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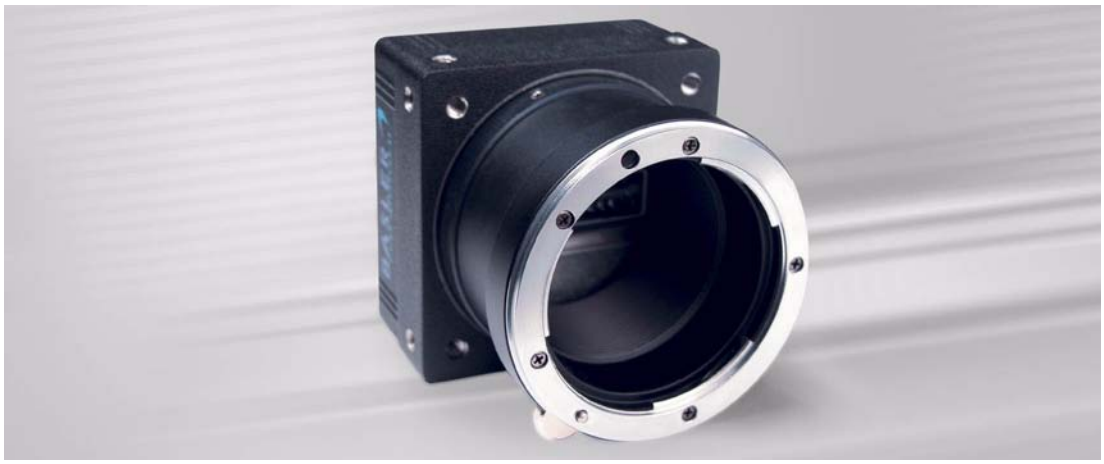
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Basler L301kc



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

The **BASLER L301kc** line scan camera is a versatile camera designed for industrial use. Superb image sensing features are combined with a robust, high precision manufactured housing.

Important features are:

- Tri-linear Color Array
- High responsivity
- Electronic exposure time control
- High signal-to-noise ratio
- Spatial Correction
- Area of Interest (AOI) scanning
- Digital Shift
- Programmable via an RS-644 serial port (as specified in the Camera Link standard)
- Industrial housing manufactured with high planar, parallel, and angular precision
- Super compact size
- Complies with the Camera Link standard

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1.1 Performance Specifications

Category	Specification
Sensor	Kodak KLI-2113 Tri-linear CCD Image Sensor
Pixels	2098 pixels X 3
Pixel Size	14 µm x 14 µm (14 µm pitch)
Center-to-center spacing between color channels	112 µm
Fill Factor	100%
Spectral Response	See Figure 1-1
Photo Response Non-uniformity	< 5% ave, < 10% max
Dark Signal Non-uniformity	± 1 DN (8 bit, typical) @ gain = 0 dB
Pixel Clock Speed	20 MHz (in 8 Bit RGB output mode) 40 MHz (in Dual 8 Bit or 10 Bit output mode) 60 MHz (in Single 8 Bit or 10 Bit output mode)
Maximum Line Rate	8.0 kHz (with spatial correction enabled), or 9.20 kHz (with spatial correction not enabled)
Minimum Line Rate	1 kHz
Video Output Type	Camera Link LVDS (RS-644 LVDS when used with the optional Basler Interface Converter for k cameras (k-BIC))
Video Output Formats	Single 8 Bit, Single 10 Bit, Dual 8 Bit, Dual 10 Bit, or 8 Bit RGB
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%), < 5.1 W
Lens Adapter	F-mount
Housing Size (L x W x H)	without lens adapter: 38.1 mm x 62 mm x 62 mm with F-mount adapter: 69.6 mm x 62 mm x 62 mm
Weight	without lens adapter: ~ 174 g with F-mount adapter: ~ 282 g
Conformity	CE, FCC

Table 1-1: **L301kc** Performance Specifications

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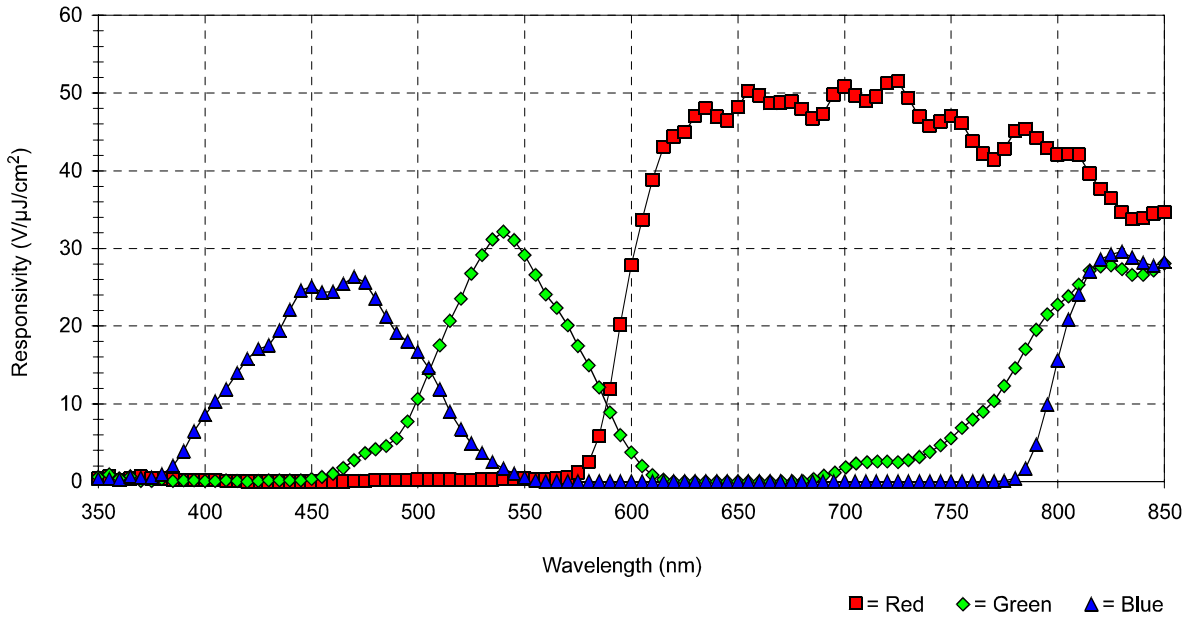


Figure 1-1: **L301kc** Spectral Responsivity

	Color filter arrays become transparent after 700 nm. To maintain spectral balance, use of a suitable IR cut-off filter is recommended. The filter should transmit in a range of 400 nm to 700 nm. A suitable filter type is the B+W486, for example.

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1.2 Environmental Requirements

1.2.1 Temperature and Humidity

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

1.2.2 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.

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1.3 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.

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.

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

To ensure that your warranty remains in force:

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 housing. Touching internal components may damage them.

Be careful not to allow liquids, 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 high quality window cleaner. Do not use methylated alcohol. Because electrostatic discharge can damage the CCD sensor, you must use a cloth that will not generate electrostatic charge 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.

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2 Camera Interface

2.1 Connections

2.1.1 General Description

The **L301kc** is 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.

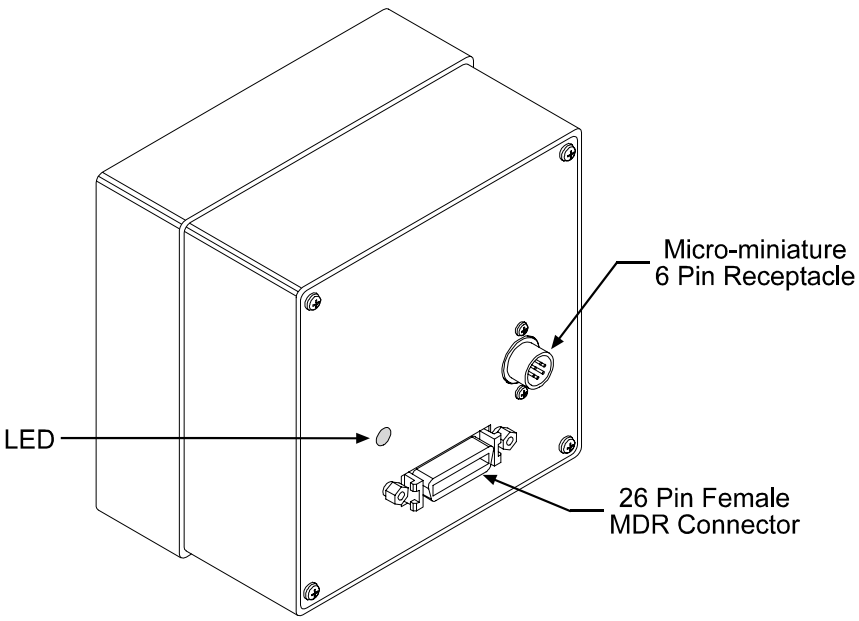


Figure 2-1: **L301kc** Connectors and LED

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2.1.2 Pin Assignments

26-Pin MDR Connector

The pin assignments for the 26 pin, MDR connector used to transmit video data, control signals, and configuration commands 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: **L301kc** 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.

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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: **L301kc** Pin Assignments for the 6-pin Micro-miniature Receptacle



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.

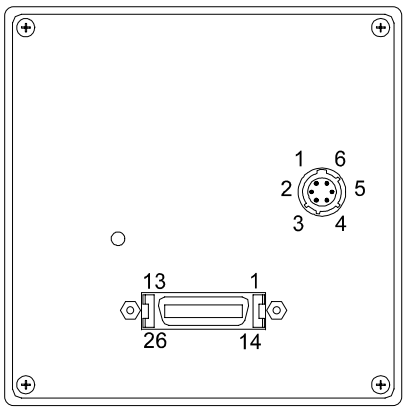


Figure 2-2: **L301kc** Pin Numbering

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). A plug of this type will be shipped with each camera. The plug should be used to terminate the cable on the power supply for the camera.

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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 recommended length for the MDR cable used with an **L301kc** is 10 meters.



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.

The maximum allowed length for the power cable used with an **L301kc** is 6 meters.
Power requirements can be found in Section 2.8.

2.3 Camera Link Implementation in the L301kc

The **L301kc** 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 **L301kc** 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

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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 **L301kc** and a typical implementation for the frame grabber interface.

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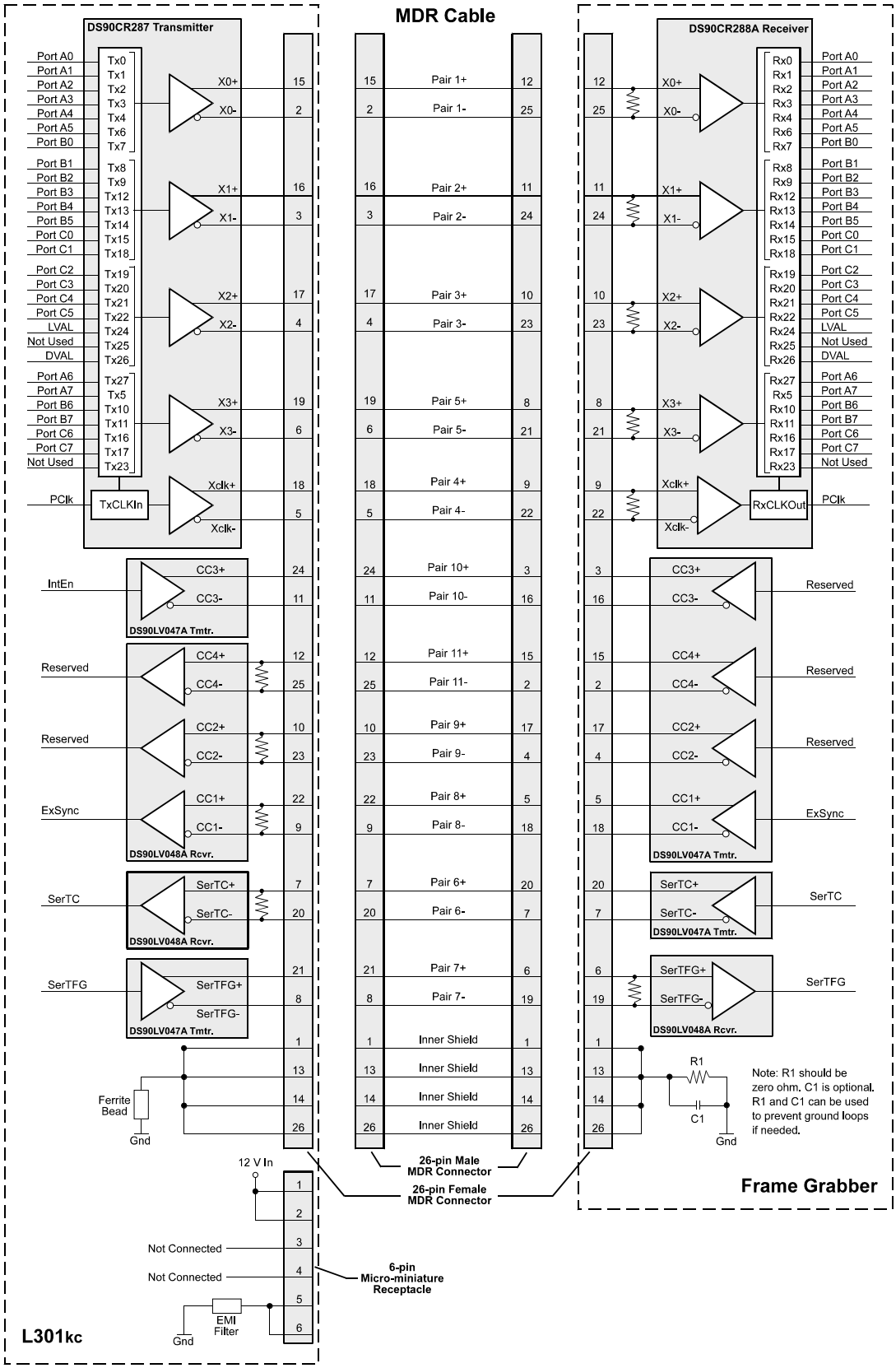


Figure 2-3: Camera / Frame Grabber Interface

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2.4 Input Signals

The only control signal that can be input into the **L301kc** is an external sync (ExSync) signal. ExSync is an RS-644 LVDS signal as specified in the Camera Link standard (see Figure 2-3). 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 readout.

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 0.35 µs.

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 to determine how to set up the ExSync signal.

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 and recommendations for ExSync controlled operation, see Section 3.2.

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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. In addition, an integrate enabled signal can be used to monitor the start and stop of exposure. Sections 2.5.1 through 2.5.6 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 Figure 2-4 through Figure 2-9. The transmitter used in **L301kc** cameras requires pixel data to be sampled and transmitted on the rising edge of the clock.

The frequency of the pixel clock is indicated in Table 1-1 on page 1-2.



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 Figure 2-4 through Figure 2-9, 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 not used on this camera and should be ignored. The status of this bit is always identical to the line valid bit.

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.

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Port	Camera	Frame Grabber	20 MHz 8 Bit RGB Output Mode[1]	60 MHz Single Pixel 10 Bit Output Mode[2]	60 MHz Single Pixel 8 Bit Output Mode[2]	40 MHz Dual Pixel 10 Bit Output Mode[3]	40 MHz Dual Pixel 8 Bit Output Mode[3]
A0	TxIN0	RxOUT0	Red Pixel Bit 0	Pixel Bit 0	Pixel Bit 0	Pixel A Bit 0	Pixel A Bit 0
A1	TxIN1	RxOUT1	Red Pixel Bit 1	Pixel Bit 1	Pixel Bit 1	Pixel A Bit 1	Pixel A Bit 1
A2	TxIN2	RxOUT2	Red Pixel Bit 2	Pixel Bit 2	Pixel Bit 2	Pixel A Bit 2	Pixel A Bit 2
A3	TxIN3	RxOUT3	Red Pixel Bit 3	Pixel Bit 3	Pixel Bit 3	Pixel A Bit 3	Pixel A Bit 3
A4	TxIN4	RxOUT4	Red Pixel Bit 4	Pixel Bit 4	Pixel Bit 4	Pixel A Bit 4	Pixel A Bit 4
A5	TxIN6	RxOUT6	Red Pixel Bit 5	Pixel Bit 5	Pixel Bit 5	Pixel A Bit 5	Pixel A Bit 5
A6	TxIN27	RxOUT27	Red Pixel Bit 6	Pixel Bit 6	Pixel Bit 6	Pixel A Bit 6	Pixel A Bit 6
A7	TxIN5	RxOUT5	Red Pixel Bit 7	Pixel Bit 7	Pixel Bit 7 (MSB)	Pixel A Bit 7	Pixel A Bit 7 (MSB)
B0	TxIN7	RxOUT7	Green Pixel Bit 0	Pixel Bit 8	Not Used	Pixel A Bit 8	Pixel B Bit 0
B1	TxIN8	RxOUT8	Green Pixel Bit 1	Pixel Bit 9 (MSB)	Not Used	Pixel A Bit 9 (MSB)	Pixel B Bit 1
B2	TxIN9	RxOUT9	Green Pixel Bit 2	Not Used	Not Used	Not Used	Pixel B Bit 2
B3	TxIN12	RxOUT12	Green Pixel Bit 3	Not Used	Not Used	Not Used	Pixel B Bit 3
B4	TxIN13	RxOUT13	Green Pixel Bit 4	Not Used	Not Used	Pixel B Bit 8	Pixel B Bit 4
B5	TxIN14	RxOUT14	Green Pixel Bit 5	Not Used	Not Used	Pixel B Bit 9 (MSB)	Pixel B Bit 5
B6	TxIN10	RxOUT10	Green Pixel Bit 6	Not Used	Not Used	Not Used	Pixel B Bit 6
B7	TxIN11	RxOUT11	Green Pixel Bit 7	Not Used	Not Used	Not Used	Pixel B Bit 7 (MSB)
C0	TxIN15	RxOUT15	Blue Pixel Bit 0	Not Used	Not Used	Pixel B Bit 0	Not Used
C1	TxIN18	RxOUT18	Blue Pixel Bit 1	Not Used	Not Used	Pixel B Bit 1	Not Used
C2	TxIN19	RxOUT19	Blue Pixel Bit 2	Not Used	Not Used	Pixel B Bit 2	Not Used
C3	TxIN20	RxOUT20	Blue Pixel Bit 3	Not Used	Not Used	Pixel B Bit 3	Not Used
C4	TxIN21	RxOUT21	Blue Pixel Bit 4	Not Used	Not Used	Pixel B Bit 4	Not Used
C5	TxIN22	RxOUT22	Blue Pixel Bit 5	Not Used	Not Used	Pixel B Bit 5	Not Used
C6	TxIN16	RxOUT16	Blue Pixel Bit 6	Not Used	Not Used	Pixel B Bit 6	Not Used
C7	TxIN17	RxOUT17	Blue Pixel Bit 7	Not Used	Not Used	Pixel B Bit 7	Not Used
DVAL	TxIN26	RxOUT26	Data Valid				
LVAL	TxIN24	RxOUT24	Line Valid				
Not Used	TxIN23	RxOUT23	Connected to Ground.				
Not Used	TxIN25	RxOUT25	Connected to Ground.				
PClk	Tx-CLKIn	RxCLKOut	Pixel Clock				

Table 2-3: Bit Assignments

[1] See pages 2-10 through 2-12 for more detailed information about how pixel data is transmitted in this mode.

