 in the digital values output for the odd pixels of the sensor. An increase of 4 (decimal) in the even pixel setting will result in a positive offset of 1 in the digital values output for the even pixels of the sensor.

If the camera is operating in 8 bit output mode, an increase of 16 (decimal) in the odd pixel setting will result in a positive offset of 1 in the digital values output for odd pixels of the sensor. An increase of 16 (decimal) in the even pixel setting will result in a positive offset of 1 in the digital values output for the even pixels of the sensor.

3.6 Shading Correction

In theory, when the camera captures an image of a uniform object, the values output from the pixels in the camera should be uniform. In practice, however, variations in optics and lighting can cause the camera output to be non-uniform even when the camera is viewing a uniform object. The **L100k** camera is equipped with a shading correction feature that allows the camera to correct the captured image for variations caused by optics and lighting.

The camera corrects for shading variations by applying a “shading correction table” to each captured image. Before you enable the shading correction feature, you must create a shading correction table and upload it to the camera. You can use either the Camera Configuration Tool Plus (CCT+) or binary commands to create and upload the table and to enable the shading correction feature. See Section 3.6.2 for instructions on using the CCT+ to perform these functions and Section 3.6.3 for instructions on performing them with binary commands.

Please note that when using Shading Correction, you must follow the guidelines listed in Section 3.6.1.

3.6.1 Shading Correction Guidelines

When using shading correction, make sure that you take the following guidelines into account:

- Shading correction is only available in 8-bit output mode. Activating 10-bit output mode will disable shading correction.
- Any time that you make a change to optics or lighting, you must create a new shading correction table. You must also create a new shading table any time that you change the gain settings on the camera or the digital shift.
  Using an out of date shading correction table can result in poor quality images.
- During the process of creating a shading table, you will capture lines while the camera is focused on a uniform gray target. The ratio of the value for the lightest pixel in the captured lines to the value for the darkest pixel in the captured lines must not be more than 2/1. If it is greater than 2/1, the shading correction feature will not be able to fully correct the shading variations.

3.6.2 Using the CCT+ to Work With Shading Correction

To create and upload a shading correction table and to enable shading correction using the CCT+:

1. Open the CCT+. Use the Shading Correction setting in the Output parameter group to set shading correction to off (Shading Correction *must* be off when you capture data for the shading table).
2. Use the Video Data Output Mode setting to set your camera for **Single 8 bit** or **Dual 8 bit** output mode. (Before selecting Dual 8 bit mode, make sure that your frame grabber is capable of supporting dual output.)
3. Place a uniform gray target in the camera‘s field of view.
4. Make sure that your optics and lighting are set to their normal operating conditions. Optics and lighting *must* be set before you capture any data.
5. Make sure that your grabber is properly configured to accept the output mode that you selected in step 2.
6. Use the software included with your frame grabber to capture and store at least 100 lines of data to a file. Save the resulting file as an image in GIF, JPG, JPEG, or PNG format. (The

software included with most frame grabbers includes a function that will allow you to capture and store a specific number of lines and to save the captured lines as an image file.)

7. In many cases, when a frame grabber is receiving pixel data for a captured line, the grabber drops the data for the first few pixels. Since you are using captured pixel data from the frame grabber to create the shading table, you must make sure that you know how many pixels your grabber is dropping.

   You can use Test Image One (see Section 3.9.1), consult the documentation for your frame grabber, or speak to your frame grabber manufacturer to determine the number of pixels that the grabber drops at the start of each line.

   Determine the number of pixels that your grabber drops and make note of it.

8. In the CCT+, double-click on “Upload Correction Data”. A Specify Shading Correction Image window will open.

9. Click on the  button and an Open Shading Correction Image window will appear. Use the window to navigate to the image file that you stored in step 6 and then click the Open button.

10. If you want the shading correction table to be stored in the camera’s non-volatile memory when you upload it to the camera, make sure that the **Permanently store shading data in the camera** box is checked. (See the notebox below for more information.)

11. In the **Offset** box, enter the number of pixels that the frame grabber drops from each line.

12. Click the **Load to camera** button. The CCT+ will use the image data in the file you selected to create a shading table and then will upload the table to the camera.

    If this process is successful, a message will appear informing you about the ratio of the lightest pixel to the darkest pixel in the image .

    If the process is not successful, an error message will appear. The usual cause of the error is that the ratio of the lightest pixel in the image to the darkest pixel is greater than 2/1. When this is the case, the shading feature will not be able to fully correct the shading variations.

13. Once the correction table has been successfully created and uploaded, you can use the shading correction feature. To enable shading correction, use the Shading Correction setting in the CCT+.



Normally, a copy of the shading table is stored in a volatile memory location and a copy is also stored in a non-volatile memory location. When shading correction is enabled, the FPGA in the camera uses the table stored in volatile memory to perform shading correction by applying the correction values in the table to the pixel values for each captured line.

When you store shading correction data to the camera with the CCT+, you can store the data in both the volatile and the non-volatile memory or in the volatile memory only. A shading table stored in the non-volatile memory will not be lost when power is switched off.

When you upload the shading table and the **Permanently store shading data in the camera** box is checked, the table will be loaded to both the non-volatile and the volatile memories. Any table already in these memories will be overwritten.

When you upload the shading table and the **Permanently store shading data in the camera** box is *not* checked, the table will be loaded to the volatile memory only. This feature is useful if you wish to load and test a shading table without overwriting the table that is currently stored in the non-volatile memory.

3.6.3 Using Binary Commands to Work With Shading Correction

When using binary commands to create and upload a shading table and to enable the shading correction feature, follow the instructions given in Sections 3.6.3.1 through 3.6.3.3.

3.6.3.1 Creating a Shading Correction Table

When shading correction is active on the **L100k** camera, each pixel value is multiplied by a correction factor and the corrected pixel values are transferred out of the camera.

There is an individual correction factor for each of the sensor's pixels, that is, there are 1024 correction factors for cameras with a 1024 pixel sensor or 2048 for cameras with a 2048 pixel sensor.

The correction factors are multipliers that are applied to the pixels in each captured line to make them better represent what they would be if no shading was present.

The correction factors are determined by capturing an image of a uniform target and then for each pixel, calculating the multiplier that would make the pixel value equal to the lightest pixel in the image.

$$\text{Correction factor} = \frac{\text{Lightest pixel}}{\text{Current pixel}}$$

Correction factors are floating point numbers. Since floating point numbers cannot be written into the camera, each correction factor must be converted into an integer value that represents the correction factor. Here is the formula that is used for conversion:

$$\text{Correction factor} = \frac{\text{Correction value} + 256}{256}$$

The range of possible correction factors is 1 to 1.996 where 1 converts to an integer value of 0 and 1.996 converts to an integer value of 255.

The individual integer correction values make up the shading correction table that is uploaded into the camera. Creating a shading correction table is a three step process: 1) capturing and storing 100 lines of image data, 2) calculating shading correction data from the captured data, and 3) writing the correction data to the camera.

Capturing and Storing Image Data

Follow this procedure to capture and store data:

1. Switch off the shading correction using the Shading Correction binary command described in Section 4.2.4.8. (Shading Correction ***must*** be disabled when you capture the data).
2. Use the Video Data Output Mode binary command described in Section 4.2.4.1 to set your camera into **Single 8 bit** or **Dual 8 bit** output mode. Before selecting Dual 8 bit mode, make sure that your frame grabber is capable of supporting dual output.
3. Place a uniform gray target in the camera's field of view.
4. Make sure that your optics and lighting are set to their normal operating conditions. Optics and lighting ***must*** be set before you capture any data.
5. Make sure that your grabber is properly configured to accept the output mode that you selected in step 2.
6. Use the software included with your frame grabber to capture and store 100 lines of data to a data file. (The software included with most frame grabbers includes a function that will allow you to capture and store a specific number of lines.)

Calculating Shading Correction Data

Create an averaged line from the 100 captured lines by calculating the average of the 100 values for each pixel:

1. Average the 100 pixel number one values in the image data file.
2. Average the 100 pixel number two values in the image data file.
3. Average the 100 pixel values for pixels number three through 1024 for cameras with a 1024 pixel sensor or for pixels three through 2048 for cameras with a 2048 pixel sensor.
4. Once the pixel values are averaged, find the lightest pixel (the averaged pixel with the highest gray value).
5. For each averaged pixel, calculate a correction value that would make the value of the pixel equal to the value of the lightest pixel. Use the formula shown below:

$$\text{Correction value N} = \frac{\text{Value of lightest pixel x 256}}{\text{Averaged value of pixel N}} - 256$$

where N = Number of the pixel

Sample Calculation 1: If the gray value of the lightest averaged pixel on the sensor was 170 and the averaged value for pixel number one was 160, the calculation for pixel number one would look like this:

$$\text{Correction value one} = \frac{170 \times 256}{160} - 256 = 16$$

The correction value for pixel number one would be 16 (decimal).

Sample Calculation 2: If the gray value of the lightest averaged pixel on the sensor was 170 and the averaged value for pixel number two was 165, the calculation for pixel number two would look like this:

$$\text{Correction value two} = \frac{170 \times 256}{165} - 256 = 7.75 = 8 \text{ (rounded)}$$

The correction value for pixel number two would be 8 (decimal), and so on.

The resulting table of correction values is the “shading correction table“.

Uploading Shading Correction Data to the Camera

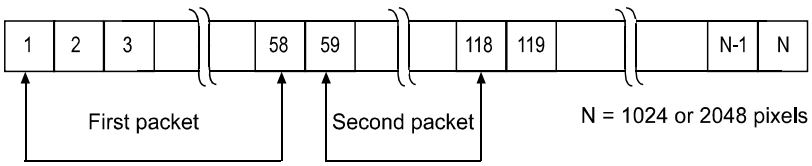
Once the shading correction table is created, you must write the correction values to the camera.

	Before starting to write the data, check whether dropped pixels must be taken into account (see Section 3.6.3.2).

The following steps describe how to access the shading correction register fields, when writing data to the camera.

1. Use the Shading Correction Data Transfer binary *write* command described in Section 4.2.4.9 to open the registers.
2. Use the Shading Correction Data Transfer binary *read* command to verify that the registers have been opened.

   Shading data must be written in packets of up to 58 bytes, one byte per correction value according to their actual sequence:
3. Use the Shading Correction Data *write* command described in Section 4.2.4.10 to write the first packet of size 58 bytes including the correction values of pixels 1 to 58.



4. Use the Shading Correction Data write command to write the next packet of 58 bytes including the correction values of pixels 59 to 116.
5. Continue using the Shading Correction Data write command to write packets of 58 bytes to the camera until all correction values have been written to the camera. For example, for cameras with a 1024 pixel sensor, you write 17 packets of 58 bytes and one packet of 38 bytes. Make sure that the values are uploaded according to their actual sequence. The camera will place every uploaded packet of data directly after the previous one.
6. Once all data has been loaded, use the Shading Correction Data Transfer binary *write* command described in Section 4.2.4.9 to close the registers.
7. Use the shading data test image (see Section 3.6.4) to verify the current shading correction values.

	Normally, a copy of the shading table is stored in a volatile memory location and a copy is also stored in a non-volatile memory location. When shading correction is enabled, the FPGA in the camera uses the table stored in volatile memory to perform shading correction by applying the correction values in the table to the pixel values for each captured line. When you store shading correction data to the camera, you can use three types of binary commands (see Section 4.2.4.9): • Upload data to the camera's non-volatile memory location. Any table already in this memory will be overwritten. A table stored in the non-volatile memory will not be lost when power is switched off. • Upload data to volatile memory. This feature is useful if you wish to load and test a shading table without overwriting the table that is currently stored in the non-volatile memory. • Copy the shading table from non-volatile memory to volatile memory.

3.6.3.2 Taking Dropped Pixels into Account

In many cases, when a frame grabber is receiving pixel data for a captured line, the grabber drops the data for the first few pixels. Since you have used captured pixel data from the frame grabber to create the shading table, you must make sure that at the beginning of your shading data, you fill in a dummy correction value for every pixel dropped by the frame grabber.

You can use Test Image One (see Section 3.9.1), consult the documentation for your frame grabber, or speak to your frame grabber manufacturer to determine the number of pixels that the grabber misses at the start of each line. Use this value to determine the dummy correction values that must be added to the sdahing correction data that you upload to the camera. For example, if your grabber misses 5 pixels at the beginning of each line, add 5 dummy correction values before the actual correction values (see Figure 3-9).

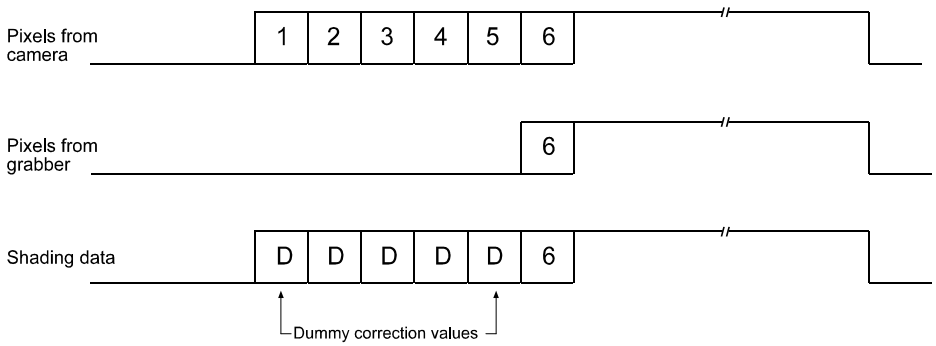


Figure 3-9: Adding Dummy Correction Values

3.6.3.3 Enabling Shading Correction

To enable the shading correction feature, use the Shading Correction binary command described in Section 4.2.4.8.

3.6.4 The Shading Data Test Image

L100k cameras offer a “shading data” test image. When the camera is operating in this mode, it outputs the values in the shading correction table as though they were a line of image data. If you place the camera in the shading data test image mode and you capture a line, you can examine the values in the captured line to see what is stored in the shading correction table.

