

Basler sprint



USER'S MANUAL FOR COLOR CAMERAS

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For customers in the USA

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 B 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.

Life support applications

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Basler customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Basler for any damages resulting from such improper use or sale.

Warranty Information

To ensure that your warranty remains in force, adhere to the following guidelines:

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.

Do not open the camera housing

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

Prevent ingress or insertion of foreign substances into the camera housing

Prevent liquid, flammable, or metallic substances from entering the camera housing. If operated with any foreign substances inside, the camera may fail or cause a fire.

Avoid electromagnetic fields

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

Transport in original packaging

Transport and store the camera in its original packaging only. Do not discard the packaging.

Clean with care

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 solvents or thinners to clean the housing; they can damage the surface finish.

For information about cleaning the sensor, see Section 1.8 on [page 18](#) ("Avoid dust on the sensor.").

Read the manual

Read the manual carefully before using the camera.

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1 Specifications, Requirements, and Precautions

This section lists the camera models covered by the manual. It provides the general specifications for each model and outlines the basic requirements for using the cameras.

This section also includes specific precautions that you should keep in mind when using the cameras. We strongly recommend that you read and follow the precautions.

1.1 Document Applicability

This User's Manual applies to sprint color cameras.



The number of available features and parameters depends on the camera version. Cameras with a lower or higher camera version ID number may have fewer features or have more features than described in this manual. Features on cameras with a lower or a higher ID number may not operate exactly as described in this manual.

There are two possibilities to see the camera version ID number for a sprint camera:

- by using the CCT+ or
- by using binary commands to read the Camera Version Inquiry register. (See Section 7.2.1 on [page 213](#) for an explanation of inquiry registers and Section 7.3 on [page 265](#) for information about using binary commands.)

To see the camera version ID number using the CCT+:

1. Double click the CCT+ icon on your desktop. The CCT+ window will open and the software will connect to your camera.
2. Scroll down until you find the **Camera Information** group heading. If there is a plus sign beside the Camera Information group heading, click on the plus sign to show the list of parameters in the group.
3. Find the parameter called **Camera Version**.
The last two numbers of this parameter are the camera version ID number.

1.2 General Specifications

For information about the combinations of parameter settings for achieving the maximum specified line rates, see Table 9 on [page 107](#).

1.2.1 Camera Models with 2k Pixels

Specification	spL2048-39kc	spL2048-50kc, spL2048-50kcESC (*)	spL2048-70kc
Sensor Size	2 lines - 2048 pixels per line, 20.48 mm width		
Sensor Type	Linear CMOS with Bayer color filter		
Pixel Size	10 μm x 10 μm		
Camera Link Clock Speed	40 MHz or 80 MHz (switchable)		
Maximum Line Rate in Raw Line Acquisition Mode	38.6 kHz	50 kHz	70 kHz
~ in Enhanced Raw Line Acquisition Mode	77.2 kHz	100 kHz	140 kHz (**) ** In ExSync operation: max. 137 kHz, see note on page 92 .
ADC Bit Depth	12 bits		
Data Output Type	Camera Link base configuration		Camera Link base and medium/full configuration
Data Output Modes	2 tap - 8, 10, or 12 bit 3 tap - 8 bit	2 tap - 8, 10, or 12 bit 3 tap - 8 or 10 bit 4 tap - 8, 10, or 12 bit 6 tap - 8 bit 8 tap - 8 bit	
Synchronization	Via external trigger signal or free run		
Exposure Time Control	Edge controlled, level controlled, or programmable		
Gain and Offset	Programmable via a serial link		
Connectors	One 6-pin Hirose micro-miniature receptacle One 26-pin female MDR connector		One 6-pin Hirose micro-miniature receptacle Two 26-pin female MDR connectors

Table 1: General Specifications for 2k Cameras

Specification	spL2048-39kc	spL2048-50kc, spL2048-50kcESC (*)	spL2048-70kc
Power Requirements	+12 VDC ($\pm 10\%$) Max 6.0 W @ 12 VDC		
Lens Adapter	F-mount, M42		
Housing Size (L x W x H)	48.0 mm x 87.0 mm x 62.0 mm (without lens adapter or connectors) 84.9 mm x 87.0 mm x 62.0 mm (with F-mount adapter and connectors)		
Weight	≈ 360 g (without lens adapter)		
Conformity	CE (includes RoHS), FCC The EU Declaration of Conformity is available on the Basler website: www.baslerweb.com		
* For this camera model the enhanced shading correction (ESC) is available.			

Table 1: General Specifications for 2k Cameras

1.2.2 Camera Models with 4k Pixels

Specification	spL4096-39kc, spL4096-39kcESC (*)	spL4096-50kc
Sensor Size	2 lines - 4096 pixels per line, 40.96 mm width	
Sensor Type	Linear CMOS with Bayer color filter	
Pixel Size	10 μm x 10 μm	
Camera Link Clock Speed	40 MHz or 80 MHz (switchable)	
Maximum Line Rate in Raw Line Acquisition Mode	38.6 kHz	50 kHz
~ in Enhanced Raw Line Acquisition Mode	77.2 kHz	100 kHz
ADC Bit Depth	12 bits	
Data Output Type	Camera Link base and medium/full configuration	
Data Output Modes	2 tap - 8, 10, or 12 bit 3 tap - 8 or 10 bit 4 tap - 8, 10, or 12 bit 6 tap - 8 bit 8 tap - 8 bit	
Synchronization	Via external trigger signal or free run	
Exposure Time Control	Edge controlled, level controlled, or programmable	
Gain and Offset	Programmable via a serial link	
Connectors	One 6-pin Hirose micro-miniature receptacle Two 26-pin female MDR connectors	
Power Requirements	+12 VDC (\pm 10%) Max 10.0 W @ 12 VDC	
Lens Adapter	F-mount, M42	
Housing Size (L x W x H)	48.0 mm x 87.0 mm x 62.0 mm (without lens adapter or connectors) 84.9 mm x 87.0 mm x 62.0 mm (with F-mount adapter and connectors)	
Weight	\approx 360 g (without lens adapter)	
Conformity	CE (includes RoHS), FCC The EU Declaration of Conformity is available on the Basler website: www.baslerweb.com	
* For this camera model the enhanced shading correction (ESC) is available.		

Table 2: General Specifications for 4k Cameras

Specification	spL4096-70kc, spL4096-70kcESC (*)	spL4096-140kc
Sensor Size	2 lines - 4096 pixels per line, 40.96 mm width	
Sensor Type	Linear CMOS with Bayer color filter	
Pixel Size	10 µm x 10 µm	
Camera Link Clock Speed	40 MHz or 80 MHz (switchable)	
Maximum Line Rate in Raw Line Acquisition Mode	70 kHz	140 kHz
~ in Enhanced Raw Line Acquisition Mode	140 kHz (**) ** In ExSync operation: 137 kHz, see note on page 92 .	
ADC Bit Depth	12 bits	
Data Output Type	Camera Link base and medium/full configuration	
Data Output Modes	2 tap - 8, 10, or 12 bit 3 tap - 8 or 10 bit 4 tap - 8, 10, or 12 bit 6 tap - 8 bit 8 tap - 8 bit	
Synchronization	Via external trigger signal or free run	
Exposure Time Control	Edge controlled, level controlled, or programmable	
Gain and Offset	Programmable via a serial link	
Connectors	One 6-pin Hirose micro-miniature receptacle Two 26-pin female MDR connectors	
Power Requirements	+12 VDC (± 10%) Max 10.0 W @ 12 VDC	
Lens Adapter	F-mount, M42	
Housing Size (L x W x H)	48.0 mm x 87.0 mm x 62.0 mm (without lens adapter or connectors) 84.9 mm x 87.0 mm x 62.0 mm (with F-mount adapter and connectors)	
Weight	≈ 360 g (without lens adapter)	
Conformity	CE (includes RoHS), FCC The EU Declaration of Conformity is available on the Basler website: www.baslerweb.com	
* For this camera model the enhanced shading correction (ESC) is available.		

1.2.3 Camera Models with 8k Pixels


Specification	spL8192-39kc, spL8192-39kcCI (*)
Sensor Size	2 lines - 8192 pixels per line, 81.92 mm width
Sensor Type	Linear CMOS with Bayer color filter
Pixel Size	10 µm x 10 µm
Camera Link Clock Speed	40 MHz or 80 MHz (switchable)
Maximum Line Rate in Raw Line Acquisition Mode	38.6 kHz
~ in Enhanced Raw Line Acquisition Mode	77.2 kHz
ADC Bit Depth	12 bits
Data Output Type	Camera Link base, medium/full configuration
Data Output Modes	2 tap - 8, 10, or 12 bit 3 tap - 8 or 10 bit 4 tap - 8, 10, or 12 bit 6 tap - 8 bit 8 tap - 8 bit
Synchronization	Via external trigger signal or free run
Exposure Time Control	Edge controlled, level controlled, or programmable
Gain and Offset	Programmable via a serial link
Connectors	One 6-pin Hirose micro-miniature receptacle Two 26-pin female MDR connectors
Power Requirements	+12 VDC (± 10%) Max 13.5 W @ 12 VDC
Lens Adapters	For information on suitable lens adapters, please contact Basler technical support.
Housing Size (L x W x H)	49.0 mm x 92.0 mm x 102.0 mm (without optical components or connectors) 53.5 mm x 92.0 mm x 102.0 mm (without optical components, with connectors)
Weight	≈ 580 g (without optical components) ≈ 1480 g (with UNIFOC 100/95/_/_V-Basler helical mount) ≈ 780 g (with M58 x 0.75/_/_V-Basler lens mount)
Conformity	CE (includes RoHS), FCC The EU Declaration of Conformity is available on the Basler website: www.baslerweb.com
* For this camera model the color improvement feature (CI = Color Improvement) is available. See Section 6.6.1 on page 166 .	

Table 3: General Specifications for the 8k Camera

1.3 Lens Adapters


For 2k and 4k cameras, the following lens adapters are available:

- F-mount
- M42

	<p>For information on lens adapters for 8k cameras, please contact Basler technical support.</p>
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1.4 Spectral Response

The following graphs show the spectral response for color cameras

	<p>The spectral response curves exclude lens characteristics and light source characteristics.</p> <p>To obtain best performance from color models of the camera, use of a dielectric IR cut filter is recommended. The filter should transmit in a range from 400 nm to 650 nm, and it should cut off from 650... 680 nm to at least 1100 nm.</p>
---	--

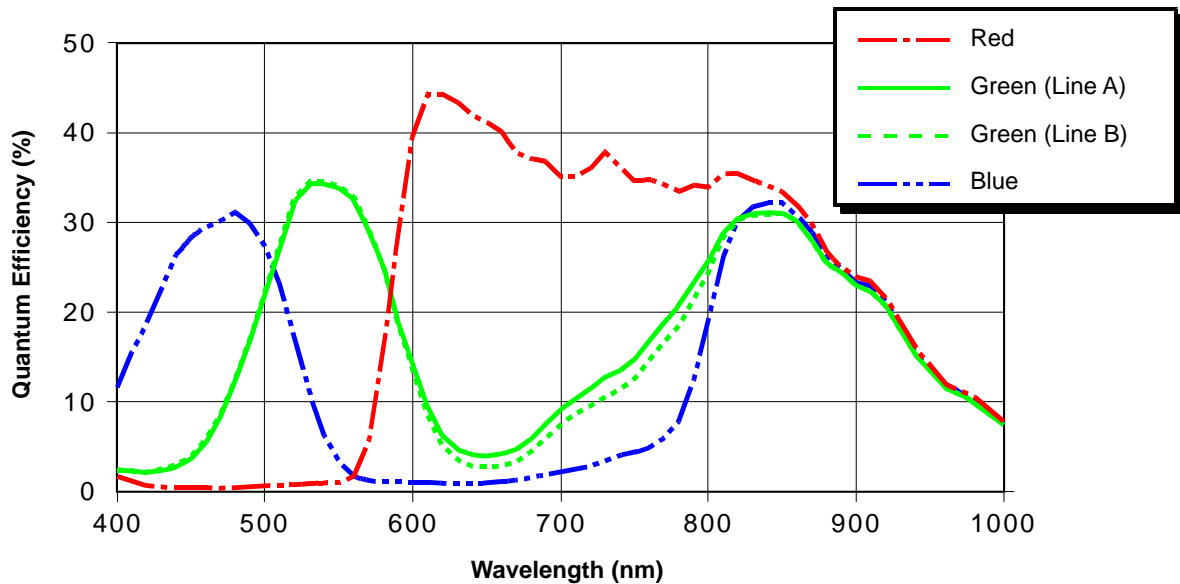


Fig. 1: Camera Spectral Response

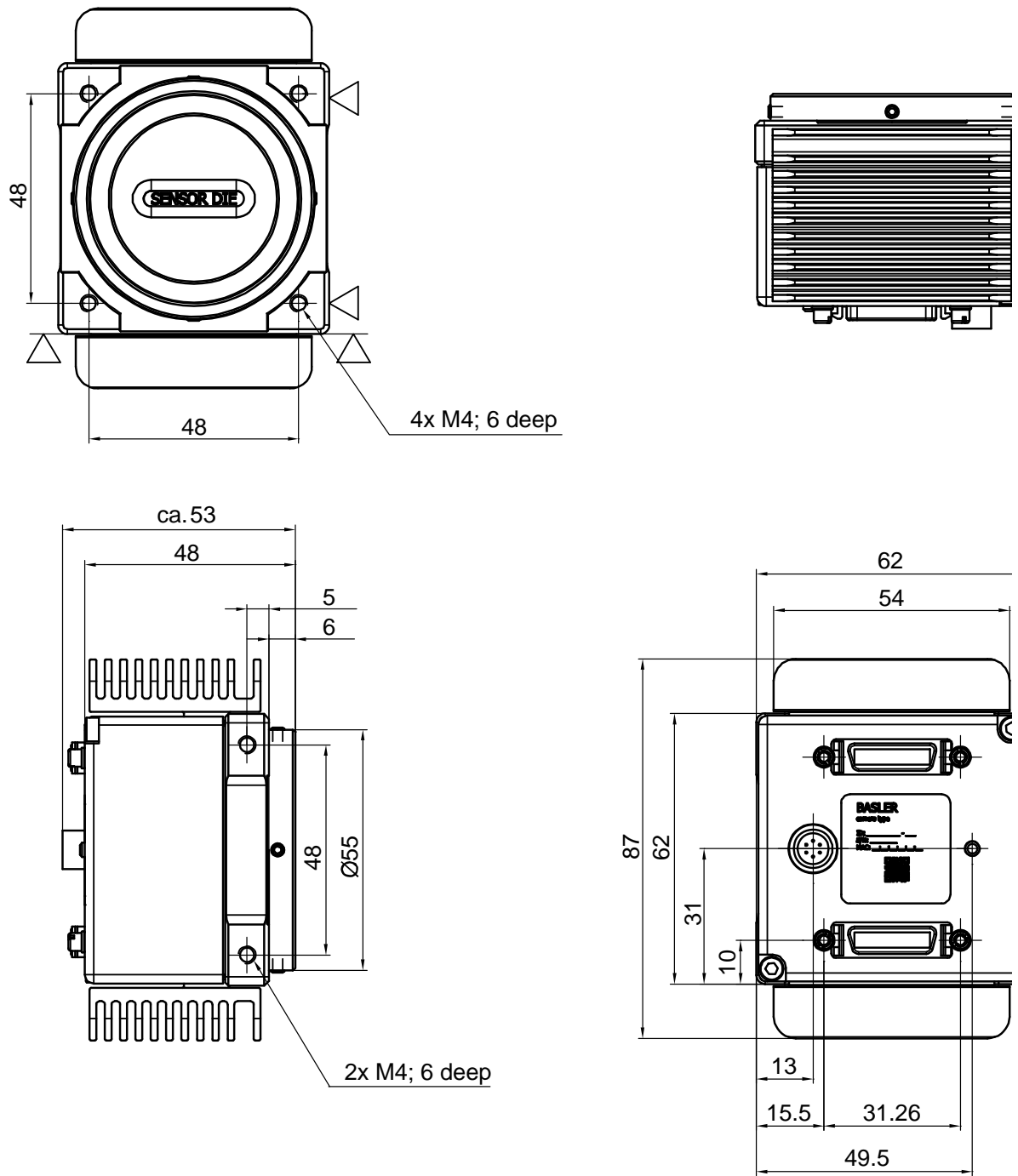
1.5 Mechanical Specifications

1.5.1 Camera Dimensions and Mounting Points for 2k and 4k Cameras

The cameras are manufactured with high precision. Planar, parallel, and angular sides ensure precise mounting with high repeatability.

The camera's dimensions in millimeters are as shown in Figure 2 on [page 9](#).

Camera housings are equipped with four mounting holes on the front and two mounting holes on the sides as shown in the drawings.



▷ = reference plane

Drawings are not to scale

Fig. 2: Mechanical Dimensions (in mm; 2k and 4k Cameras)

1.5.2 Sensor Positioning Accuracy for 2k and 4k Cameras

The sensor positioning accuracy is as shown in the drawings below.

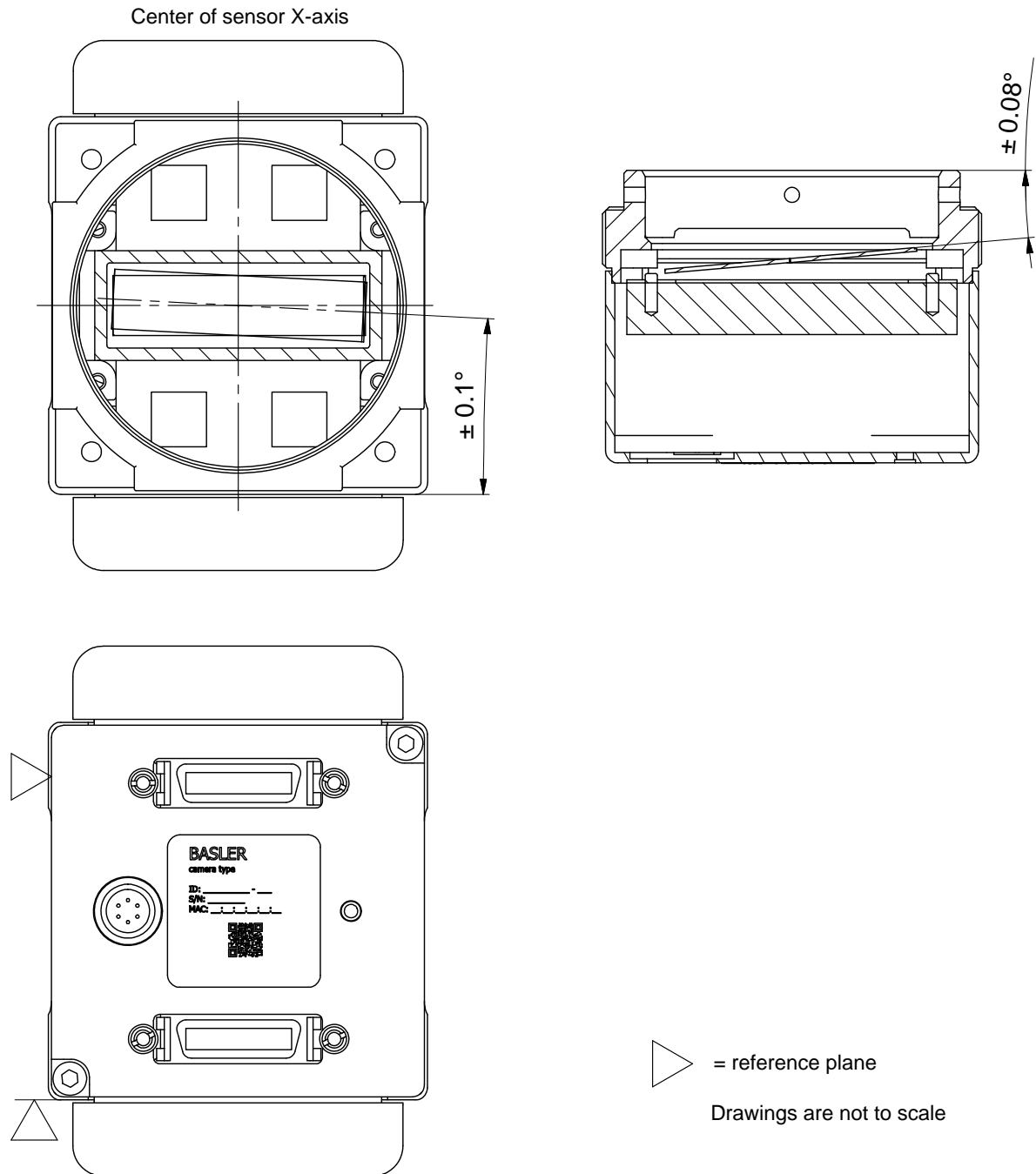


Fig. 3: Sensor Positioning Accuracy (in mm unless otherwise noted; 2k and 4k Cameras)

1.5.3 Sensor Line Location for 2k and 4k Cameras

The location of the sensor lines on the sensor chip is as shown in the drawings below.

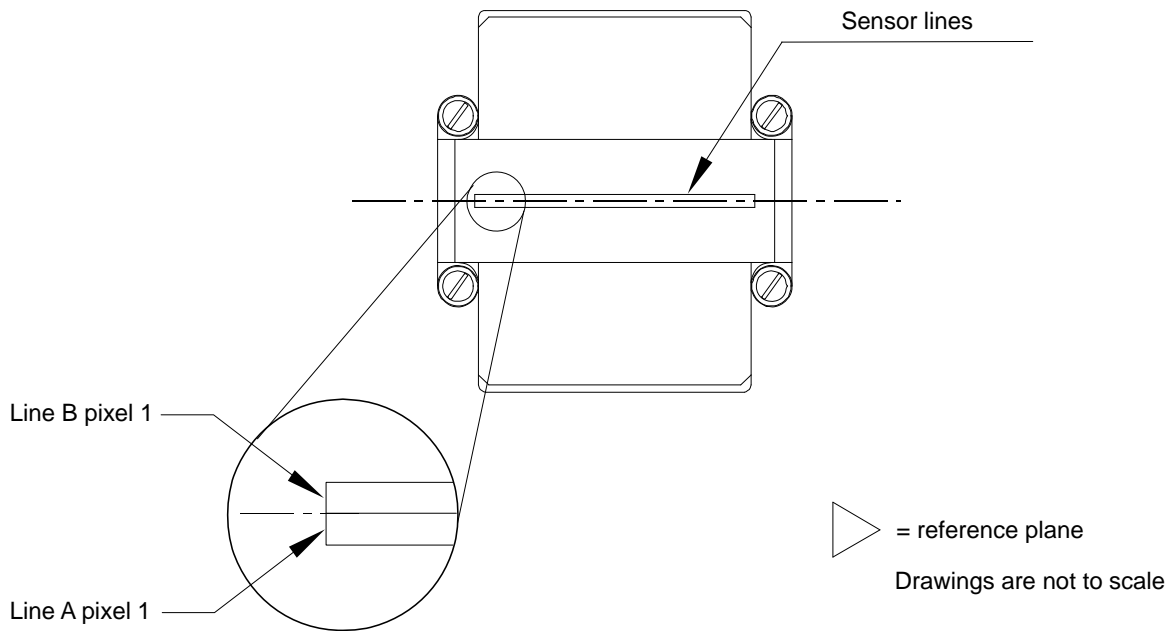
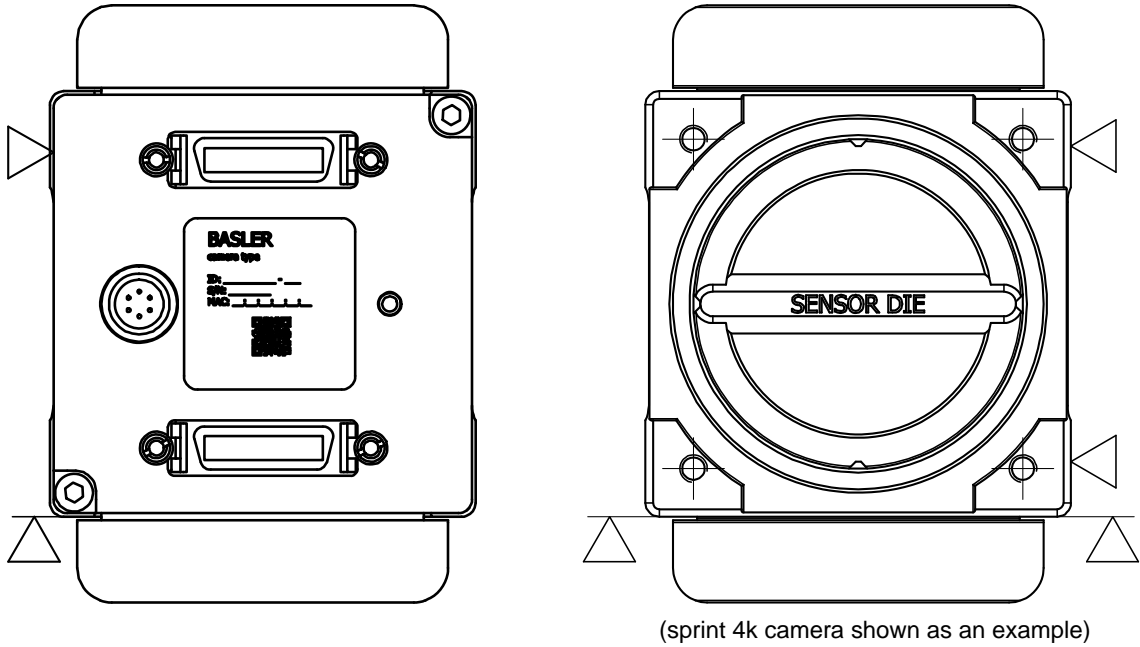


Fig. 4: Sensor Line Location (2k and 4k Cameras)

1.5.4 F-mount Adapter Dimensions (2k and 4k Cameras)

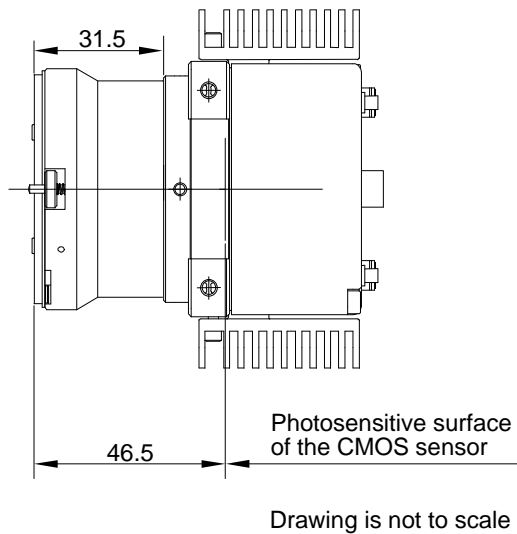


Fig. 5: Camera with F-mount Adapter Attached (in mm; 2k and 4k Cameras)

1.5.5 Camera Dimensions and Mounting Points for 8k Cameras

The cameras are manufactured with high precision. Planar, parallel, and angular sides ensure precise mounting with high repeatability.

The camera's dimensions in millimeters are as shown in Figure 6 on [page 13](#).

Camera housings are equipped with four mounting holes on the front and two mounting holes on the sides as shown in the drawings.

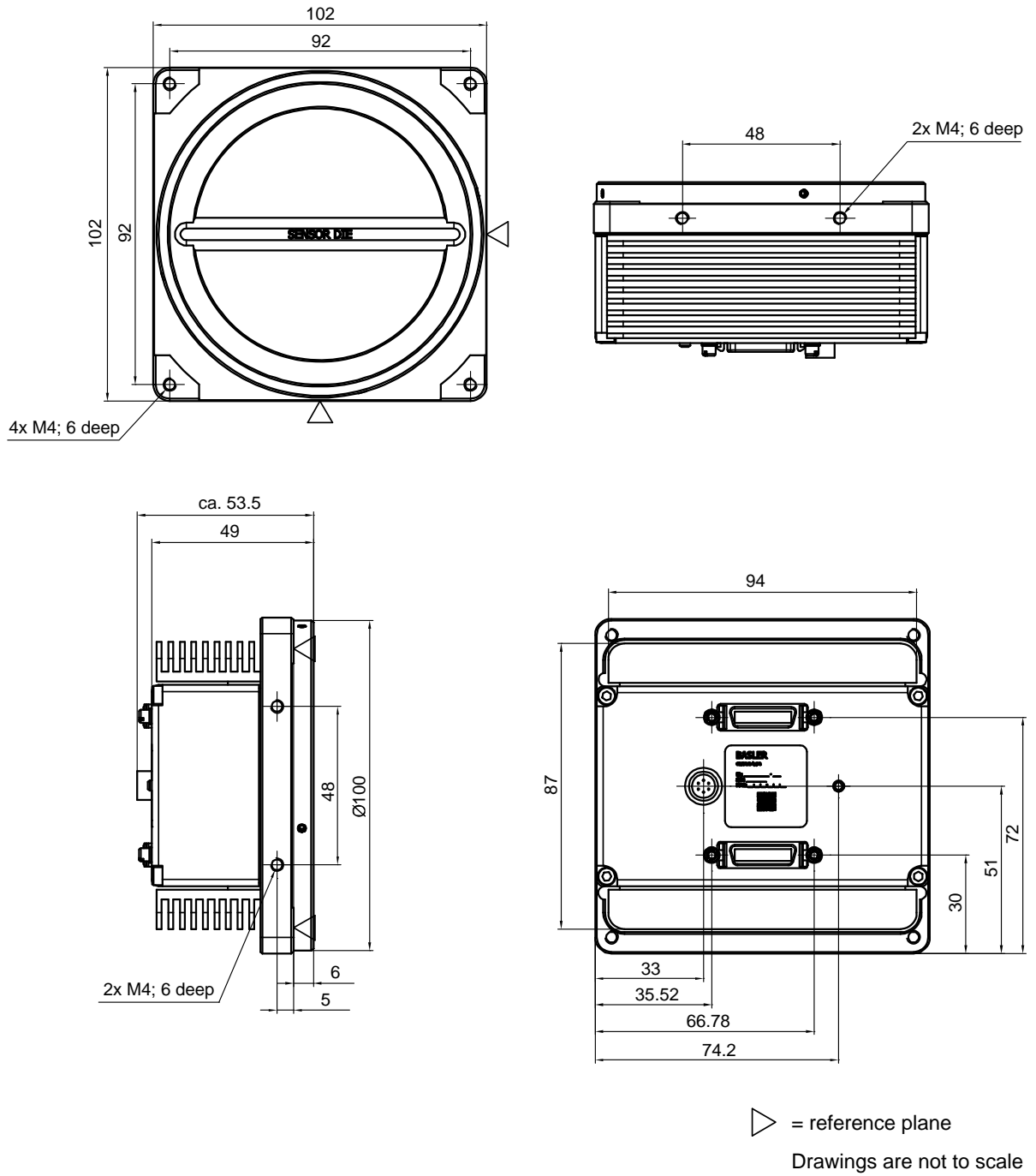


Fig. 6: Mechanical Dimensions (in mm; 8k Cameras)

1.5.6 Sensor Positioning Accuracy for 8k Cameras

The sensor positioning accuracy is as shown in the drawings below.