[2] See pages 2-13 and 2-14 for more detailed information about how pixel data is transmitted in this mode.

[3] See pages 2-15 through 2-17 for more detailed information about how pixel data is transmitted in this mode.

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2.5.5 Video Data Output Modes

The **L301kc** can operate in the following modes:

- 20 MHz 8 Bit RGB mode
- 60 MHz Single Pixel 10 Bit mode
- 60 MHz Single Pixel 8 Bit mode
- 40 MHz Dual Pixel 10 Bit mode
- 40 MHz Dual Pixel 8 Bit mode.

Operation in 20 MHz 8 Bit RGB Mode

In 20 MHz 8 Bit RGB mode, the pixel clock operates at 20 MHz. On each clock cycle, the camera transmits 8 bits of data for a red pixel, 8 bits of data for a blue pixel, 8 bits of data for a green pixel, and a line 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 Figure 2-4 and Figure 2-5, the **L301kc** 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 this bit is high.



The data sequence outlined below, along with Figure 2-4 and Figure 2-5, 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

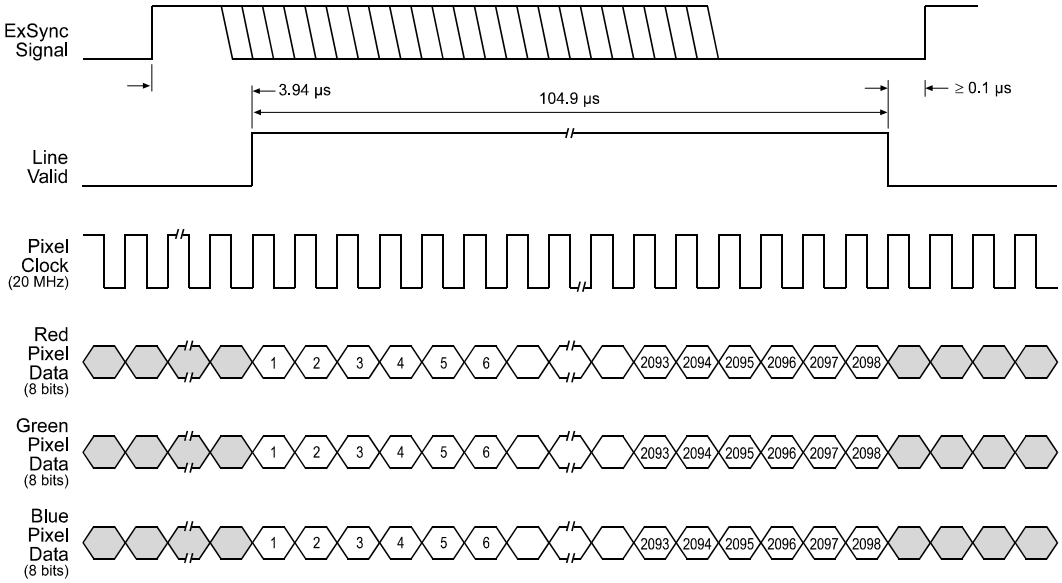
When the camera is not transmitting valid data, the line valid bit sent on each cycle of the pixel clock will be low. Once the camera has completed line acquisition, it will begin to send valid data:

- On the pixel clock cycle where valid line data transmission begins, the line valid bit will become high. Eight of the bits transmitted during this clock cycle will contain the data for pixel number one in the red line, eight of the bits will contain the data for pixel number one in the green line, and eight of the bits will contain the data for pixel number one in the blue line.
- On the next cycle of the pixel clock, the line valid bit will be high. Eight of the bits transmitted during this clock cycle will contain the data for pixel number two in the red line, eight of the bits will contain the data for pixel number two in the green line, and eight of the bits will contain the data for pixel number two in the blue line

  This pattern will continue for 2098 cycles of the pixel clock as the data for the 2098 pixels in the lines is transmitted.
- After the data for all 2098 pixels in the lines has been transmitted, the line valid bit will become low indicating that valid line data is no longer being transmitted.

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



1 pixel clock cycle (PClk) = 0.05 µs

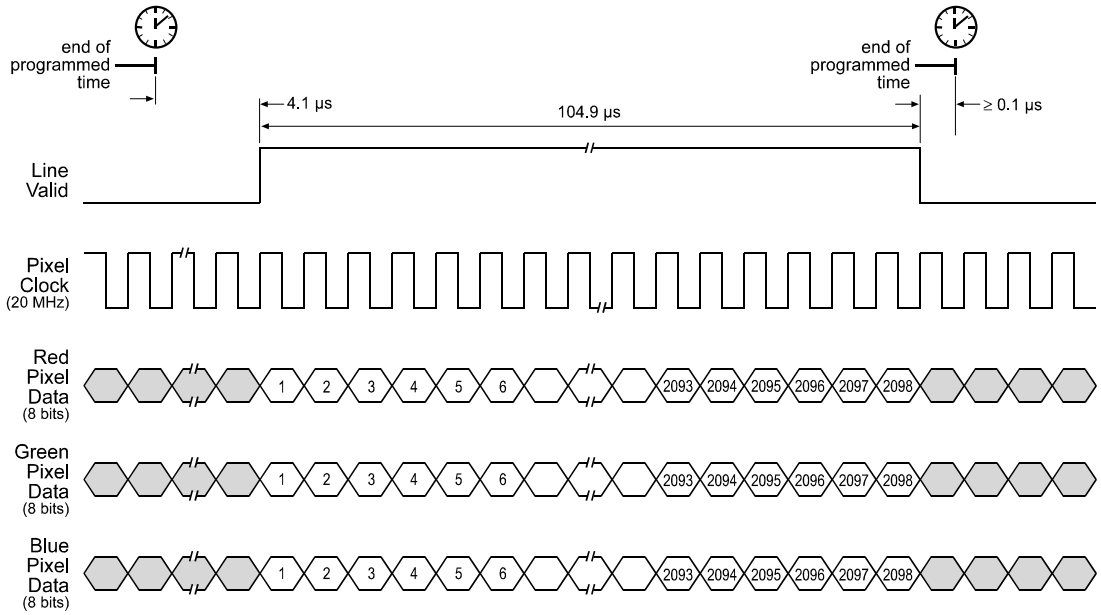
The pixel data that is transmitted out of the camera is affected by the spatial correction settings. (see Section 3.5.5)

This diagram assumes that the area of interest feature is not being used. With the area of interest feature enabled, the number of pixels transferred could be smaller. (see Section 3.8)

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-4: 20 MHz 8 Bit RGB Mode with Edge or Level Controlled Exposure

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1 pixel clock cycle (PClk) = 0.05 µs

The pixel data that is transmitted out of the camera is affected by the spatial correction settings. (see Section 3.5.5)

This diagram assumes that the area of interest feature is not being used. With the area of interest feature enabled, the number of pixels transferred could be smaller. (see Section 3.8)

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-5: 20 MHz 8 Bit RGB Mode with Programmable Exposure

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Operation in 60 MHz Single Pixel 10 Bit Mode or Single Pixel 8 Bit Mode

In 60 MHz Single Pixel 10 Bit mode, the pixel clock operates at 60 MHz. On each clock cycle, the camera transmits data for one pixel at 10 bit depth and a line 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 Figure 2-6 and Figure 2-7, the **L301kc** 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 this bit is high.

Operation in 60 MHz Single Pixel 8 Bit mode is similar to 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 Figure 2-6 and Figure 2-7, 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]

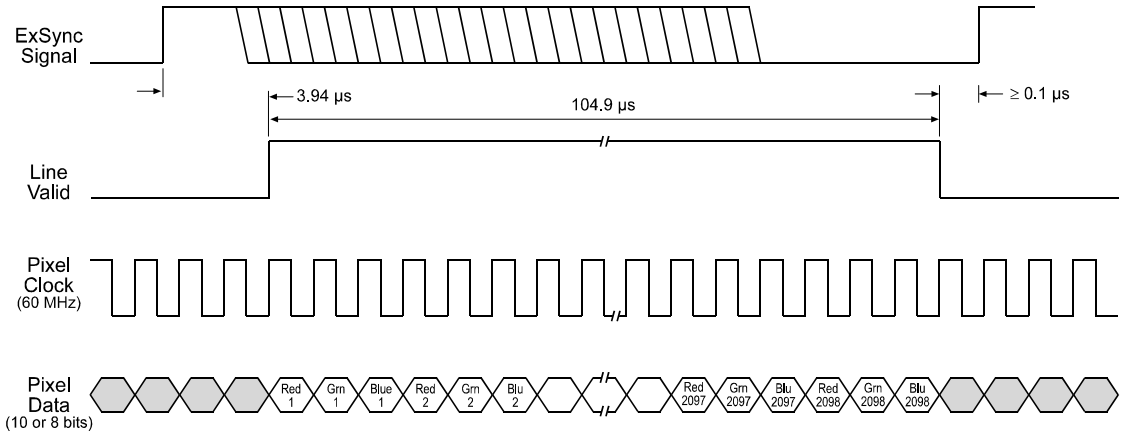
When the camera is not transmitting valid data, the line valid bit sent on each cycle of the pixel clock will be low. Once the camera has completed line acquisition, it will begin to send valid data:

- On the pixel clock cycle where valid 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 in the red line.
- 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 one in the green line.
- 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 one in the blue line.
- On the fourth 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 in the red line.
- On the fifth 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 in the green line.
- On the sixth 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 in the blue line.
- This pattern will continue for 6294 cycles of the pixel clock. (The camera must transmit data for 2098 pixels in each line and there are three lines; 3 x 2098 = 6294.)
- After the data for all 6294 pixels has been transmitted, the line valid bit will become low indicating that valid line data is no longer being transmitted.

Figure 2-6 shows the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode. Figure 2-7 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.

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1 pixel clock cycle (PClk) = 0.01667 µs

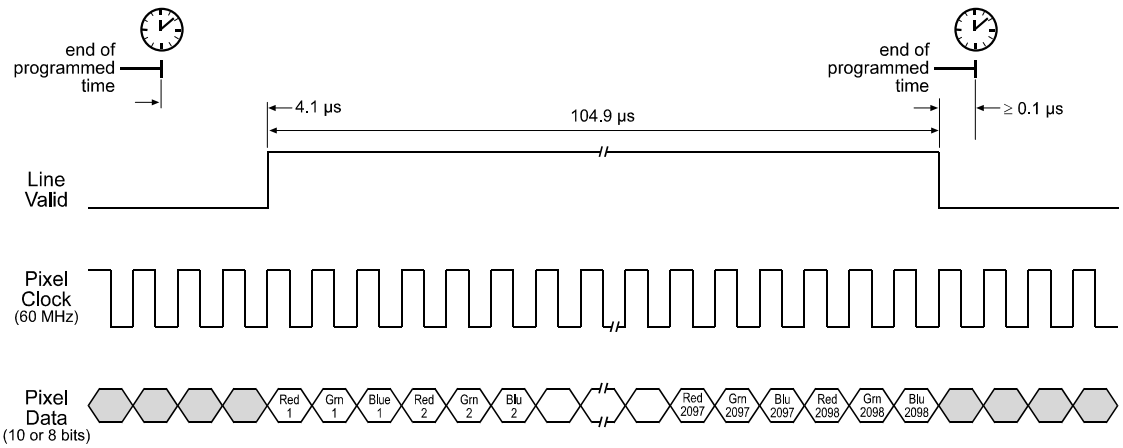
The pixel data that is transmitted out of the camera is affected by the spatial correction settings. (see Section 3.5.5)

Pixel data is always transmitted in red - green - blue order.

This diagram assumes that the area of interest feature is not being used. With the area of interest feature enabled, the number of pixels transferred could be smaller. (see Section 3.8)

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-6: 60 MHz Single Pixel 10 Bit or Single Pixel 8 Bit Mode with Edge or Level Controlled Exposure



1 pixel clock cycle (PClk) = 0.01667 µs

The pixel data that is transmitted out of the camera is affected by the spatial correction settings. (see Section 3.5.5)

Pixel data is always transmitted in red - green - blue order.

This diagram assumes that the area of interest feature is not being used. With the area of interest feature enabled, the number of pixels transferred could be smaller. (see Section 3.8)

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-7: 60 MHz Single Pixel 10 Bit or Single Pixel 8 Bit Mode with Programmable Exposure

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Operation in 40 MHz Dual Pixel 10 Bit Mode or Dual Pixel 8 Bit Mode

In 40 MHz Dual Pixel 10 Bit mode, the pixel clock operates at 40 MHz. On each clock cycle, the camera transmits data for two pixels at 10 bit depth and a line 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 Figure 2-8 and Figure 2-9, the **L301kc** 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 this bit is high.

Operation in 40 MHz Dual Pixel 8 Bit mode is similar to 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 Figure 2-8 and Figure 2-9, 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:

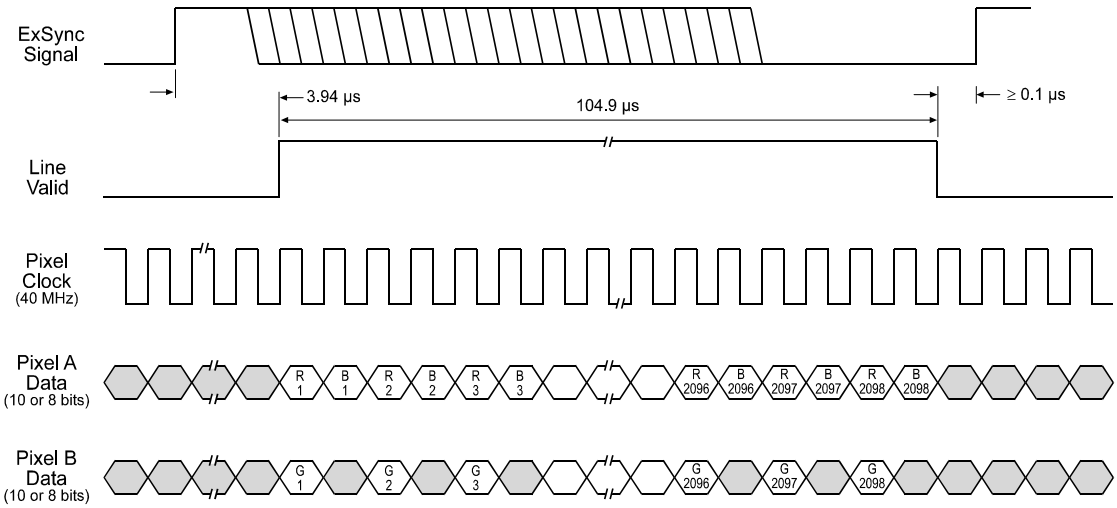
- On the pixel clock cycle where valid line data transmission begins, the line valid bit will become high. The ten “Pixel A” bits transmitted during this clock cycle will contain the data for pixel number one in the red line and the ten “Pixel B” bits will contain the data for pixel number one in the green line.
- On the second cycle of the pixel clock, the line valid bit will be high. The ten “Pixel A” bits transmitted during this clock cycle will contain the data for pixel number one in the blue line and the ten “Pixel B” bits will contain dummy data which should be ignored.
- On the third cycle of the pixel clock, the line valid bit will be high. The ten “Pixel A” bits transmitted on this cycle will contain the data for pixel number two in the red line and the ten “Pixel B” bits will contain the data for pixel number two in the green line.
- On the fourth cycle of the pixel clock, the line valid bit will be high. The ten “Pixel A” bits transmitted during this clock cycle will contain the data for pixel number two in the blue line and the ten “Pixel B” bits will contain dummy data which should be ignored.

  This pattern will continue for 4196 cycles of the pixel clock as the data for the 2098 pixels in the lines is transmitted.
- After the data for all 2098 pixels has been transmitted, the line valid bit will become low indicating that valid line data is no longer being transmitted.

[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.

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Figure 2-8 shows the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode. Figure 2-9 shows the data sequence when the camera is operating in programmable exposure mode.



1 pixel clock cycle (PClk) = 0.025 µs

The pixel data that is transmitted out of the camera is affected by the spatial correction settings. (see Section 3.5.5)

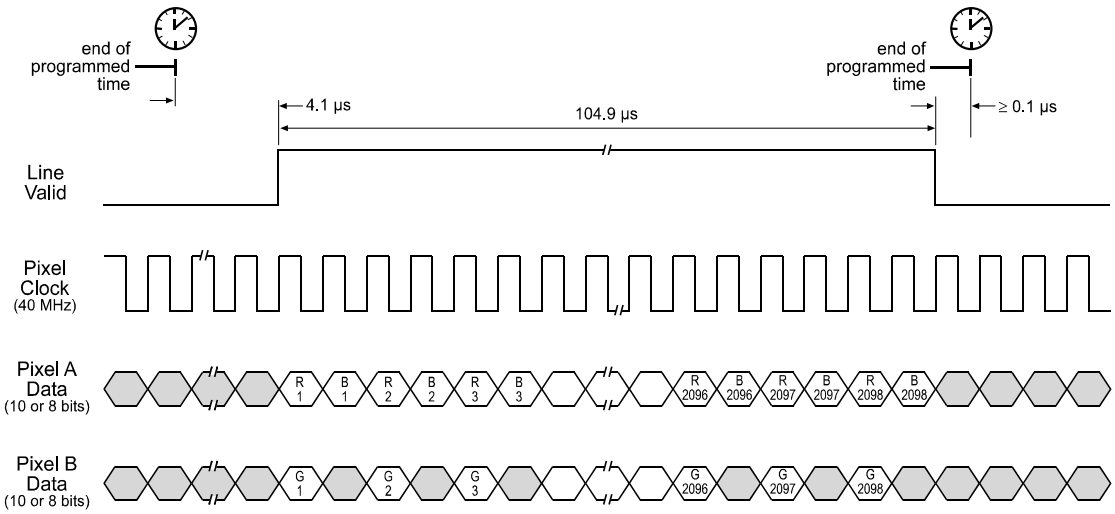
Pixel data is always transmitted in red - green - blue order.