The shading data test image can be enabled using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the Shading Correction setting in the Output parameter group to enable this mode.

With binary commands, you use the Shading Correction command (see Section 4.2.4.8).

3.7 Digital Shift

The “digital shift” feature allows you to change the group of bits that is output from each ADC. Using the digital shift feature will effectively multiply the output of the camera by 2 times, 4 times or 8 times. Section 3.7.1 describes how digital shift works when the camera is operating in a 10 bit output mode and Section 3.7.2 describes how digital shift works when the camera is operating in an 8 bit output mode.

Please note the precautions you must observe to effectively use this feature (see Section 3.7.3).

You can set digital shift using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2).

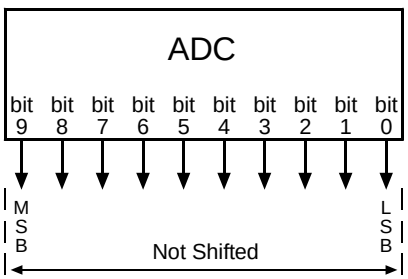
With the Camera Configuration Tool Plus, you use the Digital Shift setting in the Output parameter group.

With binary commands you use the Digital Shift command.

3.7.1 Digital Shift in 10 bit Output Mode

No Shift

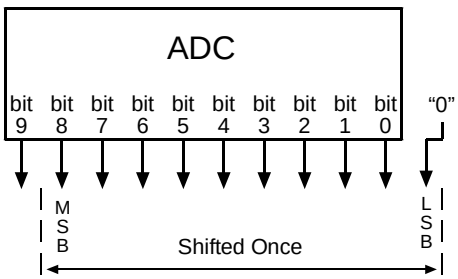
As mentioned in Section 3.1, the **L‌i100k** uses 10 bit ADCs to digitize the output from the CCD sensor. When the camera is operating in 10 bit output mode, by default, the camera transmits the 10 bits that are output from each ADC.



Shift Once

When the camera is set to shift once, the output from the camera will include bit 8 through bit 0 from each ADC along with a zero as an LSB.

The result of shifting once is that the output of the camera is effectively doubled. For example, assume that the camera is set for no shift, that it is viewing a uniform white target, and that under these conditions the reading for the brightest pixel is 100. If you changed the digital shift setting to shift once, the reading would increase to 200.

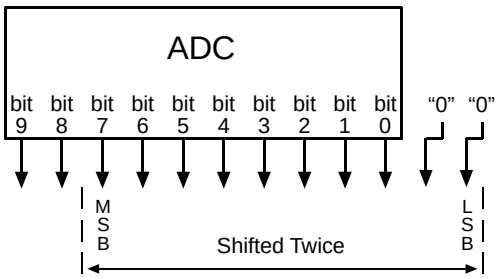


	Note that if bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 10 bit mode with no digital shift are all below 512. Since the shift once setting requires that the least significant bit is always a "0" and never a "1", no odd gray values can be output. The gray value scale will only include gray values of 2, 4, 6 and so forth. The absence of gray values is commonly referred to as "Missing Codes".

Shift Twice

When the camera is set to shift twice, the output from the camera will include bit 7 through bit 0 from each ADC along with two zeros as LSBs.

The result of shifting twice is that the output of the camera is effectively multiplied by four. For example, assume that the camera is set for no shift, that it is viewing a uniform white target, and that under these conditions the reading for the brightest pixel is 100. If you changed the digital shift setting to shift twice, the reading would increase to 400.

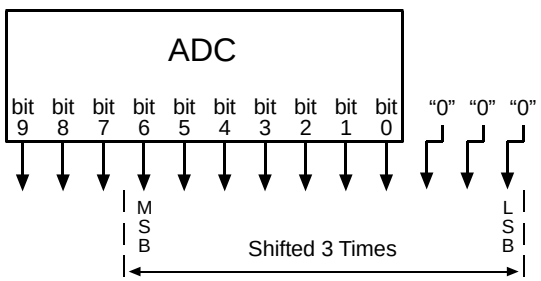


	Note that if bit 9 or bit 8 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 10 bit mode with no digital shift are all below 256. Since the shift twice setting requires that the two least significant bits are always "0" and never "1", the gray value scale will only include every 4th gray value. For example, 4, 8, 16 and so forth.

Shift Three Times

When the camera is set to shift three times, the output from the camera will include bit 6 through bit 0 from each ADC along with three zeros as LSBs.

The result of shifting three times is that the output of the camera is effectively multiplied by eight. For example, assume that the camera is set for no shift, that it is viewing a uniform white target, and that under these conditions the reading for the brightest pixel is 100. If you changed the digital shift setting to shift three times, the reading would increase to 800.

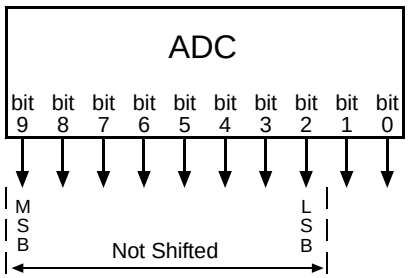


	Note that if bit 9, bit 8 or bit 7 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift three times setting when your pixel readings in 10 bit mode with no digital shift are all below 128. Since the shift three times setting requires that the three least significant bits are always "0" and never "1", the gray value scale will only include every 8th gray value. For example, 8, 16, 24 and so forth.

3.7.2 Digital Shift in 8 bit Output Modes

No Shift

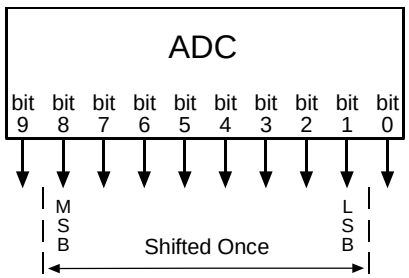
As mentioned in Section 3.1, the **L100k** uses 10 bit ADCs to digitize the output from the CCD sensor. When the camera is operating in 8 bit output mode, by default, it drops the least two significant bits from each ADC and transmits the 8 most significant bits (bit 9 through bit 2).



Shift Once

When the camera is set to shift once, the output from the camera will include bit 8 through bit 1 from each ADC.

The result of shifting once is that the output of the camera is effectively doubled. For example, assume that the camera is set for no shift, that it is viewing a uniform white target and that under these conditions the reading for the brightest pixel is 20. If you changed the digital shift setting to shift once, the reading would increase to 40.

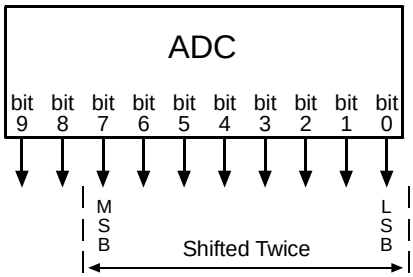


	Note that if bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 8 bit mode with no digital shift are all below 128.

Shift Twice

When the camera is set to shift twice, the output from the camera will include bit 7 through bit 0 from each ADC.

The result of shifting twice is that the output of the camera is effectively multiplied by four. For example, assume that the camera is set for no shift, that it is viewing a uniform white target, and that under these conditions the reading for the brightest pixel is 20. If you changed the digital shift setting to shift twice, the reading would increase to 80.

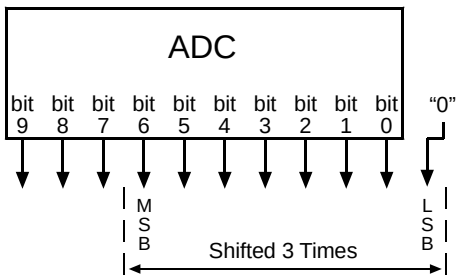


	Note that if bit 9 or bit 8 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 8 bit mode with no digital shift are all below 64.

Shift Three Times

When the camera is set to shift three times, the output from the camera will include bit 6 through bit 0 from each ADC along with a zero as the LSB.

The result of shifting three times is that the output of the camera is effectively multiplied by eight. For example, assume that the camera is set for no shift, that it is viewing a uniform white target and that under these conditions the reading for the brightest pixel is 20. If you changed the digital shift setting to shift three times, the reading would increase to 160.



	Note that if bit 9, bit 8 or bit 7 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 8 bit mode with no digital shift are all below 32. Since the shift three times setting requires that the least significant bit is always a "0" and never a "1", no odd gray values can be output. The gray value scale will only include gray values of 2, 4, 6 and so forth.

3.7.3 Precautions When Using Digital Shift

There are several checks and precautions that you must follow before using the digital shift feature. The checks and precautions differ depending on whether you will be using the camera in 10 bit output mode or in 8 bit output mode.

If you will be using the camera in 10 bit output mode, make this check:

1. Use binary commands or the Camera Configuration Tool Plus (CCT+) to put the camera in 10 bit output mode.
2. Use binary commands or the CCT+ to set the camera for no digital shift.
3. Check the output of the camera under your normal lighting conditions with no digital shift and note the readings for the brightest pixels.
   - If any of the readings are above 512, do not use digital shift.
   - If all of the readings are below 512, you can safely use the 2X digital shift setting.
   - If all of the readings are below 256, you can safely use the 2X or 4X digital shift setting.
   - If all of the readings are below 128, you can safely use the 2X, 4X or 8X digital shift setting.

If you will be using the camera in 8 bit output mode, make this check:

1. Use binary commands or the Camera Configuration Tool Plus (CCT+) to put the camera in 8 bit output mode.
2. Use the binary commands or the CCT+ to set the camera for no digital shift.
3. Check the output of the camera under your normal lighting conditions with no digital shift and note the readings for the brightest pixels.
   - If any of the readings are above 128, do not use digital shift.
   - If all of the readings are below 128, you can safely use the 2X digital shift setting.
   - If all of the readings are below 64, you can safely use the 2X or 4X digital shift setting.
   - If all of the readings are below 32, you can safely use the 2X, 4X or 8X digital shift setting.

3.8 Area of Interest (AOI)

The area of interest feature allows you to specify a portion of the CCD array and during operation, all pixels are transferred out of the camera but only the pixel information from the specified portion is signalled as valid to the frame grabber. Pixels outside of the AOI are read out of the sensor, but transferred to the frame grabber as black pixels and signalled as invalid to the grabber.

The size of the area of interest is defined by declaring a starting pixel and a length in pixels (see Figure 3-10). For example, if you specify the starting pixel as 10 and the length in pixels as 15, the camera will output all pixels from the array but only pixels 10 through 24 will be valid.

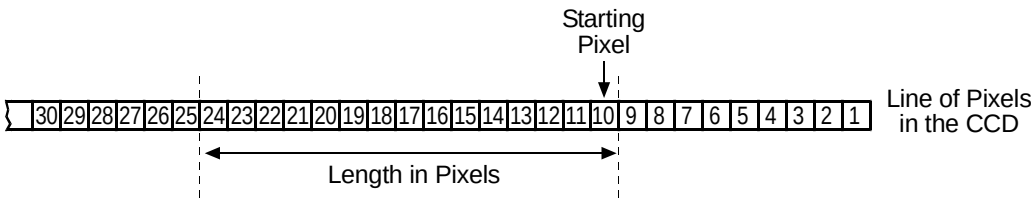


Figure 3-10: Area of Interest

The number of transferred pixels does not decrease when the area of interest feature is used.

The maximum achieveable line rate does not increase when the area of interest feature is used.

Validity of pixels is signalled using the line valid bit.

On the pixel clock cycle where AOI data transmission begins, the line valid bit will become high. For example, if you specify the starting pixel as 5, the line valid bit will become high on the clock cycle where pixel 5 is transmitted (see Figure 3-11). After all of the pixels in the AOI have been transmitted, the line valid bit will become low indicating that valid line data is no longer being transmitted.

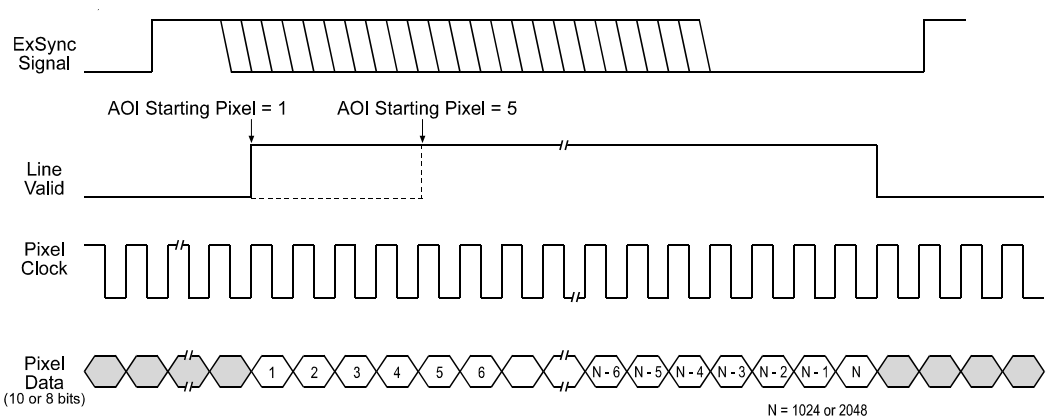


Figure 3-11: Single 10 Bit or Single 8 Bit Output Mode with Edge or Level Controlled Exposure

	If you use a frame grabber which does not take the falling edge of the line valid bit into account, you must also set the frame grabber to the number of pixels in the area of interest. For example, when you have an area of interest of 500 pixels, you must also set the grabber to 500 pixels. Otherwise, the grabber will show no effect.



In normal operation, the camera is set to use all of the pixels in the array. To use all of the pixels, the starting pixel should be set to 1 and the length in pixels to 1024 for cameras with a 1024 pixel sensor or 2048 for cameras with a 2048 pixel sensor.

You can set the area of interest using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the AOI Starting Pixel and the AOI Length settings in the AOI parameter group to set the area of interest.

With binary commands you use the Area of Interest Starting Pixel and Area of Interest Length in Pixel commands.