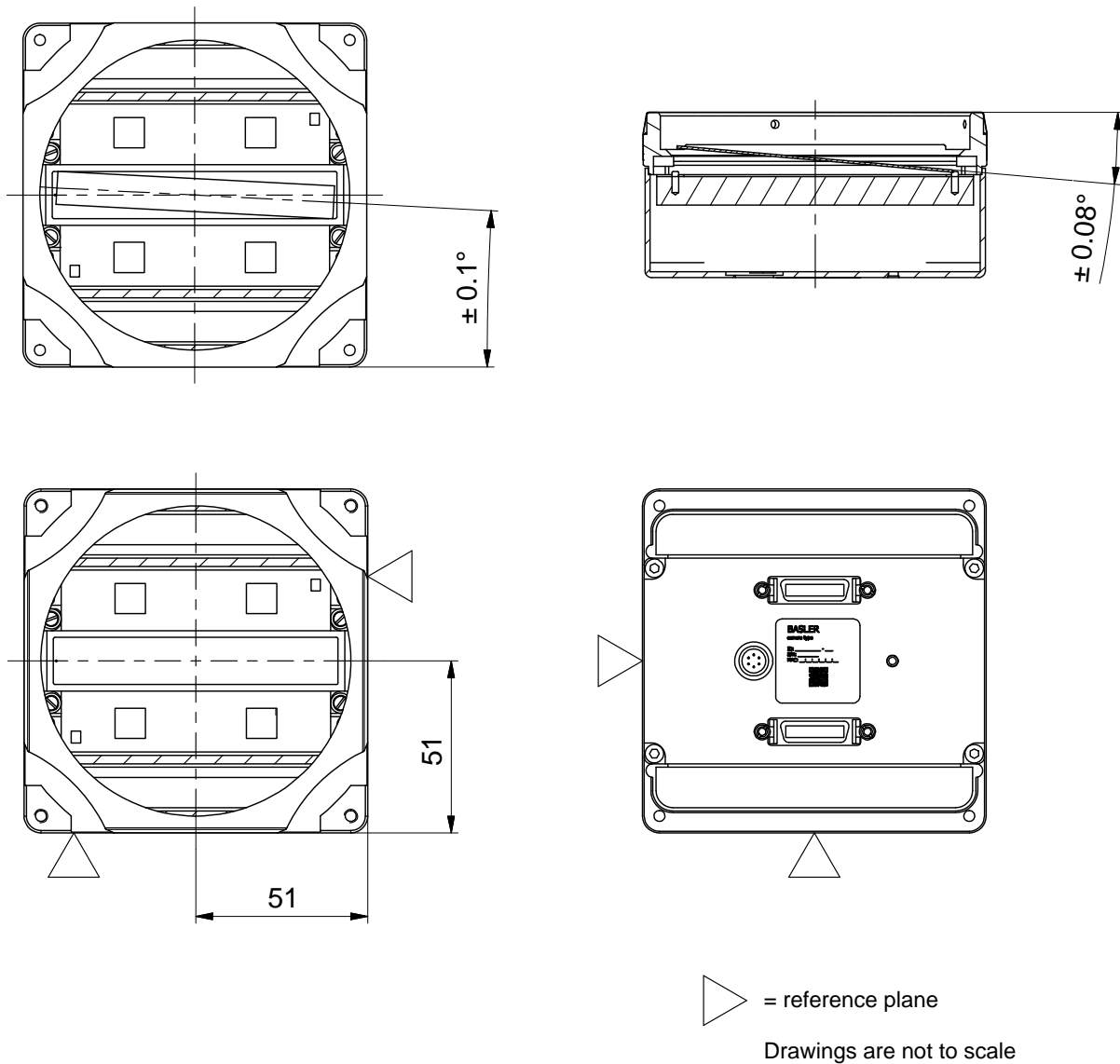


Fig. 7: Sensor Positioning Accuracy (in mm Unless Otherwise Noted; 8k Cameras)

1.5.7 Sensor Line Location for 8k Cameras

The location of the sensor lines on the sensor chip is as shown in the drawing below.

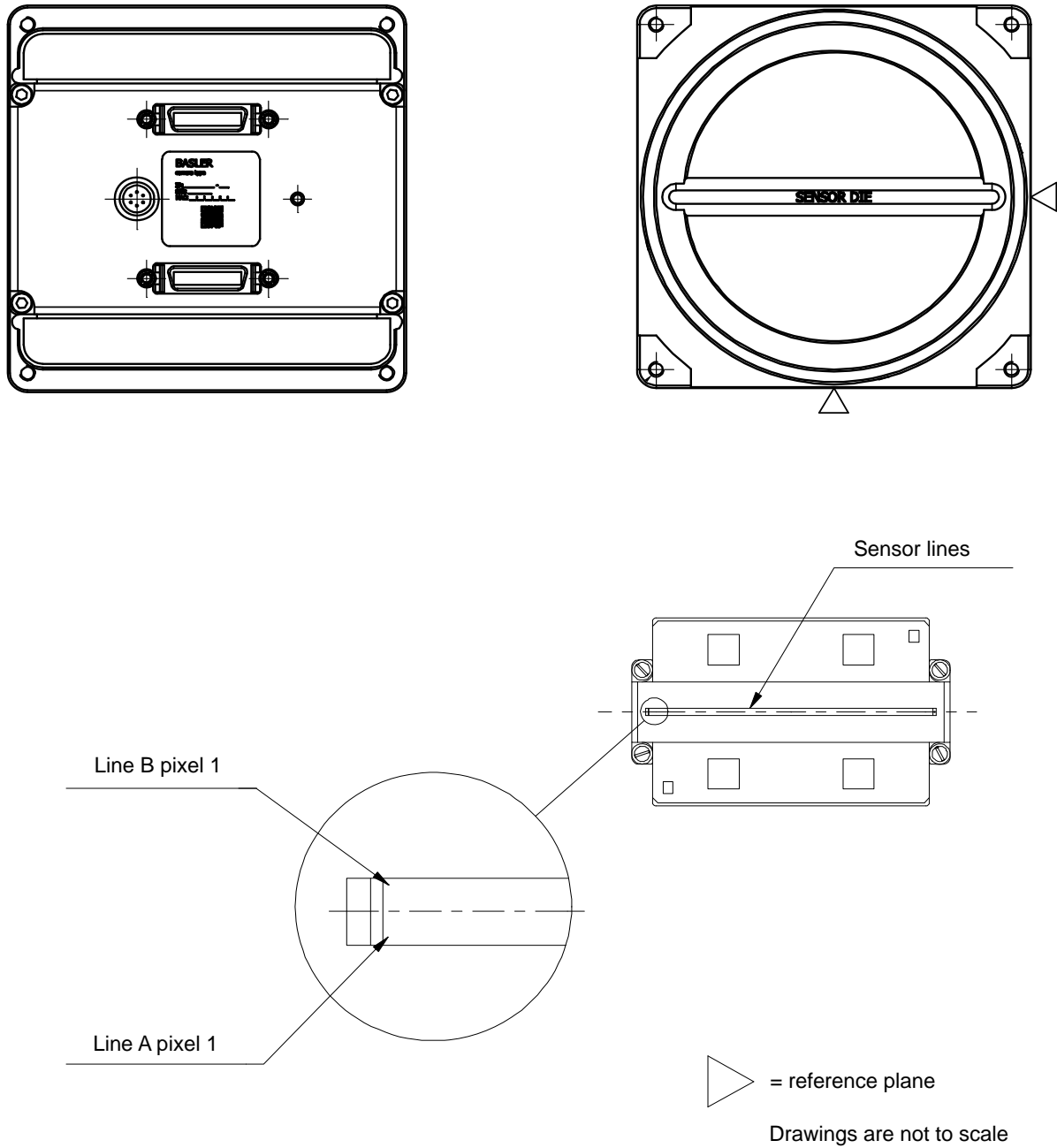


Fig. 8: Sensor Line Location (8k Cameras)

1.6 Color Creation

The sensor used in the camera is equipped with an additive color separation filter known as a Bayer filter. The pixel data output formats are related to the Bayer pattern, so you need a basic knowledge of the Bayer filter to understand the pixel formats.

With the Bayer filter, each individual pixel of the sensor is covered by a filter that allows light of only one color to strike the pixel. The pattern of the Bayer filter used on the camera is as shown in the figure below.

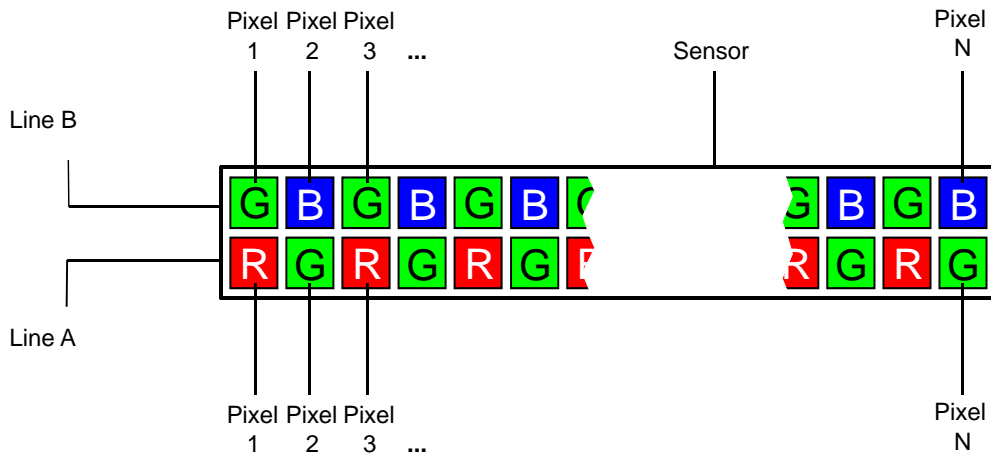


Fig. 9: Bayer Filter Pattern (RG Alignment)

As the figure illustrates, within each square of four pixels, one pixel sees only red light, one sees only blue light, and two pixels see only green light. This combination mimics the human eye's sensitivity to color. The alignment of the Bayer filter to the pixels is RG. Bayer RG alignment means that pixel one and two in each image transmitted from line A will be red and green, respectively. And pixel one and two in each image transmitted from line B will be green and blue, respectively. Since the pattern of the Bayer filter is fixed, you can use this information to determine the color of all of the other pixels in each line.

Because the size and the position of the area of interest must be adjusted in increments of 32, the color filter alignment will remain the same regardless of the camera's area of interest (AOI) settings.

For more information about the camera's AOI feature, see Section 6.3 on [page 152](#).

1.7 Environmental Requirements

1.7.1 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

1.7.2 Heat Dissipation

You must provide sufficient heat dissipation to maintain the temperature of the camera housing at 50° C or less. Since each installation is unique, Basler does not supply a strictly required technique for proper heat dissipation. Instead, we provide the following general guidelines.

- In all cases, you should monitor the temperature of the camera housing and make sure that the temperature does not exceed 50° C. Keep in mind that the camera will gradually become warmer during the first 1.5 hours of operation. After 1.5 hours, the housing temperature should stabilize and no longer increase.
- If your camera is mounted on a substantial metal component in your system, this may provide sufficient heat dissipation.
- Use of a fan to provide air flow over the camera is an extremely efficient method of heat dissipation. Using a fan to provide air flow over the camera's heat sinks provides the best heat dissipation.

The camera includes an overtemperature protection function that will switch off the imaging sensor circuitry if the temperature of the sensor is too high. See Section 6.12.1 on [page 203](#) for more information.

The camera also includes an internal temperature sensor that lets you monitor the temperature of the imaging sensor. See Section 6.10 on [page 202](#) for more information.



Keeping the camera cool will give you the best signal-to-noise ratio. When the camera operates hot, the signal-to-noise ratio is reduced.

1.8 Precautions

NOTICE

Applying incorrect input power can damage the camera.

The nominal voltage for the camera power is 12 VDC ($\pm 10\%$). Do not apply a voltage less than 10.8 VDC or greater than 13.2 VDC.

The camera has camera power undervoltage protection that is triggered if the input voltage drops below 10.5 VDC. It also has camera power overvoltage protection up to 25 VDC. For more information, see Section 6.11 on [page 202](#).

Applying a camera power voltage greater than 25 VDC can seriously damage the camera.

NOTICE

Making or breaking connections incorrectly can damage the camera.

Be sure that all power to your camera and to your host computer 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 or to the frame grabber.

If you can't switch off the power, be sure that the camera power plug is the last connector that you plug into the camera when making connections and the first connector that you unplug from the camera when breaking connections.

NOTICE

An incorrect plug can damage the camera's 6-pin connector.

The plug on the cable that you attach to the camera's 6-pin connector must be a plug for 6 pins. Using a plug designed for a smaller or a larger number of pins can damage the pins in the camera's 6-pin connector.

NOTICE**Avoid dust on the sensor.**

- The camera is shipped with a plastic cap (2k and 4k cameras) or a protective seal (8k cameras) on the lens mount. To avoid collecting dust on the camera's sensor, make sure that you always put the plastic cap or protective seal in place when there is no lens mounted on the camera.
- Every time you remove or replace the plastic cap, the protective seal, a lens, or a lens adapter, make sure that the camera is pointing down.
- When cleaning the camera, use clean compressed air that conforms to ISO 8573-1:2010 [2:2:1].
- The sensor is covered with a coated glass. Wet-chemical cleaning of the glass can easily attack the coating, leading to anomalous pixel responses. Therefore, we recommend using compressed air to clean the sensor. If using compressed air is not sufficient, use a soft, lint free cloth dampened with a small quantity of high quality window cleaner. Because electrostatic discharge can damage the sensor, you must use a cloth that will not generate static during cleaning (cotton is a good choice).

2 Physical Interface

This section describes the camera's physical interface. It includes details about connections, input signals, and output signals. It also includes a description of how the Camera Link standard is implemented in the camera.

NOTICE

Applying Incorrect Camera Power Can Damage the Camera.

The nominal voltage for the camera power is 12 VDC ($\pm 10\%$). Do not apply a voltage less than 10.8 VDC or greater than 13.2 VDC.

The camera has camera power undervoltage protection that is triggered if the input voltage drops below 10.5 VDC. It also has camera power overvoltage protection up to 25 VDC. For more information, see Section 6.11 on [page 202](#).

Applying a camera power voltage greater than 25 VDC can seriously damage the camera.

NOTICE

Making or Breaking Connections Incorrectly Can Damage the Camera.

Be sure that all power to your camera and to your host computer 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 or to the frame grabber.

If you can't switch off the power, be sure that the camera power plug is the last connector that you plug into the camera when making connections and the first connector that you unplug from the camera when breaking connections.

2.1 General Description of the Connections

The camera is interfaced to external circuitry via connectors located on the back of the housing:

- one or two, 26-pin, 0.050 inch Mini D Ribbon (MDR) female connectors used to transfer pixel data, control data, and configuration data. The number of MDR connectors present on the camera varies by camera model as shown in Table 4.
- a 6-pin, micro-miniature, push-pull receptacle used to provide power to the camera.

An LED located on the back of the camera is used to indicate power present and to display the camera's status. Figure 10 shows the connectors and the LED for 2k and 4k cameras. The connectors and the LED for 8k cameras are analogous.

Model	MDR Connectors	Camera Link Configuration
spL2048-39kc	MDR Conn. 1 only	Base
All other models	MDR Conn. 1 and MDR Conn. 2	Base, Medium/full

Table 4: MDR Connectors by Camera Model

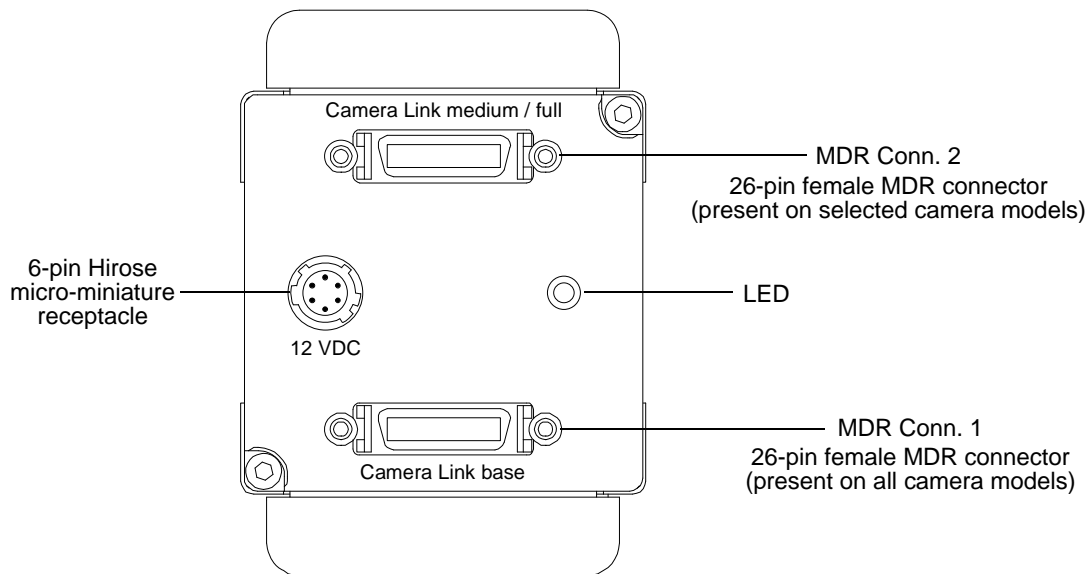


Fig. 10: Connectors and LED (2k and 4k Cameras; 8k Cameras are Analogous)

2.2 Connector Pin Assignments and Numbering

2.2.1 Pin Assignments for the MDR Connectors

The pin assignments for MDR Connector 1 (see Figure 10 on [page 21](#)) are shown in Table 5. The pin assignments for MDR connector 2 are shown in Table 6.

Pin Number	Signal Name	Direction	Level	Function
1, 13, 14, 26 ¹	Gnd	Input	Ground	Ground for the inner shield of the cable
2	X0-	Output	Camera Link LVDS	Data from the Camera Link transmitter
15	X0+			
3	X1-	Output	Camera Link LVDS	Data from the Camera Link transmitter
16	X1+			
4	X2-	Output	Camera Link LVDS	Data from the Camera Link transmitter
17	X2+			
6	X3-	Output	Camera Link LVDS	Data from the Camera Link transmitter
19	X3+			
5	XClk-	Output	Camera Link LVDS	Transmit clock from the Camera Link transmitter
18	XClk+			
7	SerTC+	Input	RS-644 LVDS	Serial communication data receive (SerTC = "serial to camera")
20	SerTC-			
8	SerTFG-	Output	RS-644 LVDS	Serial communication data transmit (SerTFG = "serial to frame grabber")
21	SerTFG+			
9	CC1-	Input	RS-644 LVDS	ExSync (external trigger)
22	CC1+			
10	CC2+	Input	RS-644 LVDS	Not used
23	CC2-			
11	CC3-	Input	RS-644 LVDS	Not used
24	CC3+			
12	CC4+	Input	RS-644 LVDS	Not used
25	CC4-			

Table 5: Pin Assignments for MDR Connector 1

¹ Pins 1, 13, 14, and 26 are all tied to ground inside of the camera.

Pin Number	Signal Name	Direction	Level	Function
1, 13, 14, 26 ¹	Gnd	Input	Ground	Ground for the inner shield of the cable
2	Y0-	Output	Camera Link LVDS	Data from the Camera Link transmitter
15	Y0+			
3	Y1-	Output	Camera Link LVDS	Data from the Camera Link transmitter
16	Y1+			
4	Y2-	Output	Camera Link LVDS	Data from the Camera Link transmitter
17	Y2+			
6	Y3-	Output	Camera Link LVDS	Data from the Camera Link transmitter
19	Y3+			
5	YClk-	Output	Camera Link LVDS	Transmit clock from the Camera Link transmitter
18	YClk+			
8	Z0-	Output	Camera Link LVDS	Data from the Camera Link transmitter
21	Z0+			
9	Z1-	Output	Camera Link LVDS	Data from the Camera Link transmitter
22	Z1+			
10	Z2-	Output	Camera Link LVDS	Data from the Camera Link transmitter
23	Z2+			
12	Z3-	Output	Camera Link LVDS	Data from the Camera Link transmitter
25	Z3+			
11	ZClk-	Output	Camera Link LVDS	Transmit clock from the Camera Link transmitter
24	ZClk+			

Table 6: Pin Assignments for MDR Connector 2

¹ Pins 1, 13, 14, and 26 are all tied to Ground inside of the camera.

2.2.2 Pin Assignments for the 6-pin Micro-miniature Receptacle

The pin assignments for the 6-pin micro-miniature receptacle are as shown in Table 7.

Pin Number	Signal Name	Direction	Level	Function
1, 2 ¹	+12 VDC	Input	+12 VDC ($\pm 10\%$)	Camera power
3, 4	---	---	---	Not used
5, 6 ²	DC Gnd	Input	Ground	DC ground

Table 7: Pin Assignments for the 6-Pin Receptacle

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

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

2.2.3 Pin Numbering

Figure 11 shows the pin numbering for the connectors on the back of the camera for 2k and 4k cameras. The pin numberings for 8k cameras are analogous.

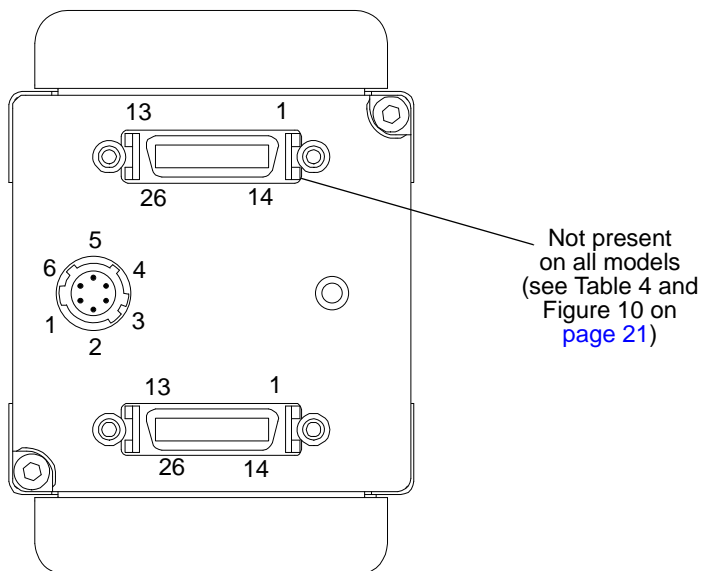


Fig. 11: Pin Numbering (2k and 4k Cameras; 8k Cameras are Analogous)

2.3 Connector Types

2.3.1 26-pin Connectors

Each 26-pin connector on the back of the camera is a female, 0.050 inch MDR connector as called for in the Camera Link specification.

2.3.2 6-pin Connector

The 6-pin connector on the camera is a Hirose micro-miniature locking receptacle (part number HR10A-7R-6PB) or the equivalent.

The recommended mating connector is the Hirose micro-miniature locking plug (part number HR10A-7P-6S). A plug of this type should be used to terminate the cable on the power supply for the camera.

A power supply that has an output cable terminated with the correct connector is available from Basler. Contact your Basler sales representative for more information.

2.4 Cabling Requirements

2.4.1 Camera Link Cable

The Mini D Ribbon (MDR) cables used between the camera and your frame grabber must comply with the Camera Link cable specification specified in the Camera Link Standard.

Compliant MDR cable assemblies in several different lengths are available from Basler as stock items. Contact your Basler sales representative for more information.

The maximum allowed length for the MDR cable used with a sprint camera is 10 meters.



Generally, Camera Link cables of up to 10 m length can be used for Camera Link cameras.

However, when operating cameras at pixel clock speeds of **80 MHz**, we **strongly recommend** to use shorter cables to ensure the integrity of data transmission (e.g. 6 m cables).

Keep in mind that the maximum cable length not only depends on the Camera Link clock speed but also on other factors e.g. on the capabilities of the frame grabber and on the harshness of the electromagnetic environment.

2.4.2 Power Cable

A Hirose, 6-pin locking plug will be shipped with each camera. This plug should be used to connect the output cable on your power supply to the camera.

For proper EMI protection, the power supply cable that is terminated with the Hirose connector and attached to the camera must be a twin-cored, shielded cable. Also, the Hirose plug must be connected to the cable shield and the shield must be connected to earth ground at the power supply.

NOTICE

An Incorrect Plug Can Damage the Camera's 6-pin Connector.

The plug on the cable that you attach to the camera's 6-pin connector must be a plug for 6 pins. Using a plug designed for a smaller or a larger number of pins can damage the pins in the camera's 6-pin connector.

2.5 Camera Power

Camera power must be supplied to the camera's 6-pin connector via a cable from your power supply. Nominal camera power voltage is +12 VDC ($\pm 10\%$) with less than one percent ripple. Power consumption is as shown in Table 1 on [page 2](#).

The camera has camera power overvoltage protection as described in Section 6.11 on [page 202](#).

NOTICE**Applying Incorrect Camera Power Can Damage the Camera.**

The nominal voltage for the camera power is 12 VDC ($\pm 10\%$). Do not apply a voltage less than 10.8 VDC or greater than 13.2 VDC.

The camera has camera power undervoltage protection that is triggered if the input voltage drops below 10.5 VDC. It also has camera power overvoltage protection up to 25 VDC. For more information, see Section 6.11 on [page 202](#).

Applying a camera power voltage greater than 25 VDC can seriously damage the camera.

NOTICE**Making or Breaking Connections Incorrectly Can Damage the Camera.**

Be sure that all power to your camera and to your host computer 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 or to the frame grabber.

If you can't switch off the power, be sure that the camera power plug is the last connector that you plug into the camera when making connections and the first connector that you unplug from the camera when breaking connections.

2.6 Camera Link Implementation

The camera uses National Semiconductor DS90CR287 devices as Camera Link transmitters. For the Camera Link receivers on your frame grabber, 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.

The camera uses a National Semiconductor DS90LV048A and a DS90LV012 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 DS90LV011 differential line transmitter is used to transmit the serial communication output signal defined in the specification. Detailed spec sheets for these devices are available at the National Semiconductor web site (www.national.com).

All camera models have **one MDR connector** (MDR connector 1) (see Table 4 and Figure 10 on [page 21](#)) for the "base configuration" as defined in the Camera Link specification (one camera model has only the MDR connector for the base configuration). The camera models include one differential line transmitter. The transmitter in the camera is designated as Transmitter X. When a

camera is set for a 2 tap or 3 tap video data output mode, it uses the base Camera Link configuration.

Camera models with **two MDR connectors** implement the "medium/full configuration" as defined in the Camera Link specification and include three differential line transmitters. The transmitters in the camera are designated as Transmitter X, Transmitter Y, and Transmitter Z. If a camera is set for a 4 tap video data output mode, it uses the medium Camera Link configuration and employs transmitters X and Y. If a camera is set for an 8 tap video data output mode, it uses the full Camera Link configuration and employs transmitters X, Y, and Z.



Cameras that implement the medium/full configuration can also be used as base configuration cameras. To do so, simply set the camera for a 2 tap video data output mode. In this situation, only one Camera Link cable is required. The cable should be connected to MDR connector 1 on the camera and to the "base" connector on your frame grabber.

Table 5 on [page 22](#) and Table 6 on [page 23](#) show the pin assignments for the MDR connectors.

The schematic in Figure 12 on [page 29](#) shows the full configuration Camera Link implementation for the camera and a typical implementation for a full configuration frame grabber.

For more information about how the pixel data captured by the camera is assigned to the camera's transmitter(s), see Chapter 5 on [page 108](#).