This diagram assumes that the area of interest feature is not being used. With the area of interest feature enabled, the number of pixels transferred could be smaller. (see Section 3.8)

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-8: 40 MHz Dual Pixel 10 Bit Mode or Dual Pixel 8 Bit Mode with Edge or Level Controlled Exposure

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1 pixel clock cycle (PClk) = 0.025 µs

The pixel data that is transmitted out of the camera is affected by the spatial correction settings. (see Section 3.5.5)

Pixel data is always transmitted in red - green - blue order.

This diagram assumes that the area of interest feature is not being used. With the area of interest feature enabled, the number of pixels transferred could be smaller. (see Section 3.8)

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-9: 40 MHz Dual Pixel 10 Bit Mode or Dual Pixel 8 Bit Mode with Programmable Exposure

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2.5.6 Integrate Enabled Signal

An RS-644 LVDS output signal called Integrate Enabled (IntEn) is available on **L301kc** 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 **L301kc**.

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 2-10 below). If you open the connector housing, you can locate the wires and use them to access the integrate enabled signal. The blue wire carries the positive signal; the gray wire carries the negative signal. The wires require a 100 Ohm termination resistor.



If you use a standard Camera Link cable to connect the **L301kc** 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.

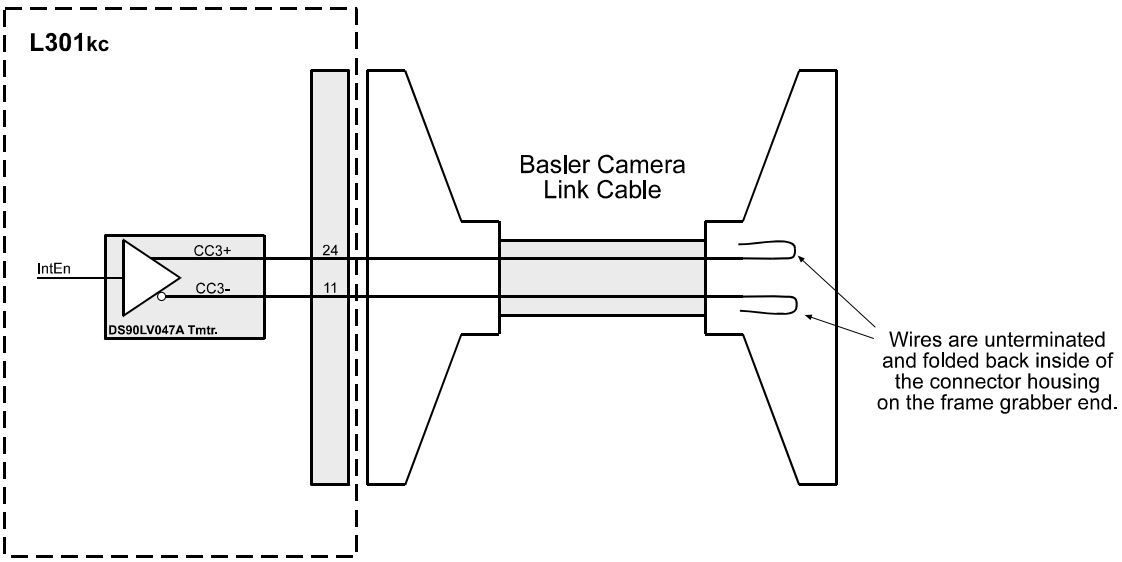


Figure 2-10: Basler Camera Link Cable

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2.6 RS-644 Serial Communication

The **L301kc** 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.

The serial port must have the following settings: 8N1 (8 data bits, no parity, 1 stop bit).

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.

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

On the **L301kc**, 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 **L301kc** 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 **L301kc** with a Camera Link compatible cable. For complete information on the k-BIC, refer to the k-BIC User's Manual and the k-BIC installation guide.

2.8 DC Power

The **L301kc** requires 12 VDC (± 10%) power. An appropriate power supply is available from Basler as a stock item (part # 1000013046).

The camera's maximum power consumption is approximately 5 watts.



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. See Section 2.1.2 for information about the input power connector pin assignments.



Caution!

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

2.9 Status LED

The **L301kc** 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 6.1 for details.

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3 Basic Operation and Features

3.1 Functional Description

The **L301kc** is a high resolution camera which employs a tri-linear CCD-sensor chip designed for color scanning. The tri-linear sensor contains three lines of photosensitive elements (pixels) with 2098 pixels per line. One line is covered with a red filter, one line with a green filter and one line with a blue filter to provide spectral separation.

Exposure time is normally controlled via an externally generated trigger signal (ExSync). The ExSync signal facilitates periodic or non-periodic pixel readout.

When exposure is controlled by an ExSync signal, exposure time can be edge-controlled, level-controlled, or programmable. In edge-controlled mode, charge is accumulated over the full 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 of accumulated charges. In programmable mode, exposure time can be programmed to a predetermined 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 signal is used to control exposure and charge readout. When operating in free-run, the camera outputs lines continuously.

At readout, accumulated charges are transported from each line of pixels to a separate shift register (see Figure 3-1). As charges move out of the shift registers, they are converted to voltages proportional to the amount of accumulated charge. The shifts are 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 10 bit, Analog-to-Digital Converter (ADC).

Depending on the spatial correction settings, the digitized data from the first two color channels is held in a temporary memory (FIFO) until the corresponding data for the third channel arrives (see Section 3.5). When the red, green and blue information for the first pixel is complete, the digitized video data is transmitted from the camera to the frame grabber using a format compatible with the Camera Link standard (see Section 2.5 for details).

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

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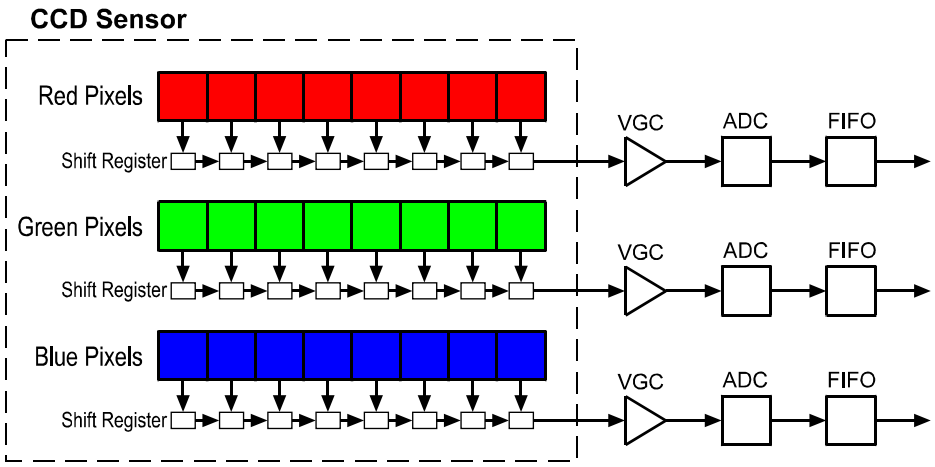


Figure 3-1: Pixels and Shift Registers

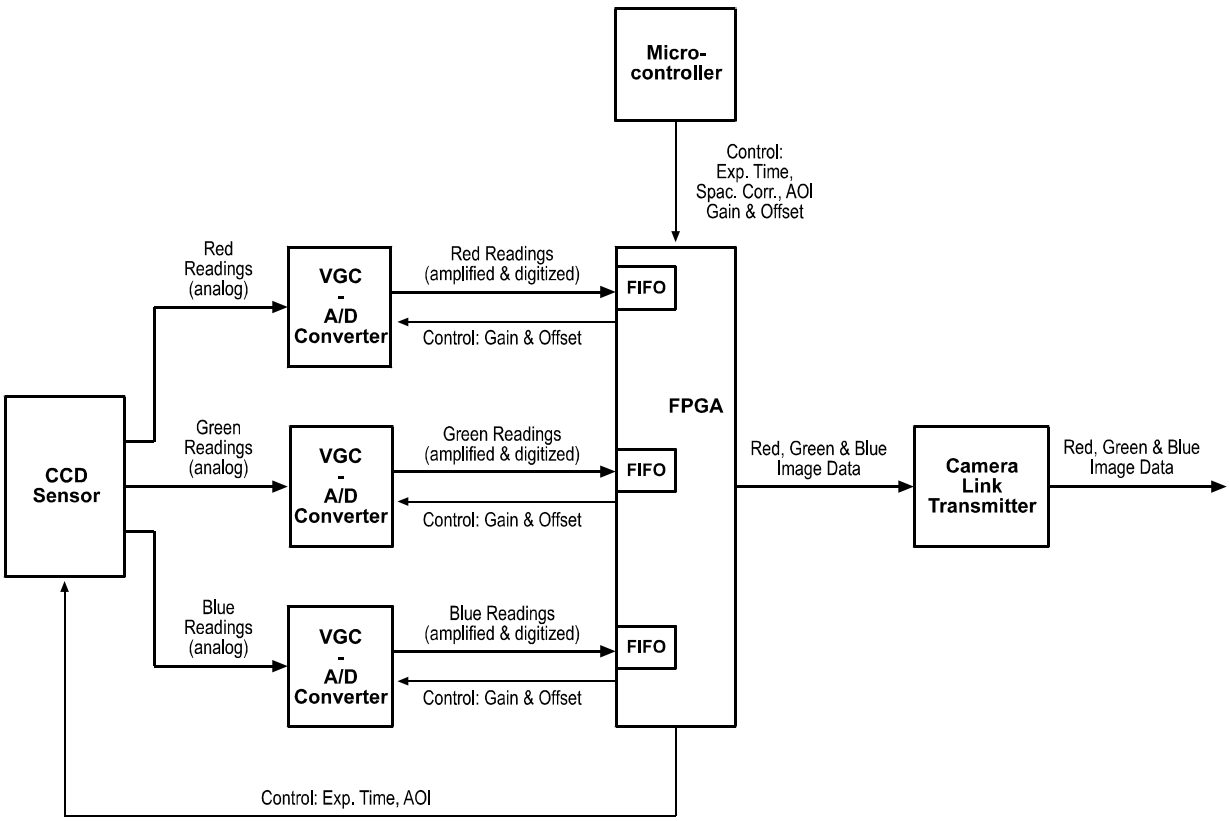


Figure 3-2: **L301kc** Block Diagram

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3.2 Exposure Time Control Mode Basics

The **L301kc** 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

In ExSync operation, the camera's line rate and exposure time are controlled by an externally generated (ExSync) signal (see Section 2.4).

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 (see Section 2.4.1).

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 actual start of exposure is 1.76 µs later than the rise of the ExSync signal. The line is read out and transferred on the rising edge of ExSync. (see Figure 3-3.)

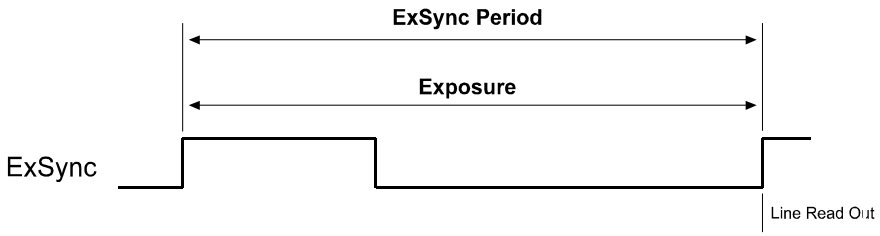


Figure 3-3: ExSync, Edge-Controlled Mode

- 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 actual start of exposure is 0.050 µs later than the fall of the ExSync signal. The actual length of the exposure time will be equal to the ExSync signal low time plus 1.76 µs. The line is read out and transferred on the rising edge of the ExSync signal (see Figure 3-4).

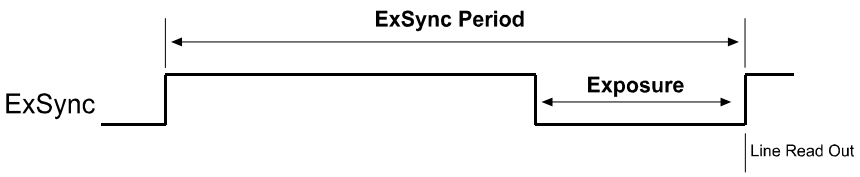


Figure 3-4: ExSync, Level-controlled Mode

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- In **ExSync**, **programmable** mode, the rising edge of ExSync triggers exposure and charge accumulation for a pre-programmed period of time.
  The actual start of exposure is 0.385 µs later than the rise of the ExSync signal. The line is read out and transferred at the end of the pre-programmed period. The falling edge of ExSync is irrelevant (see Figure 3-5).

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

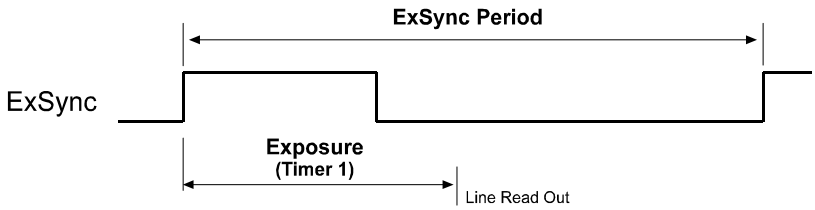


Figure 3-5: ExSync, Programmable Mode

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.

3.2.1.1 Recommendations for ExSync Controlled Operation

When using ExSync controlled operation, several general guidelines must be followed:

- ExSync is edge sensitive and therefore must toggle.
- The minimum ExSync period is 1/Maximum line rate.

  (Depending on whether spatial correction is used, this period is either 125 µs (with spatial correction enabled) or 108.7 µs (with spatial correction not enabled)).
- The ExSync signal must remain high for at least 0.35 µs.
- There must be a minimum of 0.1 µs between the end of line transfer and readout of the next line (see Figure 2-4 and Figure 2-5).
- The minimum exposure time is 1 µs.

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3.2.2 Free Run

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. The control signal period is equal to Timer 1 plus Timer 2.

When the camera is operating in free-run, the length of the control signal period determines the camera’s line rate.

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

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 3-6.

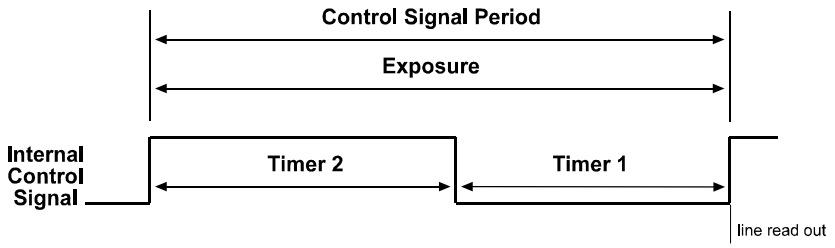


Figure 3-6: Free-run, Edge-controlled Mode

- 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 3-7.

  In this mode, the exposure time can be programmed as desired by varying the setting of the “Timer 1” parameter.

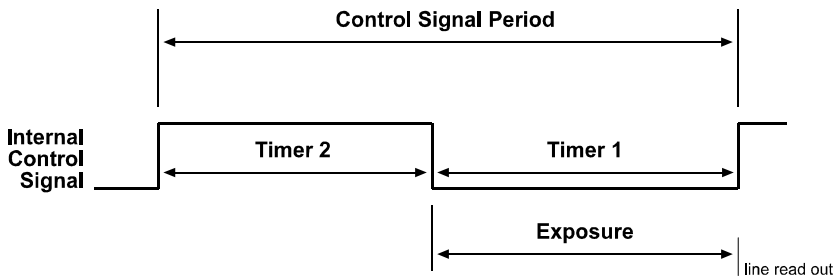


Figure 3-7: Free-run, Programmable Mode

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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 on the Exposure Tab.

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.

3.2.2.1 Recommendations for Free-run Controlled Operation

When using free-run controlled operation, a few 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.
- The sum of Timer 1 plus Timer 2 must be greater than 1/ Maximum line rate.

  (Depending on whether spatial correction is used, the maximum line rate is either 8.0 kHz (with spatial correction) or 9.2 kHz (without spatial correction)).
- The minimum line rate must not be lower than 1 kHz.
- The Timer 1 minimum (minimum exposure time) is 0.125 µs.
- The Timer 2 is minimum 4 µs.



When using binary commands to set Timer 1 and Timer 2, the timer values are determined by a multiplier. See Sections 4.2.4.3 and 4.2.4.4 for more details before you attempt to set these timers with binary commands.

3.2.3 Max Line Rate Exceeded Error Condition

The camera's maximum line rate is 8.0 kHz with spatial correction enabled or 9.20 kHz without spatial correction enabled. The maximum line rate can be exceeded, by:

- cycling the ExSync signal too quickly during ExSync controlled operation (see Section 3.2.1)
- operating in Free-run with the sum of Timer 1 plus Timer 2 set too low (see Section 3.2.2)

If the camera's maximum line rate is exceeded, the camera will enter an error condition and the camera status indicator (see Section 3.11) will show that the error is present. Also, one or more of the lines in the sensor will begin to output a value of zero for all of the pixels in the line. If at least one of the lines in the sensor is outputting a value of zero for all pixels, then the camera should be regarded as in the max line rate exceeded error condition. The error condition can be cleared by lowering the line rate below the maximum and then reading the camera's status. Reading the status resets the error condition.

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You can read the status 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 Camera Status indicator in the Camera Information parameter group to check the camera status.