3.9 Test Images

The test image mode is used to check the camera's basic functionality and its ability to transmit an image via the video data cable. A test image can be used for service purposes and for failure diagnostics. In test mode, the image is generated with a software program and the camera's digital devices and does not use the optics, CCD sensor, VGCs or ADCs. Two test images are available (see Sections 3.9.1 and 3.9.2).

When using a test image, please also follow the guidelines given in Section 3.9.3.

In addition to the two standard test images, the **L100k** also offers a shading data test image mode (see Section 3.6.4).

You can enable the test images using either the Camera Configuration Tool Plus (see Section 4.1) or use binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the Test Image setting in the Output parameter group to set the test image.

With binary commands, you use the Test Image command (see Section 4.2.5).

3.9.1 Test Image One

Test image one is formed with an odd/even gray scale gradient that ranges from 0 to 255 and repeats every 512 pixels as shown in Figure 3-12. The odd pixel gradient starts at 0 and steps up, that is, the gray value of pixel 1 is 0, the gray value of pixel 3 is 1, the gray value of pixel 5 is 2, and so forth. The even gradient starts at 255 and steps down, that is, the gray value of pixel 2 is 255, the gray value of pixel 4 is 254, the gray value of pixel 6 is 253, and so forth.

At pixels 256 and 257, the gray value for both pixels is 128. At pixels 511 and 512, a white odd pixel is next to a black even pixel. At pixels 513 and 514, a black odd pixel is next to a white even pixel. To the human eye, the gradient appears to be a varying gray field with a white vertical line every 512 pixels.

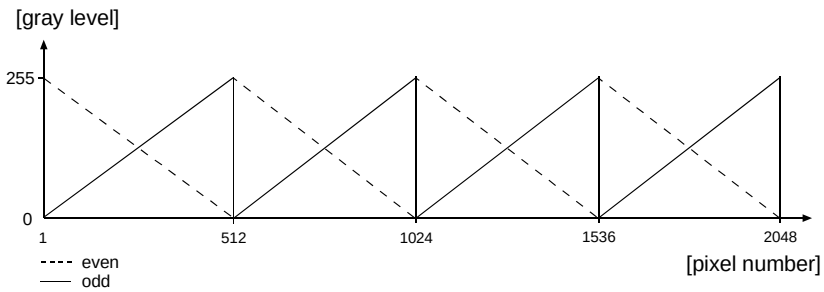


Figure 3-12: Formation of Test Image One

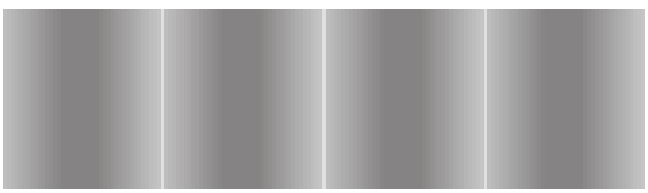


Figure 3-13: Test Image One

3.9.2 Test Image Two

Test image two is formed with a gray scale gradient that ranges from 0 to 255 and repeats every 256 pixels as shown in Figure 3-14. The gradient starts at 0 and steps up, that is, the gray value of pixel 1 is 0, the gray value of pixel 2 is 1, the gray value of pixel 3 is 2, and so forth.

This pattern moves up by one pixel each time the ExSync signal cycles. At pixel 1 of the second cycle, the new gradient starts with a gray value of 1, the gray value of pixel 2 is 2, the gray value of pixel 3 is 3, and so forth.

When you view the output of a camera that is set for test image two, the pattern should appear to be gradually moving up the screen. This feature is useful for determining if the frame grabber grabs every single line that is output from your camera.

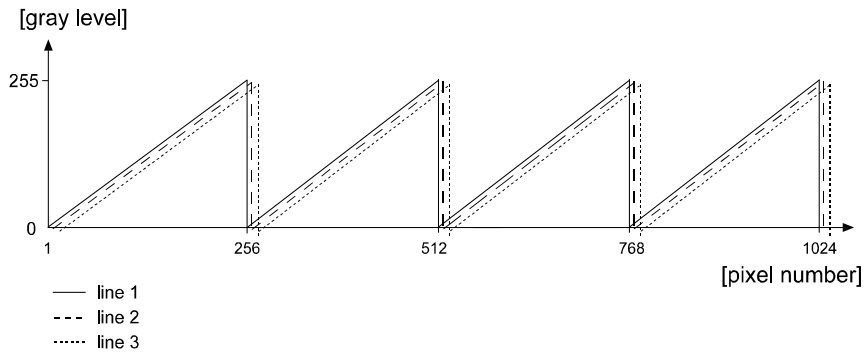


Figure 3-14: Formation of Test Image Two



Figure 3-15: Test Image Two

3.9.3 Guidelines When Using Test Images

When using a test image, please take the following guidelines into account:

- If the camera is set for an exposure mode that uses an ExSync signal, the ExSync signal must be present and must toggle in order to output a line on the test image. Multiple transitions of the ExSync signal will produce a two dimensional image as shown in Figure 3-13 or Figure 3-15.
- If the camera is set for Free-run, each cycle of the camera's internal control signal will trigger the output of a line on the test image.
- When the test image is active, the gain, offset and exposure time have no effect on the image.
- Digital shift makes the test image appear very light, therefore, digital shift should be disabled when the test image is active.

3.10 Configuration Sets

The camera's adjustable parameters are stored in configuration sets and each configuration set contains all of the parameters needed to control the camera. There are three different types of configuration sets: the Work Set, the Factory Set, and User Sets.

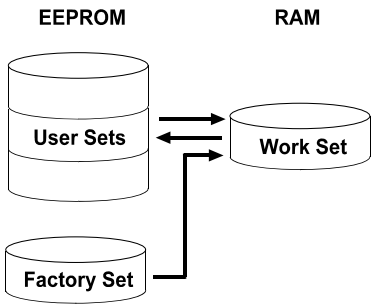


Figure 3-16: Config Sets

Work Set

The Work Set contains the current camera settings and thus determines the camera's present performance, that is, what your image currently looks like. The Work Set is stored in the camera RAM. The configuration parameters in the Work Set can be altered directly using the Camera Configuration Tool or using binary programming commands.

Factory Set

When a camera is manufactured, a test set up is performed on the camera and an optimized configuration is determined. The Factory Set contains the camera's factory optimized configuration. The Factory Set is stored in non-volatile memory on the EEPROM and can not be altered.

User Sets

User Sets are also stored in the non-volatile EEPROM of the camera. The camera has 15 User Sets. Each User Set initially contains factory settings but User Sets can be modified. Modification is accomplished by making changes to the Work Set and then copying the Work set into one of the User Sets. The Camera Configuration Tool or binary commands can be used to copy the Work Set into one of the User Sets.

Startup Pointer

When power to the camera is switched off, the Work set in the RAM is lost. At the next power on, a configuration set is automatically copied into the Work Set. The Startup Pointer is used to specify which of the configuration sets stored in the EEPROM will be copied into the Work Set at power on. The Startup Pointer is initially set so that the Factory Set is loaded into the Work Set at power on. This can be changed using the Camera Configuration Tool or binary commands. The Startup Pointer can be set to the Factory Set or to any one of the User Sets. So, for example, if the Startup Pointer is set to User Set 13, then User Set 13 will be copied into the Work Set at power on.

You can work with configuration sets and the startup pointer using either the Camera Configuration Tool Plus (see Section 4.1) or binary commands (see Section 4.2.8).

With the Camera Configuration Tool Plus, you can use the Camera selection in the File menu to copy the Work Set to a User Set, to copy a User Set or the Factory Set to the Work Set, or to set the Startup Pointer.

With binary commands, you use the Copy Work Set to User Set command, the Copy Factory Set or User Set to Work Set command, and the Select Startup Pointer command to manipulate configuration sets.

3.11 Camera Temperature

L100k series cameras include a sensor that measures the temperature on one of the electronic boards inside of the camera. The sensor's readings allow you to monitor whether ventilation is working correctly.

You can use the Read Camera Temperature binary command to read out the current temperature (see Section 4.2.7.9).



Warning!

The reading for the internal camera temperature must not exceed 90° C. If the internal camera temperature rises higher than 90° C, electronic components may be damaged.

To prevent internal heat build-up, observe the ventilation requirements described in Section 1.3.2.

3.12 Camera Status

L100k series cameras monitor their status by performing a regular series of self checks. The current status of a camera can be viewed in several ways:

- with the Camera Configuration Tool Plus (see Section 4.1). You use the Status indicator in the Camera Information parameter group to see if any error codes are present.
- with binary commands. You can use the Camera Status command (see Section 4.2.9) to check if the camera has detected any errors.
- by checking the LED on the back of the camera. If certain error conditions are present, the LED will flash (see Section 6.3).

4 Configuring the Camera

L100k series cameras come factory-set so that they will work properly for most applications with minor changes to the camera configuration. For normal operation, the following parameters are usually configured by the user:

- Exposure time control mode
- Exposure time (for ExSync programmable mode or free-run programmable mode)

To customize operation for your particular application, the following parameters can also be configured:

- Gain
- Offset
- Shading Correction
- Area of Interest
- Digital Shift

L100k series cameras are programmable via the serial port on the frame grabber. Two methods can be used to change the cameras's settings. The first and easier approach is to change the settings using the Camera Configuration Tool Plus. See Section 4.1 and the configuration tool's on-line help file for instructions on using the configuration tool. You can also change the camera's settings directly from your application using binary commands. Section 4.2 lists the binary commands and provides instructions for their use.

4.1 Configuring the Camera with the Camera Configuration Tool Plus (CCT+)

The Camera Configuration Tool Plus (CCT+) is a Windows™ based program used to easily change the camera's settings. The tool communicates via the RS-644 serial connection in the Camera Link interface between the frame grabber and the camera. The tool automatically generates the binary programming commands that are described in Section 4.2. For instructions on installing the tool, see the installation booklet that was shipped with the camera.

This manual assumes that you are familiar with Microsoft Windows and that you have a basic knowledge of how to use programs. If not, please refer to your Microsoft Windows manual.

4.1.1 Opening the Configuration Tool

1. Make sure that the properties for the RS-644 serial port on your frame grabber are properly configured and that the camera has power.
2. On the desktop of your computer, click **Start**, click **Programs**, click **Basler Vision Technologies**, click **CCT+**, and then click **CCT+** to start the CCT+ (default installation).

   During start-up, a start-up screen can be seen.

   If start-up is successful, the tool will open. To familiarize yourself with using the tool, press the F1 key and look through the online help included with the tool.

   If start-up is not successful, the tool will automatically close. If this happens, refer to the CCT+ Installation Guide for possible causes.

4.1.2 Closing the Configuration Tool

Close the configuration tool by clicking on the ☒ button in the upper right corner of the window.

4.1.3 Configuration Tool Basics

The RAM memory in the camera contains the set of parameters that controls the current operation of the camera. This set of parameters is known as the Work Set (see Section 3.10). The CCT+ is used to view the present settings for the parameters in the Work Set or to change the settings.

When the CCT+ is opened and a port is selected, it queries the camera and displays a list of the current settings for the parameters in the Work Set.

To simplify navigation, parameters are organized in related groups. For example, all parameters related to the camera output can be found in the Output group (Figure 4-1).

When you click on the plus or minus sign beside a group (+ or -), the parameters in this group will be shown or hidden, respectively.

To get an overview of all parameters available on the connected camera, maximize the CCT+ window and click the + sign beside each group.

The camera parameter names always appear in the left column of the list. The current setting for each parameter appears in the right column.

By default, an additional **Parameter Description** window is displayed. In this window, you can find basic information on the selected parameter and if present, on the dependencies that may exist between the selected parameter and other parameter(s).

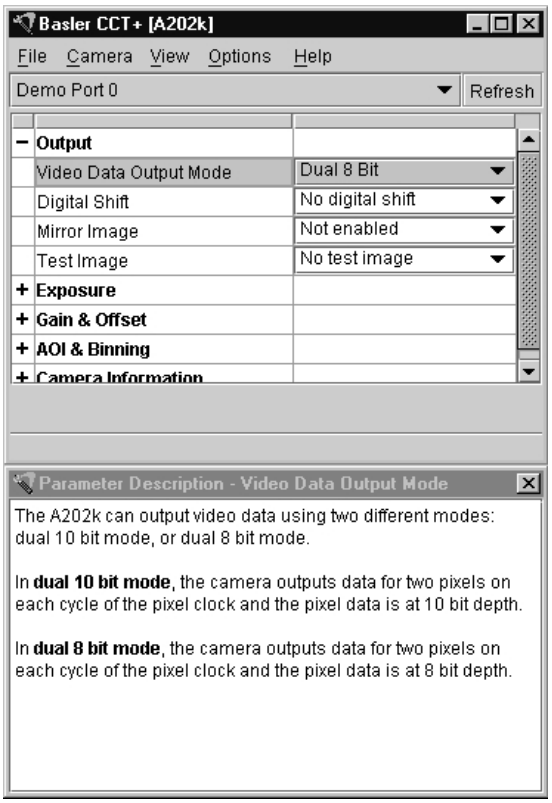


Figure 4-1: CCT+

If you make a change to one of the settings, that change will immediately be transmitted from the CCT+ to the camera's Work Set. Because the parameters in the Work Set control the current operation of the camera, you will see an immediate change in the camera's operation.

By default, the CCT+ automatically updates the displayed settings every 5 seconds. The feature behind this behavior is called Auto Refresh. If **Auto Refresh** is not enabled, the display will not update when a camera setting is changed using another tool, when power to the camera is switched off and on, or when the connected camera is exchanged while the CCT+ is displaying the camera settings. To manually refresh the display, you can use the **Refresh** button in the top right corner of the tool.



Keep in mind that the Work Set is stored in a volatile memory. Any changes you make to the Work Set using the configuration tool will be lost when the camera is switched off. To save changes you make to the Work Set, open the Camera menu of the configuration tool and save the modified Work Set into one of the camera's 15 User Sets. The User Sets are stored in non-volatile memory and will not be lost when the camera is switched off (see Section 3.10).