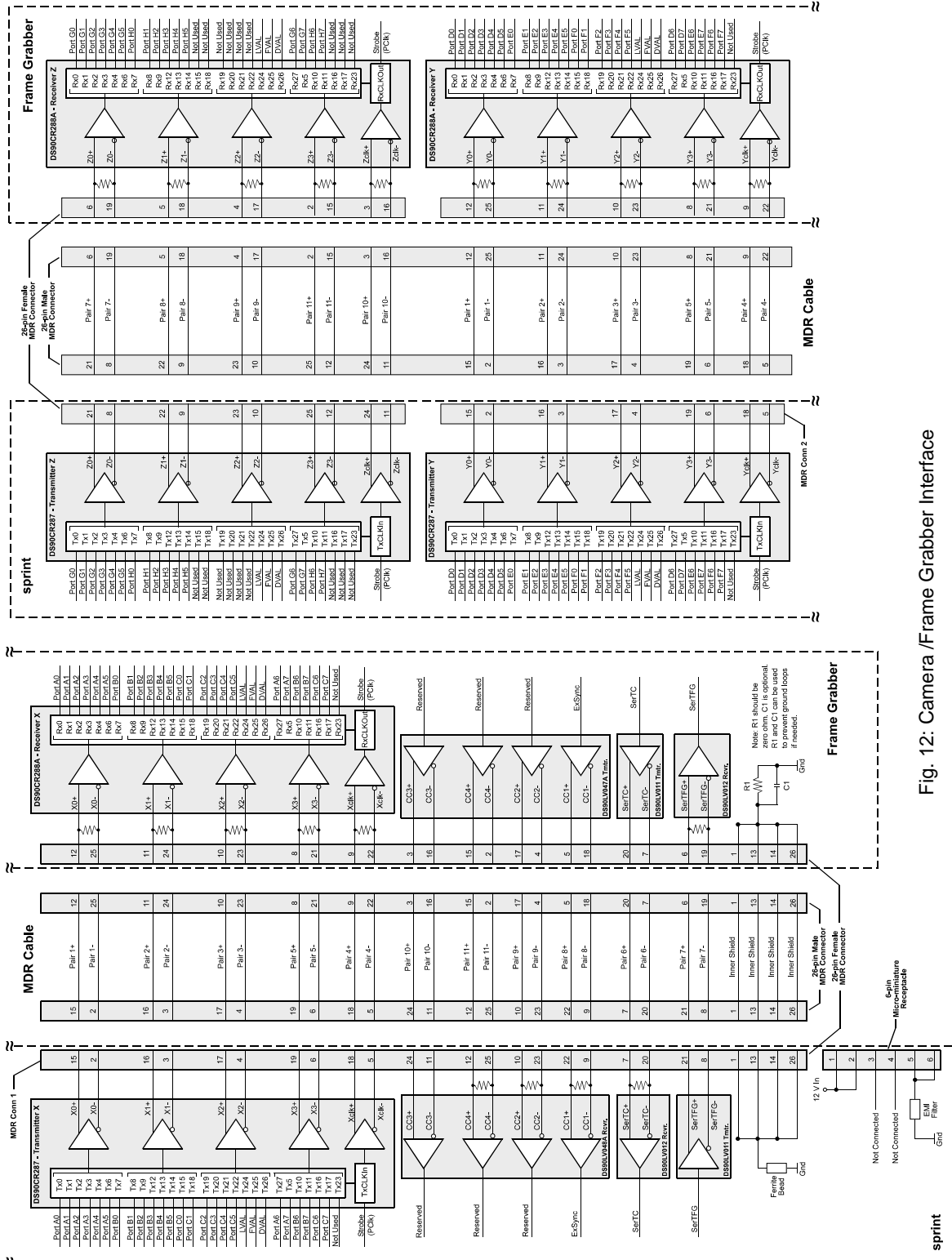


Fig. 12: Camera /Frame Grabber Interface

2.7 Input Signals

The camera's input signals include a SerTC signal and an ExSync signal as described below.

2.7.1 Serial to Camera

The Serial To Camera (SerTC) input signal is an RS-644 LVDS signal as specified in the Camera Link standard. The signal is input to the camera on pins 7 and 20 of MDR connector one as specified in the standard and as shown in Table 5 on [page 22](#) and in Figure 12 on [page 29](#).

Signals applied to the SerTC input are used to configure the camera. For more detailed information about the serial connection, see Section 2.9 on [page 33](#) and Section 7.3 on [page 265](#).

2.7.2 External Sync (ExSync)

An external sync (ExSync) signal can be input into the camera and can be used to control line acquisition and exposure time. The ExSync signal is an RS-644 LVDS signal as specified in the Camera Link standard and is usually supplied to the camera by your frame grabber. The signal is input to the camera on pins 9 and 22 of MDR connector one as shown in Table 5 on [page 22](#) and in Figure 12 on [page 29](#).

When the camera is operating under the control of an ExSync signal, three exposure time control modes are available: edge controlled, level controlled, and programmable. For more detailed information about exposure control modes, see Section 4.1 on [page 92](#).

When the camera is operating under the control of an ExSync signal, the period of the ExSync signal determines the camera's line rate:

$$\text{Line Rate} = \frac{1}{\text{ExSync Signal Period}}$$

Note that the ExSync signal is edge sensitive and therefore must toggle.

In order for the camera to detect a transition from low to high, the ExSync signal must be held high for at least 1.3 μs when the camera is set for the level controlled exposure mode and for 100 ns when the camera is set for programmable or edge controlled exposure mode.



Valid for the **spL2048-70kc**, **spL4096-70kc**, and for the **spL4096-70kcESC only**:
If the enhanced raw line acquisition mode is selected, in ExSync operation the **maximum line rate** for these camera models is 137 kHz.

2.8 Output Signals

Data is output from the camera in accordance with the Camera Link standard. The camera's output signals include pixel data qualifiers such as frame valid, line valid, and data valid, pixel data, a Camera Link clock signal, and a SerTFG signal.

2.8.1 Frame Valid Bit

As shown in Figure 12 on [page 29](#), a frame valid (FVAL) bit is assigned to the Tx25 pin on the X, Y, and Z Camera Link transmitters as defined in the Camera Link standard.

In a sequence of lines being transmitted, the frame valid bit helps to discern lines A and lines B: When the frame valid bit goes high, the line that is being transmitted is line A. And the next line transmitted will be line B.

By setting the FVAL Length parameter, you can set a number of consecutive lines and during the transmission of those lines, the frame valid bit will stay high. The number of lines can only be set in multiples of two. For example, if the setting is two, the frame valid bit will be high during the transmission of two consecutive lines and will go low after the lines have been transmitted. If the setting is four, the frame valid bit will be high during the transmission of four consecutive lines and will go low after the lines have been transmitted. If the setting is zero, the frame valid bit will stay low and you may not be able to decide which lines in a sequence of lines being transmitted are lines A and which ones are lines B.

The frame valid bit will only be included in the video data output from the camera if the Raw or the Enhanced Raw line acquisition mode is selected.

For more detailed information about the frame valid bit, see Chapter 5 on [page 108](#).

Setting the Number of Consecutive Lines the Frame Valid Bit Will Stay High

You can set the camera for the number of consecutive lines the frame valid bit will stay high with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the FVAL Length parameter in the Output Mode parameters group to set the number of consecutive lines the frame valid bit will stay high.

By Setting CSRs

You set the number of consecutive lines the frame valid bit will stay high by writing the appropriate value to the Length field of the FVAL Length CSR (see [page 222](#)).

Section 7.2.2 on [page 219](#) explains CSRs and Section 7.3.1 on [page 266](#) explains using read/write commands.

2.8.2 Line Valid Bit

As shown in Figure 12 on [page 29](#), a line valid (LVAL) bit is assigned to the Tx24 pin on the X, Y, and Z Camera Link transmitters as defined in the Camera Link standard.

The line valid bit included in the video data output from the camera indicates that a valid line is being transmitted. Pixel data is only valid when this bit is high. For more detailed information about the line valid bit, see Chapter 5 on [page 108](#).

2.8.3 Data Valid Bit

As shown in Figure 12 on [page 29](#), a data valid (DVAL) bit is assigned to the Tx26 pin on the X, Y, and Z Camera Link transmitters as defined in the Camera Link standard.

The data valid bit included in the video data output from the camera indicates that valid data is being transmitted. Pixel data is only valid when this bit is high. For more detailed information about the data valid bit, see Chapter 5 on [page 108](#).

2.8.4 Pixel Data Bits

Pixel data bits are transmitted via output ports on the X, Y, and Z Camera Link transmitters. The ports as defined in the Camera Link standard are shown in Figure 12 on [page 29](#).

The assignment of pixel data bits to output ports varies depending on the video data output mode of the camera. The available video data output modes and the bit assignments are explained in detail in Chapter 5 on [page 108](#). The bit assignments comply with the Camera Link standard.

The tables also show the assignments for the frame valid bit, the line valid bit, the data valid bit, and the pixel clock. These assignments are constant for all output modes.

2.8.5 Camera Link Pixel Clock

As shown in Figure 12 on [page 29](#), the Camera Link clock signal is assigned to the strobe port (TxClkIn pin) on the X, Y, and Z Camera Link transmitters as defined in the Camera Link standard. The Camera Link clock is used to time the transmission of acquired pixel data.

The Camera Link clock speed can be set to either 80 MHz or to 40 MHz. The default is 40 MHz.

Lowering the clock speed from 80 MHz to 40 MHz may lower the camera's maximum allowed line rate. For more information about calculating the maximum allowed line rate, see Section 4.3 on [page 99](#).

Note that a change to the Camera Link clock speed is a parameter change and that parameter changes are normally lost when the camera is reset or switched off and back on.

To avoid this, you can make changes to the camera's parameters, save the changed parameters to a "user set", and then activate the user set. This will ensure that the changed parameters are saved and are loaded into the camera at reset or power off/on.



Some frame grabbers are not compatible with an 80 MHz pixel clock speed. Refer to the documentation for your frame grabber to determine if it is compatible.

Setting the Camera Link Clock Speed

You can set the clock speed with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Camera Link Clock parameter in the Output Mode parameters group to set the clock speed.

By Setting CSRs

You set the clock speed by writing a value to the Clock Speed field of the Camera Link Clock Speed CSR (see [page 220](#)).

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.

2.8.6 Serial to Frame Grabber

The Serial To Frame Grabber (SerTFG) output signal is an RS-644 LVDS signal as specified in the Camera Link standard. The signal is output from the camera on pins 8 and 21 of MDR connector one as specified in the standard and as shown in Table 5 on [page 22](#) and in Figure 12 on [page 29](#).

Signals from the SerTFG output are used during camera configuration. For more detailed information about the serial connection, see Section 2.9 on [page 33](#) and Section 7.3 on [page 265](#).

2.9 RS-644 Serial Communication

The camera is equipped for RS-644 serial communication via a serial port integrated into 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 on your host computer as described in the Installation and Setup Guide for Camera Link Cameras. The guide is available in the downloads section of the Basler website: www.baslerweb.com.

Basler has also developed a binary read/write command protocol that can be used to change camera modes and parameters via the serial connection from within your own application software using the API delivered with the frame grabber. See Section 7.3 on [page 265](#) for details on the binary read/write command protocol.

2.9.1 Making the Serial Connection

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

If you are using the Basler Camera Configuration Tool Plus (CCT+) 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 CCT+ to detect and use the port, the characteristics of the port must comply with the Camera Link standard and the **clser****.dll** called for in the standard must be present.

When the camera is powered on or when a camera reset is performed, your computer may receive one random character on the serial interface. We recommend clearing the serial input buffers in your computer after a camera power on or reset.

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. Consult your frame grabber's documentation to determine the port access method and the port characteristics.

3 Line Acquisition Modes

3.1 Introduction

Several different methods can be used to acquire (capture) lines with the sensor in the camera. Each of these different methods is referred to as a line acquisition mode. The line acquisition modes include:

- RGB
- Raw - Line A First (B Delayed)
- Raw - Line B First (A Delayed) (2k and 4k cameras only)
- Enhanced Raw - Line A First (B Delayed)
- Enhanced Raw - Line B First (A Delayed) (2k and 4k cameras only)

The line acquisition modes are described in detail from Section 3.2 on [page 36](#) through Section 3.5 on [page 88](#).

To understand the line acquisition modes, you must be aware of the architecture of the sensor. Refer to Figure 4 on [page 11](#) for 2k and 4k cameras, and to Figure 8 on [page 15](#) for 8k cameras. When you examine a figure, notice that the sensor contains two lines that are adjacent to each other and are oriented along the center line of the camera. Also notice that one of the lines is designated as line A and the other is designated as line B.

See also Section 1.6 on [page 16](#) for an explanation of the color creation. You will notice that each individual pixel of the sensor is covered by a filter that allows light of only one color to strike the pixel. The pixels of line A are covered by a sequence of alternating red and green filters, and the pixels of line B are covered by a sequence of alternating green and blue filters.

Setting the Camera for the Line Acquisition Mode

You can set the camera for the line acquisition mode with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Line Acquisition Mode parameter in the Output Mode parameters group to set the line acquisition mode.

By Setting CSRs

You select the line acquisition mode by writing the appropriate value to the Mode field of the Line Acquisition Mode CSR (see [page 221](#)).

Section 7.2.2 on [page 219](#) explains CSRs and Section 7.3.1 on [page 266](#) explains using read/write commands.

3.2 RGB Line Acquisition Mode

The RGB line acquisition mode provides RGB pixel values of virtual pixels (see below), based on "red", "green", and "blue" pixel values of the individual pixels of the sensor.



Using virtual pixels, the effective maximum resolution of a line of a camera in RGB line acquisition mode is 1024 pixels for a 2k camera, 2048 pixels for a 4k camera, and 4096 pixels for an 8k camera.



Valid for the **spL4096-140kc** only:
If the RGB line acquisition mode is selected, the **maximum line rate** is 70 kHz.

For imaging, a sensor is used, where each individual pixel is covered by a filter that allows light of only one color - red, green, or blue - to strike the pixel. The pixel values acquired by line A will be "red" and "green" values, and the pixel values acquired by line B will be "green" and "blue" values. For more information about color creation and about the assignment of the colors to the individual pixels of the sensor, see Section 1.6 on [page 16](#).



Since lines A and B are exposed at the same time and since the pixel values of neighboring "green" pixels are averaged across both lines, make sure to move the **image** of the object by 20 µm between two successive exposures.

For details of how to relate the extent of the image movement to the extent of the object movement, see Section 3.5.3 on [page 89](#).



For the RGB line acquisition mode, the object being imaged may move in either direction with respect to the sensor: The object may cross line A first or line B first.

When the RGB line acquisition mode is active, each time an acquisition is triggered, the following will occur:

- The camera will expose line A and line B in the sensor at the same time. The exposure time you are using will apply to **both** lines.
- When exposure is complete, the pixel values are read out and processed in the following way to serve as pixel values of virtual pixels (see Figure 13):
 - The "red" value for pixel 1 in line A (RA1) will be left unchanged and will be used as the "red" pixel value of virtual pixel 1 (R1).

- The "green" value for pixel 2 in line A (GA2) and the "green" value for pixel 1 in line B (GB1) will be added and the total will be divided by 2 (and rounded up if necessary). The averaged "green" values will be used as the "green" pixel value of virtual pixel 1 (GAV1).
- The "blue" value for pixel 2 in line B (BB2) will be left unchanged and will be used as the "blue" pixel value of virtual pixel 1 (B1).
- The "red" value for pixel 3 in line A (RA3) will be left unchanged and will be used as the "red" pixel value of virtual pixel 2 (R2).
- The "green" value for pixel 4 in line A (GA4) and the "green" value for pixel 3 in line B (GB3) will be added and the total will be divided by 2 (and rounded up if necessary). The averaged "green" values will be used as the "green" pixel value of virtual pixel 2 (GAV2).
- The "blue" value for pixel 4 in line B (BB4) will be left unchanged and will be used as the "blue" pixel value of virtual pixel 2 (B2).
- And so on.

In this way, RGB data of virtual pixels of the size of 20 μm x 20 μm are created. Each virtual pixel involves lines A and B and includes four neighboring pixels, one "red" pixel, one "blue" pixel, and two "green" pixels whose pixel values are averaged.

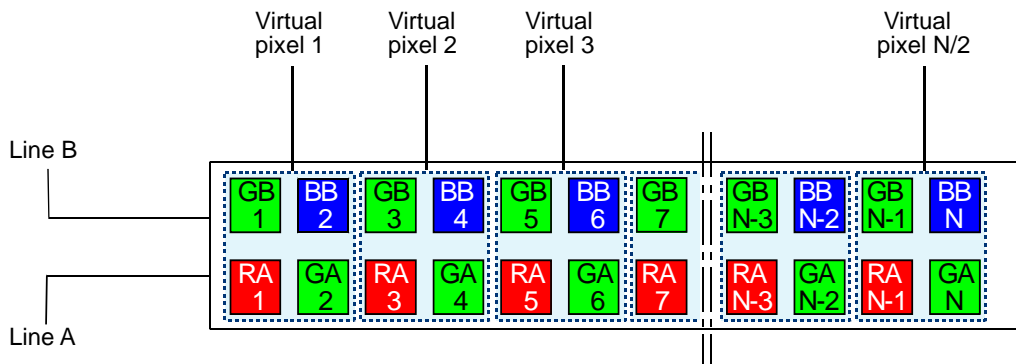


Fig. 13: Virtual Pixels of the RGB Line Acquisition Mode

- The pixel values are arranged inside the camera in this sequence: "red" pixel value of virtual pixel 1 (R1), averaged "green" pixel value of virtual pixel 1 (GAV1), "blue" pixel value of virtual pixel 1 (B1), "red" pixel value of virtual pixel 2 (R2), averaged "green" pixel value of virtual pixel 2 (GAV2), and so on.
- The pixel values are transmitted from the camera according to the selected video data output mode using a specific bit depth and number of taps.

For information about the available video data output modes, the assignment of the pixel values to the individual taps, and timing details of the data transmission, see Section 3.2.1 on [page 38](#).

For information about bit assignments, see Section 5.2 on [page 110](#).

3.2.1 Pixel Value Transmission for the RGB Line Acquisition Mode

For the RGB line acquisition mode, you can select a 2, 3, 4, 6, or 8 tap video output mode for transmitting pixel data, at bit depths of 8, 10, or 12.



Not all camera models support 4, 6 or 8 tap video data output mode. Not all combinations of video data output modes and bit depths are available.

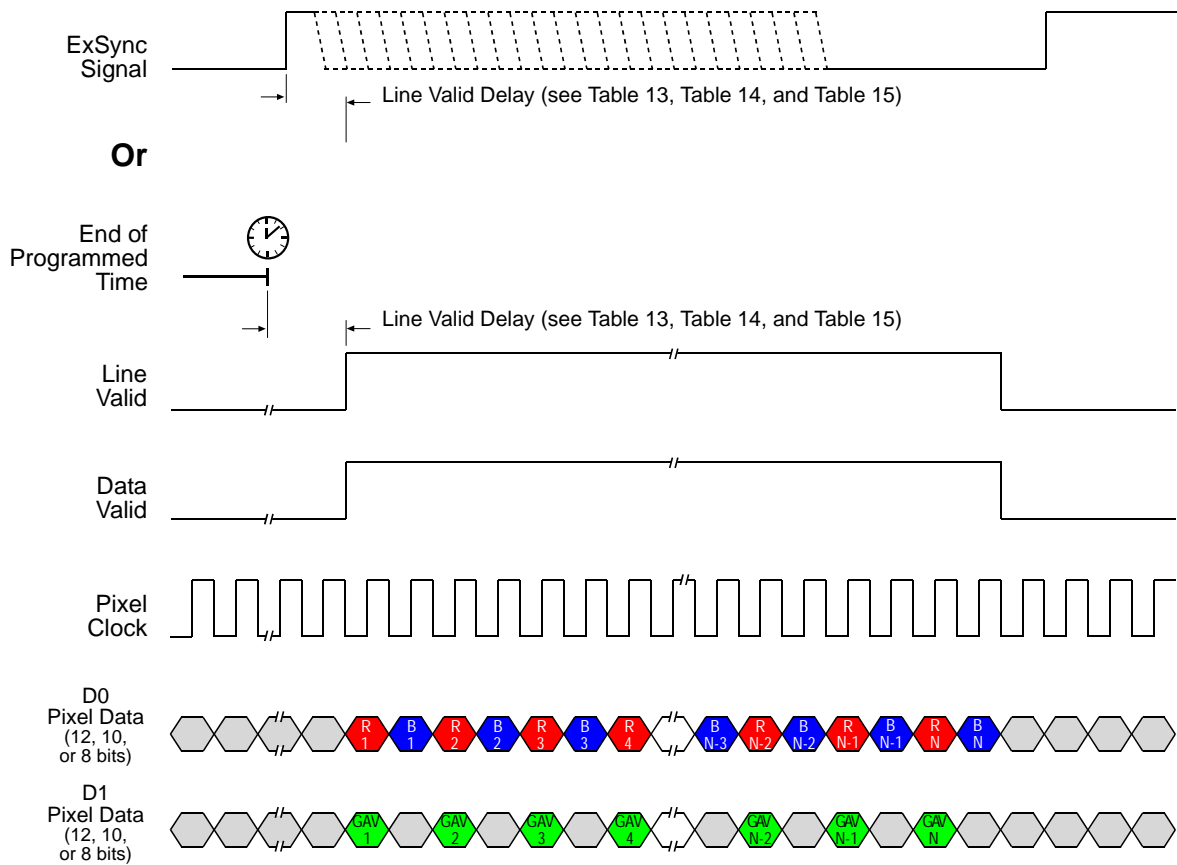
For information about the available video data output modes and bit depths for your camera model, see Section 5.1 on [page 108](#).

The assignment of pixel data bits to output ports depends on the video data output mode of the camera. The video data output modes and the bit assignments are explained in detail in Chapter 5 on [page 108](#). The bit assignments comply with the Camera Link standard.

The tables also show the assignments for the line valid bit, the data valid bit, and the pixel clock. These assignments are constant for all output modes.

The following diagrams illustrate the sequences of pixel values for each tap and the related timing patterns for the pixel clock, the line valid and the data valid signals. Edge or level controlled exposure and programmed exposure are considered.

3.2.1.1 2 Tap Output Mode



Timing diagrams are not to scale.

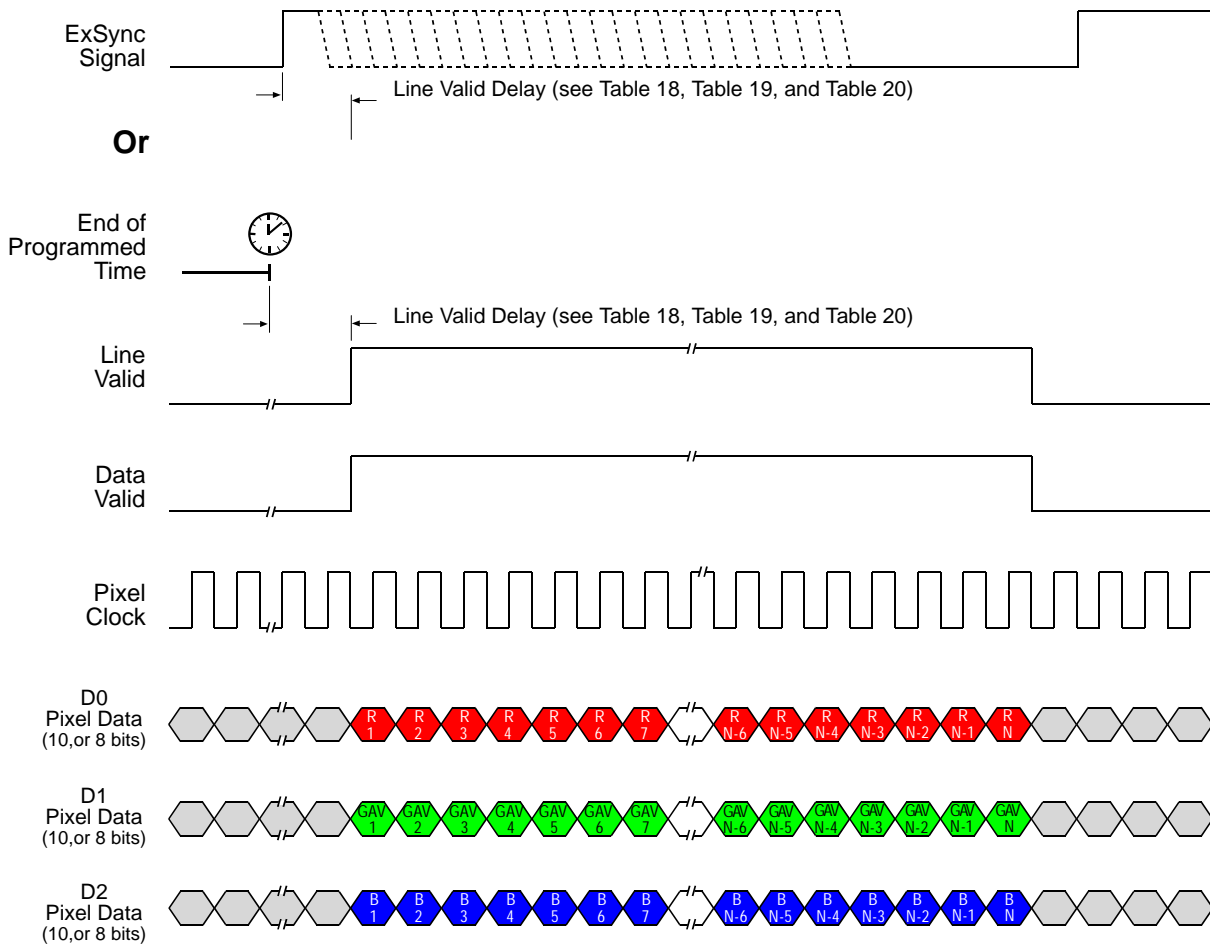
N = At full resolution (virtual pixels), N = 4096 on the 8k model, 2048 on 4k models, and 1024 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 14: Two Tap Mode with Edge/Level Controlled or Programmed Exposure (RGB)

Pixel data and dummy data are transmitted in an alternating fashion on the D1 tap.

3.2.1.2 3 Tap Output Mode



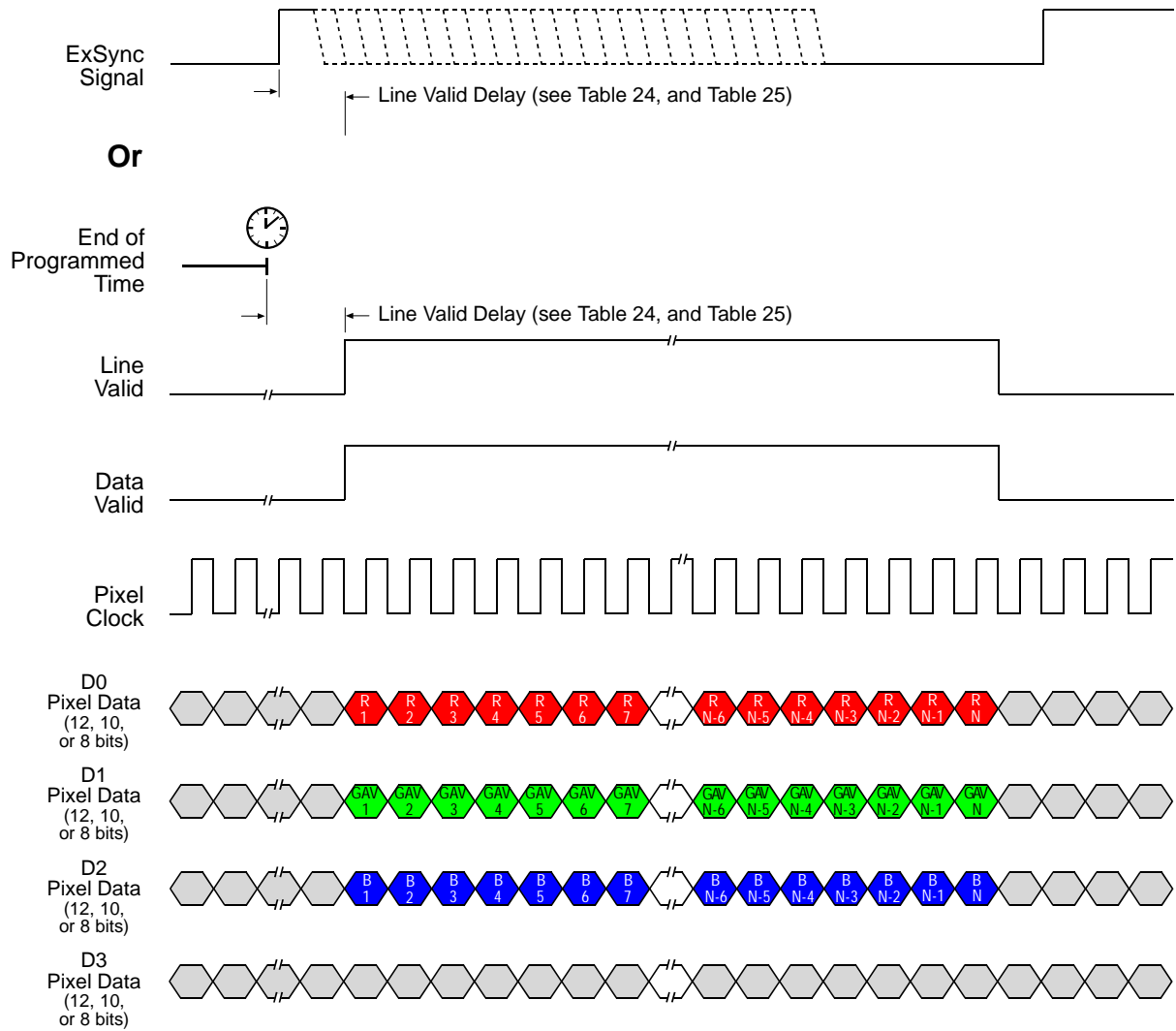
Timing diagrams are not to scale.

N = At full resolution (virtual pixels), N = 4096 on the 8k model, 2048 on 4k models, and 1024 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 15: Three Tap Mode with Edge/Level Controlled or Programmed Exposure (RGB)

3.2.1.3 4 Tap Output Mode



Timing diagrams are not to scale.