With binary commands, you use the Camera Status command (see Section 4.2.9).



Reading the camera status will reset the error condition. To be sure that you are no longer exceeding the maximum line rate, you should capture a few lines and then read the status a second time. If the line rate is now correct, the “line rate exceeded error” will not be indicated on the second reading.

3.3 Video Data Output Modes

The **L301kc** can output video data using five different modes:

- 20 MHz 8 Bit RGB mode
- 60 MHz Single Pixel 10 Bit mode
- 60 MHz Single Pixel 8 Bit mode
- 40 MHz Dual Pixel 10 bit mode
- 40 MHz Dual Pixel 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 **L301kc** 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.

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3.5 Spatial Correction

3.5.1 What is Spatial Correction?

As shown in Figure 3-8, the sensor used in the **L301kc** has three lines of pixels and the lines are spaced 112 µm apart center-to-center.

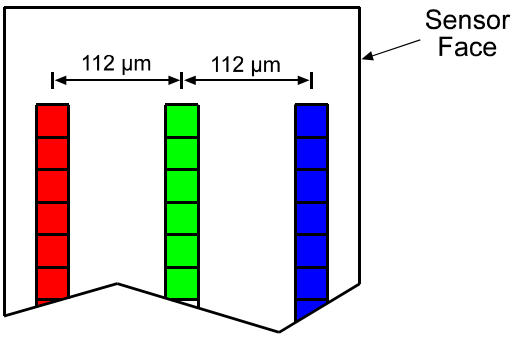


Figure 3-8: **L301kc** Sensor Face

Due to the spacing between lines, each line will have a different line of view on any object that is passing the camera, as shown in Figure 3-9. Whenever a line capture is triggered, all three lines in the sensor are exposed simultaneously. This means that for a single exposure, each line in the sensor captures a different area on the object.

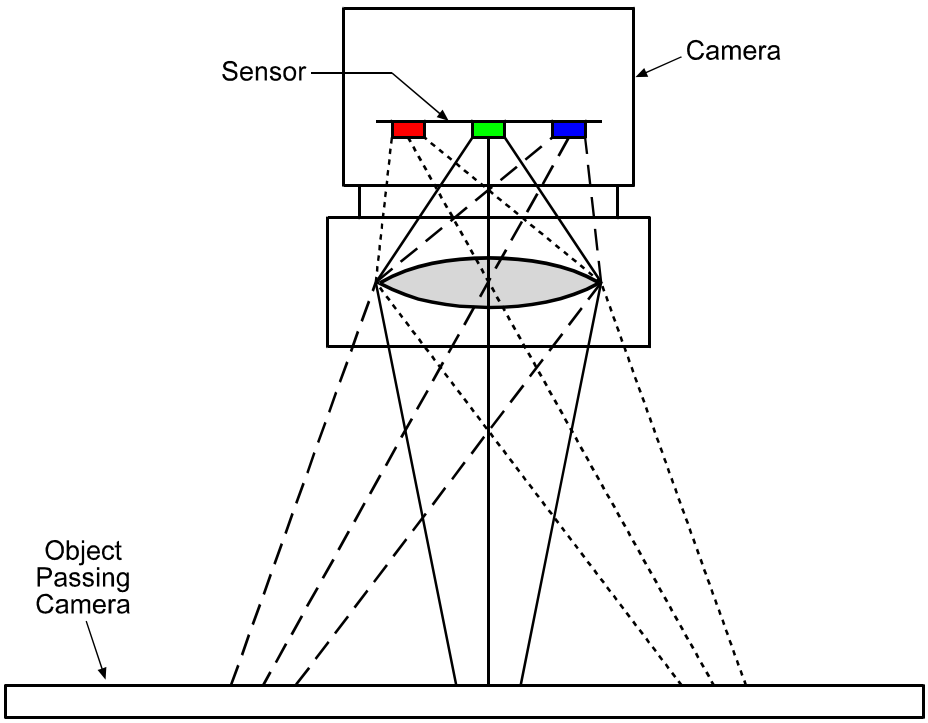


Figure 3-9: Field of View for Each Line

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Now, let's consider a single, small area on an object passing the camera and let's call it area A. Figure 3-10 illustrates that as the object passes the camera, area A will fall into the line of view of the red line, of the green line, and of the blue line at three different times. This means that the red information for area A, the green information for area A, and the blue information for area A will be collected during three different line captures. So in order to get full RGB information for area A, we must combine information from three different line captures. This need to combine information from three different captures to get full color information is known as spatial correction.

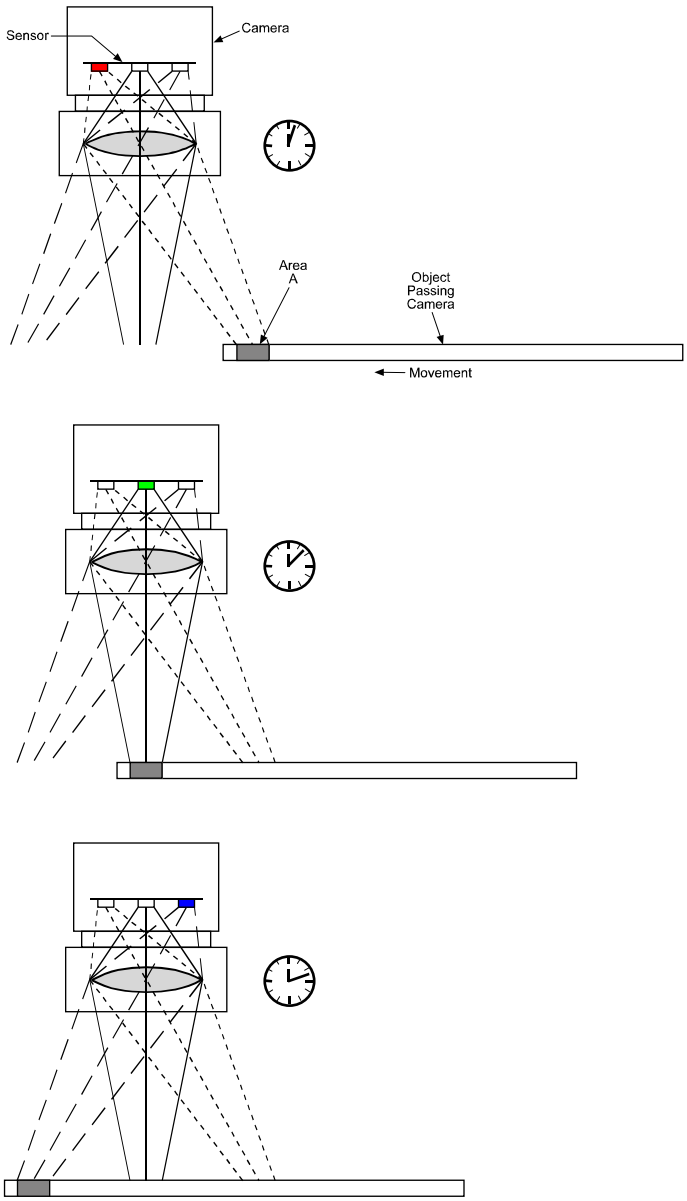


Figure 3-10: A Single Point Captured on Three Different Exposures

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To better understand the concept of spatial correction, let's consider a simple example. In our example, we will make the following assumptions:

- The optics and the distance between the camera and the conveyor have been arranged so that we have a 1 to 10 magnification. This means that an area of 0.14 mm x 0.14 mm on the object will create a 14 µm x 14 µm image on one pixel.
- Each step of the encoder represents a 0.14 mm movement of the conveyor. (This means that the image on the sensor will move 14 µm for each step of the encoder).
- We trigger a line capture on each step of the encoder.

Now, consider a single 0.14 mm wide area on the object and call this area A. Assume that the image of area A is falling directly on the red line of the sensor and that we have just performed a line capture. In order to move the image of area A from the line of view of the red sensor line to the line of view of the green sensor line, we will need 8 steps of the encoder. That is:

8 steps x 0.14 mm/step x 1/10 magnification = 112 µm movement of the image on the sensor

(112 µm is the exact center-to-center spacing between lines in the sensor)

To move the image of area A from the green sensor line to the blue sensor line, we will need 8 more steps of the encoder. Remember that we are performing a line capture on each encoder step.

To get full RGB data for area A, we must take the blue line data and combine it with the green data from 8 line captures earlier and the red data from 16 line captures earlier. In order to do this, the data from the last 17 line captures must be stored in the camera and the camera must be able to combine the information from the appropriate line captures.

Figure 3-11 sums up the line captures that must be combined to get full RGB data for area A. It also shows what must be done to get full color information for area B, that is, a 0.14 mm area on the object immediately after area A.

A parameter called the *Spatial Correction Delay in Lines* is used to tell the camera which line captures should be combined (see Section 3.5.5). In the case of our example, this parameter should be set to 8. This setting would tell the camera to combine the blue line capture with the green data from 8 line captures earlier and the red data from 16 line captures earlier

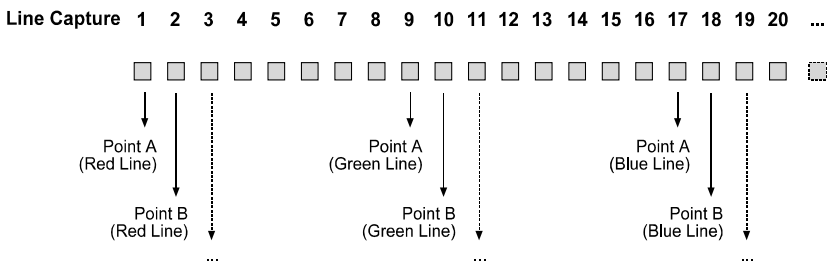


Figure 3-11: Sequence of Exposures and Line Readouts for Point A and Point B

Keep in mind that if the object is passing the camera in one direction, its image will cross over the red line first, the green line second, and the blue line third. If the object is passing the camera in the opposite direction, its image will cross over the blue line first, the green line second and the red line third. In order to properly combine the line captures, the camera must know which way the image is crossing the sensor. A parameter called the *Spatial Correction Starting Line* is used to tell the camera how the image is crossing the sensor (see Section 3.5.5 for more information)

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3.5.2 Camera Operating Requirements for Proper Spatial Correction

To achieve proper spatial correction, certain camera operating requirements must be met.

Exposure Start Control

Exposure start must be triggered with an ExSync signal.

Use of the programmable exposure mode is strongly recommended to ensure uniform exposure.

The edge controlled or level controlled exposure modes can be used but only if the conveyor speed is 100% stable. If the conveyor speed is not stable, unacceptable variations in exposure time will result.

Output Mode

The camera must be set for an 8 bit output mode. Spatial correction is disabled when the camera is used in a 10 bit mode.

Test Images

The camera must not be set for test image one or for test image two. When either of these test images is active, the *Spatial Correction Delay in Lines* is automatically set to zero. This disables spatial correction.

IR Cut Filter

Because color filter arrays become transparent after 700 nm, use of a suitable IR cut filter is strongly recommended to maintain spectral balance.

If an IR cut filter is not used, the colors in the captured images may not match the colors in the object. For example, a green color in the object may appear brown in the captured image.

Lack of an IR cut filter can also result in very poor color separation. In some cases, captured images may appear to be almost monochrome because they do not provide enough color information to produce a full color image.

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3.5.3 System Design Requirements for Proper Spatial Correction

As explained in Section 3.5.1, spatial correction is used to align color information in the image. For a given area on the object to be captured correctly, its image must fall precisely on the red line, the green line, and the blue line in the sensor.

If spatial correction is being done correctly, the captured images will be sharp and clear as shown in the right side of Figure 3-12. If there are variations in the positioning of the image when it is captured by the red line, the green line, and the blue line, the captured images will include color “halos” as shown in the left side of Figure 3-12.

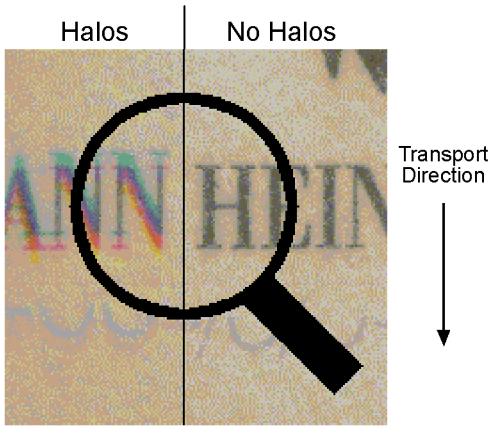


Figure 3-12: The Halo Effect

A list of system design requirements is given below. When these design requirements are met and with the camera’s shading correction parameters set properly, the image will show no color halos.

Position Encoder

You must use a position encoder to monitor the movement of the system’s conveyor. You must also use the encoder output to trigger line capture so that a given area of the object is captured when it falls precisely on the red line, the green line, and the blue line of the sensor.

If you do not use a position encoder, severe haloing in the transport direction will almost certainly result and the halos will vary in size and color.

If an encoder is used but it is not set-up correctly, haloing in the transport direction will result. In this case, the halos will be constant in size and color.

Conveyor Travel

The conveyor must travel in a straight line. If the conveyor motion is not straight, each line in the sensor will scan a different area of the object as shown in Figure 3-13. This situation will cause haloing that is perpendicular to the transport direction. The halos will vary in size and color.

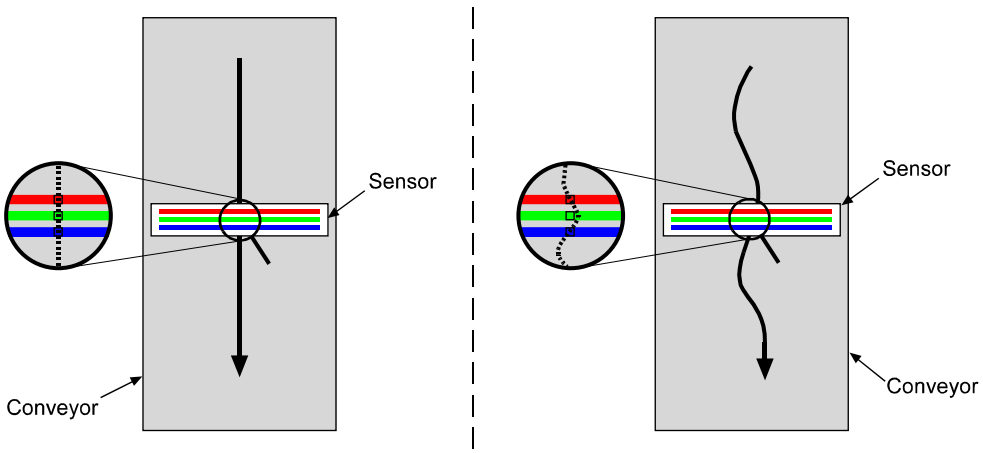


Figure 3-13: Conveyor Travel

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Sensor Perpendicularity

The sensor lines in the camera must be perpendicular to the conveyor's line of travel. If the sensor lines are not perpendicular to the line of travel, a slightly different area of the object will fall on each line as shown in Figure 3-14. This situation will cause haloing that is perpendicular to the transport direction. The halos will be constant in size. The color of the halo visible on one side of the elements in the captured image will be different from the color of the halo on the other side. For example, lettering in the captured image may show orange colored halos on the left side of each letter and blue colored haloes to the right side of each letter.

The color chart in Figure 3-15 shows the halo colorations associated with different degrees of non-perpendicularity. These halos will be apparent at black-to-white transitions.

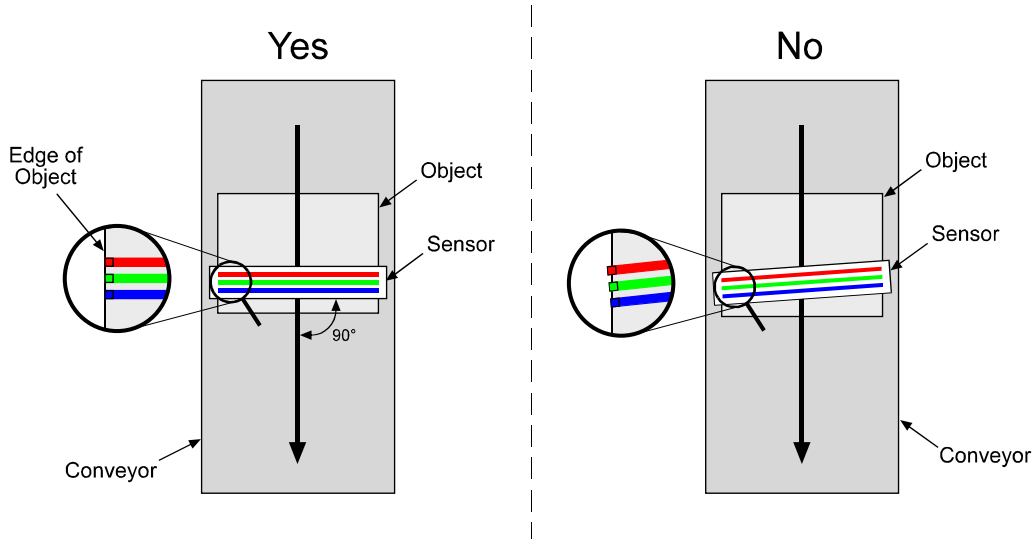


Figure 3-14: Sensor Perpendicularity

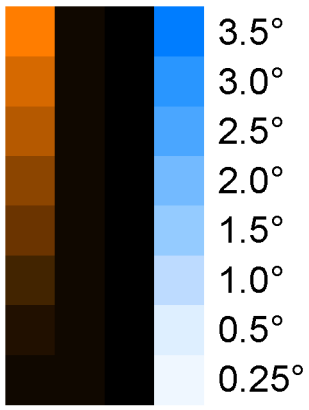


Figure 3-15: Halo Colorations for Various Degrees of Non-perpendicularity

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Sensor - Conveyor Parallelism

The face of the sensor in the camera and the surface of the conveyor should be in parallel planes. This condition should be met in order to ensure that all of the pixels in the sensor lines view the object at the same magnification.