Alternatively, you can also save the Work Set to the hard disk of your computer and load it from hard disk.

If you want your changes to be loaded into the Work Set at the next power on, go to the Camera menu and set the Startup Pointer to the User Set where you saved your changes.

4.1.4 Configuration Tool Help

The configuration tool includes a complete on-line help file which explains how to change a setting, to copy the Work Set to a User Set, to Copy a User Set or the Factory Set to the Work Set, or to set the Startup Pointer. To access on-line help, press the F1 key whenever the configuration tool is active.

4.2 Configuring the Camera with Binary Programming Commands

Configuration commands can be issued to the **L100k** via the RS-644 serial connection in the Camera Link interface between the frame grabber and the camera. Commands are issued using a binary protocol. With this protocol, data is placed into a frame and sent to the camera. Once the data is received it is checked for validity. If valid, the data is extracted and the command is executed.

If the command issued to the camera was a read command, the camera will respond by placing the requested data into a frame and sending it to the host computer.

A standard application programmer's interface (API) for asynchronous serial reading and writing via the RS-644 port on the frame grabber has been defined in the Camera Link standard (Appendix B, API Functions). All Camera Link compatible frame grabbers provide a software library (.dll file) named clser***.dll where *** is specific to the frame grabber vendor. There are four functions within that DLL:

- ISerialInit - Initialize the serial communication for a specific board.
- clSerialRead - Read bytes from the camera.
- clSerialWrite - Write bytes to the camera.
- clSerialClose - Close the serial communication.

To execute the binary programming commands, you can load the DLL for the frame grabber you are using into your programming tool. You can use either the API from the DLL delivered with the grabber or the Basler CPA driver for executing the binary commands.

The Basler CPA (Camera Port Access) is a software framework which standardizes access to the camera ports via frame grabbers from different vendors. With the help of the Basler CPA driver, you can read and write blocks of data to and from the camera. The binary command protocol is fully implemented in the CPA driver.

The CPA driver and a Programmers Guide for the driver are both part of Basler's Classic Camera Configuration Tool. The Classic Configuration Tool can be downloaded from the Basler web site at www.baslerweb.com.



The Basler Camera Configuration Tool is available in two versions: the Classic Camera Configuration Tool (Classic CCT) and the Camera Configuration Tool Plus (CCT+). The CPA driver and its Programmer's Guide are only included with the Classic CCT.

L100k cameras will only work with the CCT+ version of the configuration tool. If you want to use the configuration tool with an **L101k** camera, you must download and install the CCT+ version and you must use the CCT+ to access the camera.

If you would also like to use the CPA driver, you should download and install the Classic CCT. Once the Classic CCT is installed, you should check the path C:\Program Files\Basler\Camera Config Tool\Cpa. The Cpa folder will contain the files you need to work with the driver.



If you are using your camera with an optional Basler Interface Converter (k-BIC), you can configure the camera via the RS-232 serial connection between your PC and the k-BIC.

4.2.1 Command Frame and Response Format

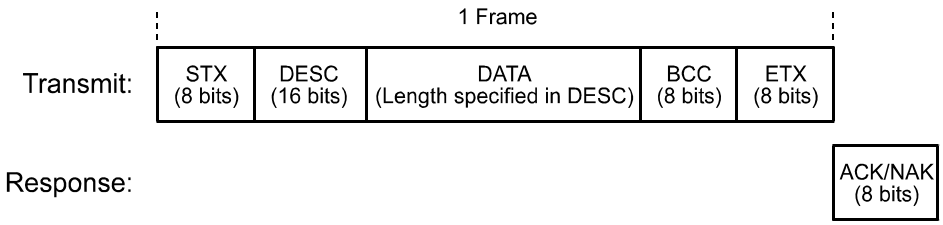


Figure 4-2: Representation of a Command Frame and Response

STX Identifies the start of the frame text
Size = 1 Byte
(The value of the STX byte is always 0x02)

DESC Descriptor
Size = 2 Bytes
The bits in the descriptor are assigned as follows:

8 bits	1 bit	7 bits
Command ID	Read/Write Flag (0 = write, 1 = read)	Data Length (in Bytes)

The MSB of the descriptor is on the left (highest bit of the command ID) and the LSB of the descriptor is on the right (lowest bit of the data length).

DATA Data field
Size = Number of bytes indicated in the Data Length portion of the descriptor.

BCC Block check character
Size = 1 Byte
The block check character is the exclusive-or sum (XOR sum) of the bytes in the descriptor field and the data field.

ETX Identifies the end of the frame text
Size = 1 Byte
(The value of the ETX byte is always 0x03)

ACK/NAK Response Positive frame acknowledge/negative frame acknowledge

Size = 1 byte

(The value for a positive frame acknowledgement is 0x06 and for a negative frame acknowledgement is 0x15.)



All values are formatted as little endian (Intel format).

4.2.2 Error Checking

4.2.2.1 ACK/NAK

When the camera receives a frame, it checks the order of the bytes in the frame and checks to see if the XOR sum of the bytes in the descriptor and the data fields matches the block check character. The camera also checks to see if the number of bytes in the data field is equal to the number specified in the descriptor.

If all checks are correct, an ACK is send to the host. If any check is incorrect, a NAK is sent.

4.2.2.2 Time-outs

Byte Time-out

The camera checks the time between the receipt of each byte in the frame. If the time between any two bytes exceeds 1 second, the camera enters a “garbage state” and discards any more incoming bytes. The camera remains in this state until it sees 1.5 seconds of silence. Once the camera sees 1.5 seconds of silence, it goes into an idle state (looking for an STX).

4.2.2.3 Read Command

In the normal case, when a read command is sent to the camera, the camera responds with an ACK and a frame. The frame will contain the data requested in the read command.

If the camera receives a read command with an unknown command ID in the descriptor, it will respond with an ACK but will not send a frame.

If the host sends a read command and gets no ACK/NAK, the host can assume that no camera is present.

If the host sends a read command and gets an ACK/NAK but does not receive a frame within 500 ms, the host can assume that there was a problem with the read command.

4.2.2.4 Write Command

In the normal case, when a write command is sent to the camera, the camera responds with an ACK.

If the camera receives a write command with an unknown command ID in the descriptor, it will respond with an ACK but will not perform the write.

After a write command has been issued by the host, the host can verify the write by issuing a corresponding read command and checking that the returned data is as expected. The host can also issue a camera status read command (see Section 4.2.9) and check the returned data to see if an error condition has been detected.



For many of the write commands listed in the Tables in on pages 4-11 through 4-33, only data within a specified range or a specified group of values is valid. The camera **does not** perform a check to see if the data in the write command is within the allowed range or specified group of allowed values.

4.2.3 Example Commands

4.2.3.1 Read Command

An example of the command message used to read the camera status is:

```
0x02, 0x43, 0x82, 0xC1, 0x03
```

`0x02` - is the STX. The STX is always `0x02`.

`0x43` - is the first byte of the descriptor. The first byte of the descriptor is the command ID. Command IDs can be found in the tables on pages 4-11 through 4-33. If you check the table on page 4-32, you will find that the ID for the camera status read command is 0x43.

`0x82` - is the second byte of the descriptor. The MSB in this byte represents the read/write flag and since this is a read command, the bit should be set to a 1. The other seven bits of this byte represent the data size (in bytes) that will be transferred using this command. If you check the table on page 4-32, the data size for the camera status command is 2 bytes. So the arrangement of the bits in the second byte of the descriptor should be 1000 0010 which translates to 0x82.

Note that for read commands, the data size specified in the descriptor represents the number of bytes of data that you expect to see in the response. No data bytes are actually included in the read command.

`0xC1` - is the block check character (BCC). See page 4-10 for instructions on calculating a BCC.

`0x03` - is the ETX. The ETX is always 0x03.

4.2.3.2 Write Command

An example of the command message used to copy the Work Set into User Set 2 is:

```
0x02, 0x46, 0x01, 0x02, 0x45, 0x03
```

`0x02` - is the STX. The STX is always 0x02.

`0x46` - is the first byte of the descriptor. If you check the table on page 4-30, you will find that the ID for the command to copy the Work Set into a User Set is 0x46.

`0x01` - is the second byte of the descriptor. The MSB in this byte represents the read/write flag and since this is a write command, the bit should be set to a 0. The other seven bits of this byte represent the data size (in bytes) that will be transferred using this command. If you check the table on page 4-30, the data size for the copy Work Set to User Set command is 1 byte. So the arrangement of the bits in the second byte of the descriptor should be 0000 0001 which translates to 0x01.

`0x02` - is the data byte. If you check the table on page 4-30, you will find that to copy the Work Set to User Set 2, the data byte must be set to 0x02.

`0x45` - is the block check character (BCC). See page 4-10 for instructions on calculating a BCC.

`0x03` - is the ETX. The ETX is always 0x03.

4.2.3.3 Calculating the Block Check Character

The block check character in any **L100k** command is the exclusive-or sum (XOR sum) of the bytes in the descriptor and the data fields. For the write command example shown in Section 4.2.3.2, the block check character is 0x45. Let's consider how this block check character was calculated.

In this case, we must find the XOR sum of three bytes. This is done by finding the XOR sum of the first two bytes and then by taking the result and finding the XOR sum of the result plus the third byte.

Calculating XOR sums is most easily understood when numbers are shown in their binary form, so in the sample calculations shown below, the hexadecimal digits in our command have been converted to binary.

To find the XOR sum of two binary numbers, you must add the two digits in each column using the following rules:

If both digits are 0, the result is 0.

If both digits are 1, the result is 0.

If one of the digits is a 1 and the other is a 0, the result is 1.

With all of this in mind, here is how the BCC for the write command shown in Section 4.2.3.2 would be calculated:

```
0 1 0 0  0 1 1 0 = the binary representation of 0x46
0 0 0 0  0 0 0 1 = the binary representation of 0x01
0 1 0 0  0 1 1 1 = the XOR sum of the first two bytes

0 1 0 0  0 1 1 1 = The XOR sum of the first two bytes
0 0 0 0  0 0 1 0 = the binary representation of 0x02
0 1 0 0  0 1 0 1 = The XOR sum

0 1 0 0  0 1 0 1 = 0x45 = the block check character
```

4.2.4 Commands for Setting Camera Parameters

4.2.4.1 Video Data Output Mode

Purpose:	To set the video data output mode or to read the current video data output mode setting. See Section 2.5.5 for an explanation of the available video data output modes.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xC0	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xC0	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xC0	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the data output mode (see the table below).		

ID	Output Mode
0x00	Single 8 Bit mode
0x01	Dual 8 Bit mode
0x02	Single 10 Bit mode
0x03	Dual 10 Bit mode

4.2.4.2 Exposure Time Control Mode

Purpose:	To set the exposure time control mode or to read the current exposure time control mode setting. See Section 3.2 for an explanation of exposure time control modes.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA0	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xA0	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xA0	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the exposure mode (see the table below).		

ID	Exposure Time Control Mode
0x00	Free-run, Programmable
0x02	Free-run, Edge-controlled
0x04	ExSync, Level-controlled
0x05	ExSync, Programmable
0x06	ExSync, Edge-controlled

4.2.4.3 Timer 1

Purpose:	To set Timer 1 or to read the current Timer 1 setting. Timer 1 is used when the camera is operating in ExSync programmable mode or in free-run mode. See Section 3.2 for details.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA6	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0xA6	R/W-Flag 0	Data Length 3	Data 3 Bytes
Write Command:	Cmd-ID 0xA6	R/W-Flag 0	Data Length 3	Data 3 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the Timer 1 setting		
	Byte 2	Mid byte of the Timer 1 setting		
	Byte 3	High byte of the Timer 1 setting		
Data Range:	This setting can range from 0x000002 to 0xFFFFFF. The setting represents a multiplier and the actual value of Timer 1 is determined by the following: Timer 1 = setting x 0.0625 µs To determine the value for this setting, simply divide your desired Timer 1 value by 0.0625 µs. For example, if you wish to set Timer 1 to 2 µs, the calculation would be as shown below: setting = 2 µs / 0.0625 µs setting = 32 In this case, the setting would be 32 (decimal) which translates to a hexidecimal setting of 0x000020. When you are setting Timer 1, be sure to follow the recommendations in Section 3.2.1.2 if you are operating the camera in the ExSync programmable exposure control mode. If you are operating the camera in a Free-run mode, be sure to follow the recommendations in Section 3.2.2.2.			

4.2.4.4 Timer 2

Purpose:	To set Timer 2 or read the current Timer 2 setting. Timer 2 is used when the camera is operating in free-run mode. See Section 3.2 for details.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA7	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0xA7	R/W-Flag 0	Data Length 3	Data 3 Bytes
Write Command:	Cmd-ID 0xA7	R/W-Flag 0	Data Length 3	Data 3 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the Timer 2 setting		
	Byte 2	Mid byte of the Timer 2 setting		
	Byte 3	High byte of the Timer 2 setting		
Data Range:	This setting can range from 0x000002 to 0xFFFFFF. The setting represents a multiplier and the actual value of Timer 2 is determined by the following: Timer 2 = setting x 0.0625 µs To determine the value for this setting, simply divide your desired Timer 2 value by 0.0625 µs. For example, if you wish to set Timer 2 to 4 µs, the calculation would be as shown below: setting = 4 µs / 0.0625 µs setting = 64 In this case, the setting would be 64 (decimal) which translates to a hexidecimal setting of 0x000040. When you are setting Timer 2, be sure to follow the recommendations in Section 3.2.2.2.			

4.2.4.5 Digital Shift

Purpose:	To enable or disable digital shift. See Section 3.7 for an explanation of digital shift.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA5	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xA5	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xA5	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the digital shift status (see the table below).		

ID	Digital Shift	
0x00	No digital shift	
0x01	Digital shift once	(multiplies output 2X)
0x02	Digital shift twice	(multiplies output 4X)
0x03	Digital shift by three	(multiplies output 8X)



See Section 3.7.3 for precautions that you must consider when using digital shift.