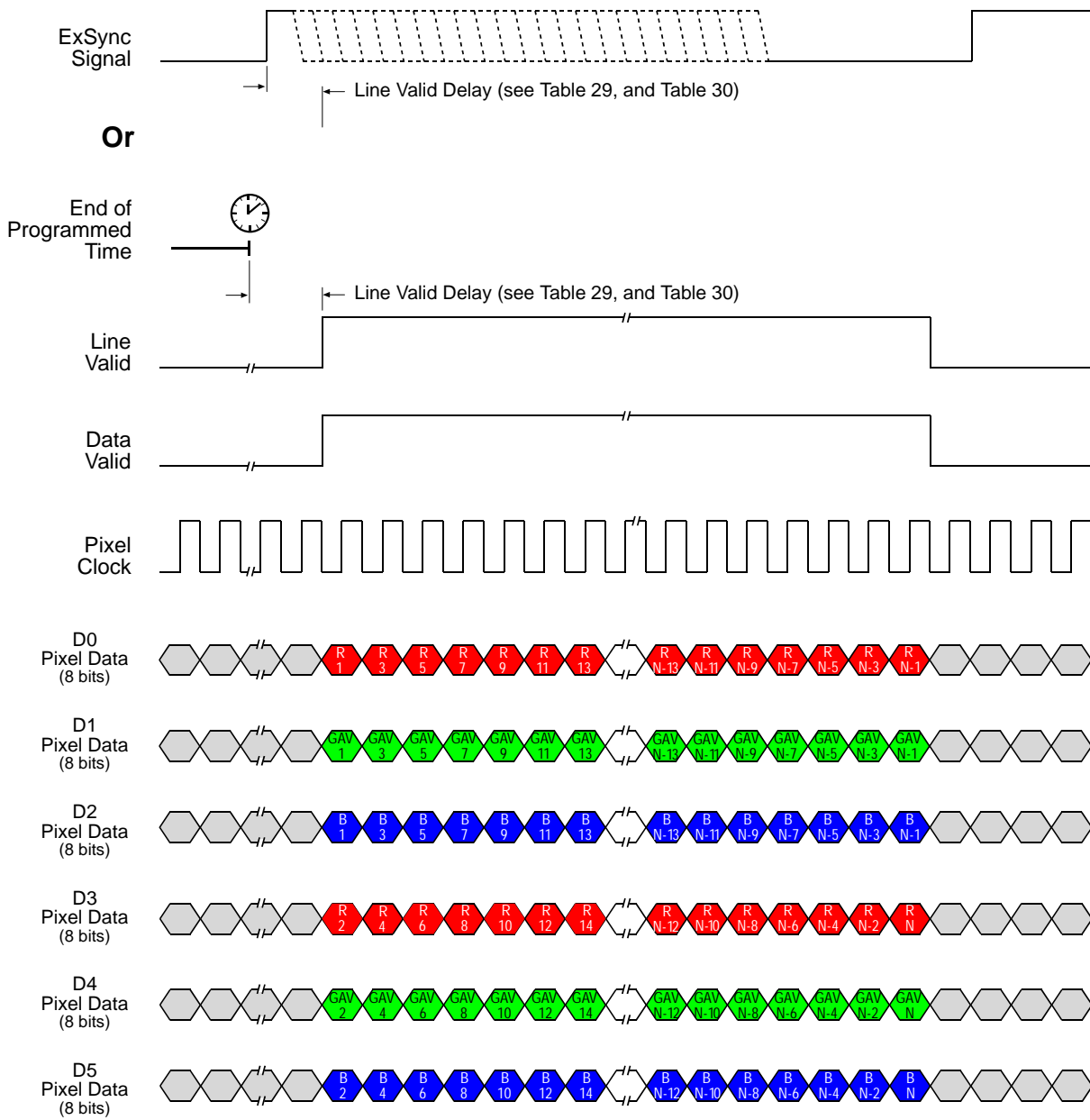
N = At full resolution (virtual pixels), N = 4096 on the 8k model, 2048 on 4k models, and 1024 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 16: Four Tap Mode with Edge/Level Controlled or Programmed Exposure (RGB)

Dummy data are transmitted on the D3 tap.

3.2.1.4 6 Tap Output Mode



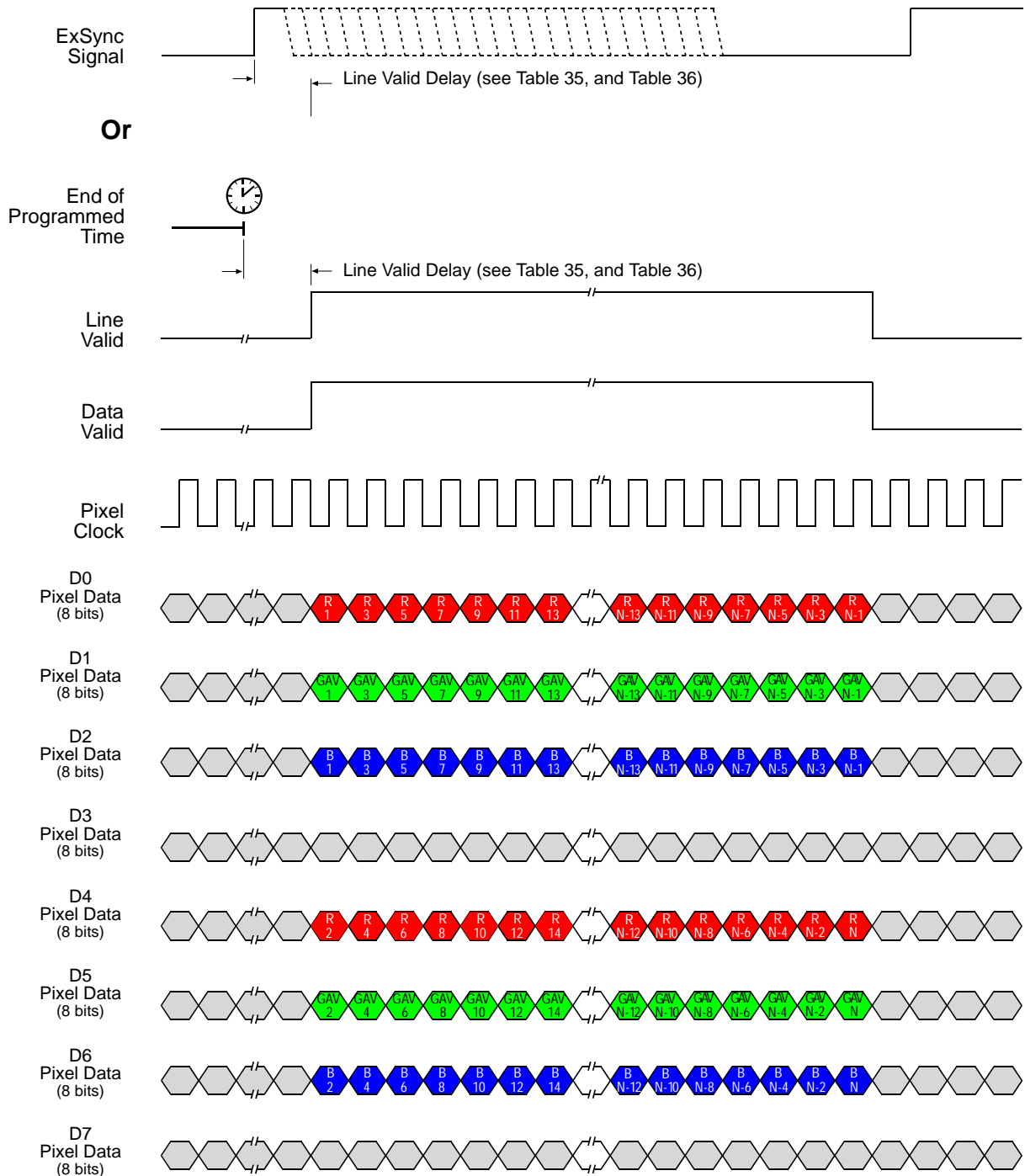
Timing diagrams are not to scale.

N = At full resolution (virtual pixels), N = 4096 on the 8k model, 2048 on 4k models, and 1024 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 17: Six Tap Mode with Edge/Level Controlled or Programmed Exposure (RGB)

3.2.1.5 8 Tap Output Mode



Timing diagrams are not to scale.

N = At full resolution (virtual pixels), N = 4096 on the 8k model, 2048 on 4k models, and 1024 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 18: Eight Tap Mode with Edge/Level Controlled or Programmed Exposure (RGB)

Dummy data are transmitted on the D3 and D7 taps.

3.3 Raw Line Acquisition Mode

The Raw line acquisition mode provides either a raw "red", a raw "green", or a raw "blue" pixel value for each point of an imaged object.

For imaging, a sensor is used, where each individual pixel is covered by a filter that allows light of only one color - red, green, or blue - to strike the pixel. The pixel values transmitted from line A will be "red" and "green" values, and the pixel values transmitted from line B will be "green" and "blue" values. For more information about color creation and about the assignment of the colors to the individual pixels of the sensor, see Section 1.6 on [page 16](#).

When the Raw line acquisition mode is active, both lines of the sensor are exposed at the same time. With each ExSync cycle, however, the pixel data of only one line are transmitted and therefore, two ExSync cycles are required to transmit the pixel data of each exposure.



Lines A and B of the sensor are exposed at the same time. For complete imaging of the object without overlap, make sure to move the **image** of the object by 20 μm between two successive exposures.

For details of how to relate the extent of the image movement to the extent of the object movement, see Section 3.5.3 on [page 89](#).



You can use the Raw - Line A First and Raw - Line B First line acquisition modes in an alternating fashion when the imaged object moves in opposite directions.

3.3.1 Raw - Line A First Line Acquisition Mode

The Raw - Line A First line acquisition mode is analogous to the Raw - Line B First line acquisition mode (see Section 3.3.2 on [page 54](#)), with the roles of lines A and B interchanged.

In the Raw - Line A First line acquisition mode, the pixel data for line A will be transmitted first, followed by the pixel data for line B.

When using the Raw - Line A First line acquisition mode, the object being imaged should cross line A first and line B second (the **image** of the object will cross line B first and line A second as is apparent from Figure 19 through Figure 22).

After having enabled the Raw - Line A First line acquisition mode, the following will occur in a sequence of ExSync cycles:

- The first cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.

- time the start of transmission of line A pixel data. The values from line B are held in a buffer in the camera.
- The second cycle of the ExSync signal will:
 - time the start of transmission of line B pixel data. No exposure will occur.
- The third cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line A pixel data. The values from line B are held in a buffer in the camera.
- The fourth cycle of the ExSync signal will:
 - time the start of transmission of line B pixel data. No exposure will occur.
- And so on

For more information about triggering line acquisition and controlling exposure, see Section 4 on [page 92](#).

To better understand how Raw - Line A First line acquisition and object movement relate, consider the example that is illustrated in Figure 19 through Figure 22.

This example describes Raw - Line A First line acquisition when an ExSync signal and the programmable exposure control mode are used. The example looks at four contiguous "points" on an object moving past the camera. Each point represents the area on the object that will be captured by one line in the sensor when a line acquisition is performed. As you look at the figures, notice that on the ExSync cycles where an acquisition is performed, line A will capture one point on the object and line B will capture a different point on the object. Also notice that on these cycles, the pixel data for line A will be transmitted while the pixel data for line B will be buffered. On the ExSync cycles where acquisition is not performed, the buffered pixel data for line B will be transmitted.

ExSync Cycle 1

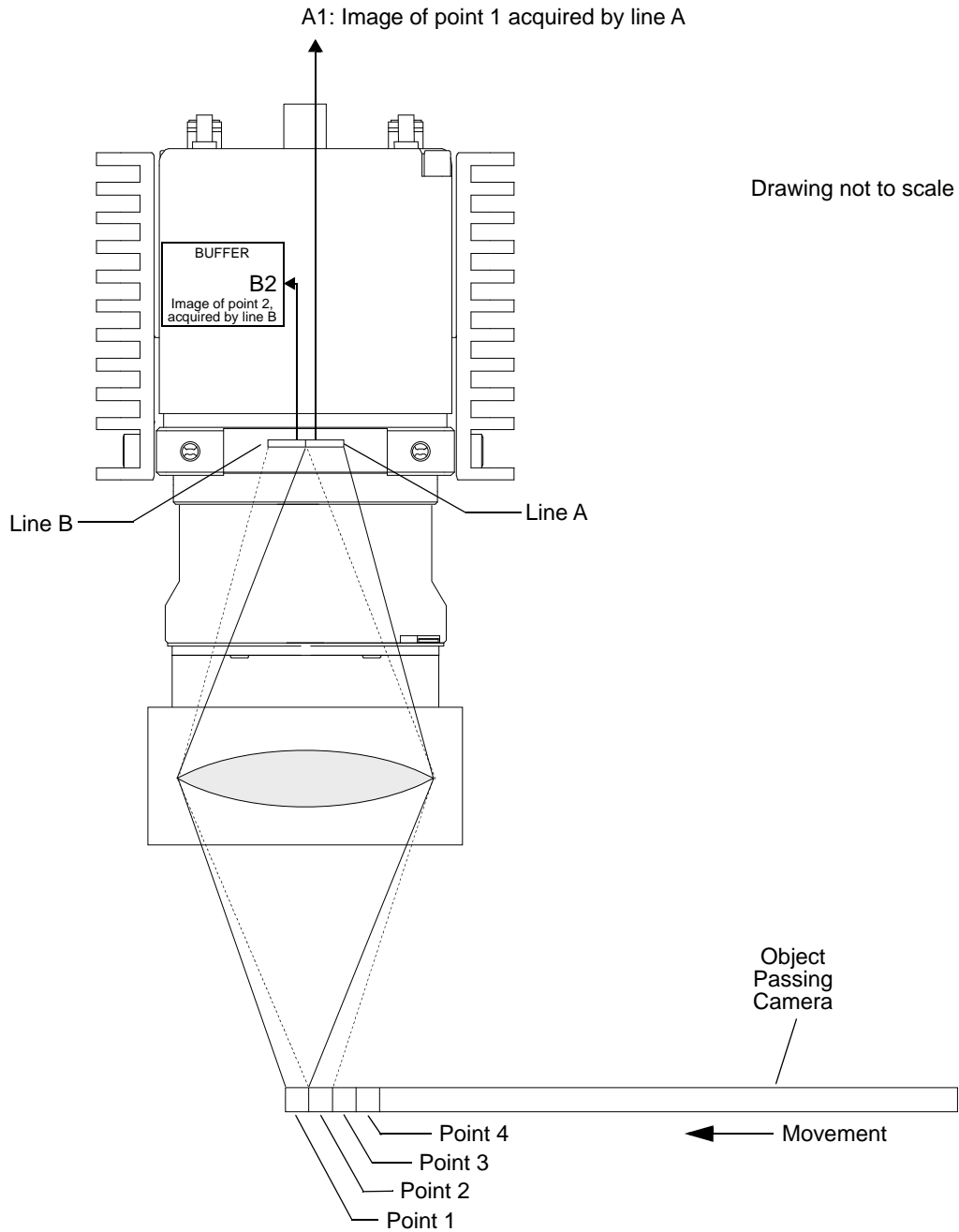


Fig. 19: Raw - Line A First Line Acquisition - ExSync Cycle 1

ExSync Cycle 2

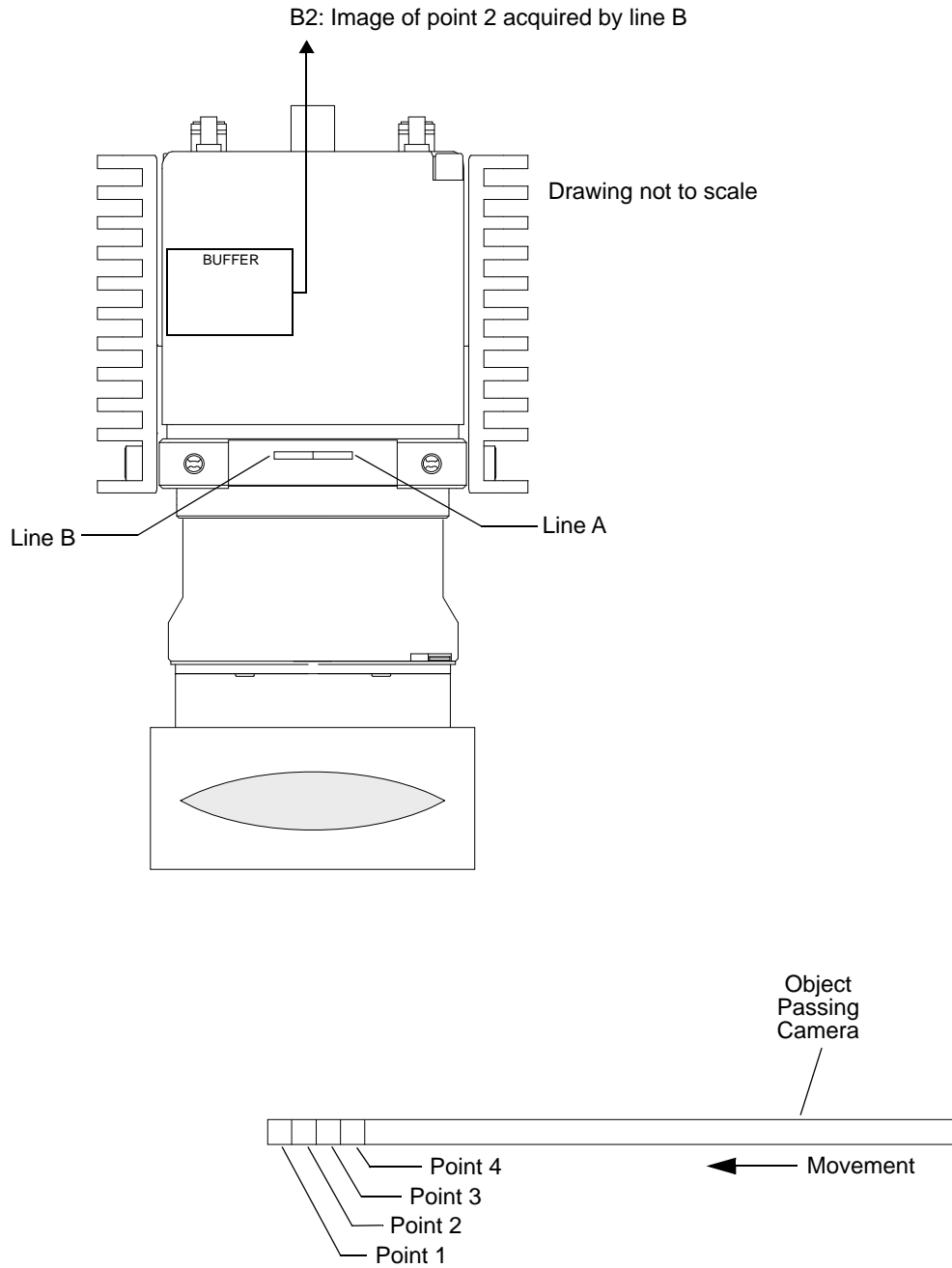


Fig. 20: Raw - Line A First Line Acquisition - ExSync Cycle 2

ExSync Cycle 3

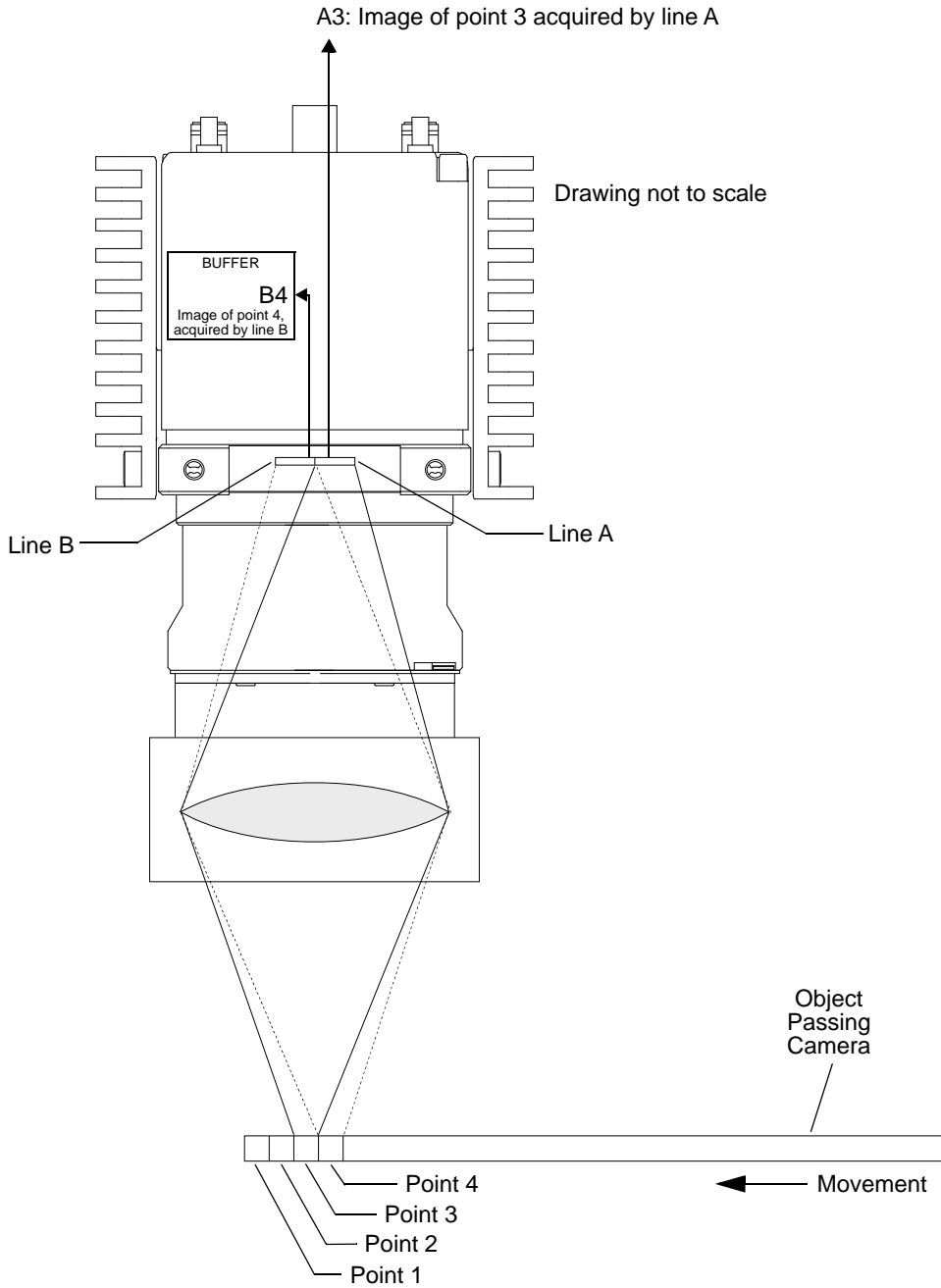


Fig. 21: Raw - Line A First Line Acquisition - ExSync Cycle 3

ExSync Cycle 4

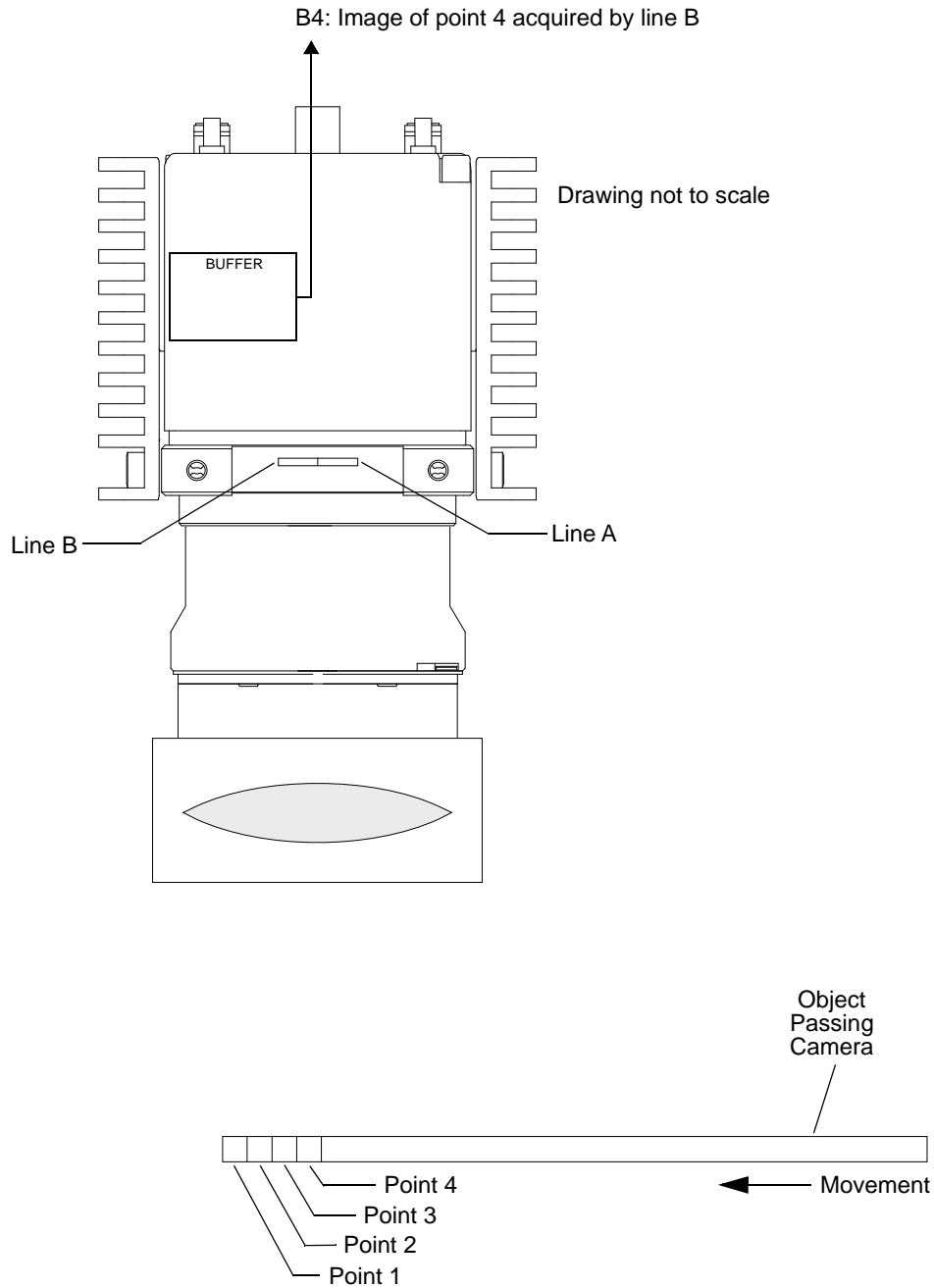


Fig. 22: Raw - Line A First Line Acquisition - ExSync Cycle 4

Before transmission, the pixel values are arranged inside the camera in this sequence:

- Line A: pixel value ("red") of pixel 1 (RA1), pixel value ("green") of pixel 2 (GA2), pixel value ("red") of pixel 3 (RA3), pixel value ("green") of pixel 4 (GA4), and so on.
- Line B: pixel value ("green") of pixel 1 (GB1), pixel value ("blue") of pixel 2 (BB2), pixel value ("green") of pixel 3 (GB3), pixel value ("blue") of pixel 4 (BB4) and so on.

The pixel values are transmitted from the camera according to the selected video data output mode using a specific bit depth and number of taps. For information about the available video data output modes, the assignment of the pixel values to the individual taps, and timing details of the data transmission, see Section 3.3.1.1 on [page 50](#).

For information about bit assignments, see Section 5.2 on [page 110](#).

3.3.1.1 Pixel Value Transmission for the Raw - Line A First Line Acquisition Mode

For the Raw - Line A First line acquisition mode, you can select a 2, 4, or 8 tap video output mode for transmitting pixel data, at bit depths of 8, 10, or 12.



Not all camera models support 4 or 8 tap video data output mode. Not all combinations of video data output modes and bit depths are available.

For information about the available video data output modes and bit depths for your camera model, see Section 5.1 on [page 108](#).

The Raw - Line A First line acquisition mode provides a frame valid (FVAL) signal which indicates line A in a sequence of consecutive lines being transmitted: When the frame valid signal goes high, the line being transmitted will include pixel data from line A with "red" and "green" pixel values. And the next line transmitted will include pixel data from line B.

The length of the frame valid signal can be set to multiples of two. If, for examples, the length is set to two, the FVAL signal will go low after two lines have been transmitted, if the length is set to four, the FVAL signal will go low after four lines have been transmitted, and so on. If the length is set to zero, the FVAL signal will stay low throughout.

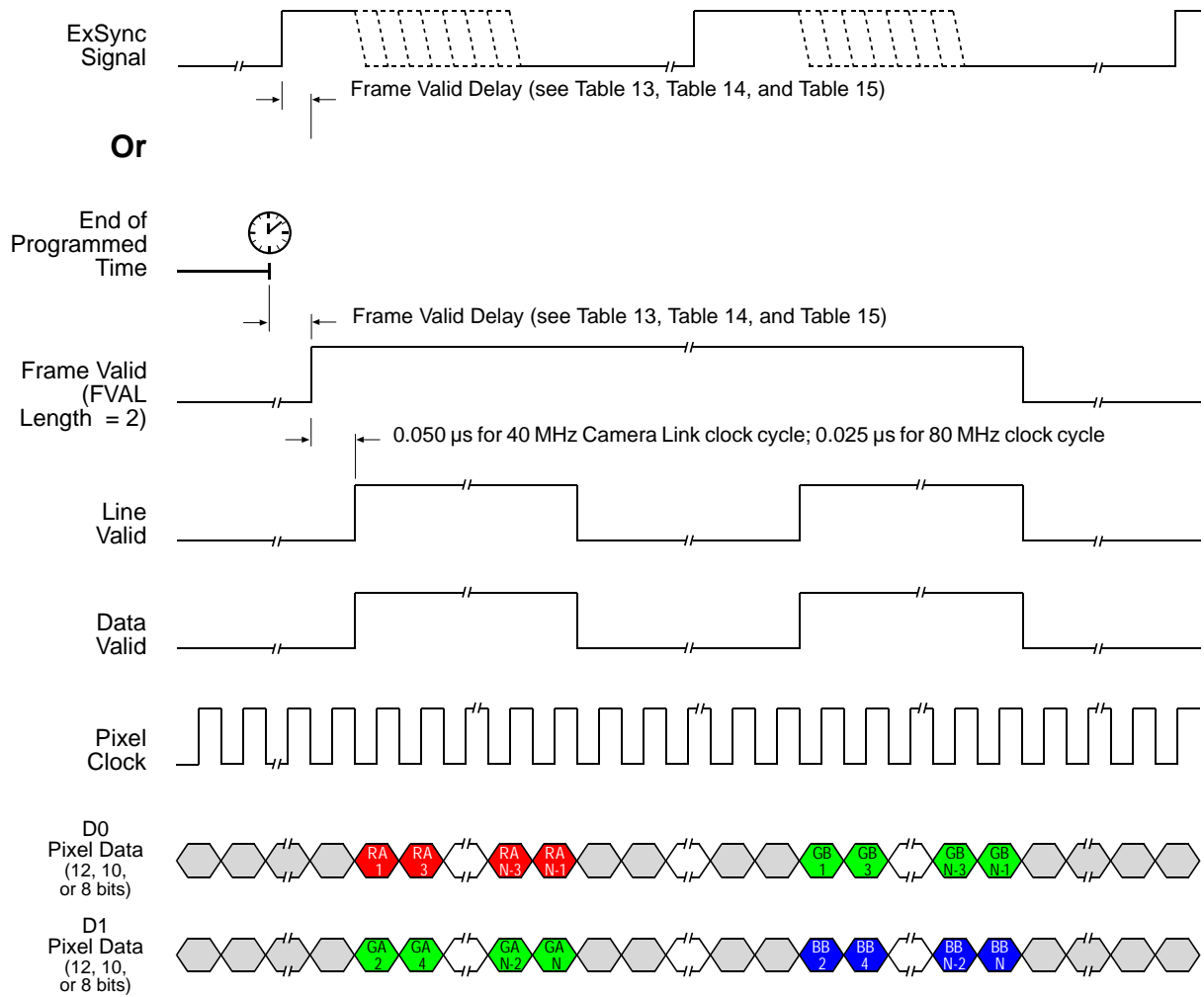
For information about setting the frame valid signal for the number of lines it will stay high, see [page 222](#).