If the camera is positioned so that the sensor is rotated on its long axis as shown in Figure 3-16, you will see haloing that is perpendicular to the transport direction. The color of the halo visible on one side of the elements in the captured image will be the same as on the other side. For example, lettering in the captured image may show orange colored halos on both sides of each letter. The haloing is less obvious on elements in the captured image that are closer to the center of the image.

If the camera is positioned so that the sensor is rotated on its short axis as shown in Figure 3-17, you will see haloing in the transport direction. The size and color of the halos in the captured image will change as you move from the X position toward the Y position on the object as indicated in the figure.

If your system design will not allow you to achieve sensor-conveyor parallelism, a telecentric lens setup can be used to overcome the problems that this will cause. A telecentric setup usually requires high illumination.

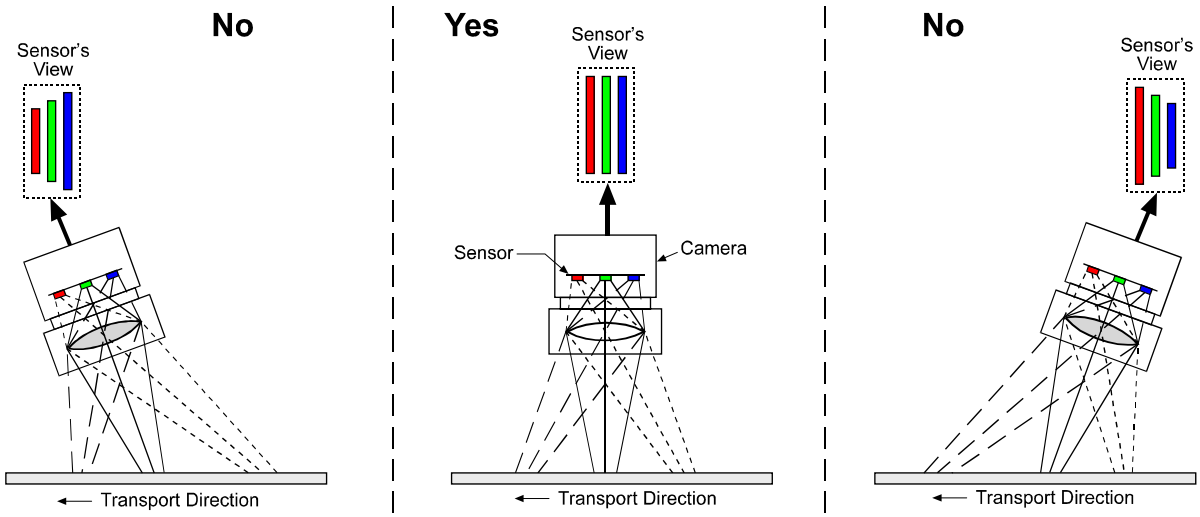


Figure 3-16: Sensor Rotated on its Long Axis

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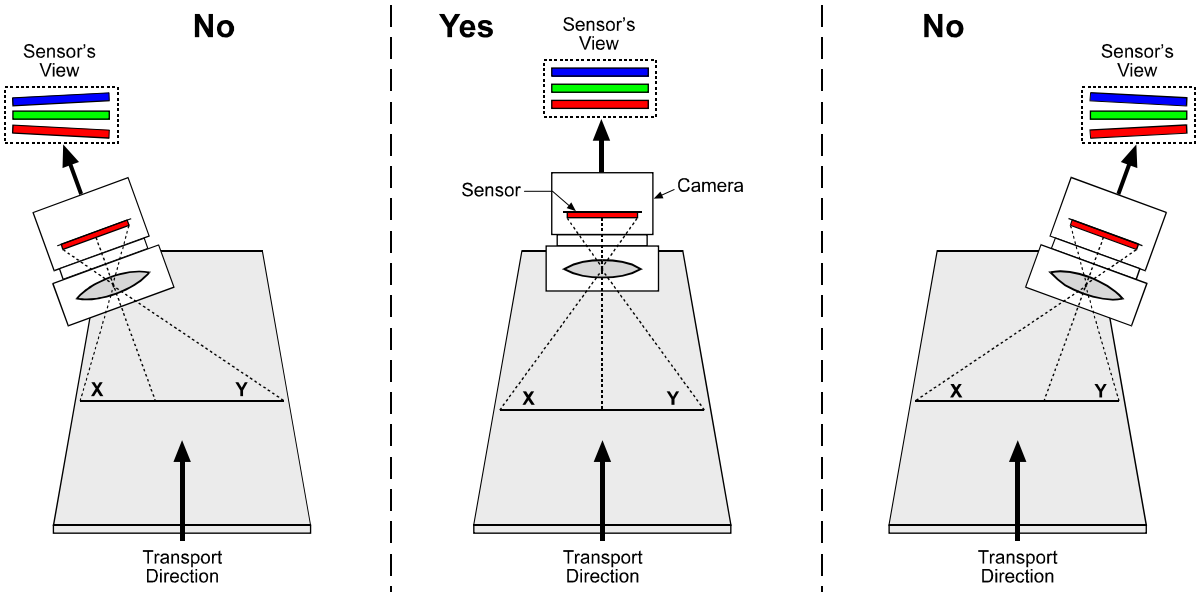


Figure 3-17: Sensor Rotated on its Short Axis

Object Height Differences

If the objects on the conveyor strongly differ in height, the lines in the sensor will view a short object from a different perspective than they view a tall object. To make sure that all objects are in perspective even if they strongly differ in height, use of a telecentric lens setup is recommended. A telecentric setup usually requires high illumination.

If the objects strongly differ in height and a telecentric setup is not used, haloing will be seen in the areas where sharp height gradients are present.

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3.5.4 System Design Calculations

Assuming that the camera operating requirements listed in Section 3.5.2 and the system design requirements met in Section 3.5.3 are met the formulas below can be used to calculate the basic design criteria for your system.

Magnification

$$\beta = \frac{112\ \mu m}{n \times \Delta y}$$

where: β = magnification

n = number of line captures needed to move the image from sensor line to sensor line (see Table 3-1)

Δy = distance the conveyor moves per line capture

Line of View

$$L = 29.372\ mm \times \frac{1}{\beta}$$

where: L = length of the line of view of each sensor line

Aspect Ratio

The aspect ratio of your captured images is determined by the value of “n” in the magnification equation. The value can be set from 1 to 16. If the value is set to 8, the aspect ratio of the captured images will be 1 to 1. The aspect ratios for various values of “n” are listed in Table 3-1. The aspect ratios in the table are width to height where width is in the direction of conveyor travel and height is along the axis of the sensor lines.

n	Ratio	n	Ratio	n	Ratio	n	Ratio
1	1/8	5	5/8	9	9/8	13	13/8
2	1/4	6	3/4	10	5/4	14	7/4
3	3/8	7	7/8	11	11/8	15	15/8
4	1/2	8	1/1	12	3/2	16	2/1

Table 3-1: Aspect Ratios for Values of n

Once the magnification has been determined, you can select a lens with the appropriate focal length and determine the correct distance between the camera and the conveyor.

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Example 1

Assume the following conditions:

- Conveyor movement per line capture = 0.2 mm
- Desired aspect ratio = 1/1
- Conveyor Width = 350 mm
- Length of Sensor Line = 29.372 mm (2098 pixels/line x 14 µm/pixel)
- With an objective lens in place, the direction of travel of the object that will cause the image to cross the red line in the sensor first.

Step 1 - Check Table 3-1 and note that for a 1/1 aspect ratio, n must be set to 8.

Step 2 - Calculate the magnification

$$\beta = \frac{112\ \mu m}{n \times \Delta y}$$

$$\beta = \frac{112\ \mu m}{8 \times 0.2\ mm}$$

$\beta = 0.07 = 1{:}14.29$

(β is the standard symbol for magnification and is usually expressed as a ratio)

Step 3 - Calculate the line of view of the sensor

$$L = 29.372\ mm \times \frac{1}{\beta}$$

$$L = 29.372\ mm \times \frac{1}{0.07}$$

$L = 419.60$ mm

Step 4 - Use the *Optics Recommendation Guide* and the *Makro.xls Spreadsheet* to select an appropriate lens and to determine the mounting distance for your camera.

Step 5- Make sure that the *Spatial Correction Starting Line* and the *Spatial Correction Delay in Lines* camera parameters (see Section 3.5.5) are set correctly. In this example, the starting line would be set to red and the delay in lines to 8.

Step 6 - Capture images

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Example 2

There is a second approach to calculating system design criteria that is less concerned with aspect ratio. This approach is more tuned towards matching the line of view of the sensor to the width of your conveyor. Example 2 illustrates this approach.

Assume the following conditions:

- Conveyor Width = 350 mm
- Conveyor Movement per Encoder Step = 0.2 mm
- Center to Center Spacing Between Sensor Lines = 112 µm
- Pixel Size = 14 µm
- Length of Sensor Line = 29.372 mm (2098 pixels/line x 14 µm/pixel)
- With an objective lens in place, the direction of travel of the object that will cause the image to cross the blue line in the sensor first.

Step 1 - Calculate the magnification needed to capture the full conveyor width on a sensor line.

$$\frac{\text{Sensor Line Length}}{\text{Conveyor Width}} = \frac{29.372\ \text{mm}}{350\ \text{mm}} = 0.08392$$

$$\frac{1}{0.08392} = 11.916$$

$\beta = 1{:}11.916$

(β is the standard symbol for magnification and is usually expressed as a ratio)

Step 2 - Calculate the conveyor movement necessary to move the image 112 µm.

$$112\ \mu\text{m} \times 11.916 = 1.335\ \text{mm}$$

Step 3 - Calculate the number of encoder steps needed to move the conveyor 1.335 mm.

$$\frac{1.335\ \text{mm}}{0.2\ \text{mm/step}} = 6.675\ \text{steps}$$

Since the encoder only counts in whole steps, we have two options, move the conveyor enough to generate six encoder steps or move the conveyor enough to generate seven encoder steps. In either of these cases, the movement of the conveyor will not result in the image moving exactly 112 µm. Therefore, we will need to adjust the magnification so that exactly 112 µm of image movement results. And we must also consider that a change in magnification will result in a change in the conveyor width that is viewed by each sensor line.

The calculations below look at the outcomes of our two options:

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Option 1

Step 1 - Calculate the conveyor movement that will generate six encoder steps:

$$6 \text{ steps} \times 0.2 \text{ mm/step} = 1.2 \text{ mm}$$

Step 2 - Calculate the magnification needed to make 1.2 mm of conveyor movement result in 112 µm movement of the image:

$$\frac{112 \text{ µm}}{1.2 \text{ mm}} = 0.0933$$

$$\frac{1}{0.0933} = 10.72$$

$$\beta = 1{:}10.72$$

Step 3 - Calculate the width of conveyor that will be viewed by each sensor line at this magnification:

29.372 mm x 10.72 = 314.87 mm

Option 2

Step 1 - Calculate the conveyor movement that will generate seven encoder steps:

$$7 \text{ steps} \times 0.2 \text{ mm/step} = 1.4 \text{ mm}$$

Step 2 - Calculate the magnification needed to make 1.4 mm of conveyor movement result in 112 µm movement of the image:

$$\frac{112 \text{ µm}}{1.4 \text{ mm}} = .08$$

$$\frac{1}{0.08} = 12.5$$

$$\beta = 1{:}12.5$$

Step 3 - Calculate the width of conveyor that will be viewed by each sensor line at this magnification:

29.372 mm x 12.5 = 367.15 mm

As you can see, if you choose to use six encoder steps to move the image 112 µm, you will require a 1:10.72 magnification and at this magnification, the field of view of each sensor line will be 314.87 mm. If you choose to use seven encoder steps to move the image 112 µm, you will require a magnification of 1:12.5 and at this magnification, the field of view of each sensor line will be

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367.15. Since it is usually more acceptable to have a field of view slightly larger than the conveyor, assume that we choose alternative 2.

Step 4 - Use the *Optics Recommendation Guide* and the *Makro.xls Spreadsheet* to select an appropriate lens and to determine the mounting distance for your camera.

Step 5 - Make sure that the *Spatial Correction Starting Line* and the *Spatial Correction Delay in Lines* camera parameters (see Section 3.5.5) are set correctly. In this example, the starting line would be set to blue and the delay in lines to 7.

Step 6 - Capture images

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3.5.5 Spatial Correction Settings

To properly set up spatial correction, two parameters must be defined: the *Spatial Correction Starting Line* and the *Spatial Correction Delay in Lines*.

Spatial Correction Starting Line

The *Spatial Correction Starting Line* setting informs the camera about the direction in which the object is passing the camera. There are two cases:

Case 1: When the object is passing the camera in the direction shown in Figure 3-18 and an objective lens is used with the camera, the spatial correction starting line parameter must be set to red line.

Case 2: When the object is passing the camera in the direction shown in Figure 3-19 and an objective lens is used with the camera, the spatial correction starting line parameter must be set to blue line.

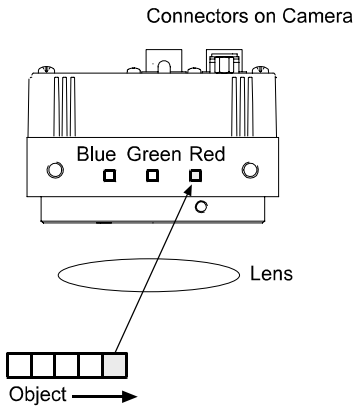


Figure 3-18: Starting Line = Red Line

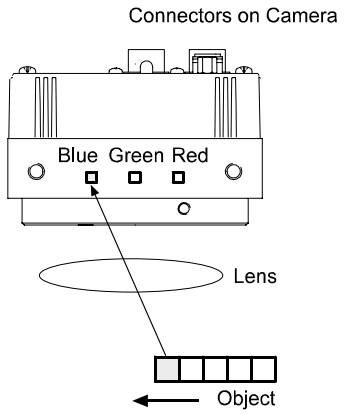


Figure 3-19: Starting Line = Blue Line

Spatial Correction Delay in Lines

The *Spatial Correction Delay in Lines* setting is used to determine which stored exposures will be combined in order to obtain full RGB data for an area on the image (see Section 3.5.1). For example, when the delay is set to 8 and the starting line is set to red line, the information from the blue line of pixels is combined with the green data from 8 exposures earlier and the red data from 16 exposures earlier.

	When the *Spatial Correction Delay in Lines* is set to 0, no line captures will be stored in the camera. The data from all three sensor lines will be transmitted out of the camera immediately after each completed exposure.

You can set the two spatial correction parameters 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 Spatial Correction Delay and the Spatial Correction Starting Line settings in the Output parameters group to set spatial correction.

With binary commands, you use the Spatial Correction Delay in Lines and Spatial Correction Starting Line commands (see Sections 4.2.4.5 and 4.2.4.6).

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3.6 Gain and Offset

The major components in the camera electronics include: a CCD sensor with three lines of pixels, a variable gain control (VGC) for each line, and an analog to digital converter (ADC) for each line (see Figure 3-1). The pixels in each line of the CCD sensor output an analog voltage signal when exposed to light. The analog voltage output from each line is amplified by a VGC and transferred to an ADC which converts the output to a digital signal.

Two parameters, gain and offset, are associated with each VGC. As shown in Figure 3-20 and Figure 3-21, increasing or decreasing the gain increases or decreases the amplitude of the signal that is input into the ADC. Increasing or decreasing the offset moves the signal up or down the measurement scale but does not change the signal amplitude.

For most applications, black should have a gray value of 1 and white should have a gray value of 254 (in 8 bit output modes) or 1023 (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 (minimum noise) and should be used if possible.

Internally, the **L301kc** processes red, green and blue pixels using three different VGCs. If the white balance of the images produced by the camera is not correct for your application, you can change the white balance by adjusting the gain on the red, green or blue pixels.

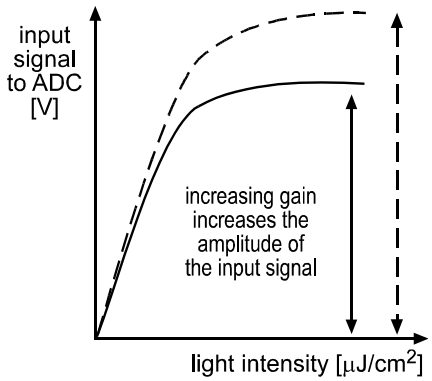


Figure 3-20: Gain

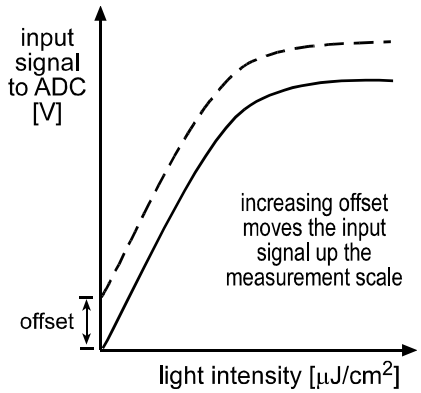


Figure 3-21: Offset

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

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3.6.1 Setting the Gain

As described on page 3-22, gain balance between the red line, the green line and the blue line is important to maintain a correct white balance.

Since the red line, green line and blue line each provide an individual spectral responsivity (see Figure 1-1 on page 1-3), gain must be adjusted separately for each line. Depending on the lighting conditions, the gain needed on the red line to obtain a certain responsivity will be different from the gain needed on the green line or the gain needed on the blue line.

Gain is adjustable and can be programmed on a decimal scale that ranges from 96 to 1023 (0x0060 to 0x03FF). The settings result in the following amplification:

Decimal Number (DN)	Hexadecimal	dB	Factor
96	0x0060	0	X1
1023	0x03FF	33.6	X42.8

Table 3-2: Gain Settings

If you know the decimal number (DN) setting for the gain on your camera, the equivalent decibel value can be calculated using the following equations:

When DN setting = 96 ... 511 $\quad$ Gain in dB $= 20 \log_{10}\left(\frac{658 + DN}{658 - DN}\right) - 2.55$

When DN setting = 512 ... 1023 $\quad$ Gain in dB $= .0354\ (DN) - 2.55$

To adjust the gain settings to the lighting conditions of your application, follow the procedure described below.

1. Set the red line gain, the green line gain and the blue line gain all to the decimal starting value of 96.
2. Out of the three lines, select the line that produces the highest output (= most responsive line).
3. Increase the gain of the most responsive line until the desired output is achieved on this line.
4. Adjust the gain on the other two line until a correct white balance is achieved.