4.2.4.6 Area of Interest Starting Pixel

Purpose:	To set the starting pixel for the Area of Interest or to read the current starting pixel setting. See Section 3.8 for details.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA9	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0xA9	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0xA9	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the starting pixel setting		
	Byte 2	High byte of the starting pixel setting		
Data Range:	1K sensors: 0 (0x0000) to 1023 (0x03FF) 2K sensors: 0 (0x0000) to 2047 (0x07FF) (When using binary commands, the **starting pixel = n +1** where n is the setting made using this binary command. For example, if you wish to define pixel 100 as starting pixel, set 99 with the help of this command.)			

4.2.4.7 Area of Interest Length in Pixels

Purpose:	To set the length in pixels for the Area of Interest or to read the current length setting. See Section 3.8 for details.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xAB	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0xAB	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0xAB	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the length in pixel setting		
	Byte 2	High byte of the length in pixel setting		
Data Range:	1K sensors: 1 (0x0001) to 1024 (0x0400) 2K sensors: 1 (0x0001) to 2048 (0x0800)			

4.2.4.8 Shading Correction

Purpose:	To enable or disable shading correction or the shading correction test image mode. See Section 3.6 for more information on shading correction.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xC5	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xC5	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xC5	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the data output mode (see the table below).		

ID	Output Mode
0x00	Shading correction off
0x01	Output shading correction data as a test image
0x02	Shading correction on

4.2.4.9 Shading Correction Data Transfer

Purpose:	To enable or disable upload of shading correction data into the camera. See Section 3.6 for more information on shading correction.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x68	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x68	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x68	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that enables or disables the upload of data (see the table below).		

ID	Data Transfer Mode
0x00	Close registers.
0x50	Open registers for upload of data to non-volatile memory.
0x51	Open registers for upload of data to volatile memory.
0x80	Copy data from non-volatile memory to volatile memory. Before issuing a command with this data ID, you must: 1. Issue a 0x68 command to open registers for upload of data to non-volatile memory. 2. Issue 0x69 commands to upload your shading correction data. 3. Issue a 0x68 command to close registers.

4.2.4.10 Shading Correction Data

Purpose:	To write the shading correction data to the camera or read the current correction data. See Section 3.6 for more information on shading correction. **Note:** Before writing shading data to the camera, you must use a 0x68 command to open the camera registers for writing.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x69	R/W-Flag 1	Data Length 1 to 58	Data -
Response:	Cmd-ID 0x69	R/W-Flag 0	Data Length 1 to 58	Data 1 to 58 Bytes
Write Command:	Cmd-ID 0x69	R/W-Flag 0	Data Length 1 to 58	Data 1 to 58 Bytes
Response:	None			
Data Format:	Byte 1	Multiplier of first pixel in the addressed section of pixels.		
	Byte 2	Multiplier of second pixel in the addressed section of pixels.		
	...			
	Byte 58	Multiplier of 58th pixel in the addressed section of pixels.		

4.2.4.11 Odd Pixel Gain

Purpose:	To set the gain for the odd pixels or to read the current odd pixel gain setting. See Section 3.5 for more information on gain.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x80	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x80	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x80	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of odd pixel gain setting		
	Byte 2	High byte of odd pixel gain setting		
Data Range:	L101k, L103k:	0 (0x0000) to 1023 (0x03FF)		
	L104k:	0 (0x0000) to 319 (0x013F)		

4.2.4.12 Odd Pixel Offset

Purpose:	To set the offset for the odd pixels or to read the current odd pixel offset setting. See Section 3.5 for more information on offset.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x84	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x84	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x84	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of odd pixel offset setting		
	Byte 2	High byte of odd pixel offset setting		
Data Range:	L101k, L103k:	0 (0x0000) to 255 (0x00FF)		
	L104k:	0 (0x0000) to 1023 (0x03FF)		

4.2.4.13 Even Pixel Gain

Purpose:	To set the gain for the even pixels or to read the current even pixel gain setting. See Section 3.5 for more information on gain.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x82	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x82	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x82	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of even pixel gain setting		
	Byte 2	High byte of even pixel gain setting		
Data Range:	L101k, L103k:	0 (0x0000) to 1023 (0x03FF)		
	L104k:	0 (0x0000) to 319 (0x013F)		

4.2.4.14 Even Pixel Offset

Purpose:	To set the offset for the even pixels or to read the current even pixel offset setting. See Section 3.5 for more information on offset.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x86	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x86	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x86	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of even pixel offset setting		
	Byte 2	High byte of even pixel offset setting		
Data Range:	L101k, L103k:	0 (0x0000) to 255 (0x00FF)		
	L104k:	0 (0x0000) to 1023 (0x03FF)		

4.2.5 Test Image Command

Purpose:	To enable or disable a test image. See Section 3.9 for an explanation of the available test images.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA1	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xA1	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xA1	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the test image (see the table below).		

ID	Test Image
0x00	No test image
0x01	Test Image 1 (gray gradient)
0x02	Test Image 2 (moving gray gradient)

4.2.6 Camera Reset Command

Purpose:	Initiates a camera reset. The behavior is similar to a power up reset.			
Type:	This is a write only command.			
Write Command:	Cmd-ID 0x42	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte	0xCF is always used	
	Byte 2	High byte	0x07 is always used	

4.2.7 Query Commands

4.2.7.1 Read Vendor Information

Purpose:	To read the camera vendor's name.			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x01	R/W-Flag 1	Data Length 16	Data -
Response:	Cmd-ID 0x01	R/W-Flag 0	Data Length 16	Data 16 Bytes
Data Format:	Zero terminated string if less than 16 bytes are needed for the vendor information. Unterminated string if all 16 bytes are needed.			

4.2.7.2 Read Model Information

Purpose:	To read the camera's model number.			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x02	R/W-Flag 1	Data Length 16	Data -
Response:	Cmd-ID 0x02	R/W-Flag 0	Data Length 16	Data 16 Bytes
Data Format:	Zero terminated string if less than 16 bytes are needed for the model information. Unterminated string if all 16 bytes are needed.			

4.2.7.3 Read Product ID

Purpose:	To read the camera's product ID number.			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x03	R/W-Flag 1	Data Length 16	Data -
Response:	Cmd-ID 0x03	R/W-Flag 0	Data Length 16	Data 16 Bytes
Data Format:	Zero terminated string if less than 16 bytes are needed for the product ID information. Unterminated string if all 16 bytes are needed.			

4.2.7.4 Read Serial Number

Purpose:	To read the camera's serial number.			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x04	R/W-Flag 1	Data Length 16	Data -
Response:	Cmd-ID 0x04	R/W-Flag 0	Data Length 16	Data 16 Bytes
Data Format:	Zero terminated string if less than 16 bytes are needed for the serial number information. Unterminated string if all 16 bytes are needed.			

4.2.7.5 Read Camera Version

Purpose:	To read the camera version information.		
Type:	This is a read only command.		
Read Command:	Cmd-ID 0x05	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0x05	R/W-Flag 0	Data Length 3	Data 3 Bytes
Data Format:	Byte 1	Low byte of camera version		BCD coded
	Byte 2	High byte of camera version		BCD coded
	Byte 3	Protocol Version		

4.2.7.6 Read Reference Gain Values

Purpose: To read the reference gain values that are determined during the camera's factory calibration procedure (see Section 3.5.1 on how to use the reference gain values).

Type: This is a read only command.

Read Command:	Cmd-ID 0x08	R/W-Flag 1	Data Length 16	Data -
Response:	Cmd-ID 0x08	R/W-Flag 0	Data Length 16	Data 16 Bytes

Data Format: Each reference gain is stored as a 16 Bits followed by a decimal point followed by 16 more Bits:

$$\text{Reference Gain} = \text{High Byte b.d.p.} \times 256 + \text{Low Byte b.d.p.} + \frac{\text{High Byte a.d.p.}}{256} + \frac{\text{Low Byte a.d.p.}}{65536}$$

b.d.p.: before decimal point
a.d.p.: after decimal point

For example:

$$\text{Odd pixel reference gain} = \text{Byte 4} \times 256 + \text{Byte 3} + \frac{\text{Byte 2}}{256} + \frac{\text{Byte 1}}{65536}$$

Byte	Even/odd reference gain	Position before/ after decimal point	High/Low byte
Byte 1	odd	after	low byte
Byte 2	odd	after	high byte
Byte 3	odd	before	low byte
Byte 4	odd	before	high byte
Byte 5	even	after	low byte
Byte 6	even	after	high byte
Byte 7	even	before	low byte
Byte 8	even	before	high byte

Bytes 9 to 16 must be ignored. These bytes are not used on the L100k.

4.2.7.7 Read Microcontroller Firmware Version

Purpose:	To read the microcontroller firmware version			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x40	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0x40	R/W-Flag 0	Data Length 3	Data 3 Bytes
Data Format:	Byte 1	Low byte of firmware version		BCD coded
	Byte 2	High byte of firmware version		BCD coded
	Byte 3	Protocol Version		

4.2.7.8 Read FPGA Firmware Version

Purpose:	To read the FPGA firmware version			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x41	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0x41	R/W-Flag 0	Data Length 3	Data 3 Bytes
Data Format:	Byte 1	Low byte of firmware version		BCD coded
	Byte 2	High byte of firmware version		BCD coded
	Byte 3	undefined - 0x00 is always used		

4.2.7.9 Read Camera Temperature

Purpose: To read the camera's internal temperature. See Section 3.11 for the allowed maximum temperature.

Type: This is a read only command.

Read Command:	Cmd-ID	R/W-Flag	Data Length	Data
	0x70	1	1	-
Response:	Cmd-ID	R/W-Flag	Data Length	Data
	0x70	0	1	1 Byte

Data Format: The temperature is given in °C as 8 bit signed number.
If the MSB is 1, a temperature below 0° C is present.
If the MSB is 0, the temperature is 0° C or higher.
For temperatures below 0° C, a two's complement representation is used, that is, to obtain the actual temperature, the digital output must be inverted and 1 must be added. For example:

A digital output of 11110110 would indicate a negative value because the MSB is 1.

11110110 would be inverted to 00001001.

00001001 translates to 9.

9 + 1 = 10

The indicated temperature is therefore - 10° C.

See more examples in the table below.

Temp.	Digital Output
- 20° C	11101100
- 10° C	1111 0110
0° C	0000 0000
+ 10° C	0000 1010
+ 25° C	0001 1001
+ 50° C	0011 0010
+ 100° C	0110 0100

4.2.8 Commands for Manipulating Configuration Sets

4.2.8.1 Copy the Factory Set or the User Set into the Work Set

Purpose: To copy the Factory Set or one of the 15 User Sets into the Work Set. See Section 3.10 for an explanation of configuration sets.

The write command will cause the selected set to be copied into the Work Set and the set will become active immediately.

The read command returns the ID of the set that was last copied into the Work Set. (If nothing has been copied to the Work Set since the last power up or reset, the read command will return the ID for “no active set.” This condition indicates that no valid Factory Set or User Sets were found. It will also cause the yellow LED on the back of the camera to show six pulses.)

Type: This is a read or write command.

Read Command:	Cmd-ID 0x45	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x45	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x45	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			

Data Format: Byte 1 — An ID that specifies the set (see the table below).

Set ID	Set
0x00	Factory Set
0x01	User Set 1
0x02	User Set 2
0x03	User Set 3
0x04	User Set 4
0x05	User Set 5
0x06	User Set 6
0x07	User Set 7
0x08	User Set 8
0x09	User Set 9
0x0A	User Set 10
0x0B	User Set 11
0x0C	User Set 12
0x0D	User Set 13
0x0E	User Set 14
0x0F	User Set 15

4.2.8.2 Copy the Work Set into a User Set

Purpose:	To copy the Work Set into one of the 15 User Sets. See Section 3.10 for an explanation of configuration sets.			
Type:	This is a write only command.			
Write Command:	Cmd-ID 0x46	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the user set (see the table below).		

Set ID	Set
0x01	User Set 1
0x02	User Set 2
0x03	User Set 3
0x04	User Set 4
0x05	User Set 5
0x06	User Set 6
0x07	User Set 7
0x08	User Set 8
0x09	User Set 9
0x0A	User Set 10
0x0B	User Set 11
0x0C	User Set 12
0x0D	User Set 13
0x0E	User Set 14
0x0F	User Set 15

4.2.8.3 Select the Startup Pointer

Purpose: The Startup Pointer is used to tag the configuration set that will be copied into the Work Set at power on (see Section 3.10).

The write command is used to set the Startup Pointer to the Factory Set or to one of the User Sets.

The read command returns the Set ID for the current setting.

Type: This is a read or write command.

Read Command:	Cmd-ID 0x47	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x47	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x47	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			

Data Format: Byte 1 — An ID that specifies the set (see the table below).

Set ID	Set
0x00	Factory Set
0x01	User Set 1
0x02	User Set 2
0x03	User Set 3
0x04	User Set 4
0x05	User Set 5
0x06	User Set 6
0x07	User Set 7
0x08	User Set 8
0x09	User Set 9
0x0A	User Set 10
0x0B	User Set 11
0x0C	User Set 12
0x0D	User Set 13
0x0E	User Set 14
0x0F	User Set 15

4.2.9 Camera Status Command

Purpose: The camera has been programmed to detect several error conditions. When an error condition is detected, a flag is set. The status command allows you to read the error flags.

Type: This is a read only command.

Read Command:	Cmd-ID	R/W-Flag	Data Length	Data
	0x43	1	2	-
Response:	Cmd-ID	R/W-Flag	Data Length	Data
	0x43	0	2	2 Bytes

Data Format:

Byte 1: Each bit specifies an error condition (see table below). If a bit is set to 1, the error condition assigned to that bit is present. If the bit is set to 0, the error is not present.

Byte 2: Each bit specifies an error condition (see table below). If a bit is set to 1, the error condition assigned to that bit is present. If the bit is set to 0, the error is not present.