The assignment of pixel data bits to output ports depends on the video data output mode of the camera. The video data output modes and the bit assignments are explained in detail in Section 5 on [page 108](#). The bit assignments comply with the Camera Link standard.

The tables also show the assignments for the frame valid bit, the line valid bit, the data valid bit, and the pixel clock. These assignments are constant for all output modes.

The following diagrams illustrate the sequences of pixel values for each tap and the related timing patterns for the pixel clock, the frame valid, the line valid and the data valid signals. Edge or level controlled exposure and programmed exposure are considered.

2 Tap Output Mode



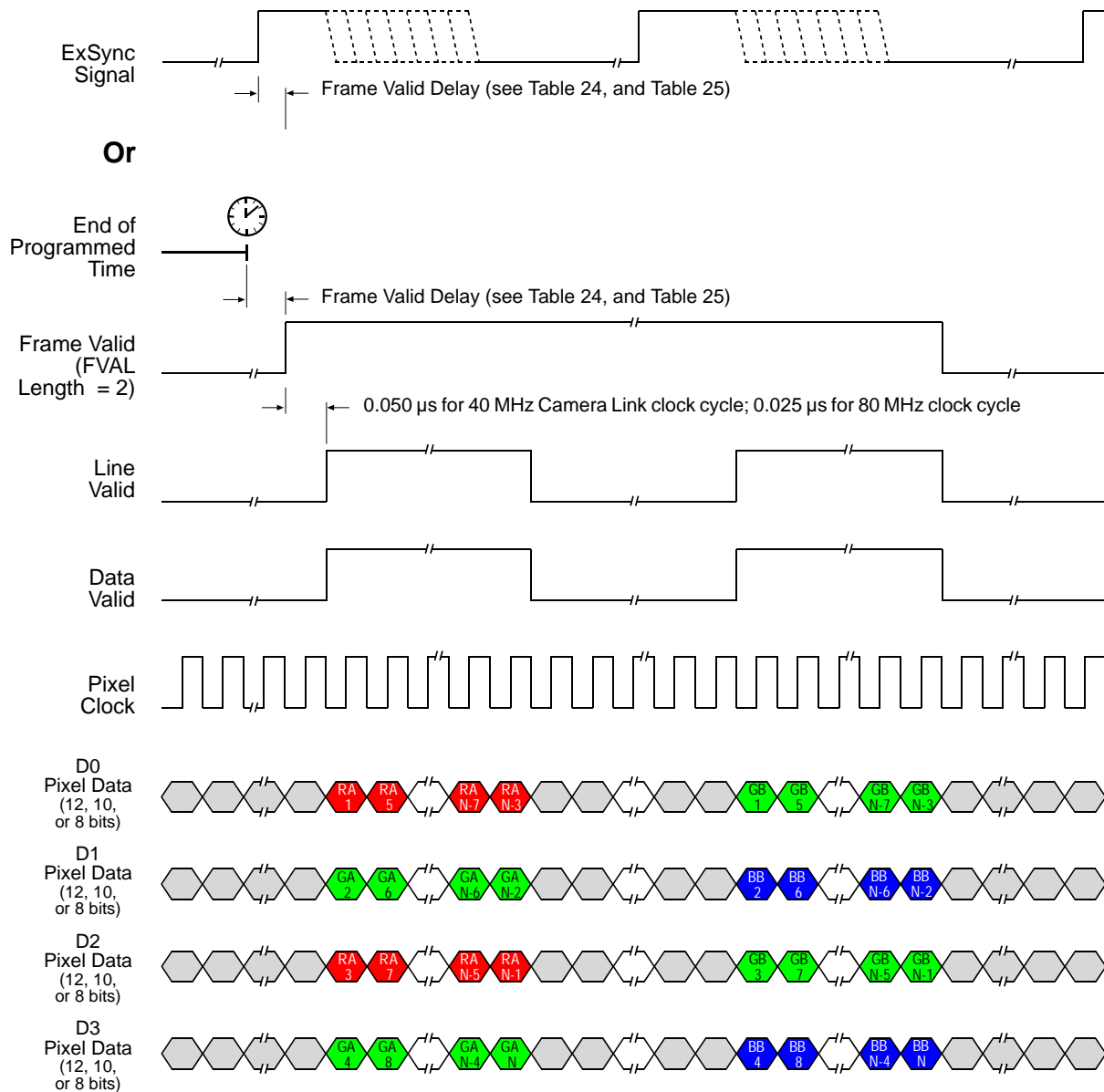
Timing diagrams are not to scale.

N = At full resolution, N = 8192 on the 8k model, 4096 on 4k models, and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 23: Two Tap Mode with Edge/Level Controlled or Programmed Exposure (Raw - Line A First)

4 Tap Output Mode



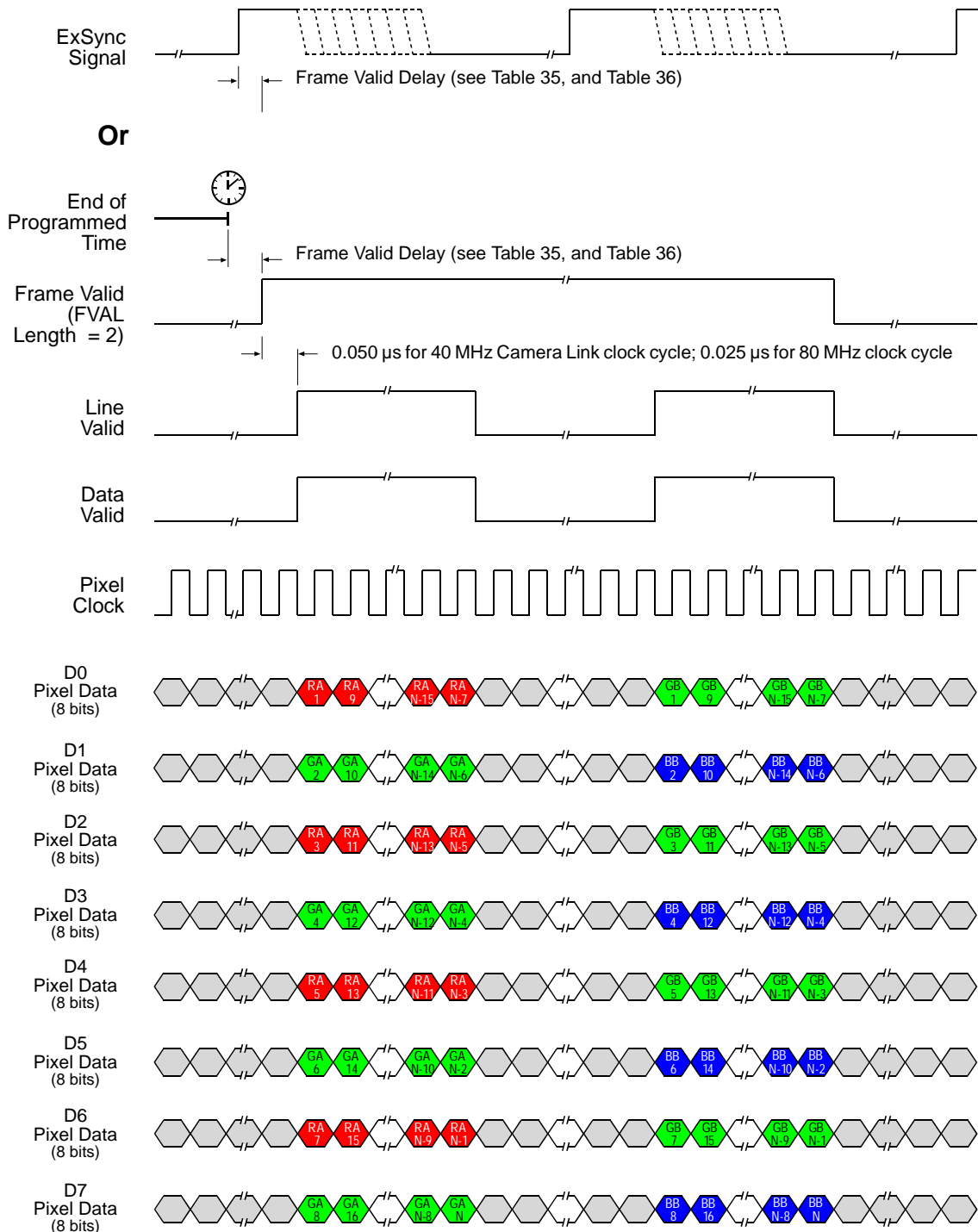
Timing diagrams are not to scale.

N = At full resolution, N = 8192 on the 8k model, 4096 on 4k models, and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 24: Four Tap Mode with Edge/Level Controlled or Programmed Exposure (Raw - Line A First)

8 Tap Output Mode



Timing diagrams are not to scale.

N = At full resolution, N = 8192 on the 8k model, 4096 on 4k models, and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 25: Eight Tap Mode with Edge/Level Controlled or Programmed Exposure (Raw - Line A First)

3.3.2 Raw - Line B First Line Acquisition Mode (2k and 4k Cameras Only)

The Raw - Line B First line acquisition mode is analogous to the Raw - Line A First line acquisition mode (see Section 3.3.1 on [page 44](#)), with the roles of lines A and B interchanged.

In the Raw - Line B First line acquisition mode, the pixel data for line B will be transmitted first, followed by the pixel data for line A.

When using the Raw - Line B First line acquisition mode, the object being imaged should cross line B first and line A second (the **image** of the object will cross line A first and line B second as is apparent from Figure 26 through Figure 29).

After having enabled the Raw - Line B First line acquisition mode, the following will occur in a sequence of ExSync cycles:

- The first cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line B pixel data. The values from line A are held in a buffer in the camera.
- The second cycle of the ExSync signal will:
 - time the start of transmission of line A pixel data. No exposure will occur.
- The third cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line B pixel data. The values from line A are held in a buffer in the camera.
- The fourth cycle of the ExSync signal will:
 - time the start of transmission of line A pixel data. No exposure will occur.
- And so on

For more information about triggering line acquisition and controlling exposure, see Section 4 on [page 92](#).

To better understand how Raw - Line B First line acquisition and object movement relate, consider the example that is illustrated in Figure 26 through Figure 29.

This example describes Raw - Line B First line acquisition when an ExSync signal and the programmable exposure control mode are used. The example looks at four contiguous "points" on an object moving past the camera. Each point represents the area on the object that will be captured by one line in the sensor when a line acquisition is performed. As you look at the figures, notice that on the ExSync cycles where an acquisition is performed, line B will capture one point on the object and line A will capture a different point on the object. Also notice that on these cycles, the pixel data for line B will be transmitted while the pixel data for line A will be buffered. On the ExSync cycles where acquisition is not performed, the buffered pixel data for line A will be transmitted.

ExSync Cycle 1

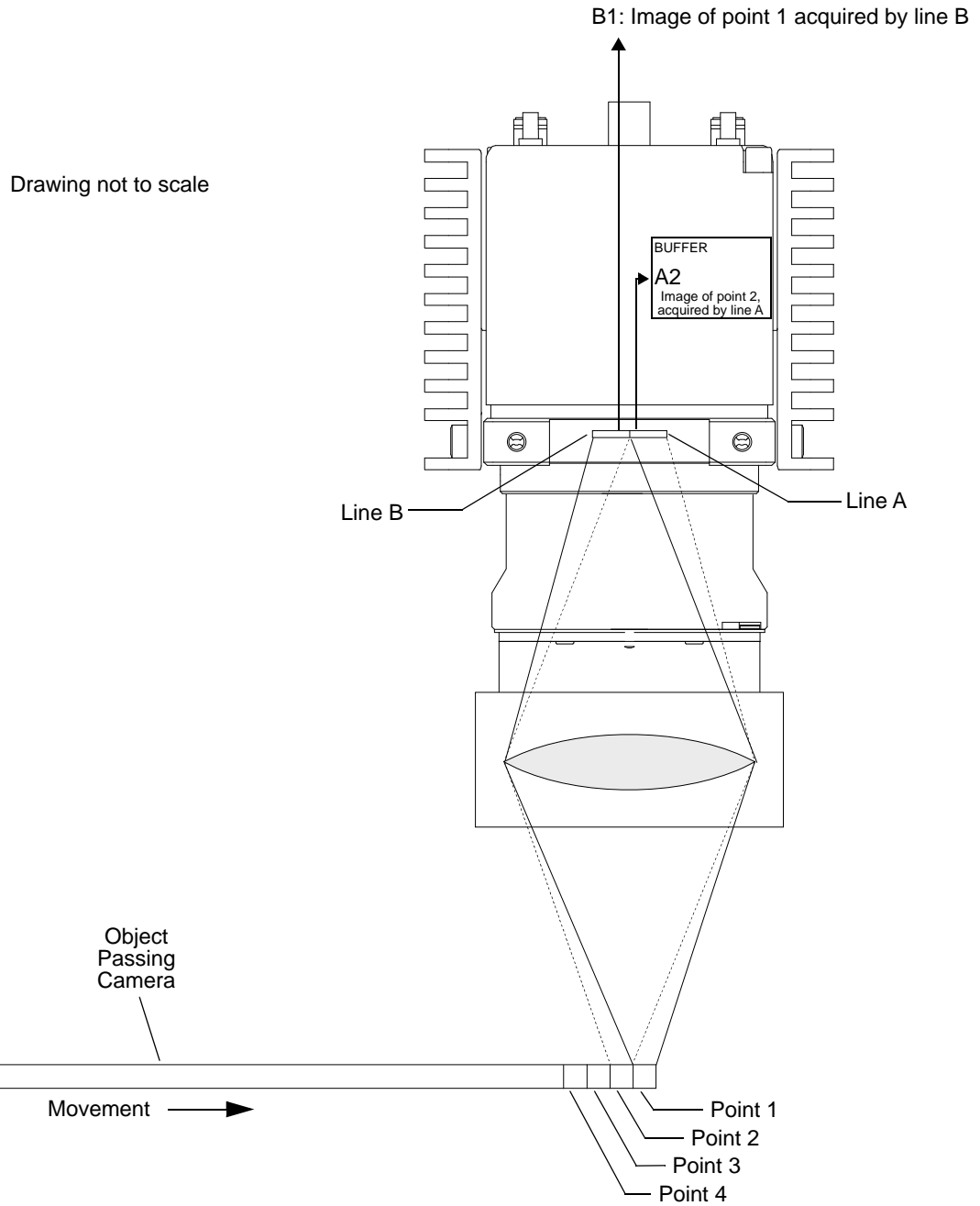


Fig. 26: Raw - Line B First Line Acquisition - ExSync Cycle 1

ExSync Cycle 2

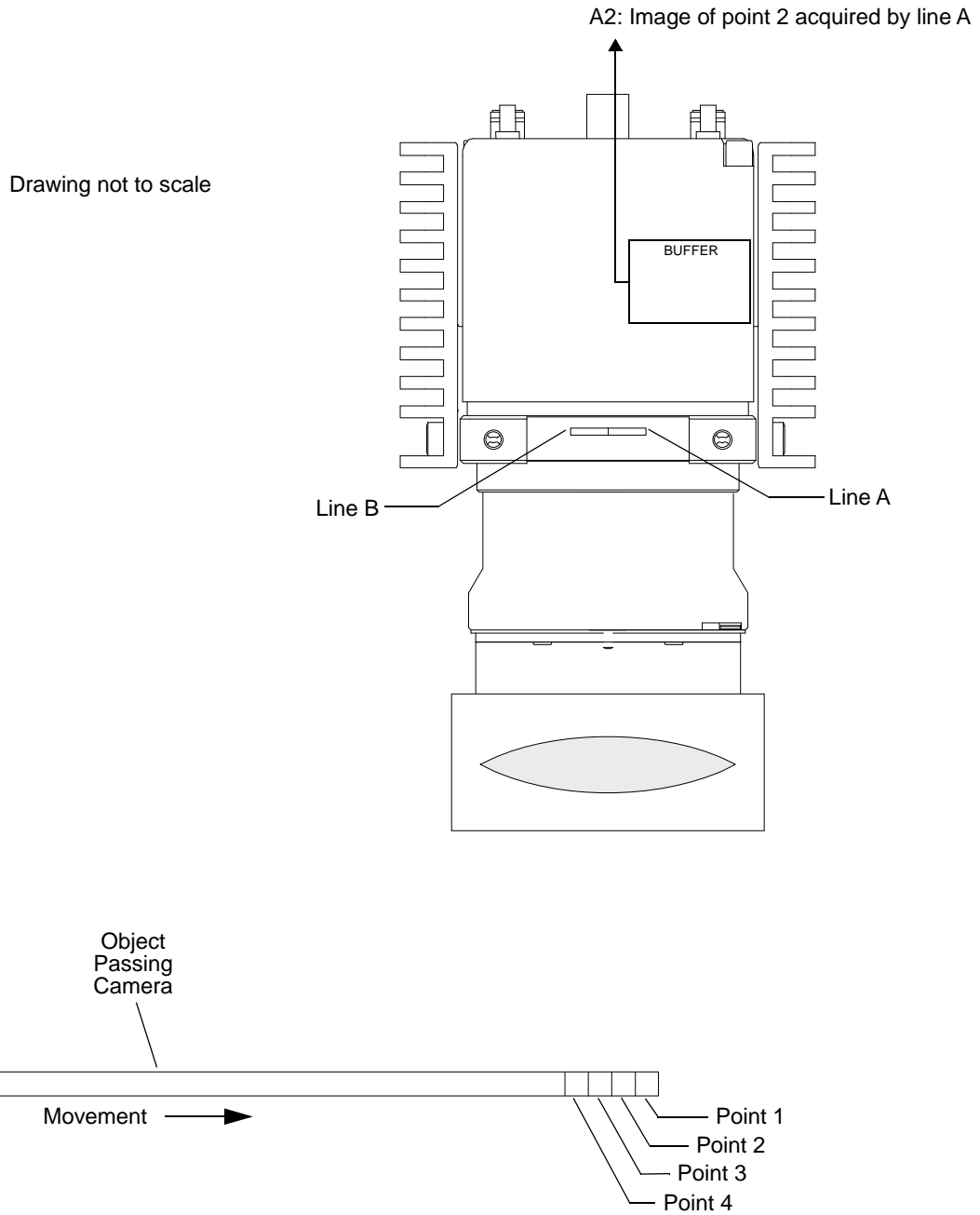


Fig. 27: Raw - Line B First Line Acquisition - ExSync Cycle 2

ExSync Cycle 3

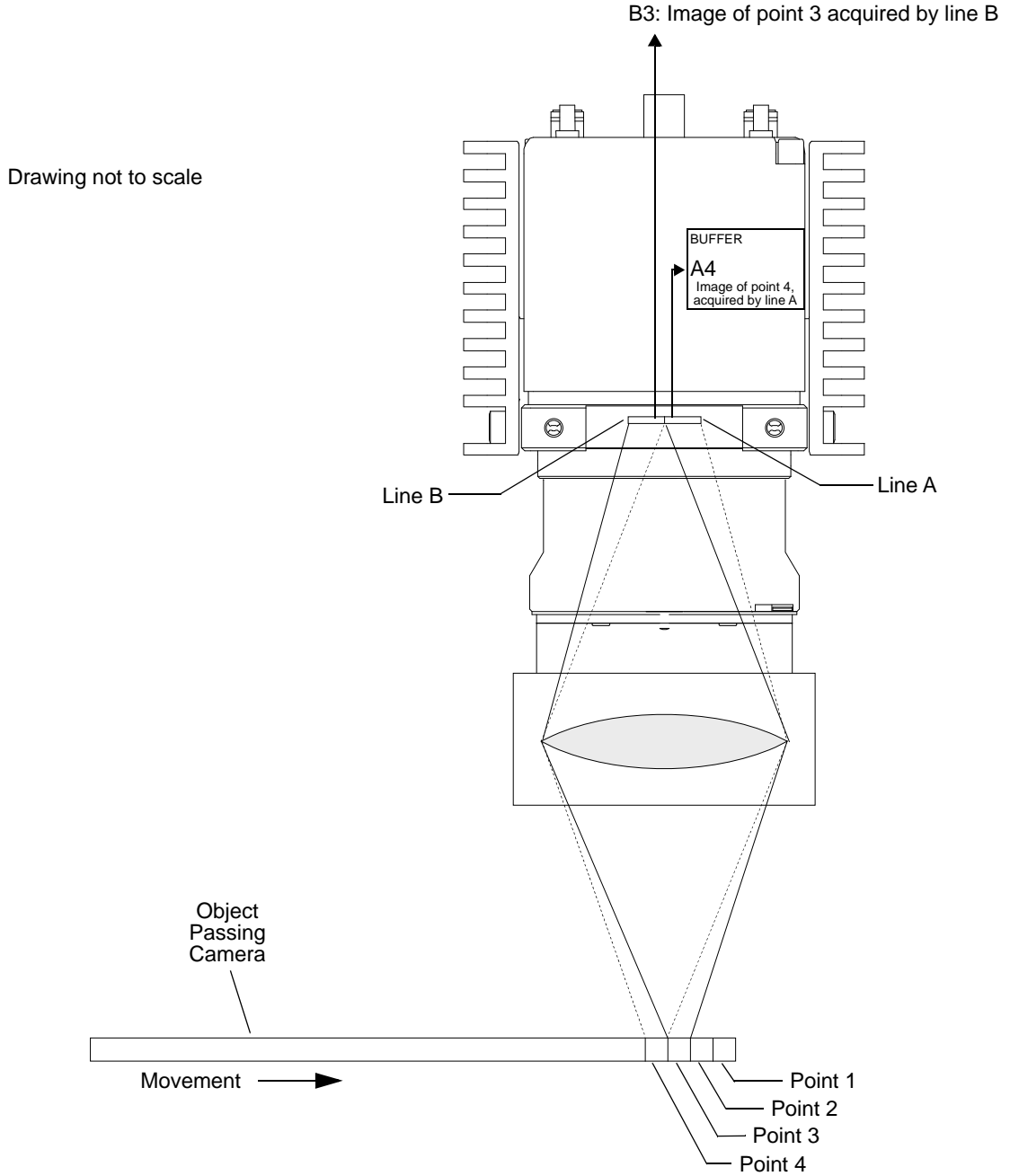


Fig. 28: Raw - Line B First Line Acquisition - ExSync Cycle 3

ExSync Cycle 4

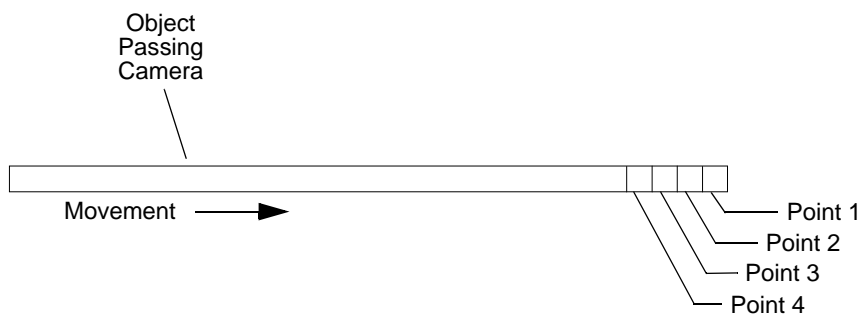
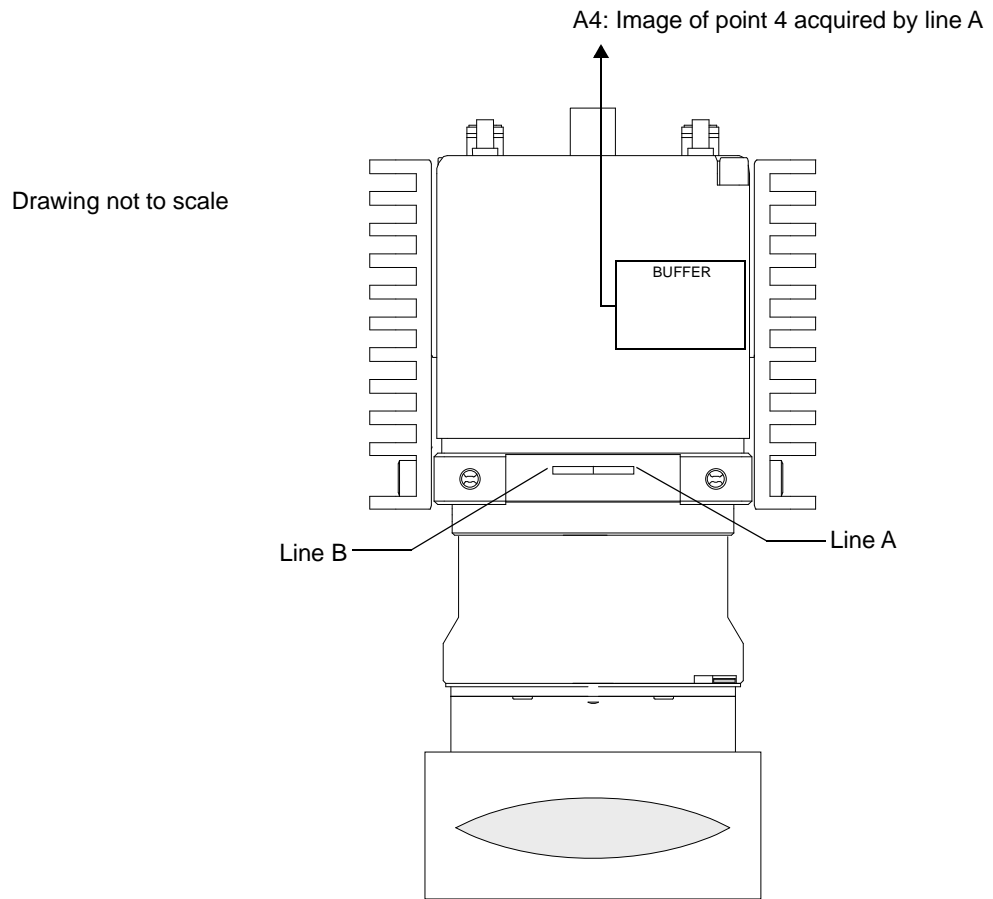


Fig. 29: Raw - Line B First Line Acquisition - ExSync Cycle 4

Before transmission, the pixel values are arranged inside the camera in this sequence:

- Line A: pixel value ("red") of pixel 1 (RA1), pixel value ("green") of pixel 2 (GA2), pixel value ("red") of pixel 3 (RA3), pixel value ("green") of pixel 4 (GA4), and so on.
- Line B: pixel value ("green") of pixel 1 (GB1), pixel value ("blue") of pixel 2 (BB2), pixel value ("green") of pixel 3 (GB3), pixel value ("blue") of pixel 4 (BB4), and so on.

The pixel values are transmitted from the camera according to the selected video data output mode using a specific bit depth and number of taps. For information about the available video data output modes, the assignment of the pixel values to the individual taps, and timing details of the data transmission, see Section 3.3.2.1 on [page 59](#).

For information about bit assignments, see Section 5.2 on [page 110](#).

3.3.2.1 Pixel Value Transmission for the Raw - Line B First Line Acquisition Mode

For the Raw - Line B First line acquisition mode, you can select a 2, 4, or 8 tap video output mode for transmitting pixel data, at bit depths of 8, 10, or 12.



Not all camera models support 4 or 8 tap video data output mode. Not all combinations of video data output modes and bit depths are available.

For information about the available video data output modes and bit depths for your camera model, see Section 5.1 on [page 108](#).

The Raw - Line B First line acquisition mode provides a frame valid (FVAL) signal which indicates line B in a sequence of consecutive lines being transmitted: When the frame valid signal goes high, the line being transmitted will include pixel data from line B with "green" and "blue" pixel values. And the next line transmitted will include pixel data from line A.

The length of the frame valid signal can be set to multiples of two. If, for examples, the length is set to two, the FVAL signal will go low after two lines have been transmitted, if the length is set to four, the FVAL signal will go low after four lines have been transmitted, and so on. If the length is set to zero, the FVAL signal will stay low throughout.