You can set the gain 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 Red Gain, Green Gain, and Blue Gain settings in the Gain and Offset parameter group to set the gain on each line.

With binary commands, you use the Red Gain, Green Gain, or Blue Gain commands to set the gain on each line (see Sections 4.2.4.10, 4.2.4.12, and 4.2.4.14).

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3.6.2 Setting the Offset

The offset settings can be programmed on a decimal scale that ranges from 0 to 255 (which translates to a hexadecimal scale of 0x0000 to 0x00FF).

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

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

You can set the 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 Red Offset, Green Offset, and Blue Offset settings in the Gain and Offset parameter group to set the offset on each line.

With binary commands, you use the Red Offset, Green Offset, or Blue Offset commands to set the offset on each line (see Sections 4.2.4.11, 4.2.4.13, and 4.2.4.15).

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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 CCD sensor by 2 times, 4 times or 8 times. Section 3.7.1 describes how digital shift works when the camera is operating in 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.

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

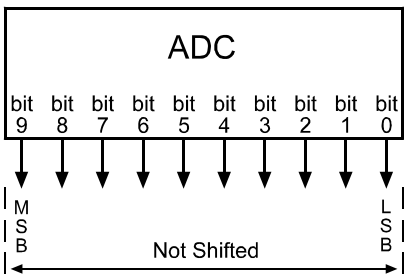
With the Camera Configuration Tool Plus, you use the Digital Shift setting in the Output parameters group to set digital shift.

With binary commands, you use the Digital Shift command (see Section 4.2.4.7).

3.7.1 Digital Shift in 10 bit Output Modes

No Shift

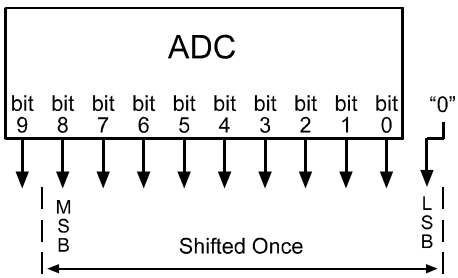
As mentioned in Section 3.1, the **L301kc** uses 10 bit ADCs to digitize the output from the CCD sensor. When the camera is operating in 10 bit output mode, by default, the camera transmits the 10 bits that are output from each ADC.



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.



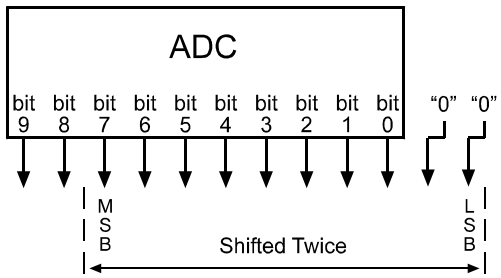
	Note that if bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 10 bit mode with no digital shift are all below 512. Since the shift once setting requires that the least significant bit always be "0", no odd gray values can be output. For this reason, the gray value scale will only include gray values of 2, 4, 6 and so forth. The absence of some gray values is commonly called "Missing Codes”.

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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.



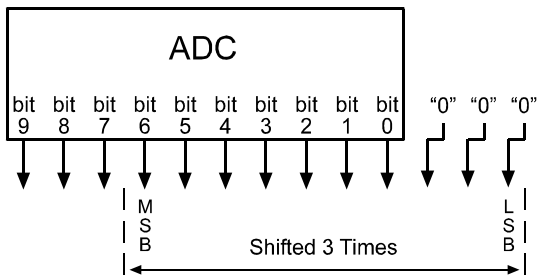
Note that if bit 9 or bit 8 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 10 bit mode with no digital shift are all below 256.

Since the shift twice setting requires that the two least significant bits always be "0", 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.

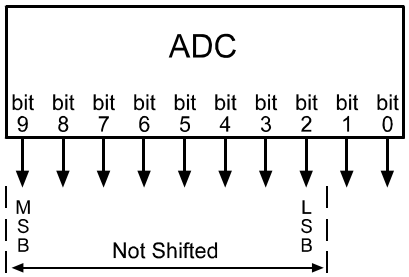
Since the shift three times setting requires that the three least significant bits always be "0", the gray value scale will only include every 8th gray value. For example, 8, 16, 24 and so forth.

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3.7.2 Digital Shift in 8 bit Output Modes

No Shift

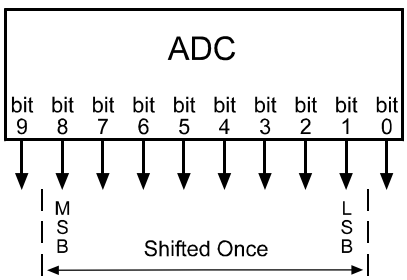
As mentioned in Section 3.1, the **L301kc** uses 10 bit ADCs to digitize the output from the CCD sensor. When the camera is operating in an 8 bit output mode, by default, it drops the least two significant bits from each ADC and transmits the 8 most significant bits (bit 9 through bit 2).



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.



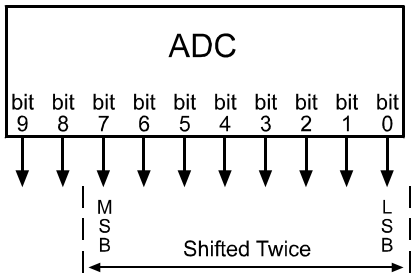
	Note that if bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 8 bit mode with no digital shift are all below 128.

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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.

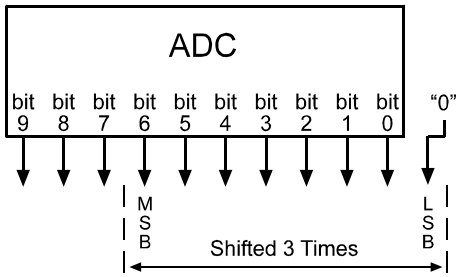


	Note that if bit 9 or bit 8 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 8 bit mode with no digital shift are all below 64.

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 always be "0", no odd gray values can be output. For this reason, the gray value scale will only include gray values of 2, 4, 6 and so forth.

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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 an 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 to put the camera in 10 bit output mode.
2. Use binary commands or the Features Tab 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 to put the camera in an 8 bit output mode.
2. Use the binary commands or the Features Tab 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.

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3.8 Area of Interest (AOI)

The area of interest feature allows you to specify a portion of the CCD array and during operation, only the pixel information from the specified portion is transferred out of the camera.

The size of the area of interest is defined by declaring a starting pixel and a length in pixels (see Figure 3-22). For example, if you specify the starting pixel as 10 and the length in pixels as 15, the camera will only output pixels 10 through 24 from each line in the array.

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

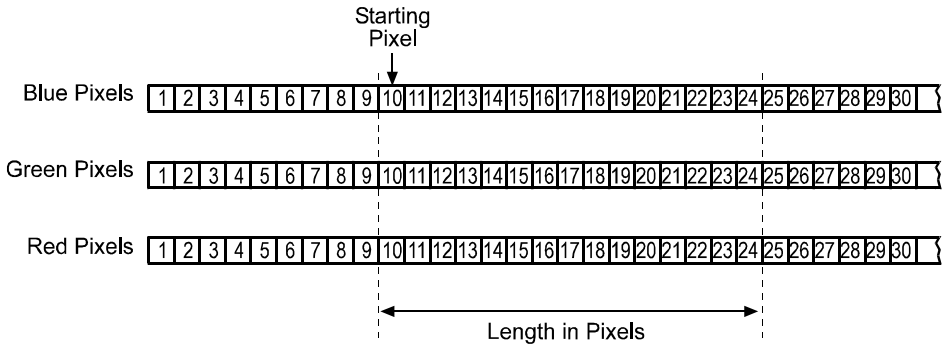


Figure 3-22: Area of Interest

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 10 and the length in pixels as 15, the line valid bit will become high on the clock cycle where pixel 10 is transmitted (see Figure 3-23). After all of the 15 pixels in the AOI have been transmitted, the line valid bit will become low on the clock cycle where pixel 24 is transmitted indicating that valid line data is no longer being transmitted.

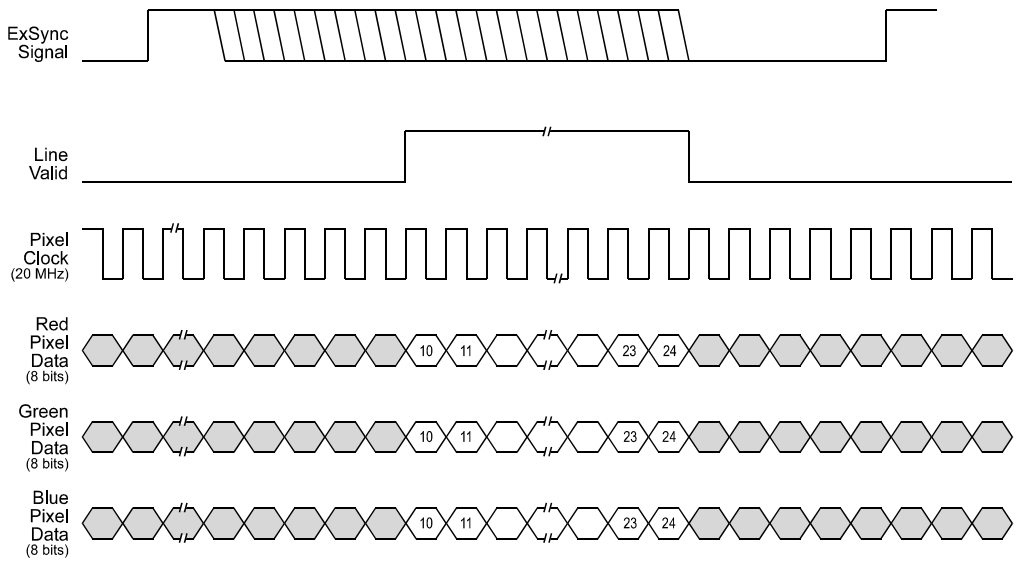


Figure 3-23: 20 MHz 8 Bit RGB Mode with Edge or Level Controlled Exposure

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	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 2098.

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 (see Sections 4.2.4.8 and 4.2.4.9).

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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. 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. The test image can be used for service purposes and for failure diagnostics. Six types of test image are available.

You can put the camera in test image 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 Test Image setting in the Output parameters 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 (Gray Gradient)

Test image one is formed with repeated gray scale gradients ranging from 0 to 255 (8-bit mode) or 0 to 1023 (10-bit mode). The first pixel in each line has a red value of 0, a green value of 0 and a blue value of 0. The second pixel has a red value of 1, a green value of 1, and a blue value of 1, and so on.

If the camera is set for an exposure mode that uses an ExSync signal, an ExSync signal is required to output a line on the test image. Multiple transitions of the ExSync signal will produce a two dimensional image as shown in Figure 3-24.

If the camera is set for free-run, each cycle of the camera's internal sync signal will trigger the output of a test image.



Figure 3-24: Test Image One (8-bit mode)

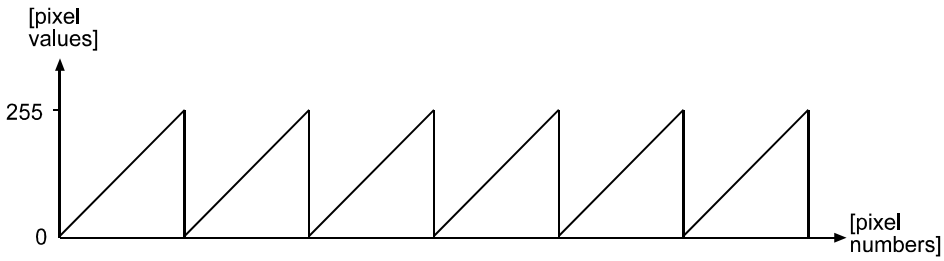


Figure 3-25: Formation of the Test Image (8-bit mode)

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3.9.2 Test Image Two (Moving Vertical Gray Gradient)

Test image two is formed with a vertical gray scale gradient that ranges from 0 to 255 (8-bit mode) or 0 to 1023 (10-bit mode) and repeats every 256 or 1023 pixels. The first pixel in the first line has a red value of 0, a green value of 0 and a blue value of 0. The second pixel has a red value of 1, a green value of 1, and a blue value of 1, and so on.

This pattern changes by one pixel each time the ExSync signal cycles. At pixel 1 of the second cycle, the new gradient starts with a red value of 1, a green value of 1, and a blue value of 1. The second pixel has a red value of 2, a green value of 2, and a blue value of 2, and so on.

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

3.9.3 Test Image Three (Moving Horizontal Gray Gradient)

Test image three consists of two parts. The left half of the image is formed with repeated vertical gray scale gradients ranging from 0 to 255. The first pixel in each line has a red value of 0, a green value of 0 and a blue value of 0. The second pixel has a red value of 1, a green value of 1, and a blue value of 1, and so on.

The right half of the image is formed with repeated horizontal gray scale gradients ranging from 0 to 255. This pattern moves up by one line each time the ExSync signal cycles.

Test image three is useful in 8-bit mode for determining if the spatial correction feature of the camera is working correctly (spatial correction is only available in 8-bit mode).

When the Spatial Correction Delay in Lines is Set to 0

When you view the output of a camera that is set for test image three and you set the spatial correction delay of the camera to 0 lines (no spatial correction), there should be no difference between the RGB values within the same pixel in the right half of the image. (Spatial correction has an effect only to the right half of the test image, the left half of the image can be ignored.)

When the Spatial Correction Delay in Lines is Set to Greater than 0

When you set the spatial correction delay of the camera to 8 lines, there should be a difference of 8 between the red value and the green value, and between the green value and the blue value within the same pixel in the right half of the image. The readings should be 0-8-16 (red-green-blue) 1-9-17, and so forth.

When you set the delay to 7 lines, there should be a difference of 7 values. The readings should be 0-7-14 (red-green-blue), 1-8-15, and so forth.



Figure 3-26: Test Image Three (8-bit mode)

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3.9.4 Test Image Four (Red Gradient)

Test image four is formed with repeated red gradients ranging from 0 to 255 (8-bit mode) or 0 to 1023 (10-bit mode). The first pixel in each line has a red value of 0, a green value of 0, and a blue value of 0. The second pixel has a red value of 1, a green value of 0, and a blue value of 0. The third pixel has a red value of 2, a green value of 0, and a blue value of 0, and so on.

3.9.5 Test Image Five (Green Gradient)

Test image three is formed with repeated green gradients ranging from 0 to 255 (8-bit mode) or 0 to 1023 (10-bit mode). The first pixel in each line has a red value of 0, a green value of 0, and a blue value of 0. The second pixel has a red value of 0, a green value of 1, and a blue value of 0. The third pixel has a red value of 0, a green value of 2, and a blue value of 0, and so on.

3.9.6 Test Image Six (Blue Gradient)

Test image four is formed with repeated blue gradients ranging from0 to 255 (8-bit mode) or 0 to 1023 (10-bit mode). The first pixel in each line has a red value of 0, a green value of 0, and a blue value of 0. The second pixel has a red value of 0, a green value of 0, and a blue value of 1. The third pixel has a red value of 0, a green value of 0, and a blue value of 2, and so on.

3.9.7 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 3-24.
- 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 a 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.

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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.

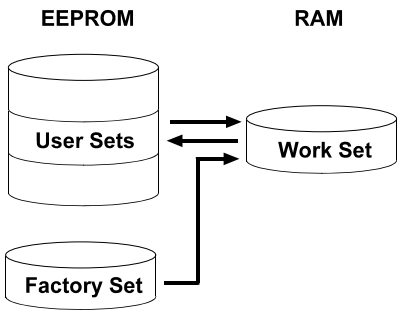


Figure 3-27: Config Sets

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).

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 (see Sections 4.2.8.1 through 4.2.8.3).

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3.11 Camera Status

The **L301kc** monitors its status by performing a regular series of self checks. The current status of the camera can be viewed in several ways:

- with the Camera Configuration Tool Plus (see Section 4.1). You check the Status indicator in the Camera Information parameter group to see if an error code is present.
- with binary commands. You use the Camera Status command to check if the camera has detected any errors (see Section 4.2.9).
- by checking the LED on the back of the camera. If certain error conditions are present, the LED will blink (see Section 6.1).

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4 Configuring the Camera

The **L301kc** comes factory-set so that it 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:

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

The **L301kc** is programmable via the Camera Link serial port on the frame grabber. Two methods can be used to change the camera'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 settings directly from your application using binary commands. Section 4.2 lists the binary commands and provides instructions for their use.

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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.

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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).

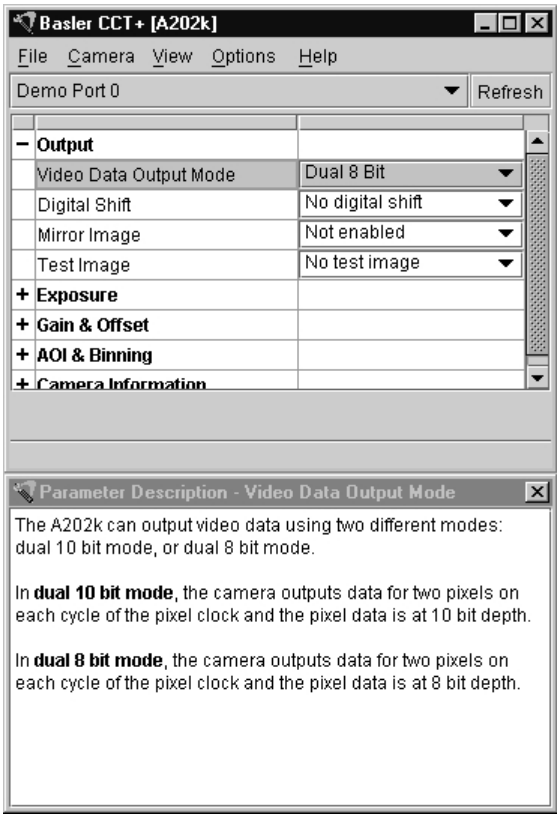


Figure 4-1: CCT+

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.

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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.

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4.2 Configuring the Camera with Binary Programming Commands

Configuration commands can be issued to the **L301kc** 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.basler-vc.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.