Byte 1	
Bit 0	No ExSync signal in the last 5 seconds
Bit 1	A reset has occurred.
Bit 2	The camera is unlocked.
Bit 3	Reserved
Bit 4	Unknown command ID specified in a read or write command
Bit 5	A read or write command could not be executed; access denied
Bit 6	The length member of the last command does not match the defined length
Bit 7	Parameter error (currently has no meaning - reserved for future use)

Byte 2	
Bit 0	FPGA; general error
Bit 1	FPGA; no FPGA firmware available
Bit 2	No FPGA/ADC command list available
Bit 3	Error in FPGA/ADC command list item
Bit 4	User set is erroneous
Bit 5	Factory set is erroneous
Bit 6	EEPROM checksum error (this is a checksum used to determine if the contents of the EEPROM are valid)
Bit 7	No EEPROM command list available

4.2.10 Bitrate Command

Purpose: To set the bitrate of the serial communications link. The bitrate is changed immediately after the successful receipt of this command. (The default bitrate is 9600.)

Type: This is a write only command.

Write Command:

Cmd-ID	R/W-Flag	Data Length	Data
0x44	0	4	4 Bytes

Response: None

Data Format:

Byte 1	An ID that specifies the bitrate (see table below).
Byte 2	undefined - always write 0x00
Byte 3	undefined - always write 0x00
Byte 4	undefined - always write 0x00

ID	Bitrate
0x12	4800
0x13	9600
0x14	14400
0x15	19200
0x17	38400
0x19	57600
0x1A	76800
0x1B	115200



When changing the bitrate for serial communication, use the following procedure:

1. Issue the write command with the new bitrate.
2. Wait one second.
3. Change the bitrate on the serial port that the camera is connected to.
4. Resume communication.

Note: At a camera reset or a power off/on, the camera will return to the 9600 bps default setting.

The RS-644 serial port on some Camera Link frame grabbers will only support a bitrate of 9600 bps. If you are using a Camera Link frame grabber, check the grabber's documentation before attempting to change the bitrate.

5 Mechanical Considerations

5.1 Camera Dimensions and Mounting Facilities

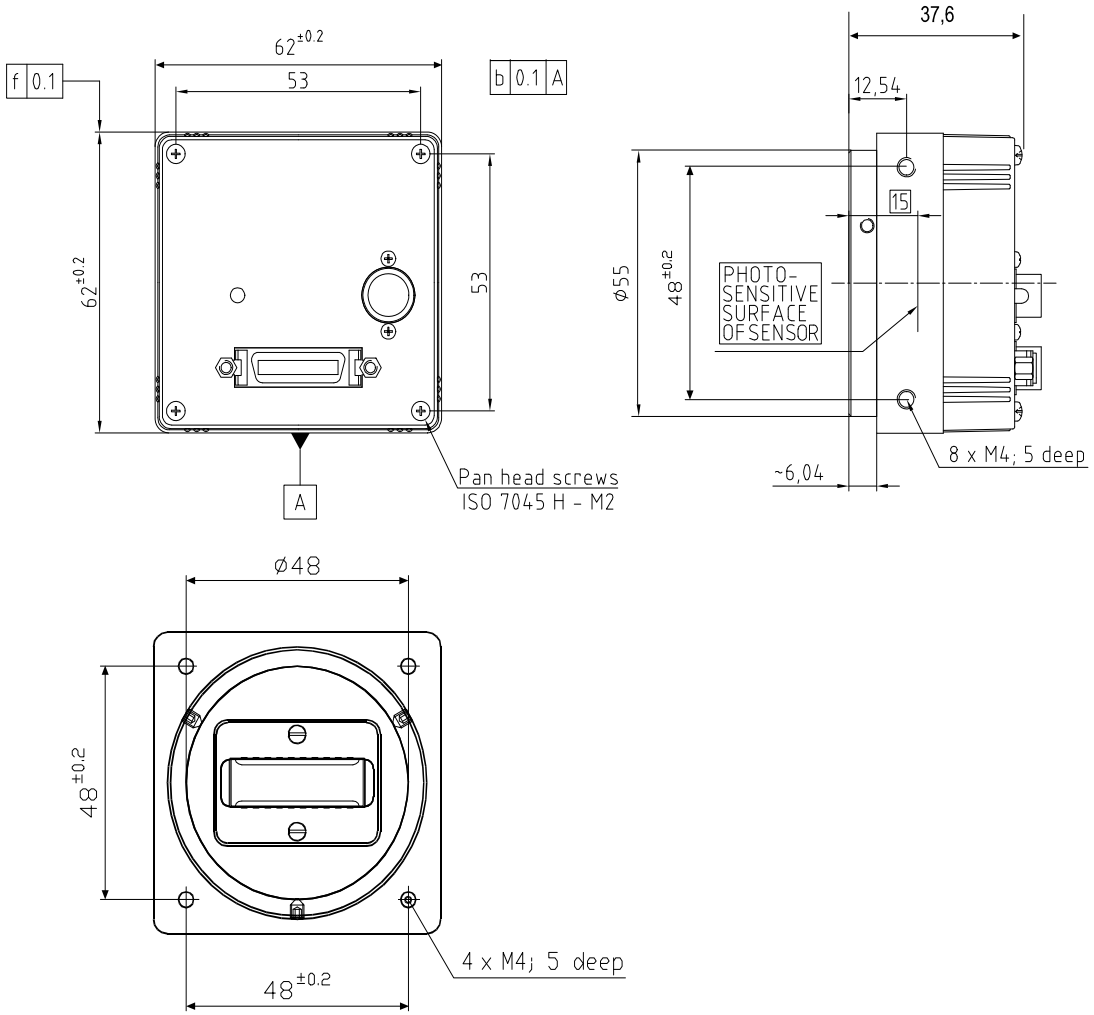
The **L100k** camera housing is manufactured with high precision. Planar, parallel, and angular sides guarantee precise mounting with high repeatability.

L100k series cameras are equipped with four M4 mounting holes on the front and two M4 mounting holes on each side as indicated in Figure 5-1.



Caution!

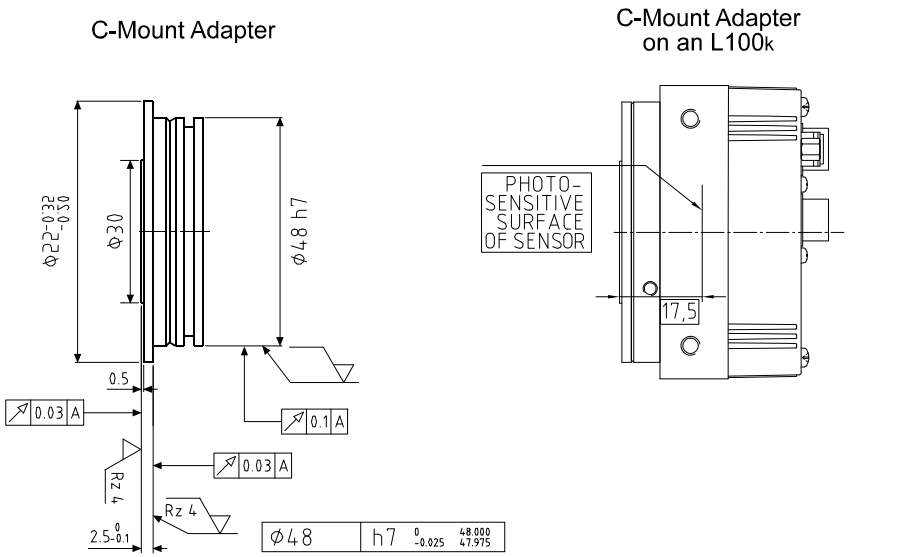
To avoid collecting dust on the sensor, mount a lens on the camera immediately after unpacking it.



Drawings are not to scale.

Figure 5-1: **L**l**00k** Mechanical Dimensions (in mm)

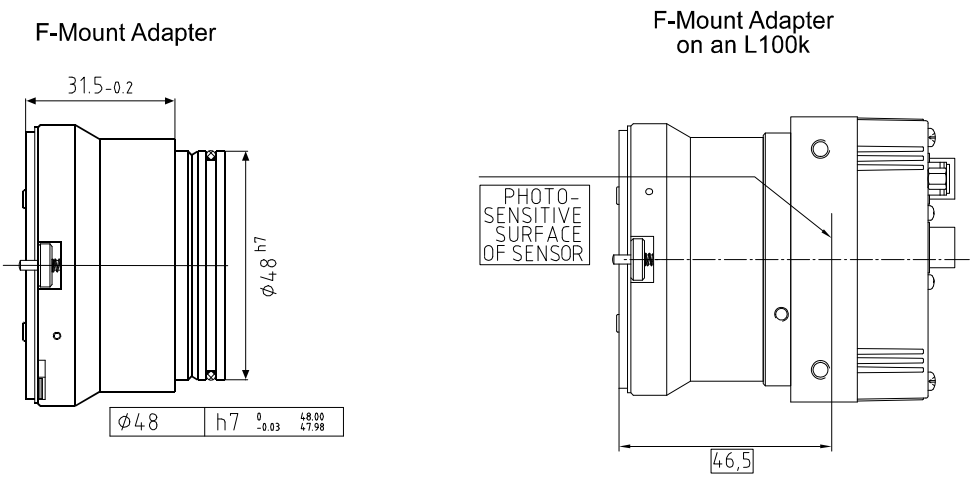
5.2 C-Mount Adapter Dimensions



Not to scale.

Figure 5-2: C-Mount Adapter Dimensions (in mm)

5.3 F-Mount Adapter Dimensions



Not to scale.

Figure 5-3: F-Mount Adapter Dimensions (in mm)

5.4 Positioning Accuracy of the Sensor Chip

Rotational positioning accuracy is as shown in Figure 5-4. Reference position is the center of the camera housing.

Since the translatory and rotational positioning tolerance depend on each other, the worst case of maximum rotational and horizontal/vertical mis-positioning cannot occur at the same time.

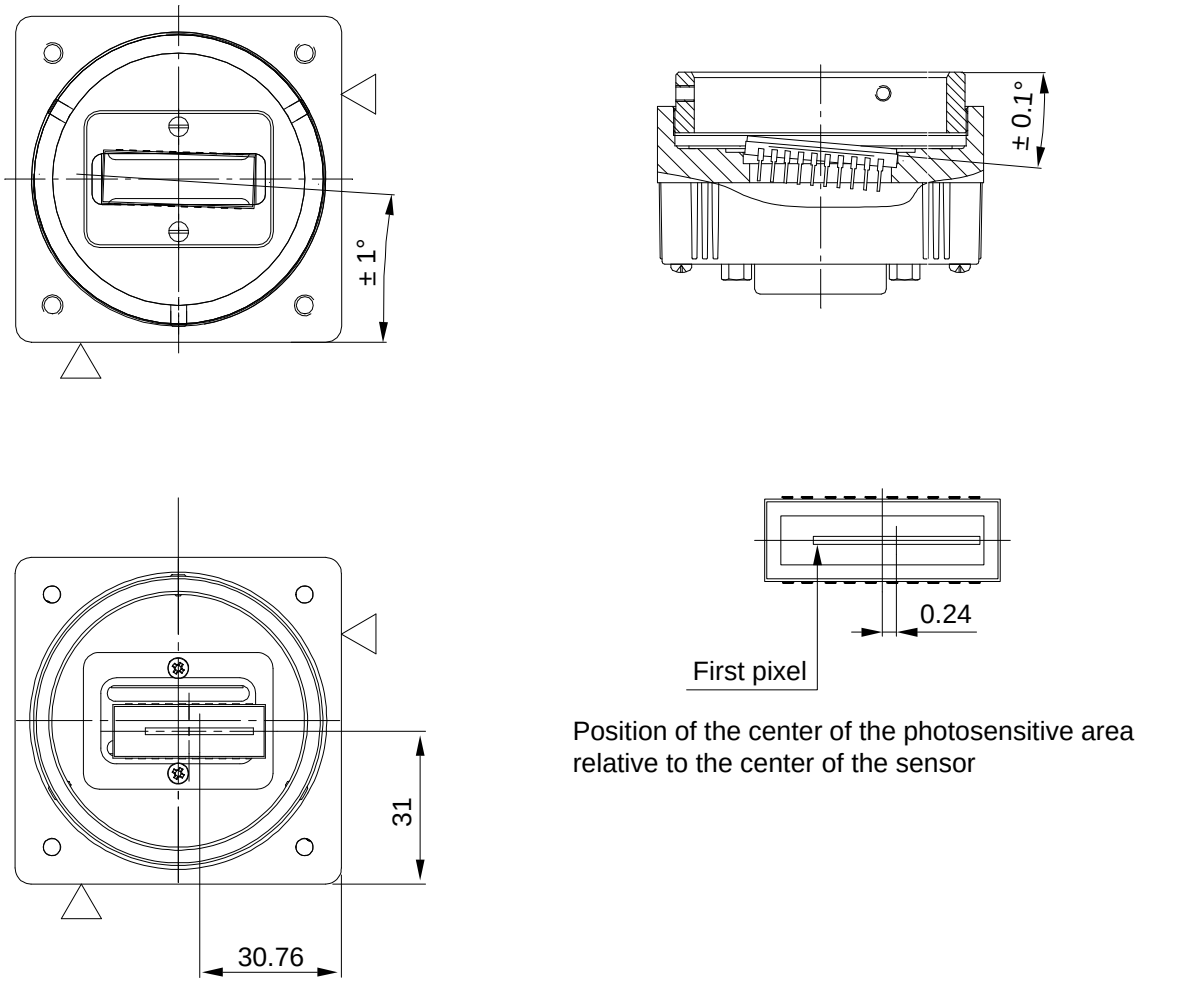


Figure 5-4: Positioning Accuracy (in mm)

6 Troubleshooting

6.1 Tech Support Resources

If you need advice about your camera or if you need assistance troubleshooting a problem with your camera, you can contact the Basler technical support team for your area. Basler technical support contact information is located in the front pages of this manual.