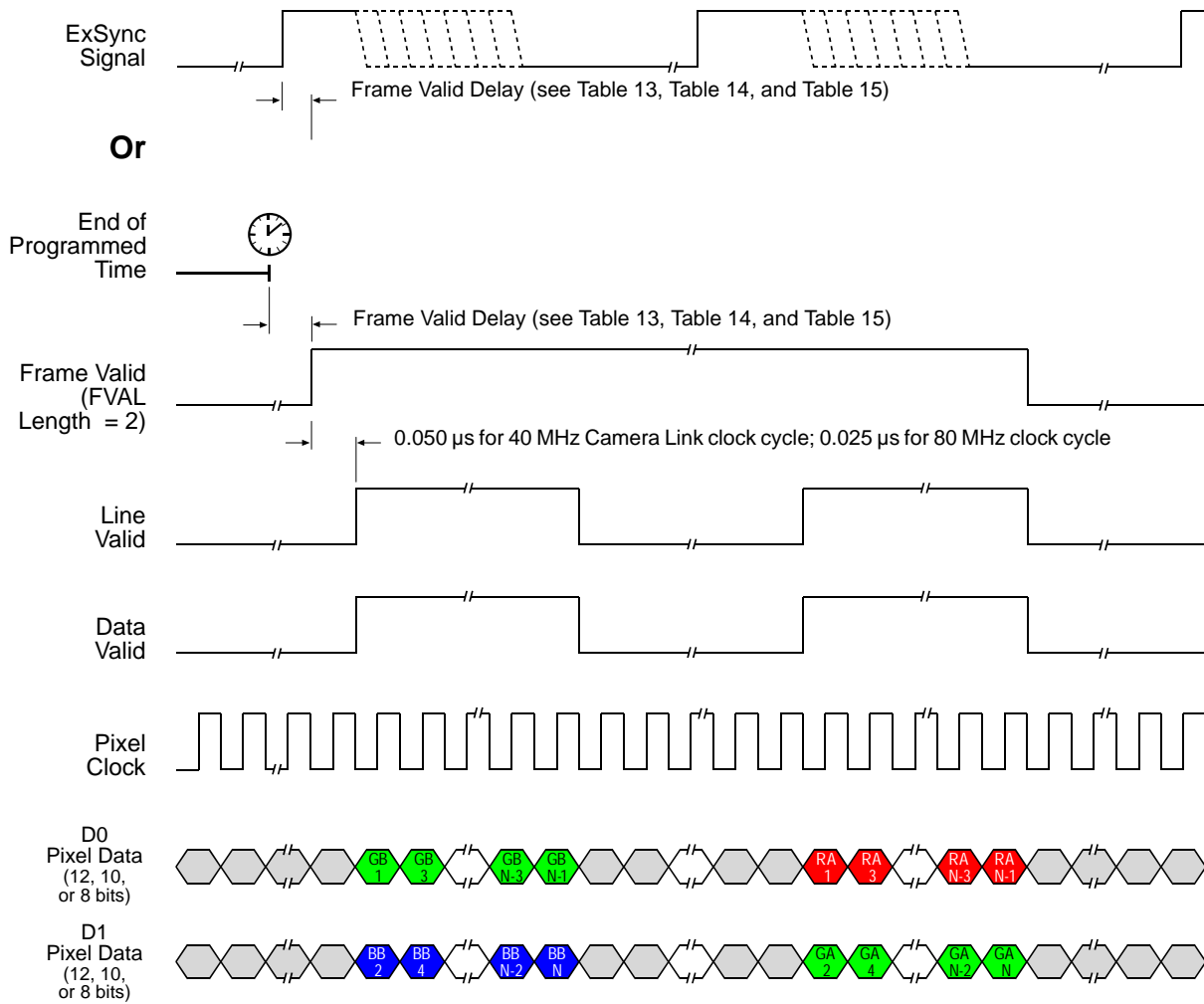
For information about setting the frame valid signal for the number of lines it will stay high, see [page 222](#).

The assignment of pixel data bits to output ports depends on the video data output mode of the camera. The video data output modes and the bit assignments are explained in detail in Section 5 on [page 108](#). The bit assignments comply with the Camera Link standard.

The tables also show the assignments for the frame valid bit, the line valid bit, the data valid bit, and the pixel clock. These assignments are constant for all output modes.

The following diagrams illustrate the sequences of pixel values for each tap and the related timing patterns for the pixel clock, the frame valid, the line valid and the data valid signals. Edge or level controlled exposure and programmed exposure are considered.

2 Tap Output Mode



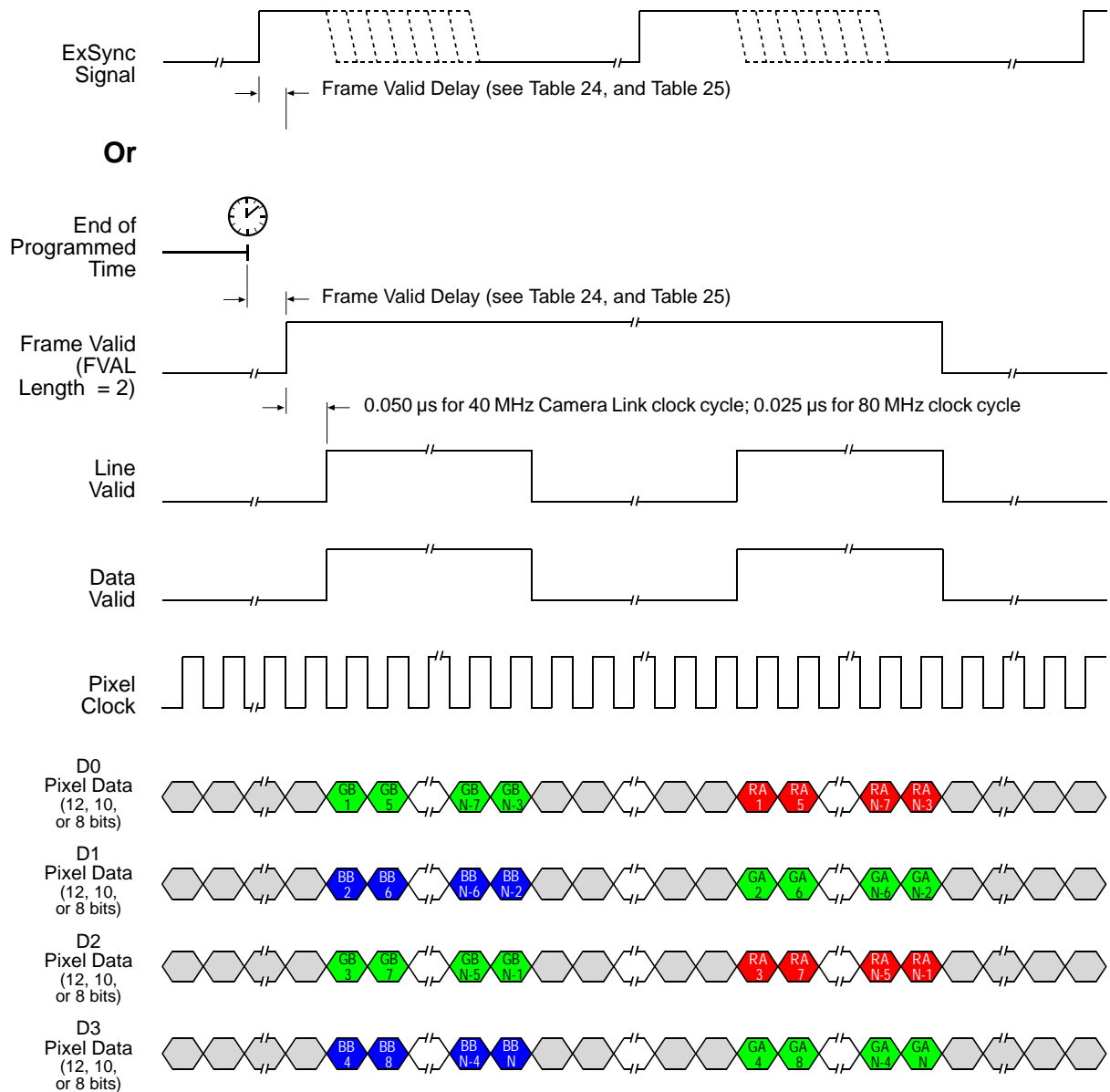
Timing diagrams are not to scale.

$N =$ At full resolution, $N = 4096$ on 4k models and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 30: Two Tap Mode with Edge/Level Controlled or Programmed Exposure (Raw - Line B First)

4 Tap Output Mode



Timing diagrams are not to scale.

N = At full resolution, N = 4096 on 4k models and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 31: Four Tap Mode with Edge/Level Controlled or Programmed Exposure (Raw - Line B First)

8 Tap Output Mode

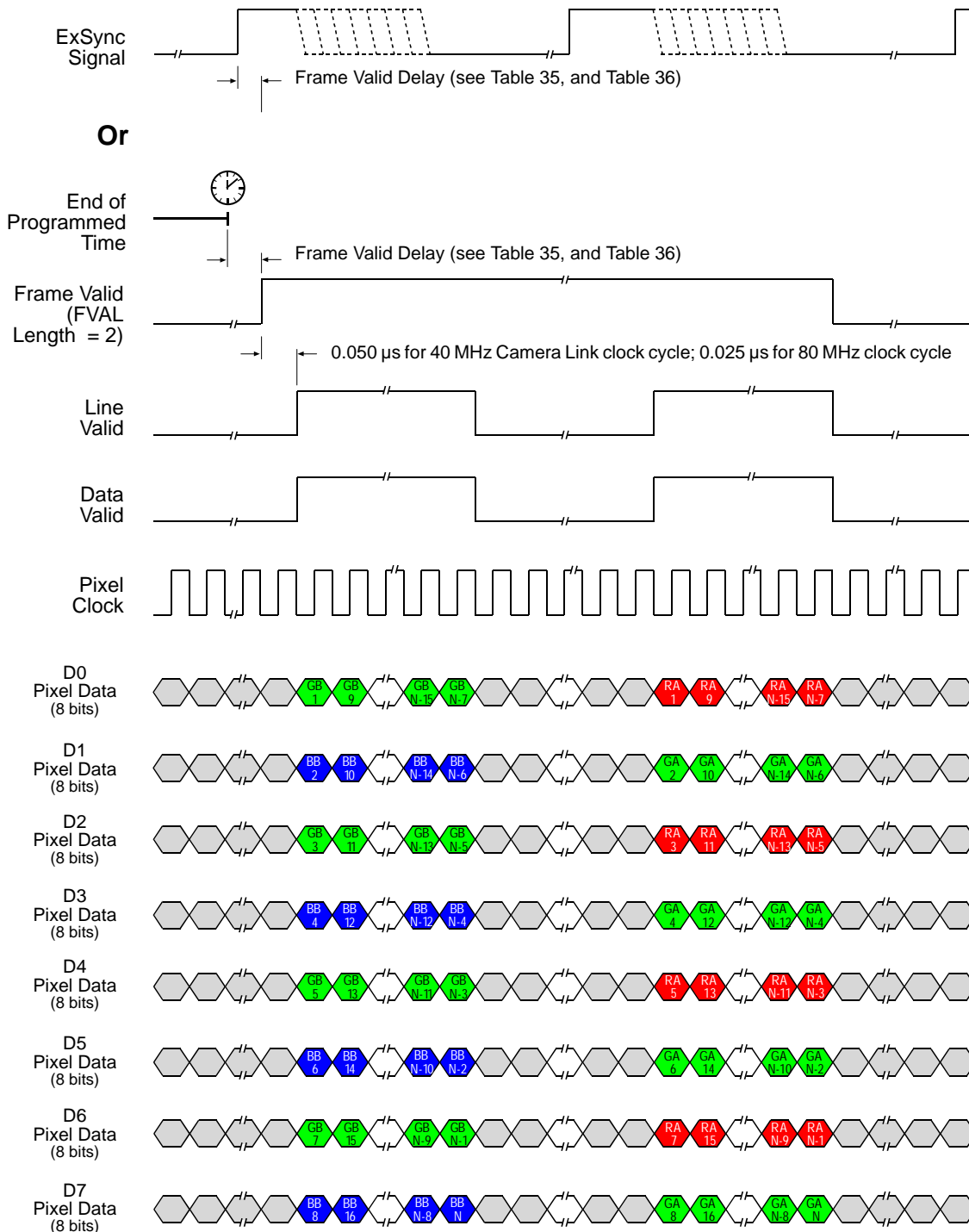


Fig. 32: Eight Tap Mode with Edge/Level Controlled or Programmed Exposure (Raw - Line B First)

3.4 Enhanced Raw Line Acquisition Mode

The Enhanced Raw line acquisition mode provides a raw "green" pixel value for each point of an imaged object and, in addition, either a raw "red" or a raw "blue" pixel value. Accordingly, each point of the object is imaged twice, once by a pixel in line B, and once by a pixel in line A.

For imaging, a sensor is used where each individual pixel is covered by a filter that allows light of only one color - red, green, or blue - to strike the pixel. The pixel values transmitted from line A will be "red" and "green" values, and the pixel values transmitted from line B will be "green" and "blue" values. For more information about color creation and about the assignment of the colors to the individual pixels of the sensor, see Section 1.6 on [page 16](#).

When the Enhanced Raw line acquisition mode is active, both lines of the sensor are exposed at the same time. With each ExSync cycle, however, the pixel data of only one line are transmitted and therefore, two ExSync cycles are required to transmit the pixel data of each exposure.



The Enhanced Raw line acquisition modes are designed for imaging each point of the object twice. Therefore, make sure to move the **image** of the object by 10 μm between two successive exposures.

For details of how to relate the extent of the image movement to the extent of the object movement, see Section 3.5.3 on [page 89](#).



You can use the Enhanced Raw - Line A First and Enhanced Raw - Line B First line acquisition modes in an alternating fashion when the imaged object moves in opposite directions.

3.4.1 Enhanced Raw - Line A First (B Delayed) Line Acquisition Mode

The Enhanced Raw - Line A First (B Delayed) line acquisition mode is analogous to the Enhanced Raw - Line B First (A Delayed) line acquisition mode (see Section 3.4.2 on [page 76](#)), with the roles of lines A and B interchanged.

In the Enhanced Raw - Line A First line acquisition mode, the two lines which include pixel data from the same area of the object, are transmitted immediately one after the other: The pixel data for line A will be transmitted first, followed by the related pixel data for line B, which are transmitted on the next clock cycle. In this way, pairs of related lines are created with both lines imaging the same area of the object.

When using the Enhanced Raw - Line A First (B Delayed) line acquisition mode, the object being imaged should cross line A first and line B second (the **image** of the object will cross line B first and line A second as is apparent from Figure 33 through Figure 38).

After having enabled the Enhanced Raw - Line A First (B Delayed) line acquisition mode, the following will occur in a sequence of ExSync cycles:

- The first cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line A pixel data. This is data for which no related data from line B will become available. The data is therefore not useful.
 - The values from line B are held in a buffer in the camera. Their output will be delayed until the fourth cycle of the ExSync signal.
- The second cycle of the ExSync signal will:
 - time the start of transmission of line B pixel data. This is data that was stored before the Enhanced Raw - Line A First (B Delayed) line acquisition mode was enabled. The data is therefore not useful.
No exposure will occur.
- The third cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line A pixel data.
 - The values from line B are held in a buffer in the camera. Their output will be delayed until the sixth cycle of the ExSync signal.
- The fourth cycle of the ExSync signal will:
 - time the start of transmission of line B pixel data. This data was acquired on the first ExSync cycle and relates to the data from line A that was transmitted on the preceding ExSync cycle (i.e. the third cycle).
No exposure will occur.
- The fifth cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line A pixel data.
 - The values from line B are held in a buffer in the camera. Their output will be delayed until the eighth cycle of the ExSync signal.
- The sixth cycle of the ExSync signal will:
 - time the start of transmission of line B pixel data. This data was acquired on the third ExSync cycle and relates to the data from line A that was transmitted on the preceding ExSync cycle (i.e. the fifth cycle).
No exposure will occur.
- An so on

Note that the pixel data from line A transmitted on the third ExSync cycle and the pixel data from line B transmitted on the fourth ExSync cycle image the same area of the object. And the pixel data from line A transmitted on the fifth ExSync cycle and the pixel data from line B transmitted on the

sixth ExSync cycle image the same area of the object, and so on. For further clarification, see Figure 33 through Figure 38.

For more information about triggering line acquisition and controlling exposure, see Chapter 4 on [page 92](#).



After having enabled the Enhanced Raw - Line A First (B Delayed) line acquisition mode, the pixel data from the first transmitted line A and the pixel data from the first transmitted line B are not useful.

To better understand how Enhanced Raw - Line A First (B Delayed) line acquisition mode and object movement relate, consider the example that is illustrated in Figure 33 through Figure 36.

This example describes Enhanced Raw - Line A First (B Delayed) line acquisition mode when an ExSync signal and the programmable exposure control mode are used. The example looks at two contiguous "points" on an object moving past the camera. Each point represents the area on the object that will be captured by each line in the sensor when a line acquisition is performed. As you look at the figures, notice that on the ExSync cycles where an acquisition is performed, line A will capture one point on the object and line B will capture a different point on the object. Also notice that on these cycles, the pixel data for line A will be transmitted while the pixel data for line B will be buffered. The transmission of the pixel data for line B will be delayed until the third ExSync cycle after the data were acquired. On the ExSync cycles where acquisition is not performed, the buffered pixel data for line B will be transmitted.

ExSync Cycle 1

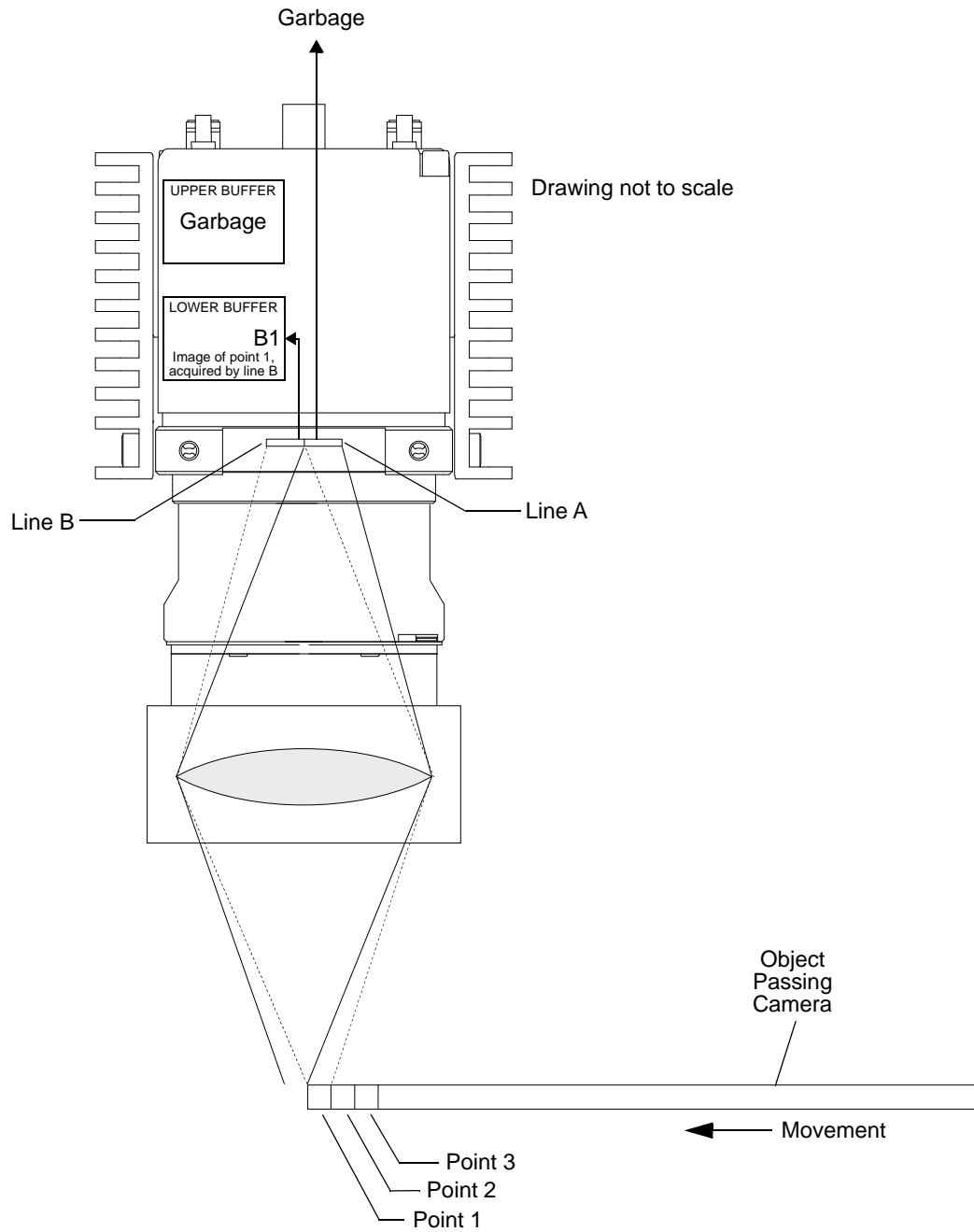


Fig. 33: Enhanced Raw - Line A First (B Delayed) Line Acquisition - ExSync Cycle 1: Start-up Situation

ExSync Cycle 2

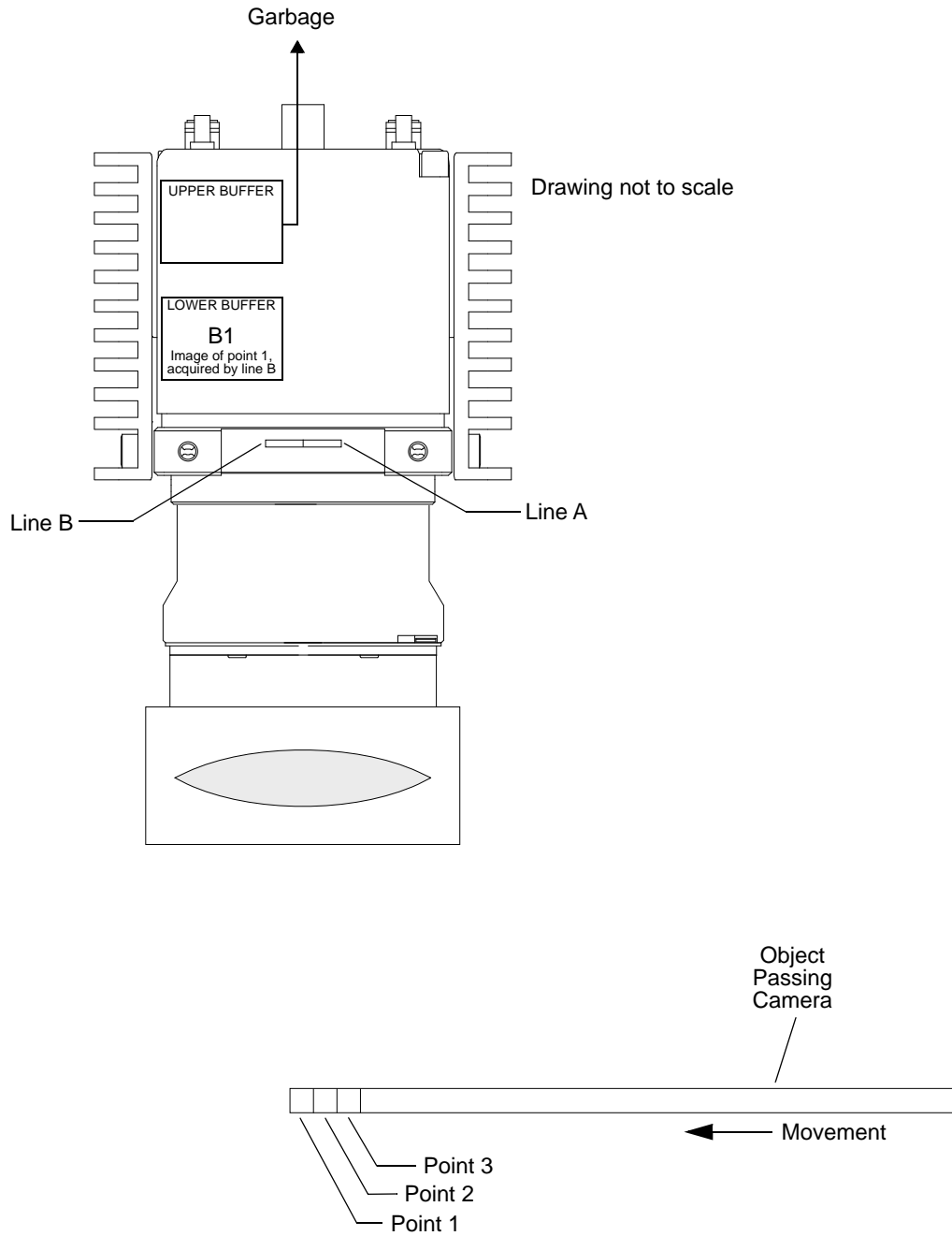


Fig. 34: Enhanced Raw - Line A First (B Delayed) Line Acquisition - ExSync Cycle 2

ExSync Cycle 3

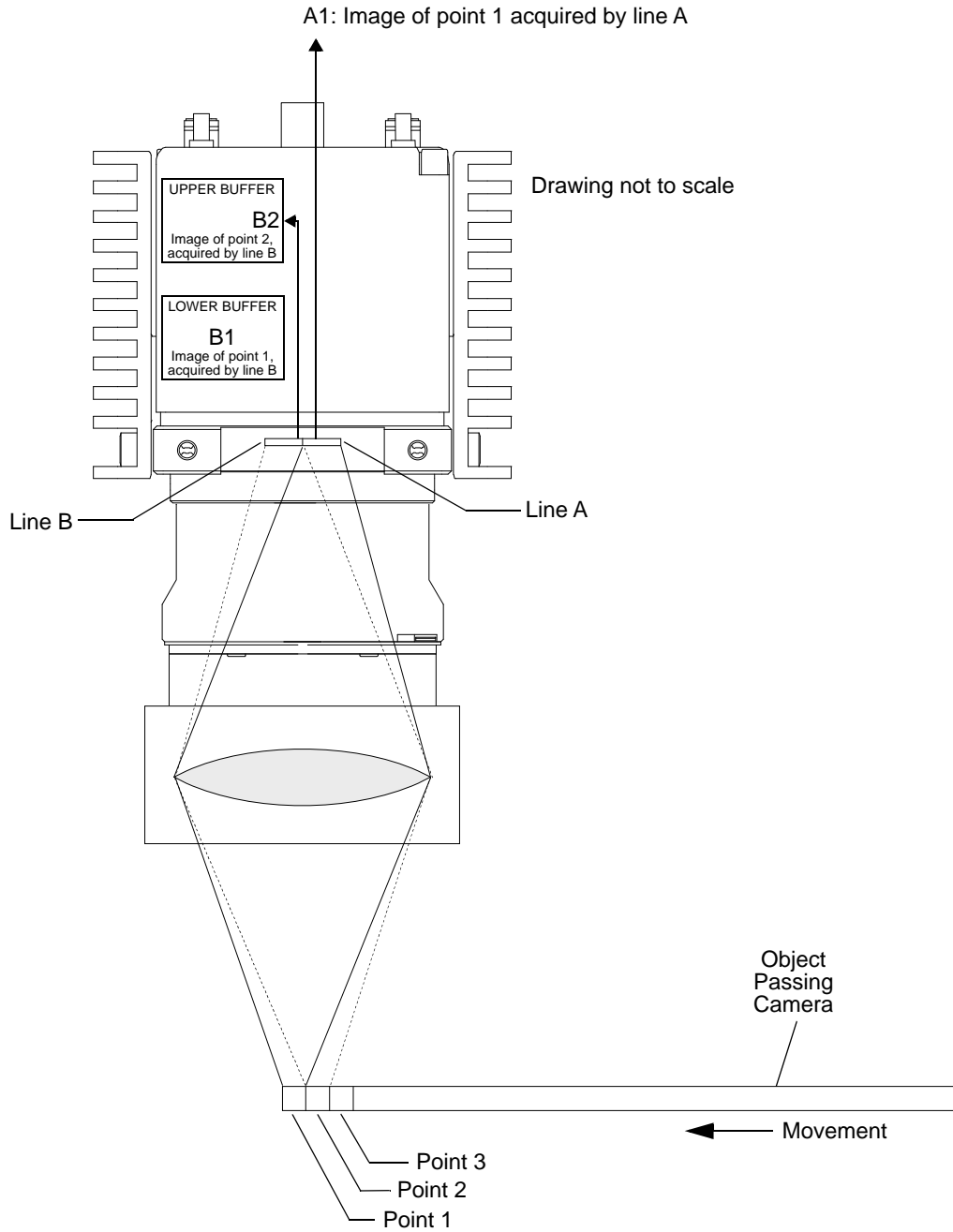


Fig. 35: Enhanced Raw - Line A First (B Delayed) Line Acquisition - ExSync Cycle 3

ExSync Cycle 4

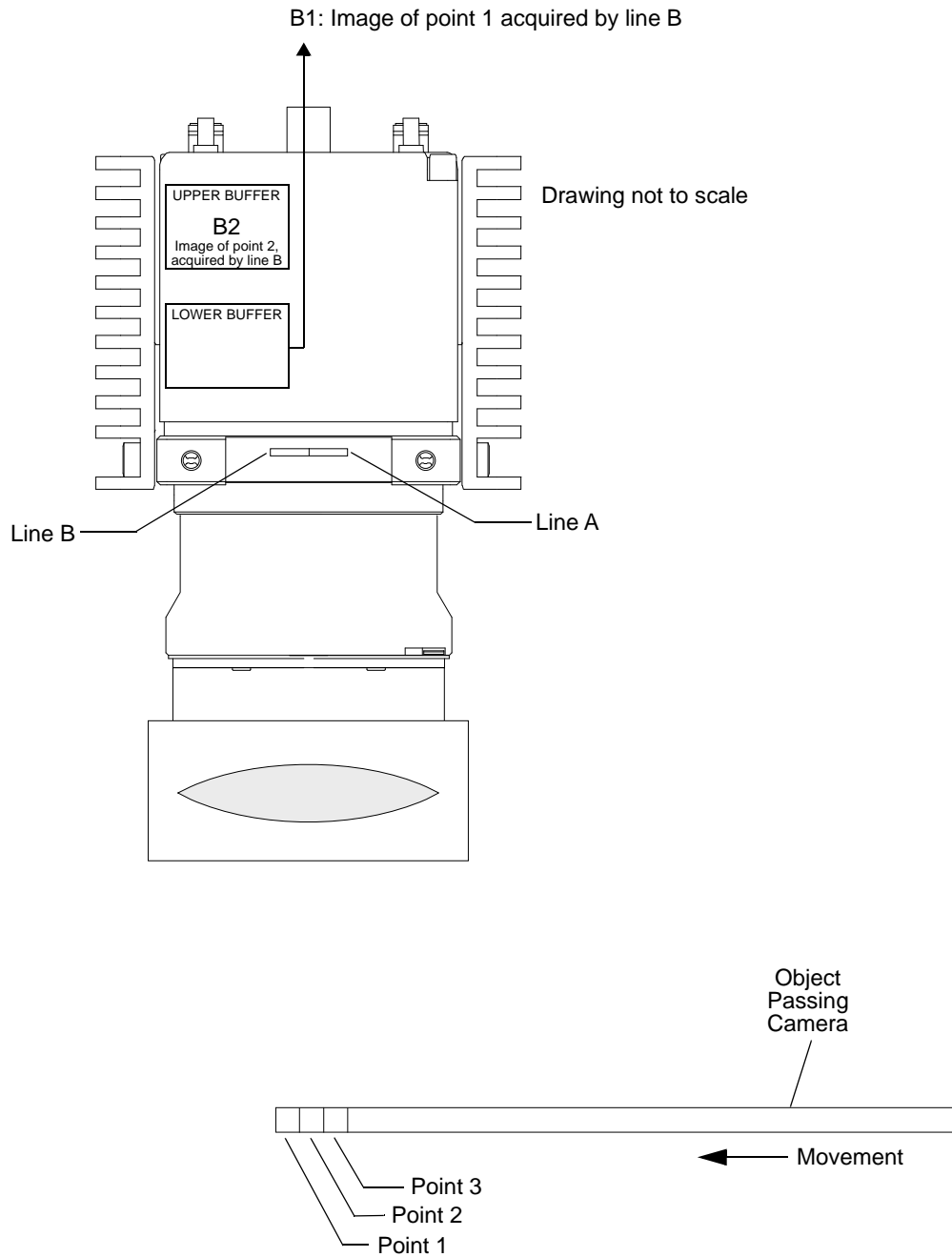


Fig. 36: Enhanced Raw - Line A First (B Delayed) Line Acquisition - ExSync Cycle 4