The **L301kc** will only work with the CCT+ version of the configuration tool. If you want to use the configuration tool with an **L301kc**, 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.

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4.2.1 Command Frame and Response Format

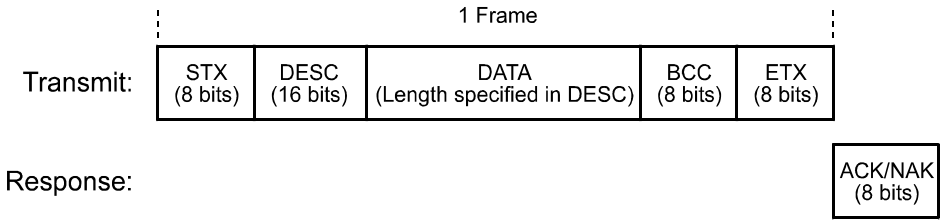


Figure 4-2: Representation of a Command Frame and Response

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

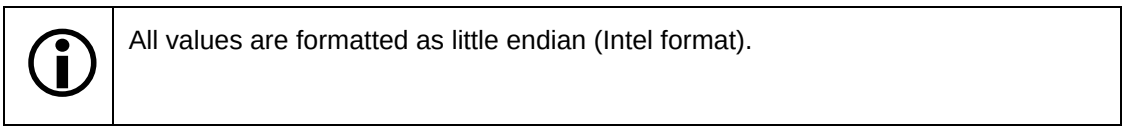
(The value of the ETX byte is always 0x03)

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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).

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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 sent 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 on pages 4-11 through 4-31, 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 allowable values.

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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 4-31. If you check the table on page 4-30, 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 4-30, 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 to 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 4-28, you will find that the ID for the command to copy the Work Set to 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 4-28, 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 4-28, 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.

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4.2.3.3 Calculating the Block Check Character