You will also find helpful information such as frequently asked questions, downloads, and application notes in the Downloads and the Support sections of our website:
www.baslerweb.com

If you do decide to contact Basler technical support, please take a look at the form that appears on the last two pages of this section before you call. Filling out this form will help make sure that you have all of the information the Basler technical support team needs to help you with your problem.

6.2 Obtaining an RMA Number

Whenever you want to return material to Basler, you must request a Return Material Authorization (RMA) number before sending it back. The RMA number **must** be stated in your delivery documents when you ship your material to us! Please be aware that if you return material without an RMA number, we reserve the right to reject the material.

You can find detailed information about how to obtain an RMA number in the Support section of our website: www.baslerweb.com

6.3 Fault Finding Using the Camera LED

When the power supply to the camera is switched on, the LED on the back of the camera will become orange colored for several seconds as the microprocessor in the camera boots up. If the LED then remains orange continuously, bootup has been successful.

Once bootup is complete, the camera performs a continuous series of self checks. If an error condition is detected, the LED will begin to flash between green and orange. The number of orange flashes indicates the detected error (see Table 6-1). If several error states are present, the LED outputs the error codes in succession.

Orange LED	Description
On Continuous	The camera is OK.
3 flashes	ExSync has not changed state for 5 seconds or longer. If you are not supplying an ExSync signal to the camera, this is a normal condition and should be ignored. Otherwise check the cable and the ExSync generating device.
5 flashes	The Work Set could not be stored into a User set. Please contact Basler technical support.
6 flashes	A User Set or the Factory Set could not be loaded into the Work Set. Please contact Basler technical support.
7 flashes	A valid list of commands was not available. Please contact Basler technical support.
8 flashes	The FPGA could not be configured. Please contact Basler technical support

Table 6-1: Camera Status Indications

If the status LED on the back of the camera is not lit, it means that power to the camera is not present or is less than 10.8 Volts.



The camera has no overvoltage protection. Always observe the maximum input voltage given in Section 2.8.

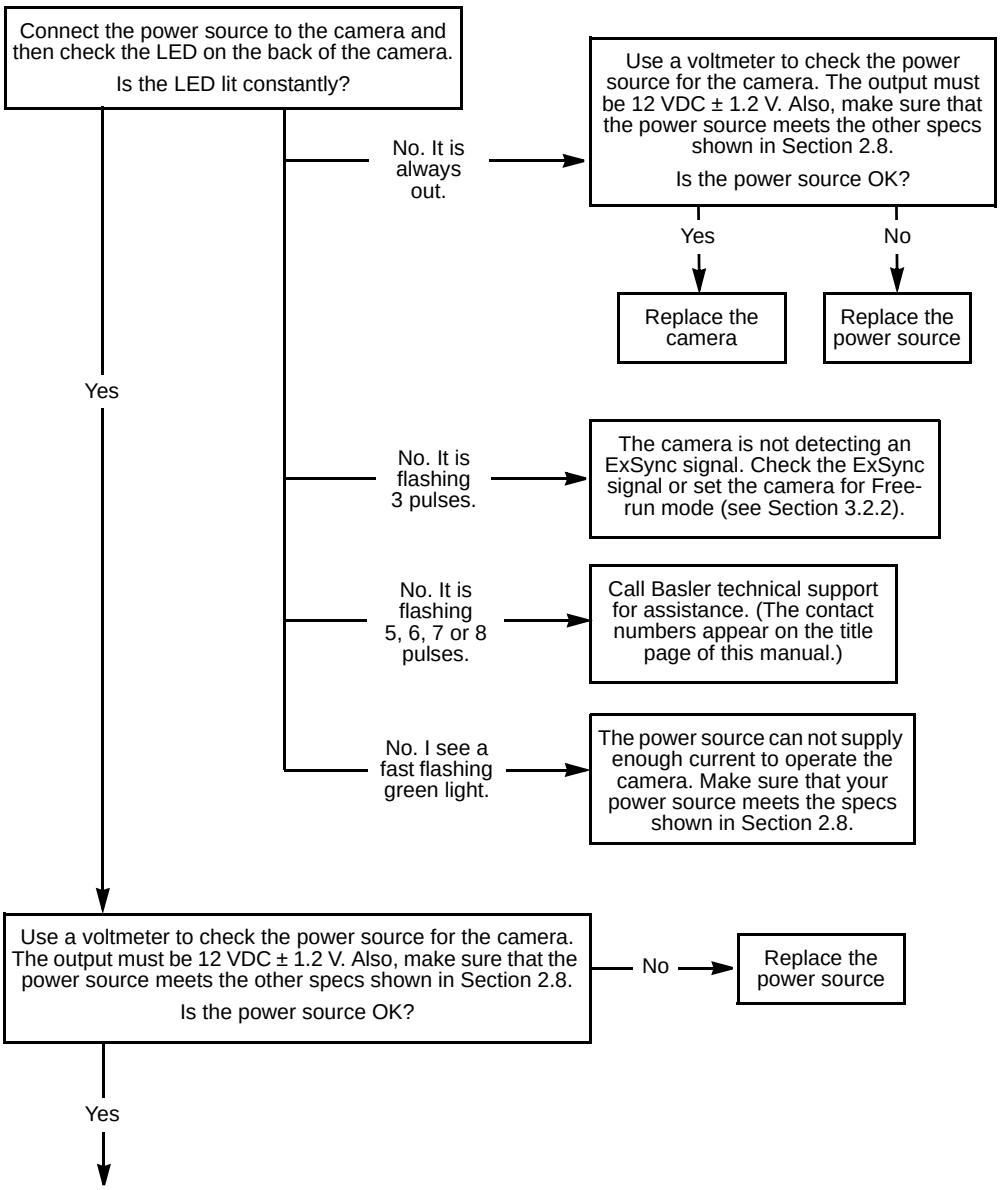
6.4 Troubleshooting Charts

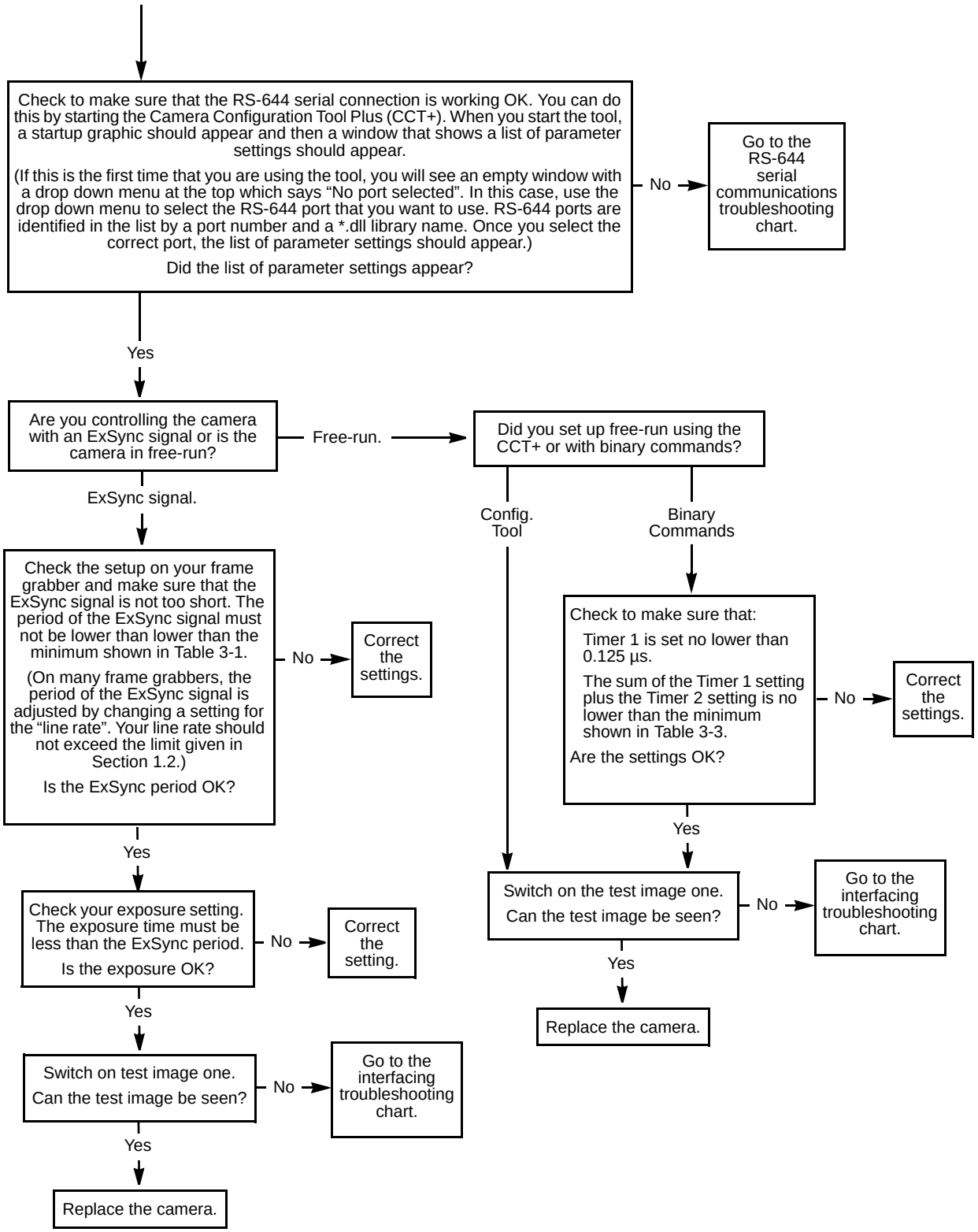
The following pages contain several troubleshooting charts which can help you find the cause of problems that users sometimes encounter. The charts assume that you are familiar with the camera's features and settings and with the settings for your frame grabber. If you are not, we suggest that you review the manuals for your camera and frame grabber before you troubleshoot a problem.

6.4.1 No Image

Use this chart if you see no image at all when you attempt to capture an image with your frame grabber (in this situation, you will usually get a message from the frame grabber such as "time-out"). If you see a poor quality image, a completely black image, or a completely white image, use the chart in Section 6.4.2.

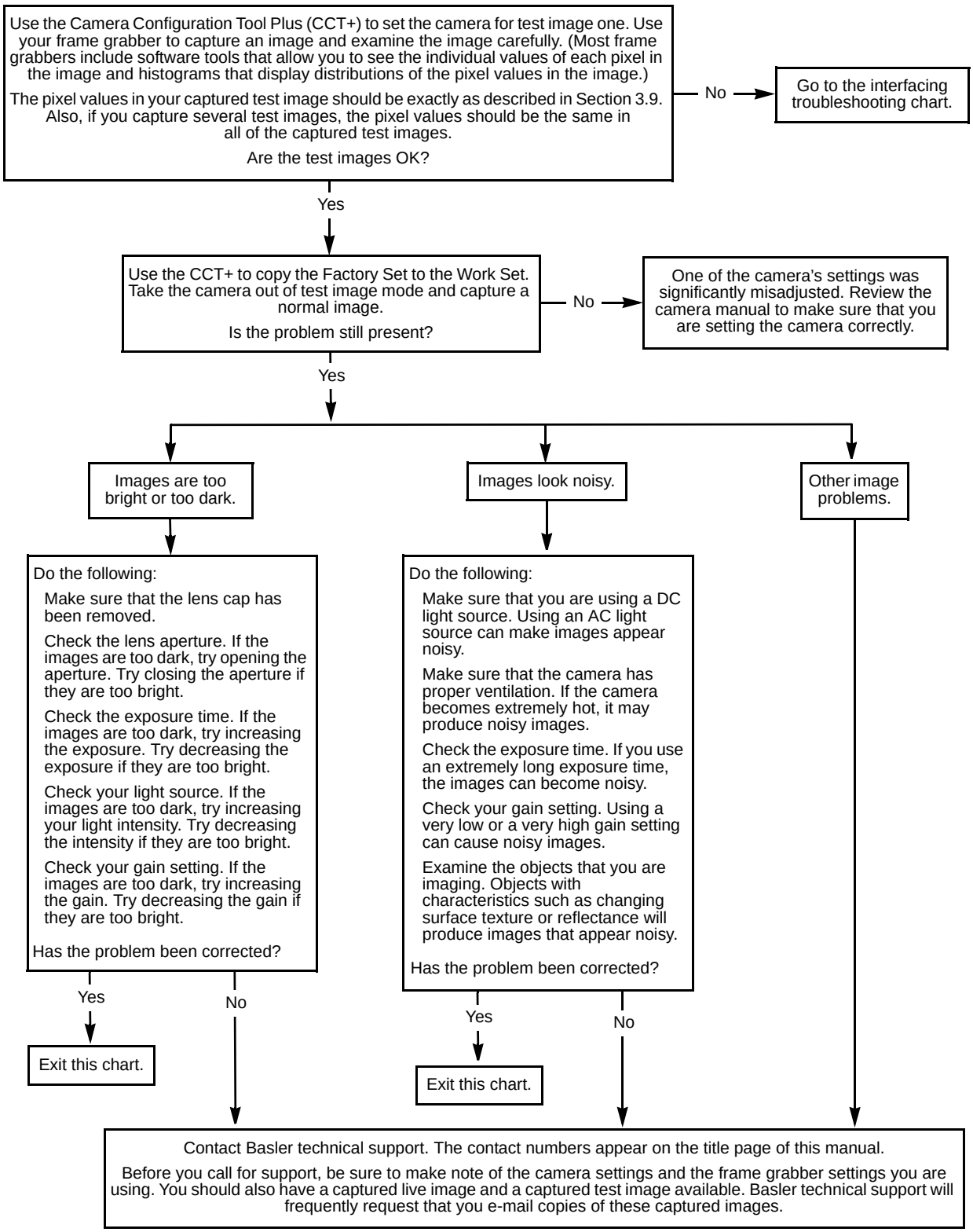
Always switch off power to the system before making or breaking any connection.