ExSync Cycle 5

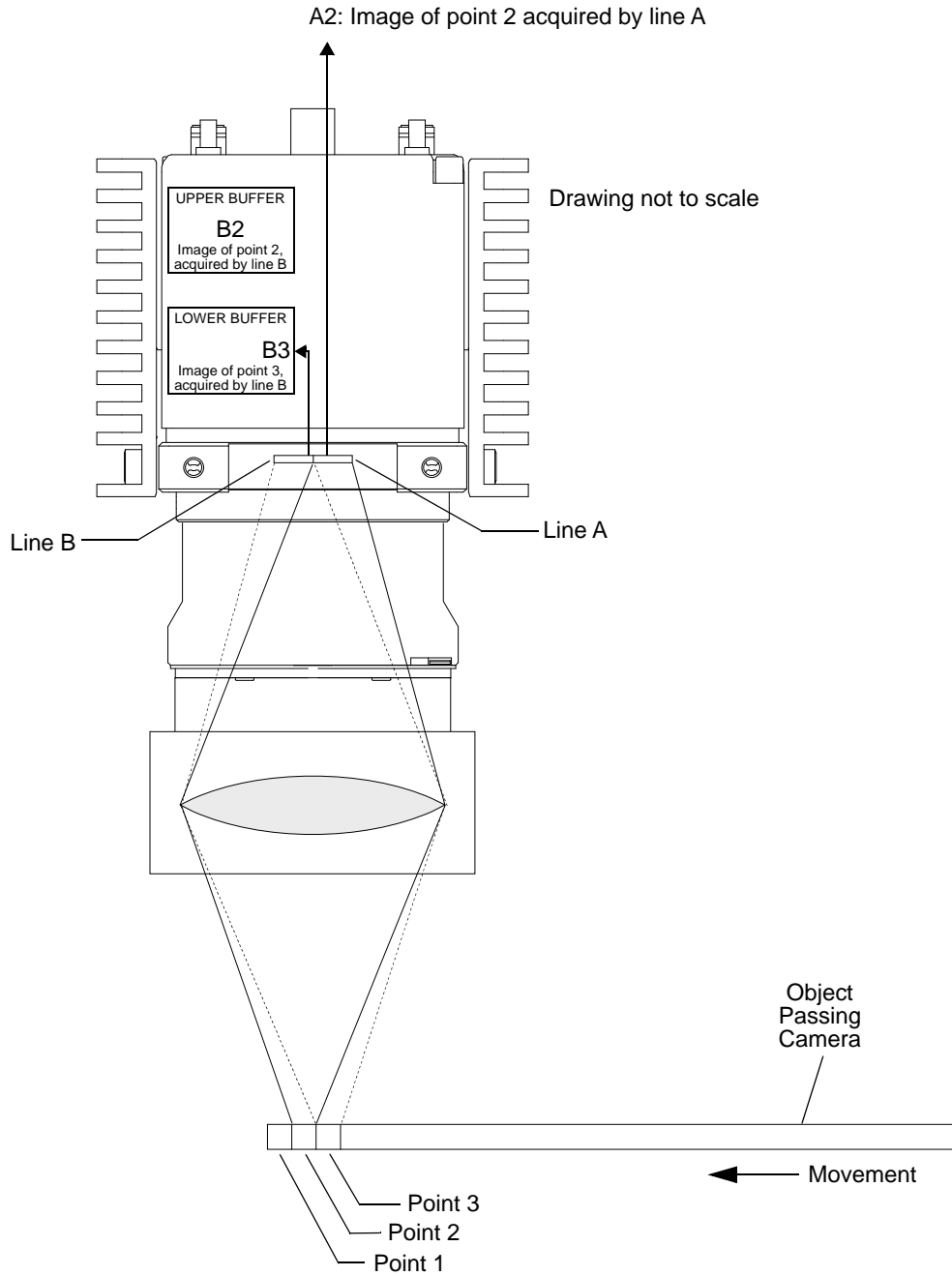


Fig. 37: Enhanced Raw - Line A First (B Delayed) Line Acquisition - ExSync Cycle 5

ExSync Cycle 6

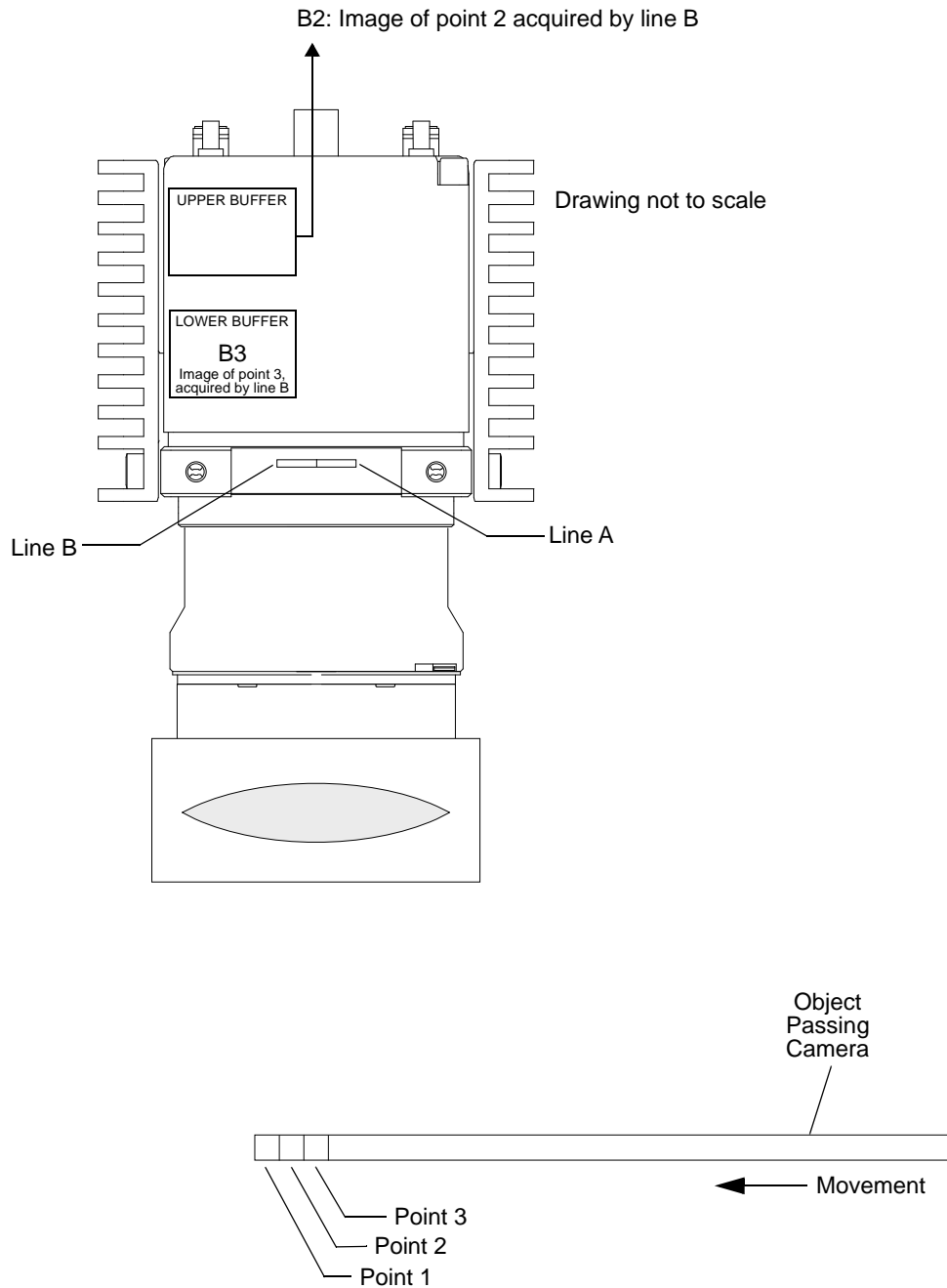


Fig. 38: Enhanced Raw - Line A First (B Delayed) - Line Acquisition - ExSync Cycle 6

Before transmission, the pixel values are arranged inside the camera in this sequence:

- Line A: pixel value ("red") of pixel 1 (RA1), pixel value ("green") of pixel 2 (GA2), pixel value ("red") of pixel 3 (RA3), pixel value ("green") of pixel 4 (GA4), and so on.
- Line B: pixel value ("green") of pixel 1 (GB1), pixel value ("blue") of pixel 2 (BB2), pixel value ("green") of pixel 3 (GB3), pixel value ("blue") of pixel 4 (BB4), and so on.

The pixel values are transmitted from the camera according to the selected video data output mode using a specific bit depth and number of taps. For information about the available video data output modes, the assignment of the pixel values to the individual taps, and timing details of the data transmission, see Section 3.4.1.1 on [page 72](#).

For information about bit assignments, see Section 5.2 on [page 110](#).

3.4.1.1 Pixel Value Transmission for the Enhanced Raw - Line A First Line Acquisition Mode

For the Enhanced Raw - Line A First line acquisition mode, you can select a 2, 4, or 8 tap video output mode for transmitting pixel data, at bit depths of 8, 10, or 12.



Not all camera models support 4 or 8 tap video data output mode. Not all combinations of video data output modes and bit depths are available

For information about the available video data output modes and bit depths for your camera model, see Section 5.1 on [page 108](#).

The Enhanced Raw - Line A First line acquisition mode provides a frame valid (FVAL) signal which indicates line A in a sequence of consecutive lines being transmitted: When the frame valid signal goes high, the line being transmitted will include pixel data from line A with "red" and "green" pixel values. And the next line transmitted will include pixel data from line B.

The length of the frame valid signal can be set to multiples of two. If, for examples, the length is set to two, the FVAL signal will go low after two lines have been transmitted, if the length is set to four, the FVAL signal will go low after four lines have been transmitted, and so on. If the length is set to zero, the FVAL signal will stay low throughout.

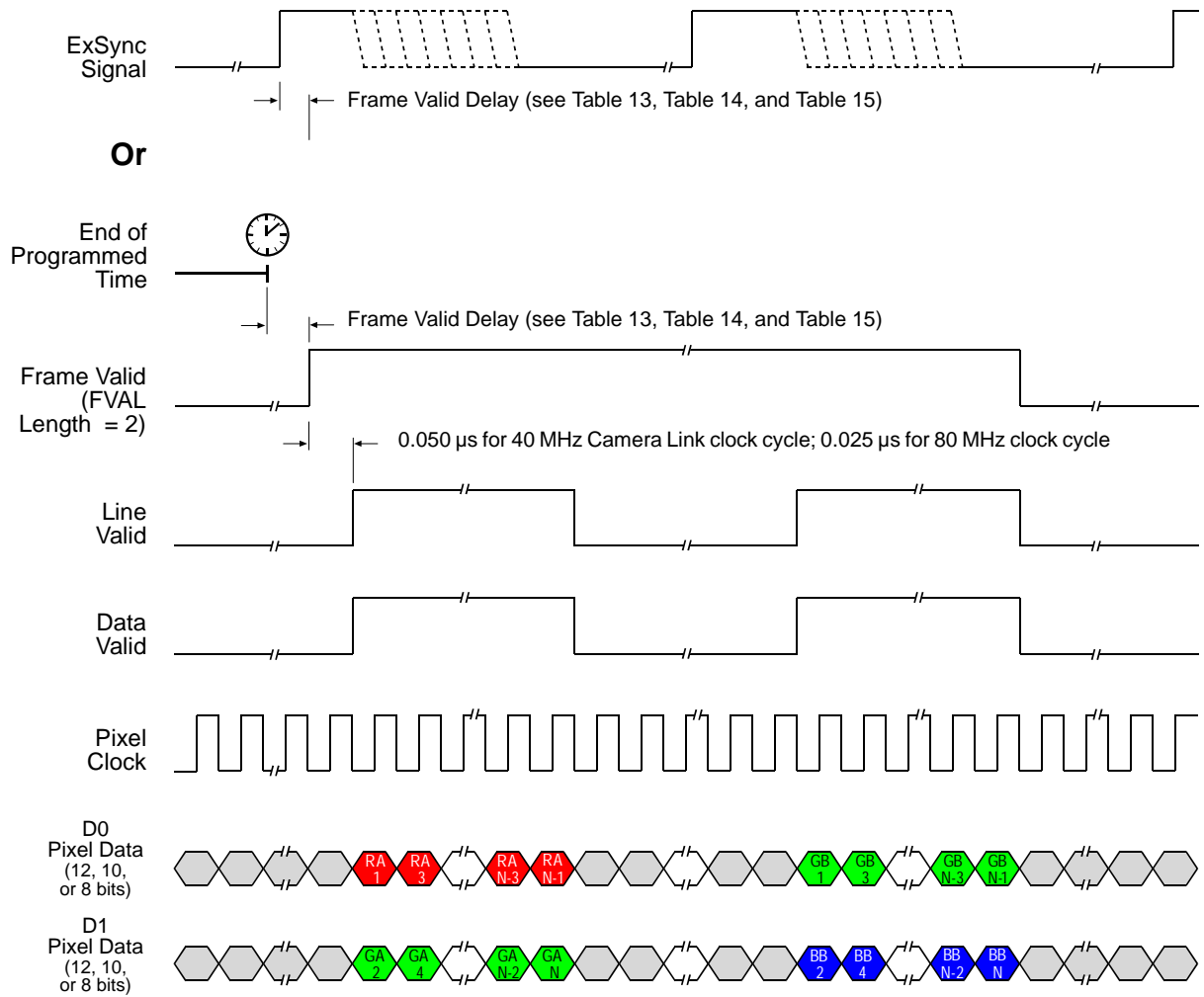
For information about setting the frame valid signal for the number of lines it will stay high, see [page 222](#).

The assignment of pixel data bits to output ports depends on the video data output mode of the camera. The video data output modes and the bit assignments are explained in detail in Chapter 5 on [page 108](#). The bit assignments comply with the Camera Link standard.

The tables also show the assignments for the frame valid bit, the line valid bit, the data valid bit, and the pixel clock. These assignments are constant for all output modes.

The following diagrams illustrate the sequences of pixel values for each tap and the related timing patterns for the pixel clock, the frame valid, the line valid and the data valid signals. Edge or level controlled exposure and programmed exposure are considered.

2 Tap Output Mode



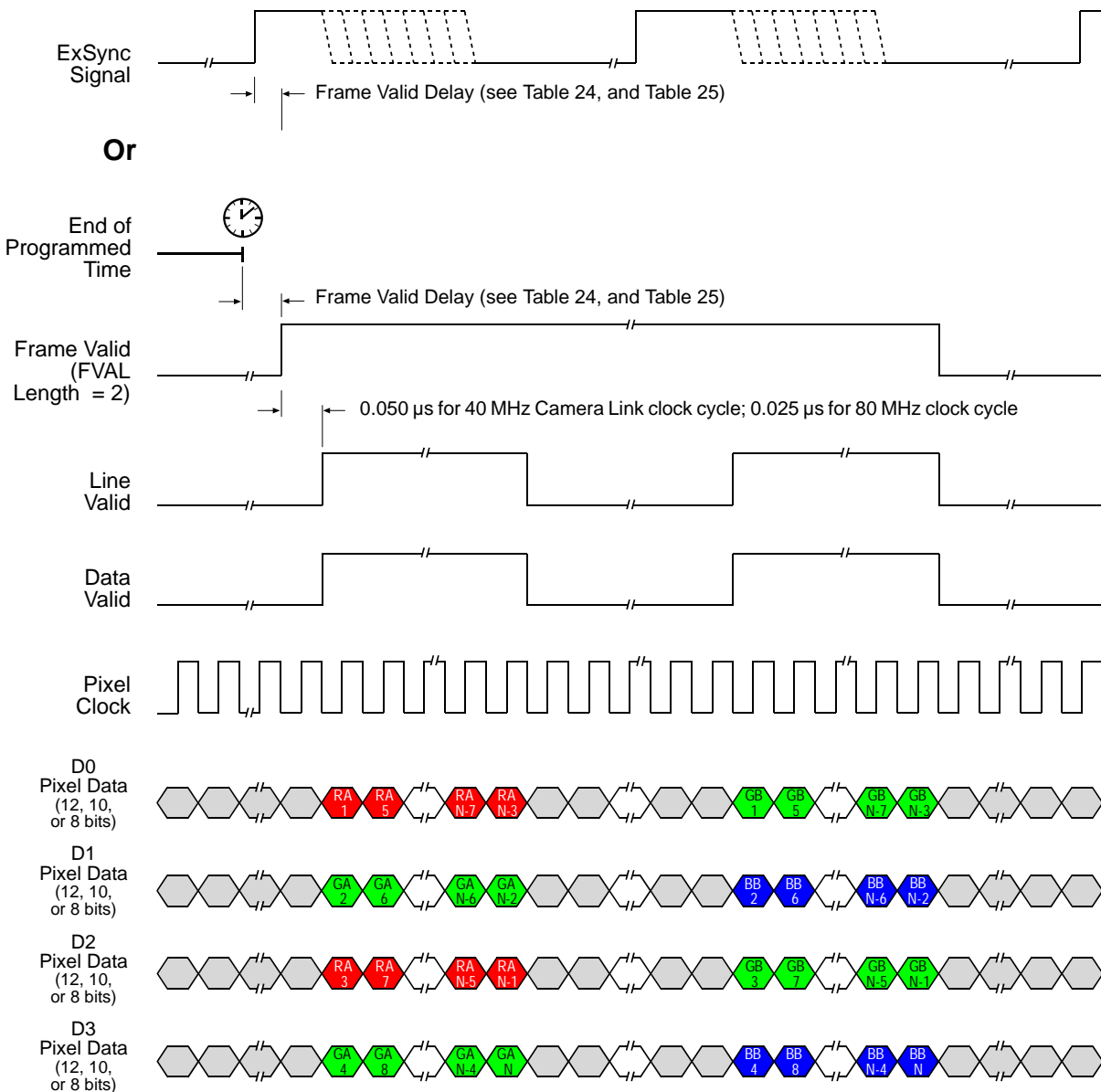
Timing diagrams are not to scale.

N = At full resolution, N = 8192 on the 8k model, 4096 on 4k models, and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 39: Two Tap Mode with Edge/Level Controlled or Programmed Exposure (Enhanced Raw - Line A First)

4 Tap Output Mode



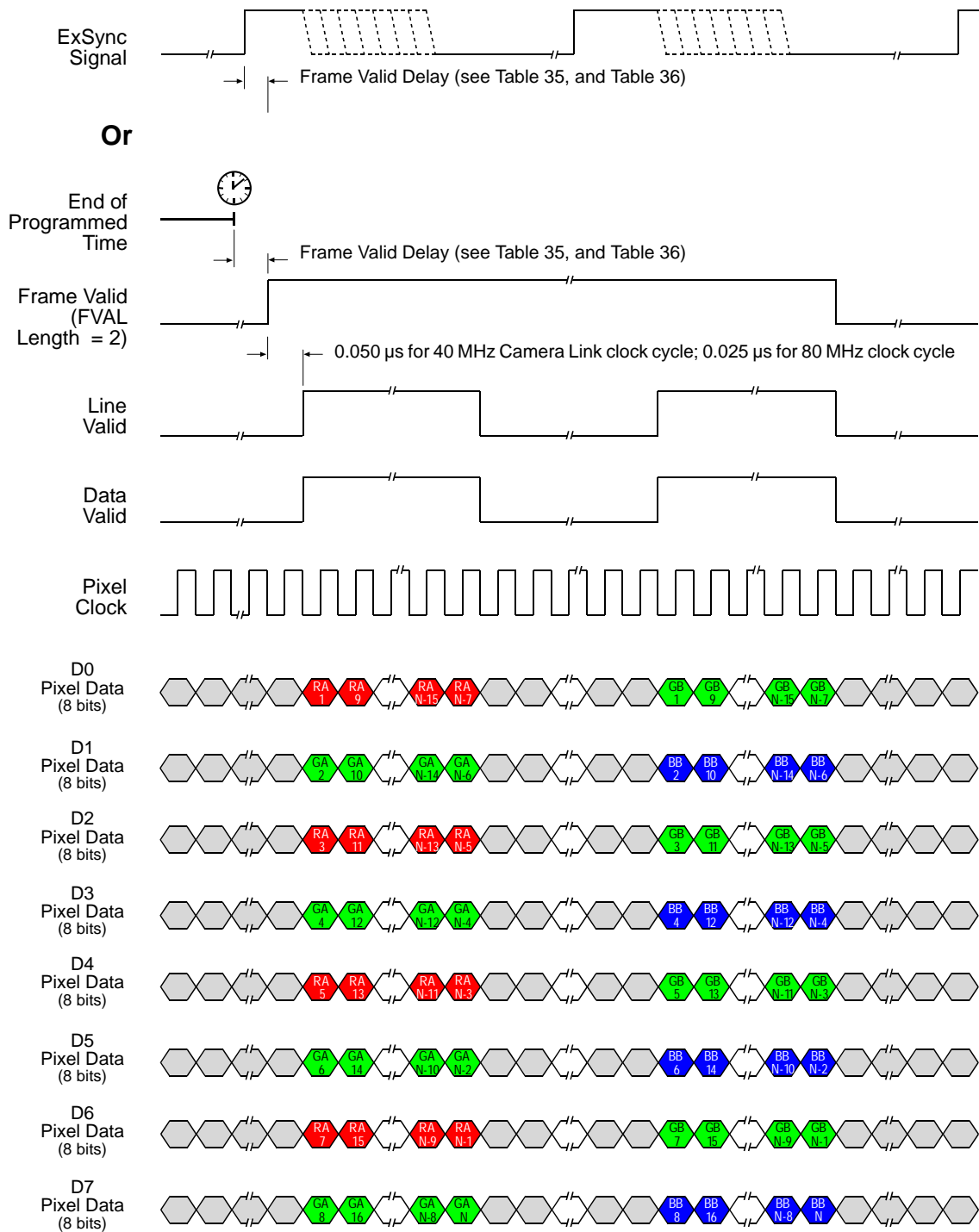
Timing diagrams are not to scale.

N = At full resolution, N = 8192 on the 8k model, 4096 on 4k models, and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 40: Four Tap Mode with Edge/Level Controlled or Programmed Exposure (Enhanced Raw - Line A First)

8 Tap Output Mode



Timing diagrams are not to scale.

N = At full resolution, N = 8192 on the 8k model, 4096 on 4k models, and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 41: Eight Tap Mode with Edge/Level Controlled or Programmed Exposure (Enhanced Raw - Line A First)

3.4.2 Enhanced Raw - Line B First (A Delayed) Line Acquisition Mode (2k and 4k Cameras Only)

The Enhanced Raw - Line B First (A Delayed) line acquisition mode is analogous to the Enhanced Raw - Line A First (B Delayed) line acquisition mode (see Section 3.4.1 on [page 63](#)), with the roles of lines A and B interchanged.

In the Enhanced Raw - Line B First line acquisition mode, the two lines which include pixel data from the same area of the object, are transmitted immediately one after the other: The pixel data for line B will be transmitted first, followed by the related pixel data for line A, which are transmitted on the next clock cycle. In this way, pairs of related lines are created with both lines imaging the same area of the object.

When using the Enhanced Raw - Line B First (A Delayed) line acquisition mode, the object being imaged should cross line B first and line A second (the **image** of the object will cross line A first and line B second as is apparent from Figure 42 through Figure 48).

After having enabled the Enhanced Raw - Line B First (A Delayed) line acquisition mode, the following will occur in a sequence of ExSync cycles:

- The first cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line B pixel data. This is data for which no related data from line A will become available. The data is therefore not useful.
 - The values from line A are held in a buffer in the camera. Their output will be delayed until the fourth cycle of the ExSync signal.
- The second cycle of the ExSync signal will:
 - time the start of transmission of line A pixel data. This is data that was stored before the Enhanced Raw - Line B First (A Delayed) line acquisition mode was enabled. The data is therefore not useful.
No exposure will occur.
- The third cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line B pixel data.
 - The values from line A are held in a buffer in the camera. Their output will be delayed until the sixth cycle of the ExSync signal.
- The fourth cycle of the ExSync signal will:
 - time the start of transmission of line A pixel data. This data was acquired on the first ExSync cycle and relates to the data from line B that was transmitted on the preceding ExSync cycle (i.e. the third cycle).
No exposure will occur.

- The fifth cycle of the ExSync signal will:
 - trigger the start of image acquisition (i.e., exposure) on **both** lines in the sensor. The exposure time you are using will apply to **both** lines.
 - time the start of pixel data readout for both lines.
 - time the start of transmission of line B pixel data.
 - The values from line A are held in a buffer in the camera. Their output will be delayed until the eighth cycle of the ExSync signal.
- The sixth cycle of the ExSync signal will:
 - time the start of transmission of line A pixel data. This data was acquired on the third ExSync cycle and relates to the data from line B that was transmitted on the preceding ExSync cycle (i.e. the fifth cycle).
No exposure will occur.
- And so on

Note that the pixel data from line B transmitted on the third ExSync cycle and the pixel data from line A transmitted on the fourth ExSync cycle image the same area of the object. And the pixel data from line B transmitted on the fifth ExSync cycle and the pixel data from line A transmitted on the sixth ExSync cycle image the same area of the object, and so on. For further clarification, see Figure 42 through Figure 47.

For more information about triggering line acquisition and controlling exposure, see Chapter 4 on [page 92](#).



After having enabled the Enhanced Raw - Line B First (A Delayed) line acquisition mode, the pixel data from the first transmitted line B and the pixel data from the first transmitted line A are not useful.

To better understand how Enhanced Raw - Line B First (A Delayed) line acquisition mode and object movement relate, consider the example that is illustrated in Figure 42 through Figure 47.

This example describes Enhanced Raw - Line B First (A Delayed) line acquisition mode when an ExSync signal and the programmable exposure control mode are used. The example looks at two contiguous "points" on an object moving past the camera. Each point represents the area on the object that will be captured by each line in the sensor when a line acquisition is performed. As you look at the figures, notice that on the ExSync cycles where an acquisition is performed, line B will capture one point on the object and line A will capture a different point on the object. Also notice that on these cycles, the pixel data for line B will be transmitted while the pixel data for line A will be buffered. The transmission of the pixel data for line A will be delayed until the third ExSync cycle after the data were acquired. On the ExSync cycles where acquisition is not performed, the buffered pixel data for line A will be transmitted.