The block check character in any **L301kc** 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
```


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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
0x08	20 MHz 8 Bit RGB mode
0x09	60 MHz Single Pixel 8 Bit mode
0x0A	40 MHz Dual Pixel 8 Bit Mode
0x0B	60 MHz Single Pixel 10 Bit mode
0x0C	40 MHz Dual Pixel 10 Bit Mode

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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

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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 2	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:	The setting can range from 0x000002 to 0xFFFFFF. This 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 will 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 hexadecimal setting of 0x000020.			

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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:	The setting can range from 0x000040 to 0xFFFFFF. This 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 will be as shown below: setting = 4 µs / 0.0625 µs setting = 64 In this case, the setting would be 32 (decimal) which translates to a hexadecimal setting of 0x000040.			

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4.2.4.5 Spatial Correction Delay in Lines

Purpose:	To set the delay in lines for spatial correction or to read the delay in lines. See Section 3.5.3 for an explanation of spatial correction.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xAD	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xAD	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xAD	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the spatial correction delay in lines (see the table below).		

ID	Spatial Correction Delay in Lines
0x00	No spatial correction
0x01	One line
0x02	Two lines
0x03	Three lines
0x04	Four lines
0x05	Five lines
0x06	Six lines
0x07	Seven lines
0x08	Eight lines
0x09	Nine lines
0x0A	Ten lines
0x0B	Eleven lines
0x0C	Twelve lines
0x0D	Thirteen lines
0x0E	Fourteen lines
0x0F	Fiveteen lines
0x10	Sixteen lines

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4.2.4.6 Spatial Correction Starting Line

Purpose:	To define the spatial correction starting line or read the defined starting line. See Section 3.5.3 for an explanation of spatial correction.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xAE	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xAE	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xAE	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the spatial correction starting line (see the table below).		

ID	Spatial Correction Starting Line
0x00	Red line
0x01	Blue line

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4.2.4.7 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.

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4.2.4.8 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:	The starting pixel setting can range from 0x0000 to 0x0830 (0 to 2096). When using binary commands, the **actual** 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, 99 + 1 = 100.			

4.2.4.9 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:	The length in pixel setting can range from 0x0001 to 0x0832 (= 1 pixel to 2098 pixels).			

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4.2.4.10 Red Line Gain

Purpose:	To set the gain on the red line or to read the current red line gain setting. See Section 3.6 for details.			
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 red gain setting		
	Byte 2	High byte of red gain setting		
Data Range:	The red line gain setting can range from 0x0060 to 0x03FF which translates to a dB range of 0 dB to 33.6 dB.			

4.2.4.11 Red Line Offset

Purpose:	To set the offset on the red line or to read the current red line offset setting.			
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 red offset setting		
	Byte 2	High byte of red offset setting		
Data Range:	The red line offset setting can range from 0x0000 to 0x00FF (max. 63.75 least significant bits).			

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4.2.4.12 Green Line Gain

Purpose:	To set the gain on the green line or to read the current green line gain setting. See Section 3.6 for details.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x81	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x81	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x81	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of green gain setting		
	Byte 2	High byte of green gain setting		
Data Range:	The green line gain setting can range from 0x0060 to 0x03FF which translates to a dB range of 0 dB to 33.6 dB.			

4.2.4.13 Green Line Offset

Purpose:	To set the offset on the green line or to read the current green line offset setting.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x85	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x85	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x85	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of green offset setting		
	Byte 2	High byte of green offset setting		
Data Range:	The green line offset setting can range from 0x0000 to 0x00FF (max. 63.75 least significant bits).			

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4.2.4.14 Blue Line Gain

Purpose:	To set the gain on the blue line or to read the current blue line gain setting. See Section 3.6 for details.			
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 blue gain setting		
	Byte 2	High byte of blue gain setting		
Data Range:	The blue line gain setting can range from 0x0060 to 0x03FF which translates to a dB range of 0 dB to 33.6 dB.			

4.2.4.15 Blue Line Offset

Purpose:	To set the offset on the blue line or to read the current blue line offset setting.			
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 blue offset setting		
	Byte 2	High byte of blue offset setting		
Data Range:	The blue line offset setting can range from 0x0000 to 0x00FF (max. 63.75 least significant bits).			

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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 Bytes
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 vertical gray gradient)
0x03	Test Image 3 (moving horizontal gray gradient)
0x04	Test Image 4 (red gradient)
0x05	Test Image 5 (green gradient)
0x06	Test Image 6 (blue 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 0x07, 0xCF
Response:	None			
Data Format:	Byte 1	Low byte	0xCF is always used	
	Byte 2	High byte	0x07 is always used	

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4.2.7 Query Commands

4.2.7.1 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		

4.2.7.2 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		

4.2.7.3 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.			

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4.2.7.4 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.			

4.2.7.5 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.			

4.2.7.6 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.			

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4.2.7.7 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		

4.2.7.8 Read EEPROM Firmware Version

Purpose:	To read the EEPROM firmware version.			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x06	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0x06	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	Register Layout ID		

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4.2.7.9 Read Camera Temperature

Purpose:	To read the camera's internal temperature.			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x70	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x70	R/W-Flag 0	Data Length 1	Data 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

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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
0xFF	No active set

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4.2.8.2 Copy Work Set into 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

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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

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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	Reserved
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	The camera's maximum line rate has been exceeded.

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

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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 using:
   a) If you are using a Camera Link frame grabber, change the bit rate on the frame grabber's RS-644 serial port.
   b) If you are using the camera with a k-BIC, change the bit rate on your PC's RS-232 serial port.
4. Resume communication.

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

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

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5 Mechanical Considerations

5.1 Camera Dimensions and Mounting Facilities

The **L301kc** camera housing is manufactured with high precision. Planar, parallel, and angular sides guarantee precise mounting with high repeatability.

The **L301kc** camera is 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.

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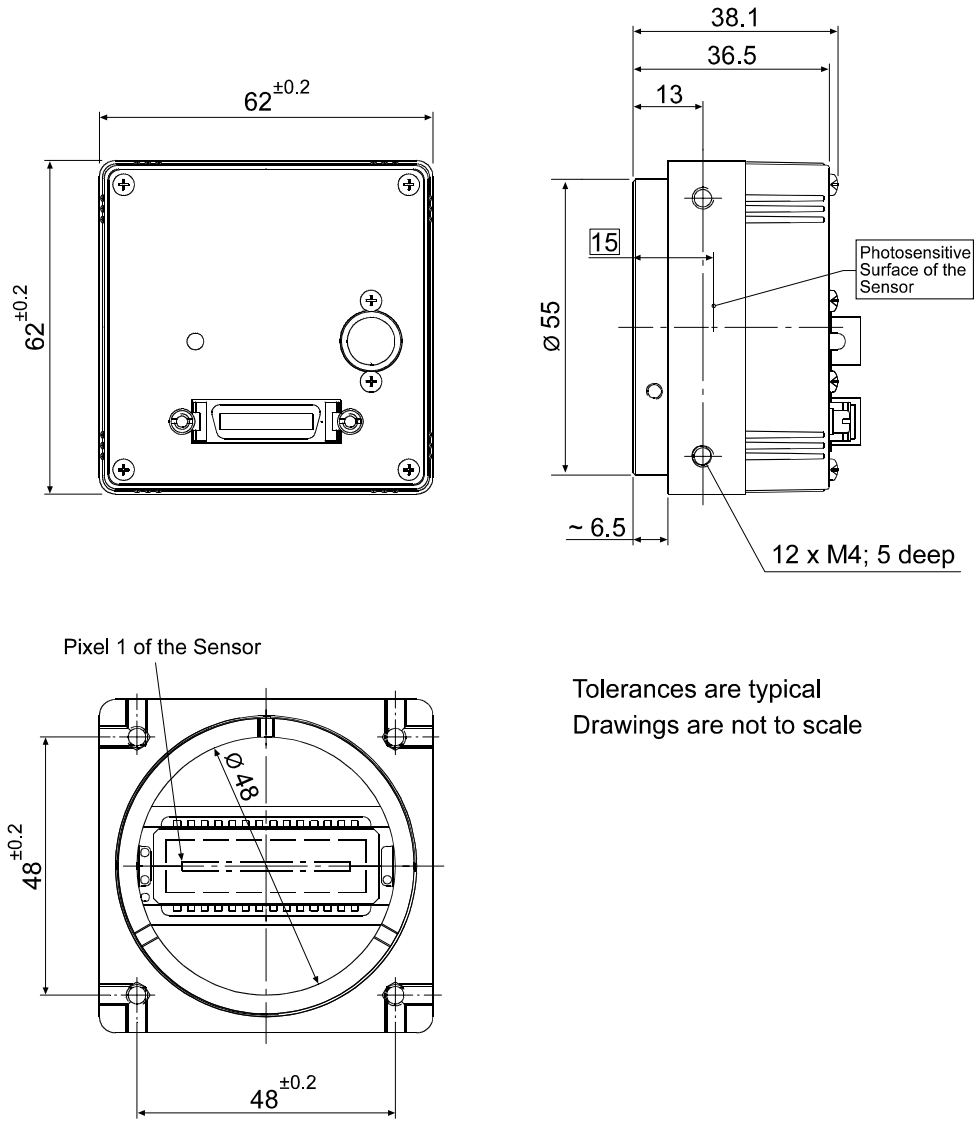
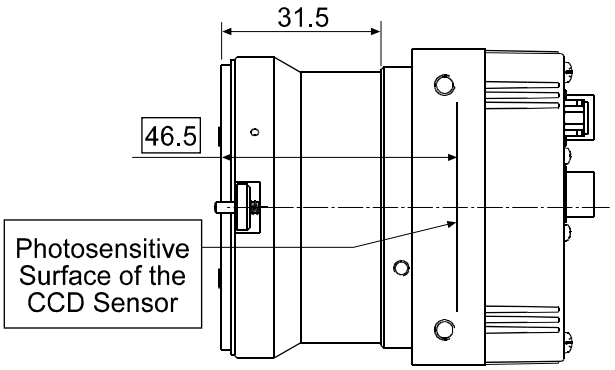


Figure 5-1: **L301kc** Mechanical Dimensions (in mm)

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5.2 F-Mount Adapter Dimensions



Drawing is not to scale

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

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5.3 Positioning Accuracy of the Sensor Chip

Positioning accuracy of the sensor chip is as shown in Figure 5-3.

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

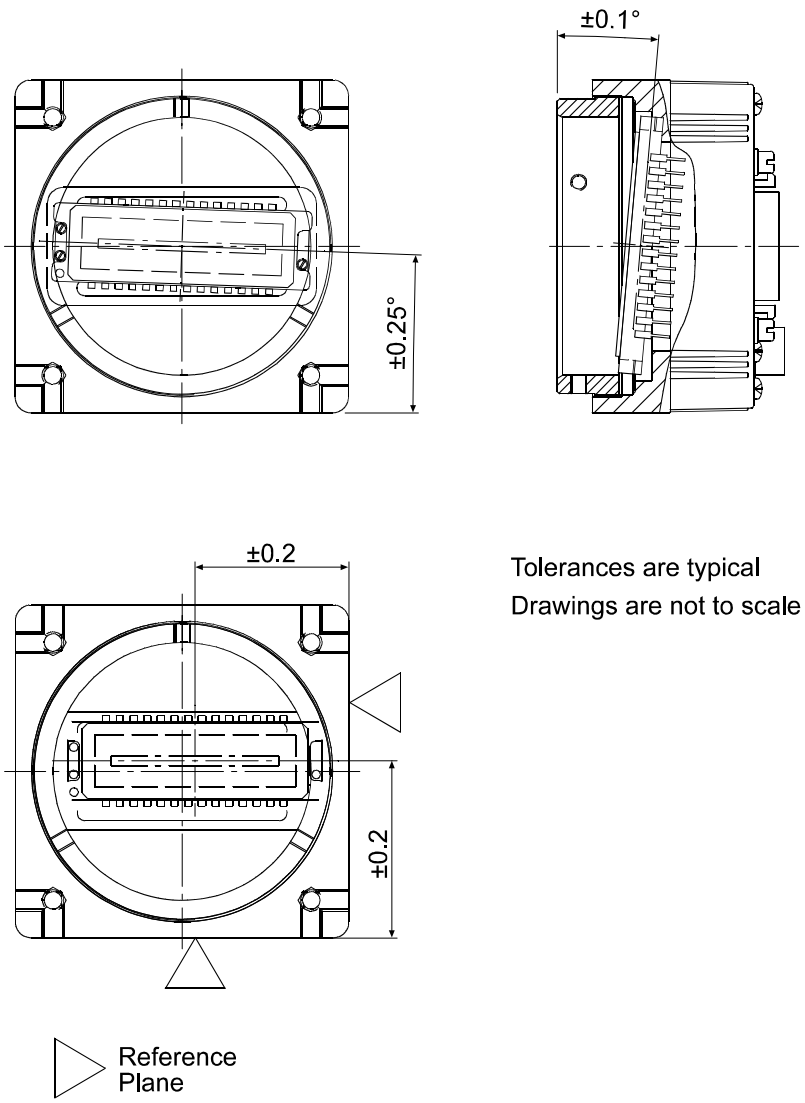


Figure 5-3: Sensor Positioning Accuracy (in mm or degrees)

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6 Troubleshooting

6.1 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 bootup is successful, the LED will then remain orange continuously.

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

LED	Description
On Continuous	The camera is OK.
3 blinks	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 blinks	The Work Set could not be stored into a User set. Please contact Basler support.
6 blinks	A User Set or the Factory Set could not be loaded into the Work Set. Please contact Basler support.
7 blinks	A valid list of commands was not available. Please contact Basler support.
8 blinks	The FPGA could not be configured. Please contact Basler support.

Table 6-1: Camera Status Indicators

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.

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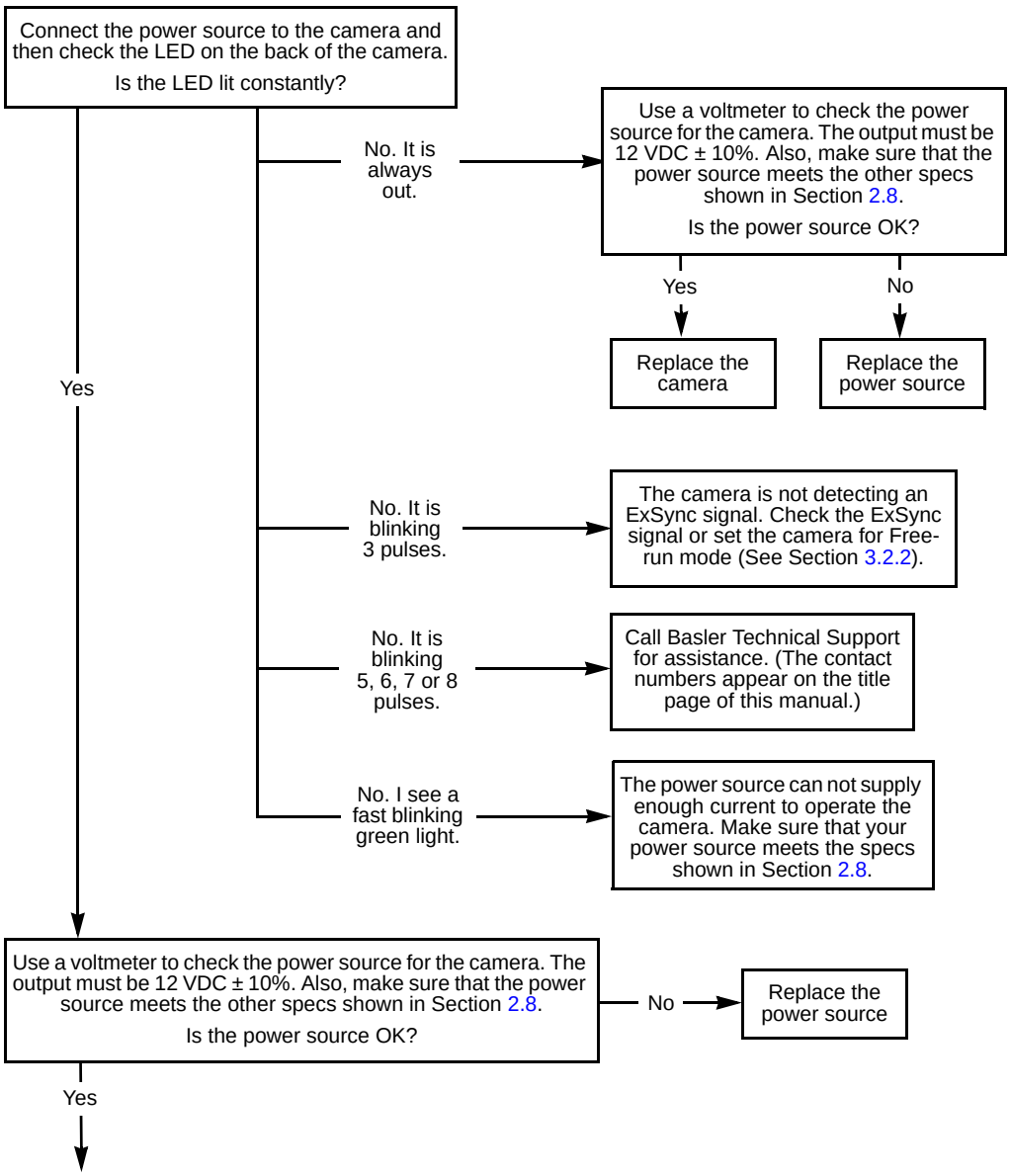
6.2 Troubleshooting Charts

The following pages contain several troubleshooting charts which can help you find the cause of problems 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.

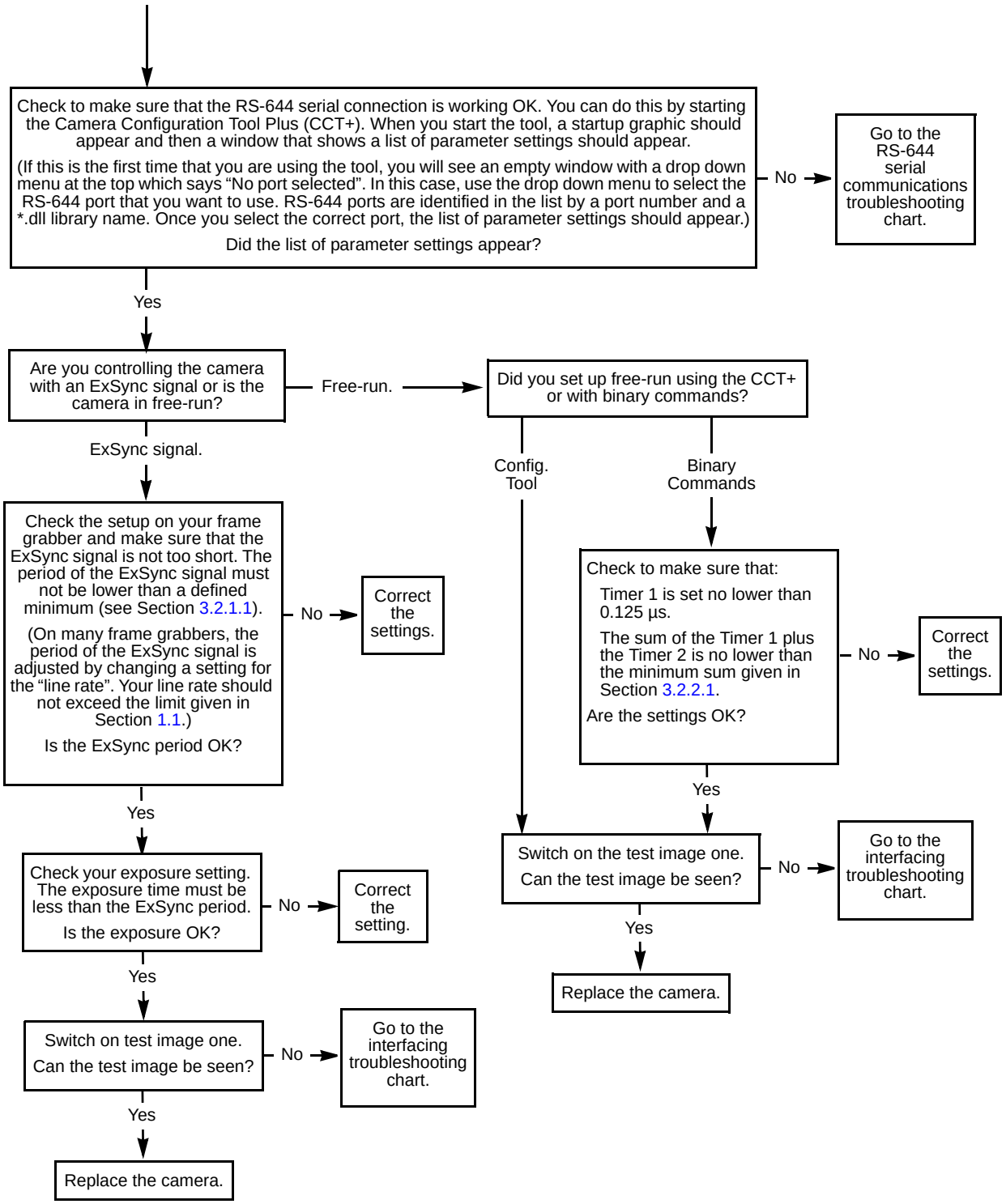
6.2.1 No Image

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 6.2.2.

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



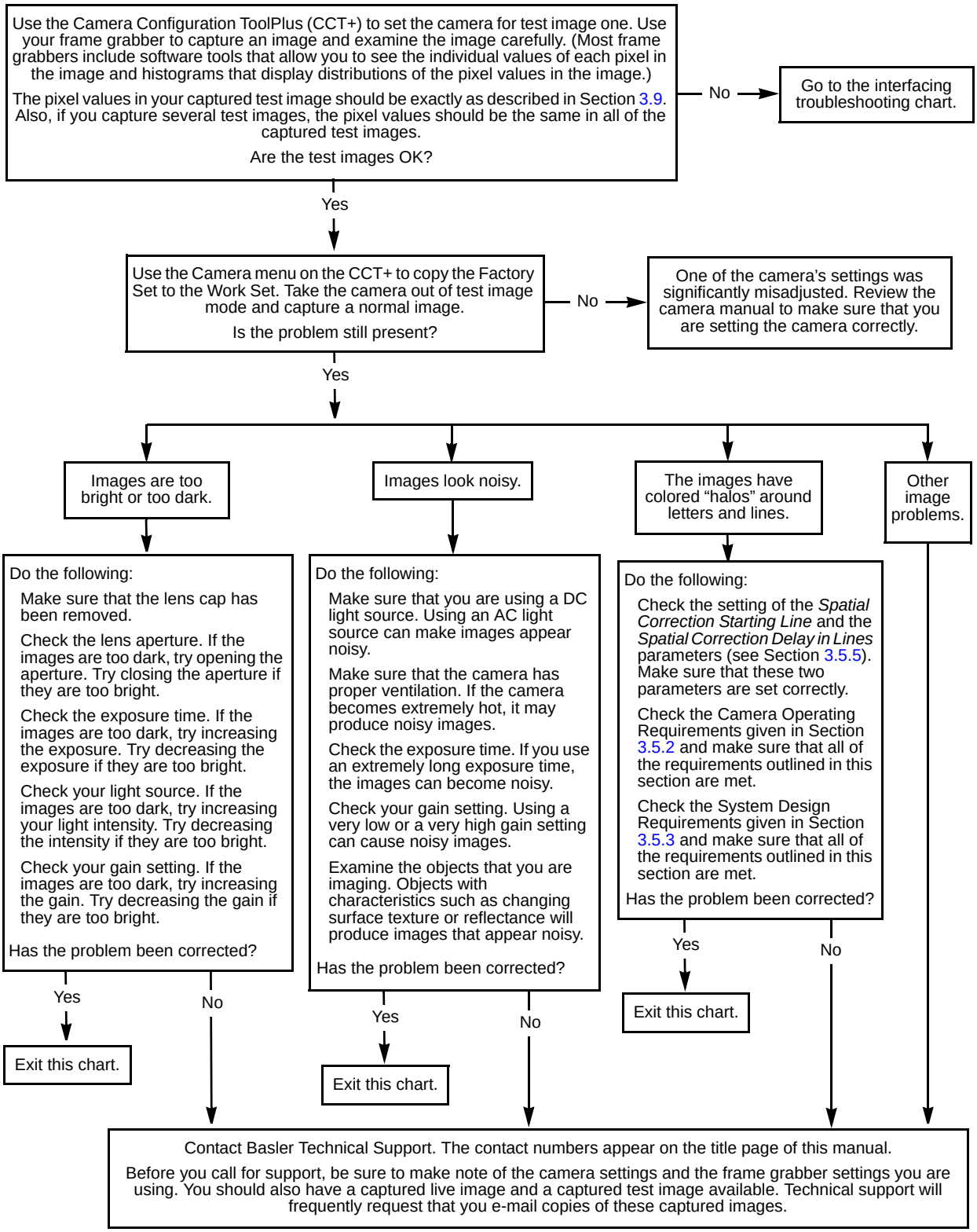
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6.2.2 Poor Quality Image

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 6.2.1.



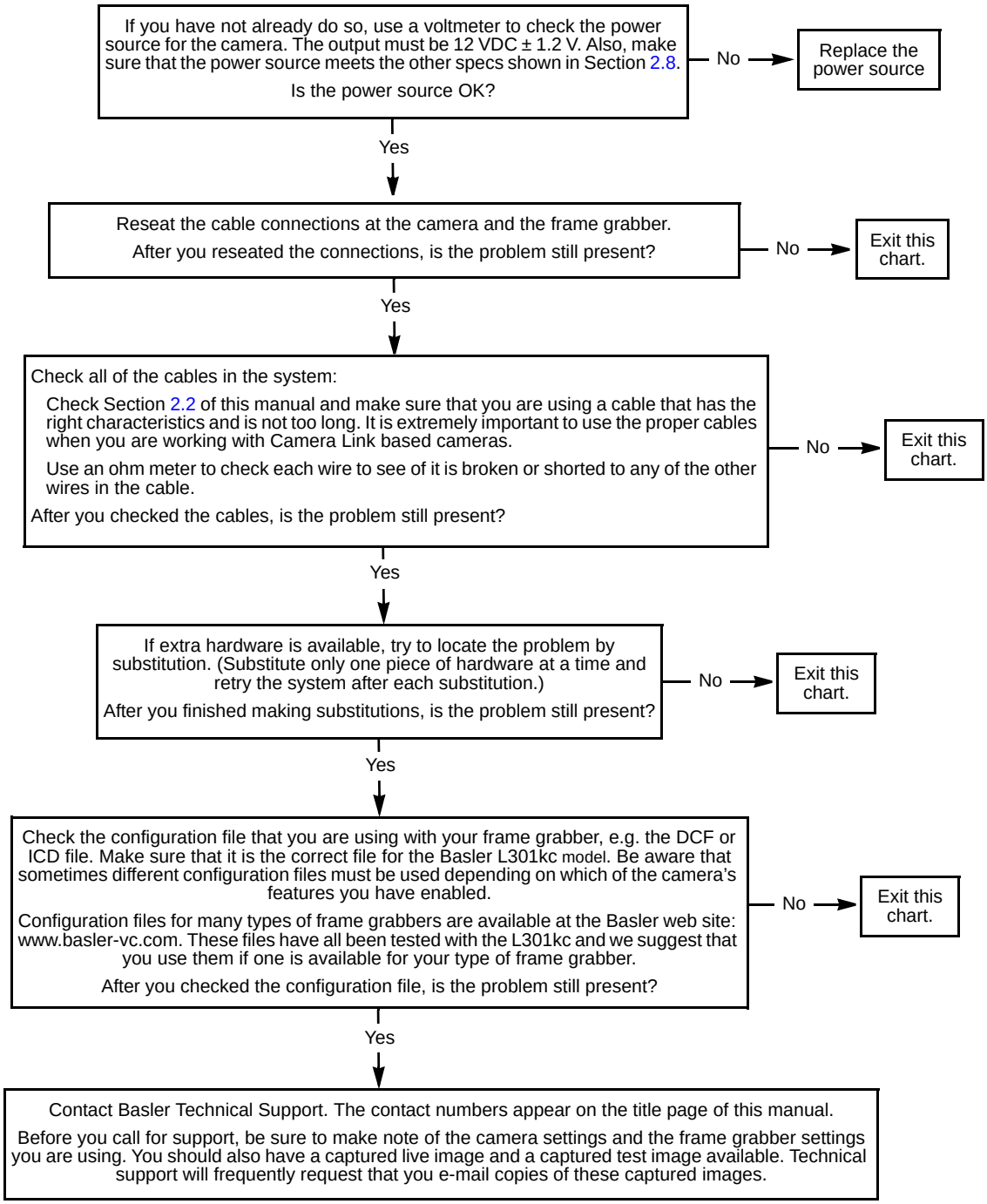
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6.2.3 Interfacing

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.



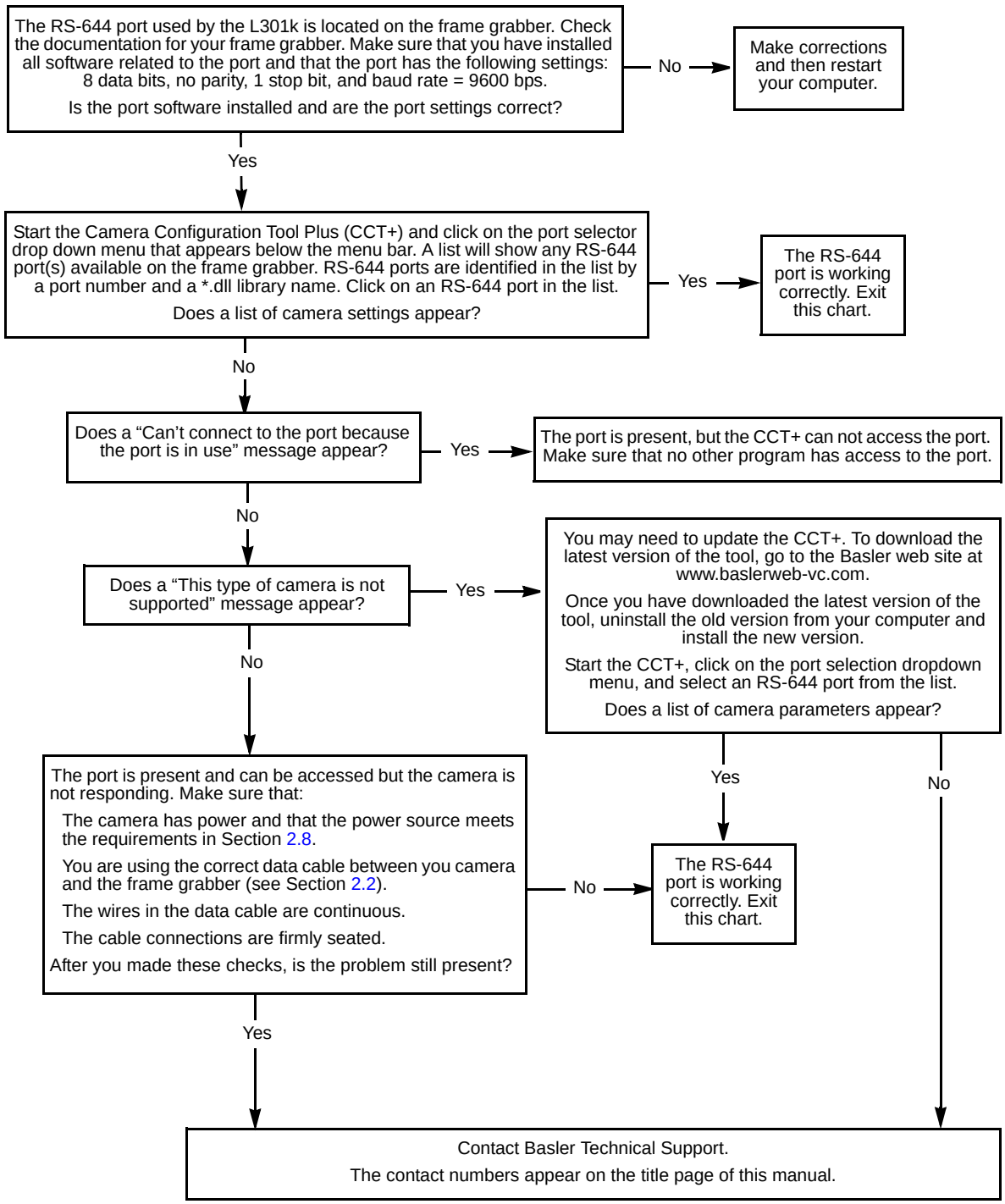
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6.2.4 RS-644 Serial Communication

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 (without a k-BIC)

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



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6.3 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 the next two pages, 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 title section of this manual.

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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:

_____

_____

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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, start the CCT+, select the File menu, and click Dump Current Settings to 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
  Red / Green / Blue: _____
- ☐ Offset:
  Red / Green / Blue: _____

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.

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Revision History

Doc. ID Number	Date	Changes
DA00051801	27 Mar 2002	Initial release covering prototype cameras only.
DA00051802	31 May 2002	Initial release covering series cameras.
DA00051803	7 Feb 2003	Revised to include instructions for using the Camera Configuration Tool Plus (CCT+).
DA00051804	29 May 2003	Revised the spectral responsivity graph on page 1-3.
DA00051805	1 Dec2004	Revised Table 2-3 and added cross references to clarify the dual pixel mode bit assignments. Revised Figure 2-3 to show which ports are assigned to each Camera Link transmitter and receiver. In Section 5.3, added sensor horizontal and vertical position tolerances referenced to the sides of the camera.
DA00051806	13 Jul 2007	Updated the cover page and the contact information page to the current standards. Added storage temperature and humidity specs to Section 1.2.1. Added warnings about not reversing input power polarity to Sections 1.3, 2.1.2, and 2.8. Corrected the connector part numbers in Section 2.1.3. Corrected the description of the camera reset command in Section 4.2.6. Corrected the steps shown in Section 4.2.10 for changing the serial communication bit rate. Added Section 6.3 that describes what information customers should gather before calling support.

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Feedback

We would like to get your feedback to help us improve our camera documentation. Please click on the link below to go to our web site and fill in our online documentation feedback form. Your input is greatly appreciated.

http://www.baslerweb.com/umfrage/survey.html

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