Check to make sure that the RS-644 serial connection is working OK. You can do this by starting the Camera Configuration Tool Plus (CCT+). When you start the tool, a startup graphic should appear and then a window that shows a list of parameter settings should appear.
(If this is the first time that you are using the tool, you will see an empty window with a drop down menu at the top which says “No port selected”. In this case, use the drop down menu to select the RS-644 port that you want to use. RS-644 ports are identified in the list by a port number and a *.dll library name. Once you select the correct port, the list of parameter settings should appear.)
Did the list of parameter settings appear?
No
Go to the RS-644 serial communications troubleshooting chart.
Yes
Are you controlling the camera with an ExSync signal or is the camera in free-run?
Free-run.
Did you set up free-run using the CCT+ or with binary commands?
ExSync signal.
Config. Tool
Binary Commands
Check the setup on your frame grabber and make sure that the ExSync signal is not too short. The period of the ExSync signal must not be lower than lower than the minimum shown in Table 3-1.
(On many frame grabbers, the period of the ExSync signal is adjusted by changing a setting for the “line rate”. Your line rate should not exceed the limit given in Section 1.2.)
Is the ExSync period OK?
No
Correct the settings.
Check to make sure that:
Timer 1 is set no lower than 0.125 µs.
The sum of the Timer 1 setting plus the Timer 2 setting is no lower than the minimum shown in Table 3-3.
Are the settings OK?
No
Correct the settings.
Yes
Yes
Check your exposure setting. The exposure time must be less than the ExSync period.
Is the exposure OK?
No
Correct the setting.
Switch on the test image one.
Can the test image be seen?
No
Go to the interfacing troubleshooting chart.
Yes
Yes
Switch on test image one.
Can the test image be seen?
No
Go to the interfacing troubleshooting chart.
Yes
Replace the camera.
Replace the camera.

6.4.2 Poor Quality Image

Use this chart if the image is poor quality, is completely white, or is completely black. If you get no image at all when you attempt to capture an image with the frame grabber, use the chart that appears in Section 6.4.1.

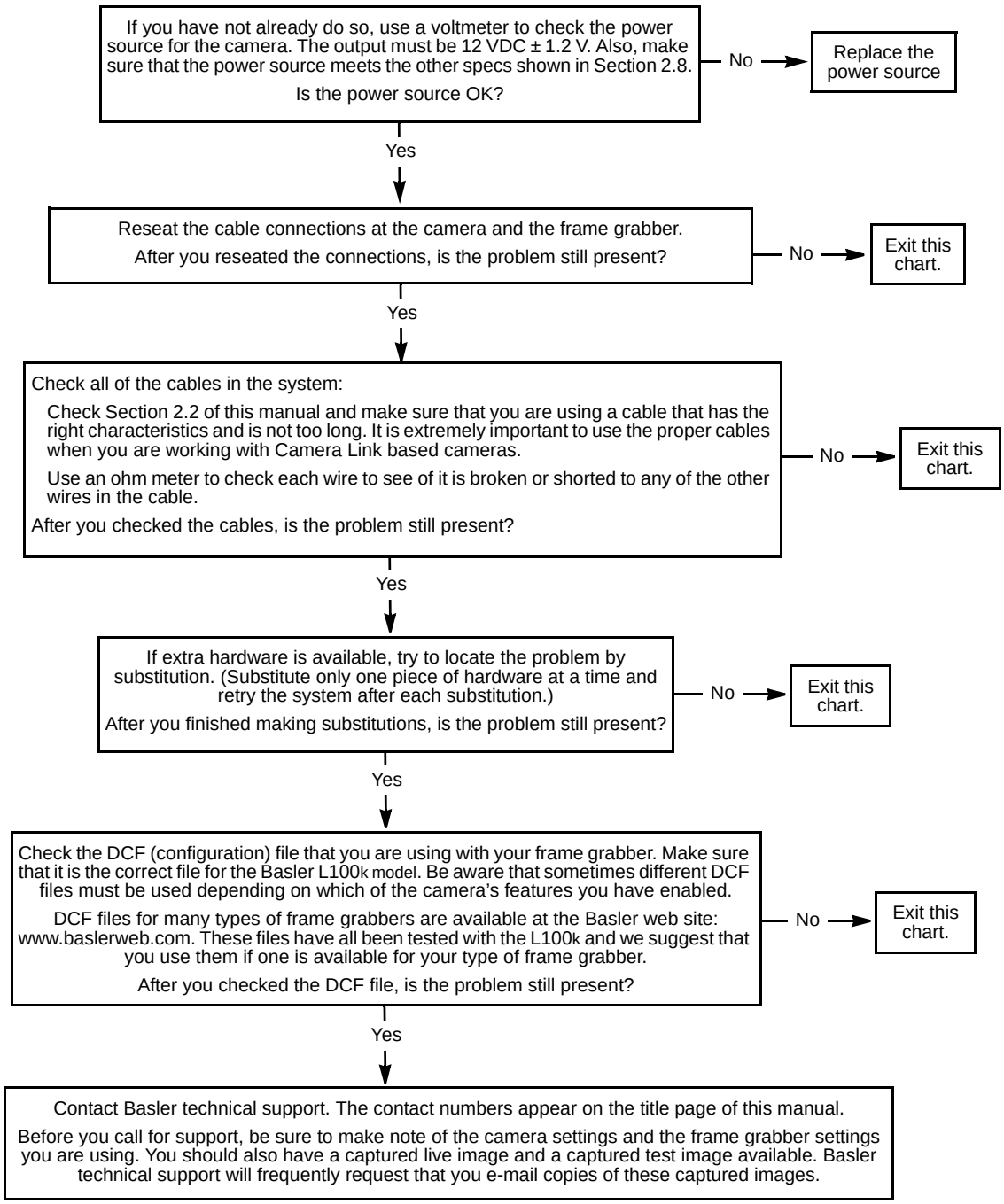


6.4.3 Interfacing

Use the interfacing troubleshooting charts if you think that there is a problem with the cables between your devices or if you have been directed here from another chart.

Interfacing Chart

Always switch off power to the system before making or breaking any connection.

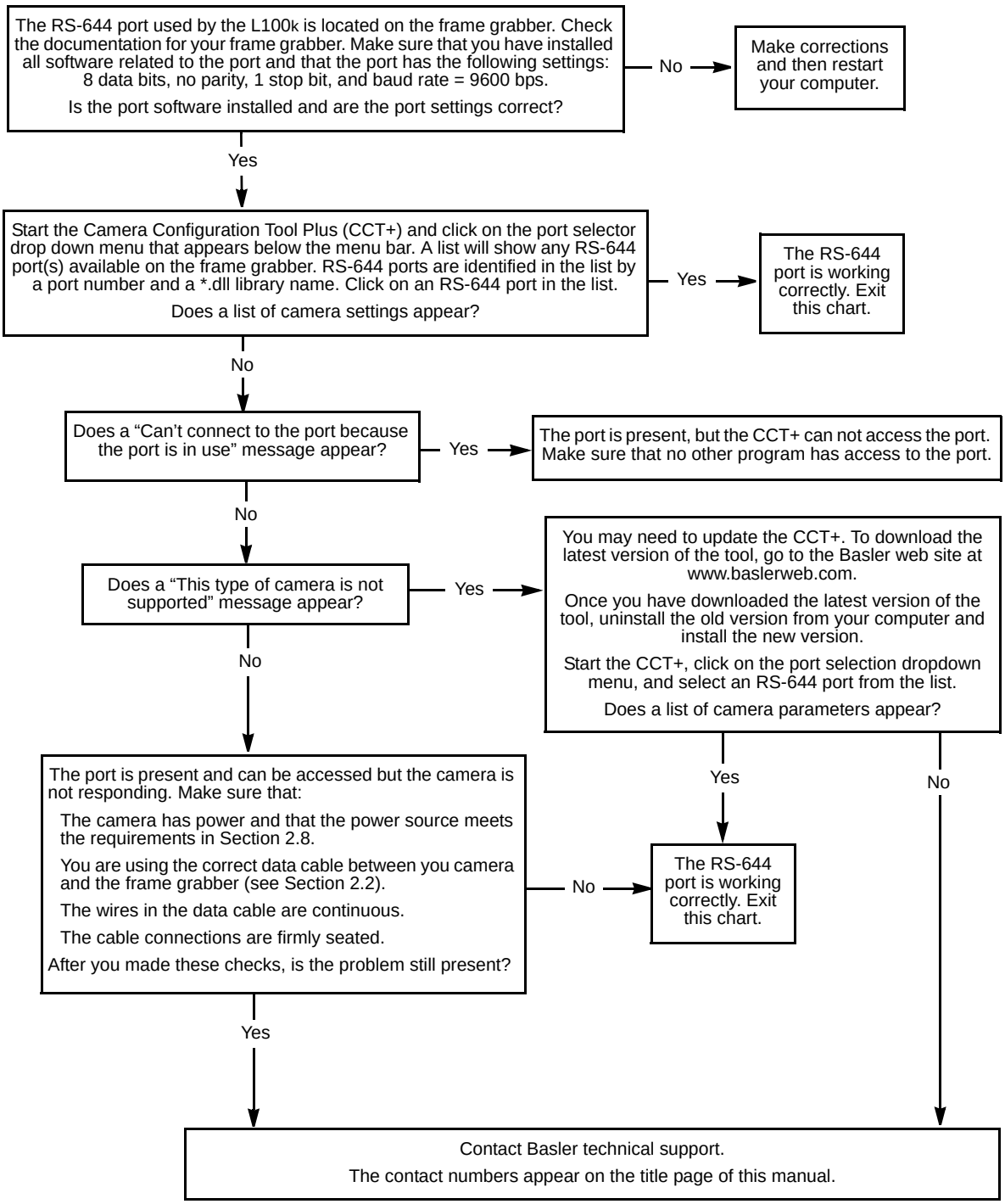


6.4.4 RS-644 Serial Communication

Use the serial communication troubleshooting charts if you think that there is a problem with RS-644 serial communication or if you have been directed here from another chart.

Serial Communication Chart A (without a BIC)

Always switch off power to the system before making or breaking any connection.



6.5 Before Calling Basler Technical Support

To help you as quickly and efficiently as possible when you have a problem with a Basler camera, it is important that you collect several pieces of information before you contact technical support.

Copy the form that appears on this and the next page (or download it from the support section of www.baslerweb.com), fill it out, and fax the pages to your local dealer or to your nearest Basler support center. Or, you can write an e-mail listing the requested pieces of information and with the requested files attached. Our technical support contact numbers are shown in the front section of this manual.

1 The camera's product ID: _____

2 The camera's serial number: _____

3 The operating system: _____

4 Frame grabber that you use with the camera: _____

_____

5 CCT+ version that you use with the camera: _____

_____

6 Describe the problem in as much detail as possible: _____

(If you need more space, use an extra sheet of paper.) _____

_____

_____

_____

_____

7 If known, what's the cause of the problem? _____

_____

_____

8 When did the problem occur? ☐ After start. ☐ While running.

☐ After a certain action (e.g., a change of parameters):

_____

_____

_____

_____

9 How often did/does the problem occur?

- ☐ Once.
- ☐ Every time.
- ☐ Regularly when: _____
- ☐ Occasionally when: _____

10 How severe is the problem?

- ☐ Camera can still be used.
- ☐ Camera can be used after I take this action: _____
- ☐ Camera can no longer be used.

11 Did your application ever run without problems?

- ☐ Yes
- ☐ No

12 Parameter set

It is very important for Basler technical support to get a copy of the exact camera parameters that you were using when the problem occurred.

To make a copy of the parameters, open the parameter set in the CCT+ and save or dump the settings to a file. Send the generated file to Basler technical support.

If you cannot access the camera, please try to state the following parameter settings:

- ☐ Video data output mode: _____
- ☐ Exposure time control mode: _____
- ☐ Exposure time: _____
- ☐ Gain: _____
- ☐ Offset: _____

13 Live image/test image

If you are having an image problem, try to generate and save live images that show the problem. Also generate and save test images. Please save the images in BMP format, zip them, and send them to Basler technical support.

Revision History

Doc. ID Number	Date	Changes
DA0005090a	5-October-2001	First draft of release covering series production cameras.
DA00050901	23-October-2001	Initial release covering series production cameras.
DA00050902	14-October-2002	Corrected the connector information in Section 1.2. Updated the Camera Link cable information in Section 2.2.1. Added more details to the Shading Correction description in Sect. 3.6.3. Added a description of the Camera Temperature feature (Sect. 3.11). Revised the troubleshooting chart in Sect. 6.4.1.
DA00050903	20-March-2003	Revised the stated maximum line rates in Section 1.2. Updated the pixel timing charts in Section 2.5.5 and the timing numbers in Sections 3.2.1.2 and 3.2.2.2 to reflect revisions made to the sensor timing by the manufacturer. Made revisions throughout to include instructions for using the Camera Configuration Tool Plus (CCT+).
DA00050904	29-June-2007	Updated Singapore and U.S. addresses. Increased weight of the camera with C-mount adapter to 220 g in Section 1.2. Added environmental requirements for storage in Section 1.3. Added warning against overvoltage in Section 1.4. Added warnings not to reverse polarity of input power in Sections 1.4 and 2.8. Corrected type of power connector in Section 2.1.3. Modified Figure 2-3 in Section 2.3. Removed step 4 and added to note box in Section 4.2.10. Corrected “Data“, “Byte 1“, and “Byte 2“ in Section 4.2.6. Added Section 6.5. Added feedback section.
DA00050905	8-April-2008	Added a warning to Section 1.4 advising users not to remove the serial number label. Corrected the connector part number in Section 2.1.3. Corrected vertical and rotational positioning accuracy in Section 5.4. Added drawing in Figure 5-4 in Section 5.4 showing the relative positions of sensor housing and photosensitive area.
DA00060905	7-February-2013	Updated cover photo. Updated Support contact details in the “Contacting Basler Support Worldwide“ section. Added a drawing of the position of the photosensitive area of the sensor in Figure 5-4 in Section 5.4. Added Sections 6.1 and 6.2 containing information about technical support and the RMA process. Removed Feedback section.

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