ExSync Cycle 1

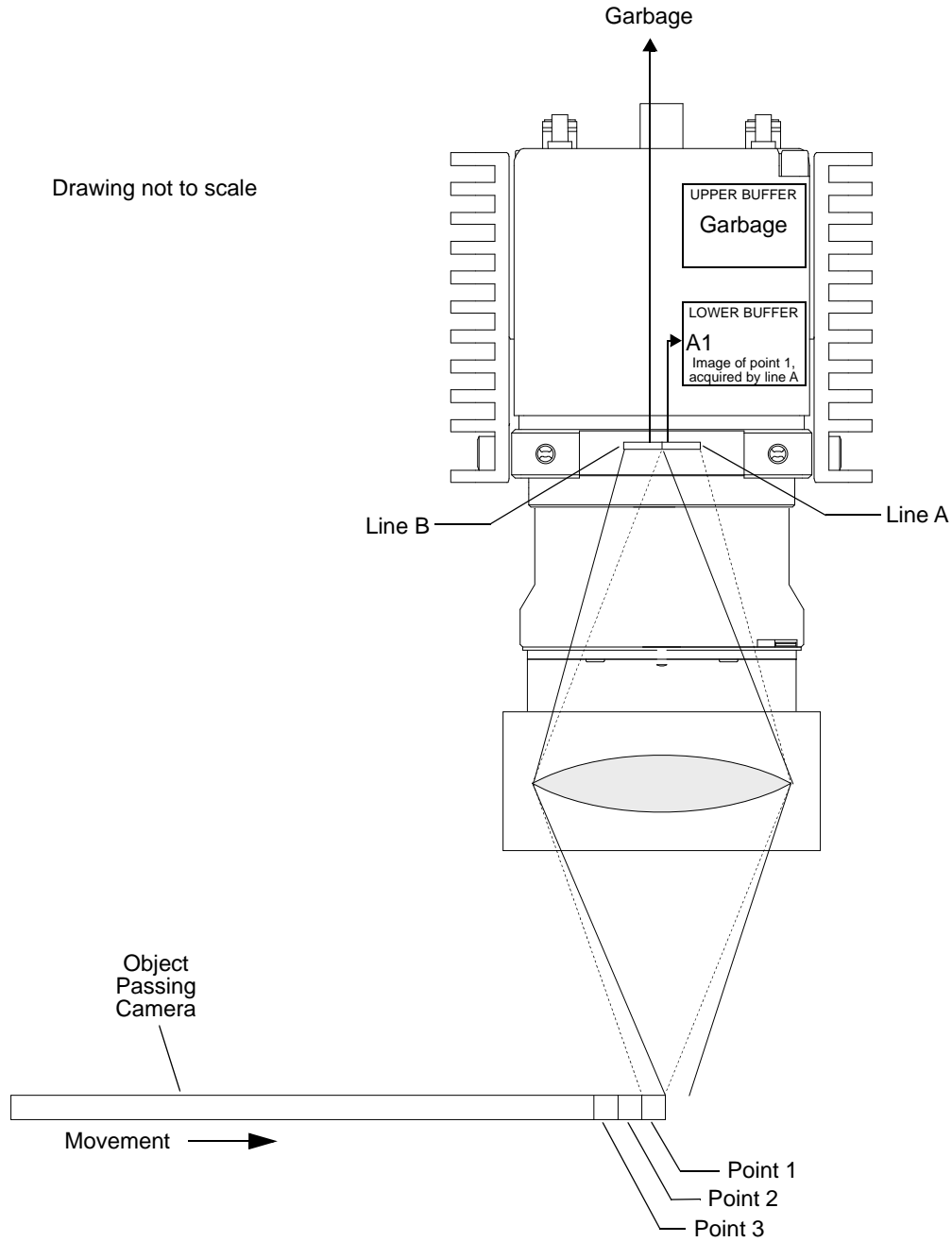


Fig. 42: Enhanced Raw - Line B First (A Delayed) Line Acquisition - ExSync Cycle 1

ExSync Cycle 2

Drawing not to scale

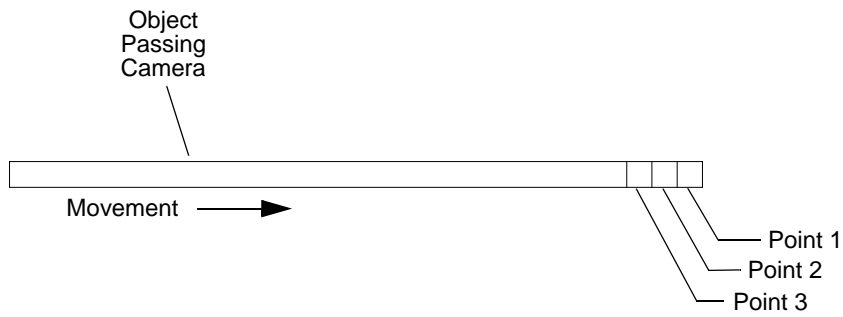
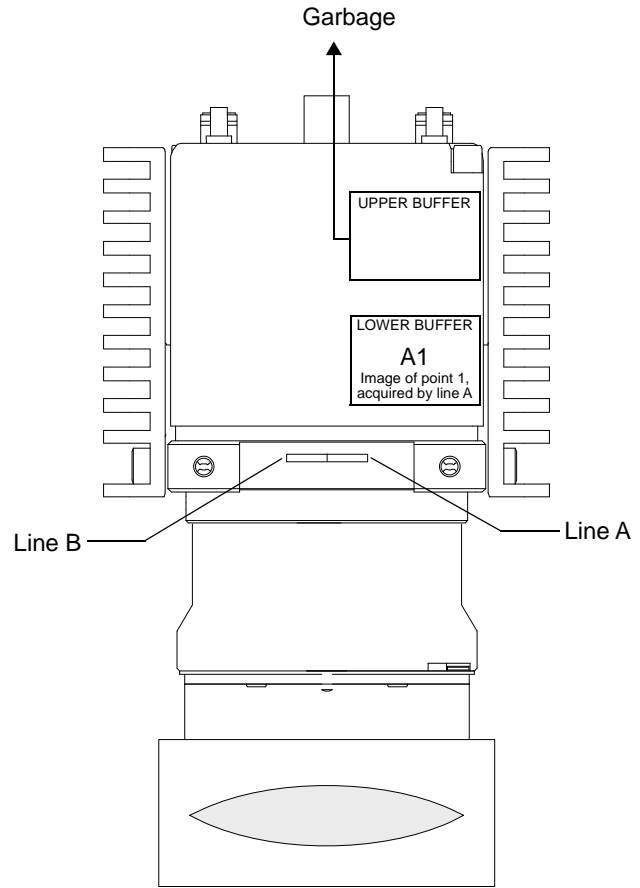


Fig. 43: Enhanced Raw - Line B First (A Delayed) Line Acquisition - ExSync Cycle 2: Start-up Situation

ExSync Cycle 3

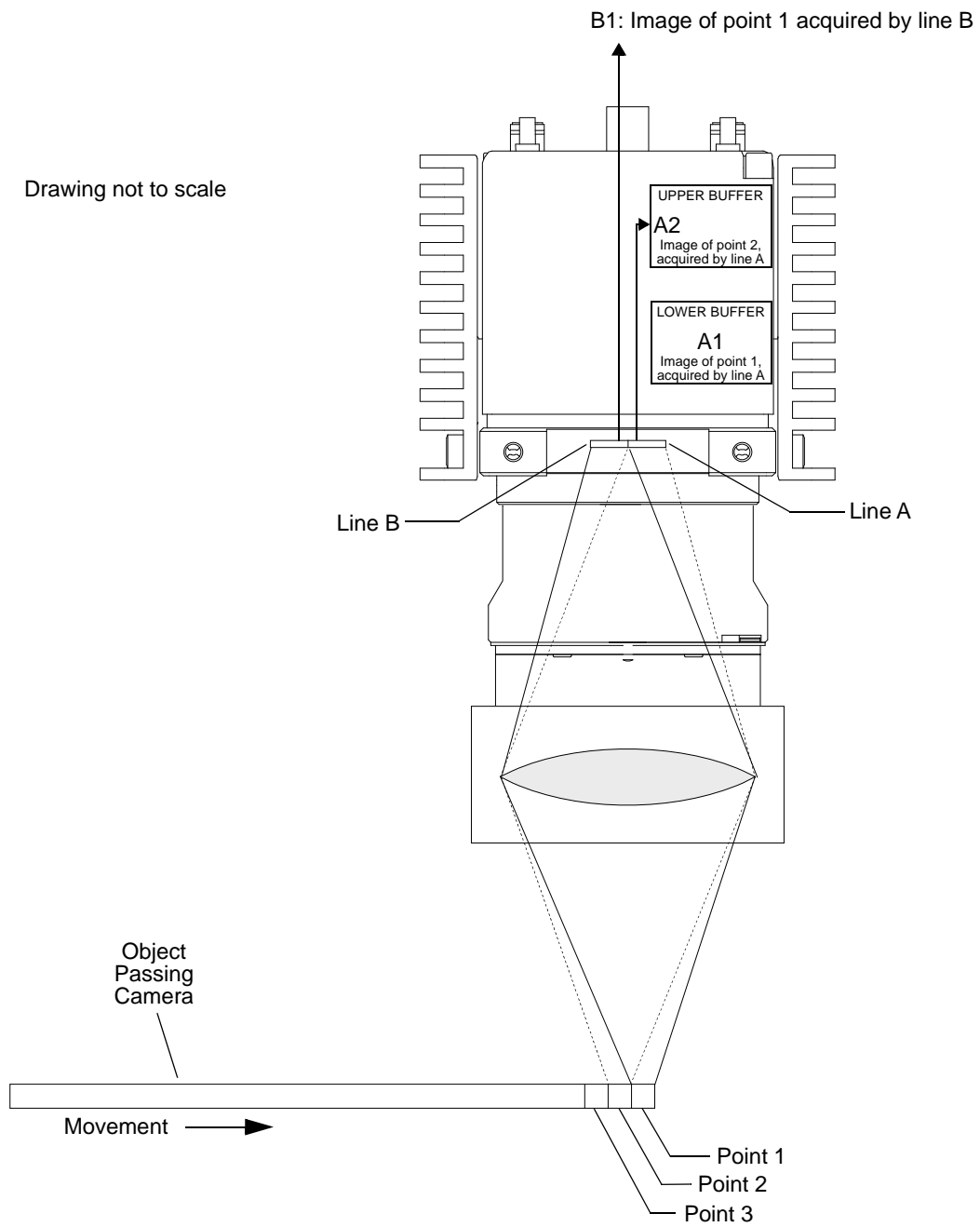


Fig. 44: Enhanced Raw - Line B First (A Delayed) Line Acquisition - ExSync Cycle 3

ExSync Cycle 4

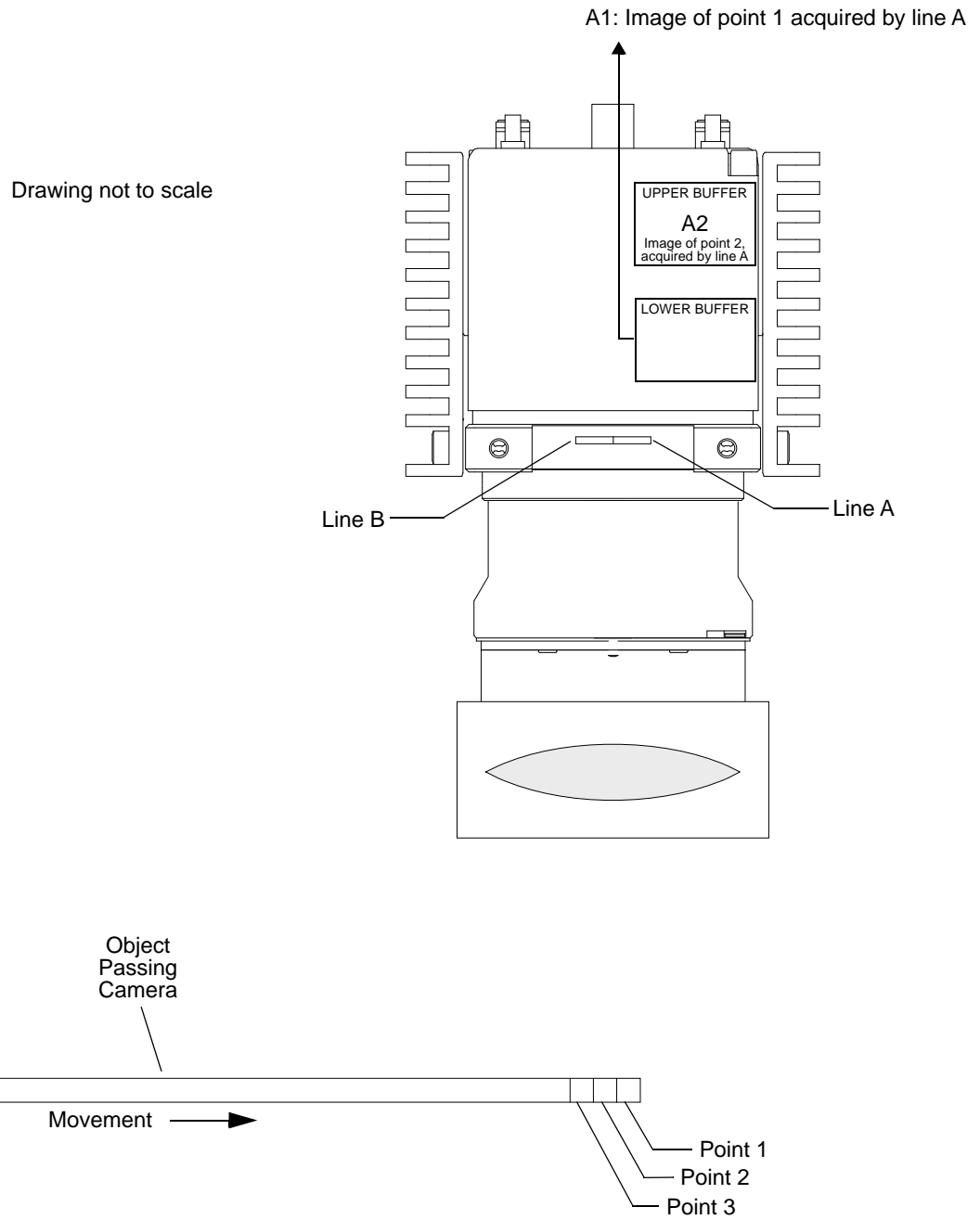


Fig. 45: Enhanced Raw - Line B First (A Delayed) Line Acquisition - ExSync Cycle 4

ExSync Cycle 5

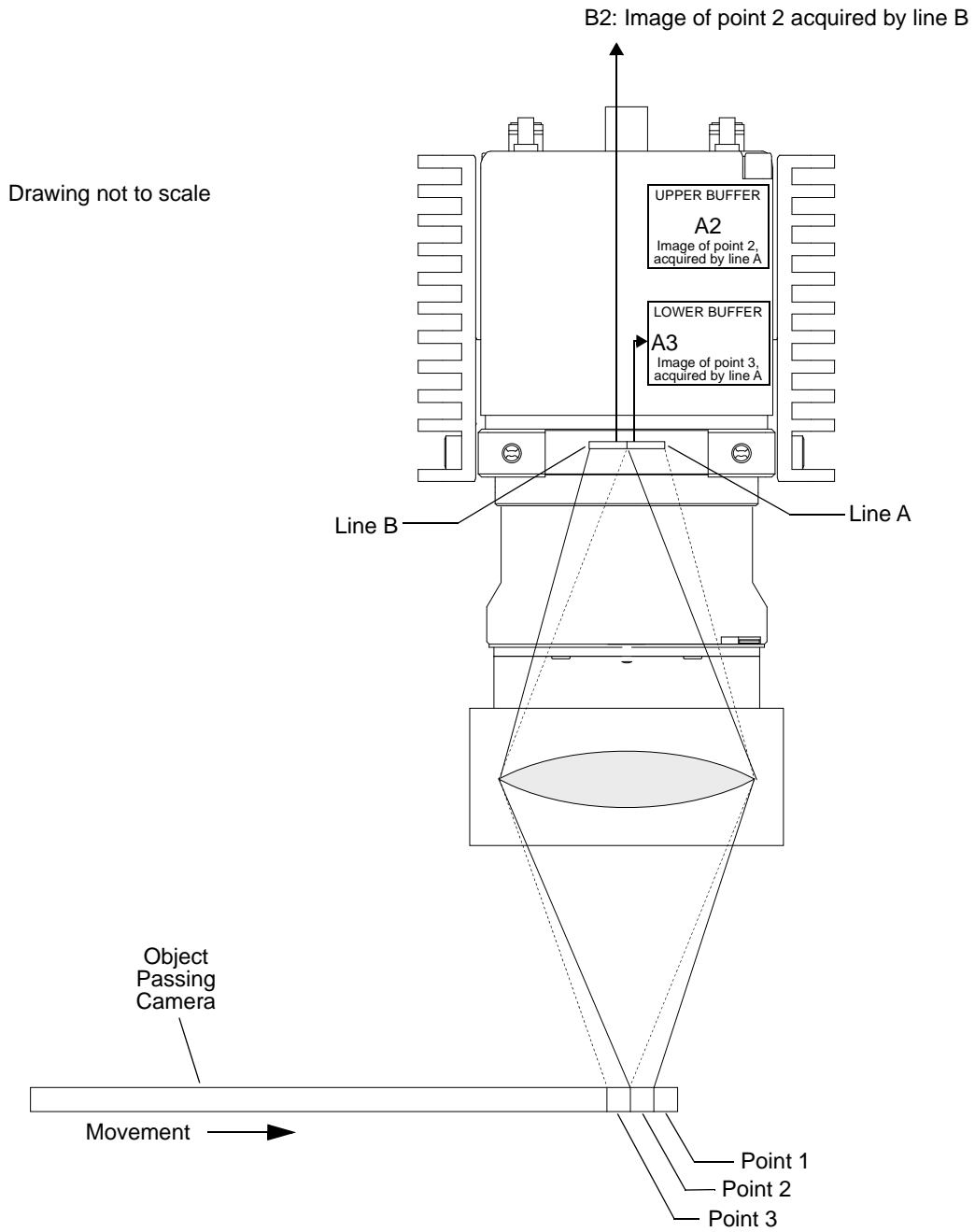


Fig. 46: Enhanced Raw - Line B First (A Delayed) Line Acquisition - ExSync Cycle 5

ExSync Cycle 6

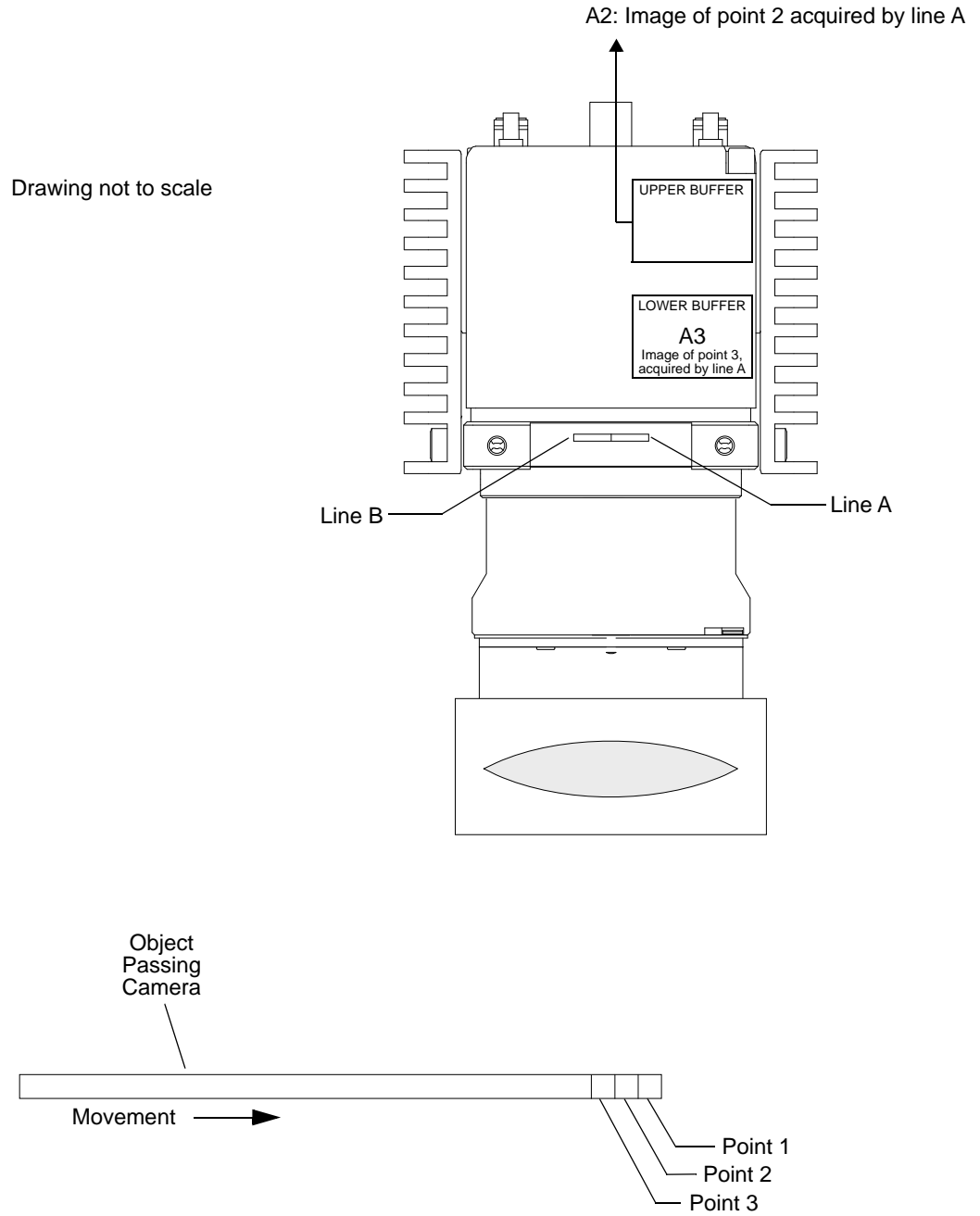


Fig. 47: Enhanced Raw - Line B First (A Delayed) - Line Acquisition - ExSync Cycle 6

3.4.2.1 Pixel Value Transmission for the Enhanced Raw - Line B First Line Acquisition Mode

For the Enhanced Raw - Line B First line acquisition mode, you can select a 2, 4, or 8 tap video output mode for transmitting pixel data, at bit depths of 8, 10, or 12.



Not all camera models support 4 or 8 tap video data output mode. Not all combinations of video data output modes and bit depths are available

For information about the available video data output modes and bit depths for your camera model, see Section 5.1 on [page 108](#).

The Enhanced Raw - Line B First line acquisition mode provides a frame valid (FVAL) signal which indicates line B in a sequence of consecutive lines being transmitted: When the frame valid signal goes high, the line being transmitted will include pixel data from line B with "green" and "blue" pixel values. And the next line transmitted will include pixel data from line A.

The length of the frame valid signal can be set to multiples of two. If, for examples, the length is set to two, the FVAL signal will go low after two lines have been transmitted, if the length is set to four, the FVAL signal will go low after four lines have been transmitted, and so on. If the length is set to zero, the FVAL signal will stay low throughout.

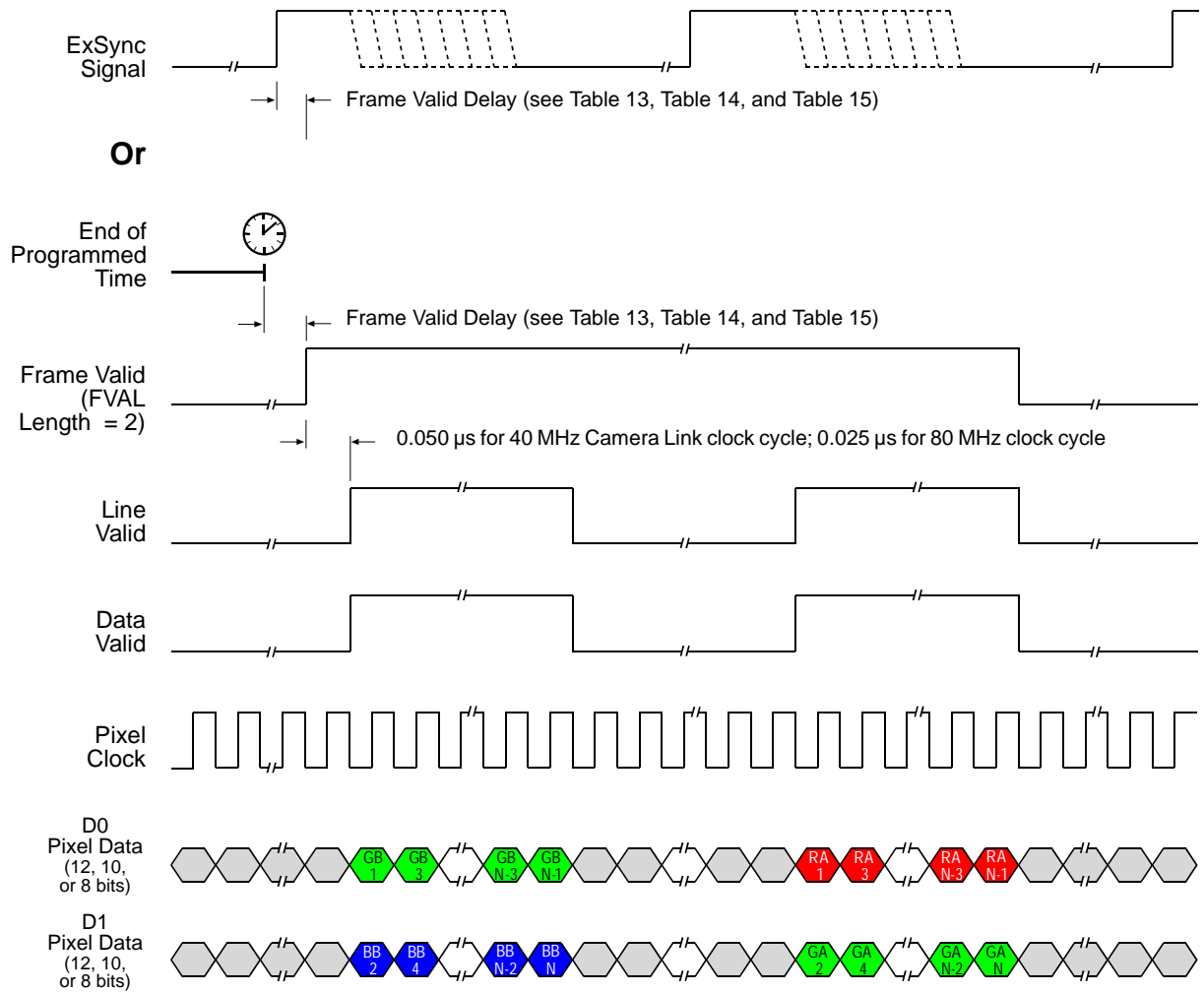
For information about setting the frame valid signal for the number of lines it will stay high, see [page 222](#).

The assignment of pixel data bits to output ports depends on the video data output mode of the camera. The video data output modes and the bit assignments are explained in detail in Section 5 on [page 108](#). The bit assignments comply with the Camera Link standard.

The tables also show the assignments for the frame valid bit, the line valid bit, the data valid bit, and the pixel clock. These assignments are constant for all output modes.

The following diagrams illustrate the sequences of pixel values for each tap and the related timing patterns for the pixel clock, the frame valid, the line valid and the data valid signals. Edge or level controlled exposure and programmed exposure are considered.

2 Tap Output Mode



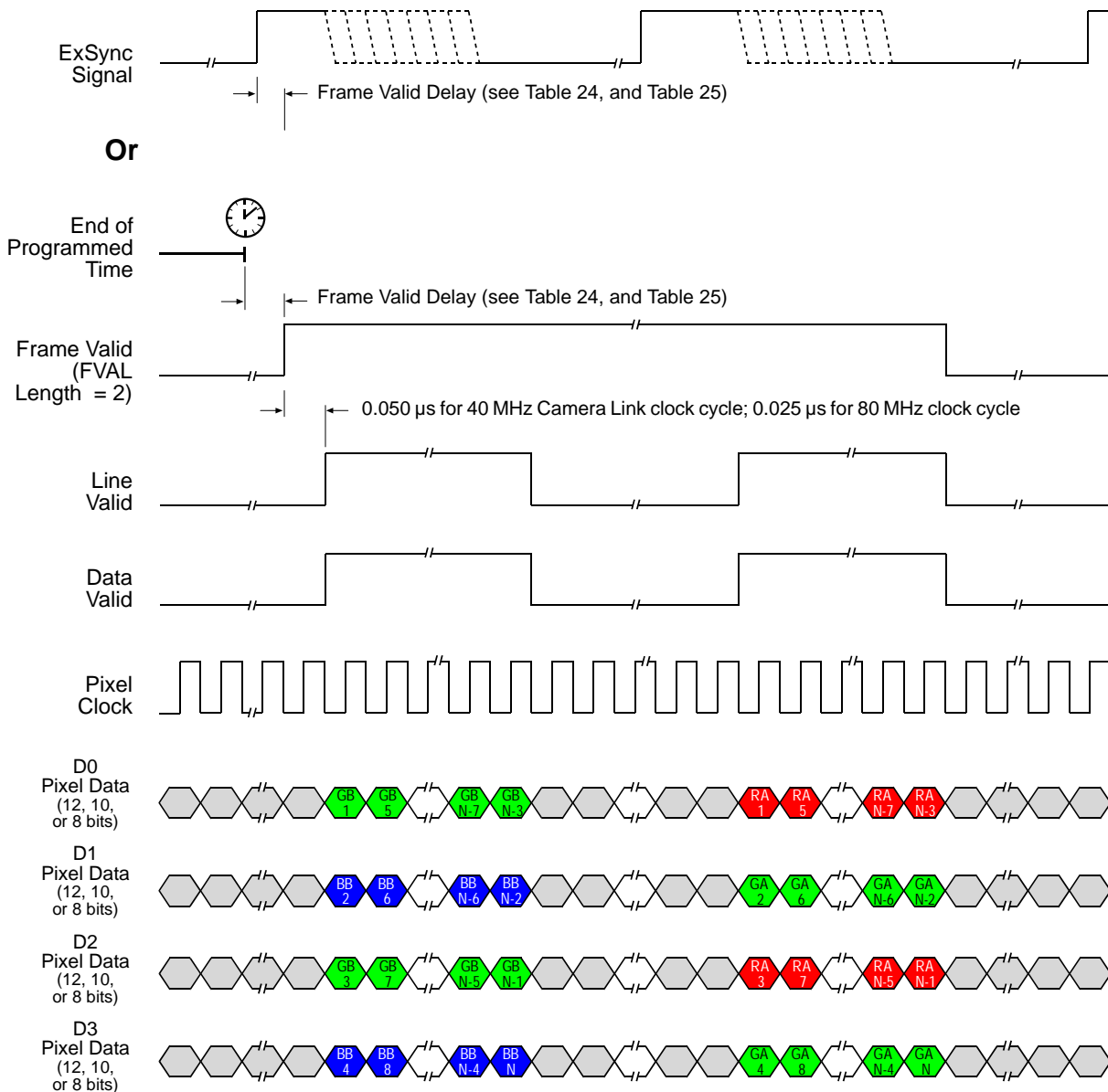
Timing diagrams are not to scale.

N = At full resolution, N = 4096 on 4k models and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 48: Two Tap Mode with Edge/Level Controlled or Programmed Exposure (Enhanced Raw - Line B First)

4 Tap Output Mode



Timing diagrams are not to scale.

N = At full resolution, N = 4096 on 4k models and 2048 on 2k models

If the AOI feature is used, N will be determined by the AOI settings

Fig. 49: Four Tap Mode with Edge/Level Controlled or Programmed Exposure (Enhanced Raw - Line B First)

8 Tap Output Mode

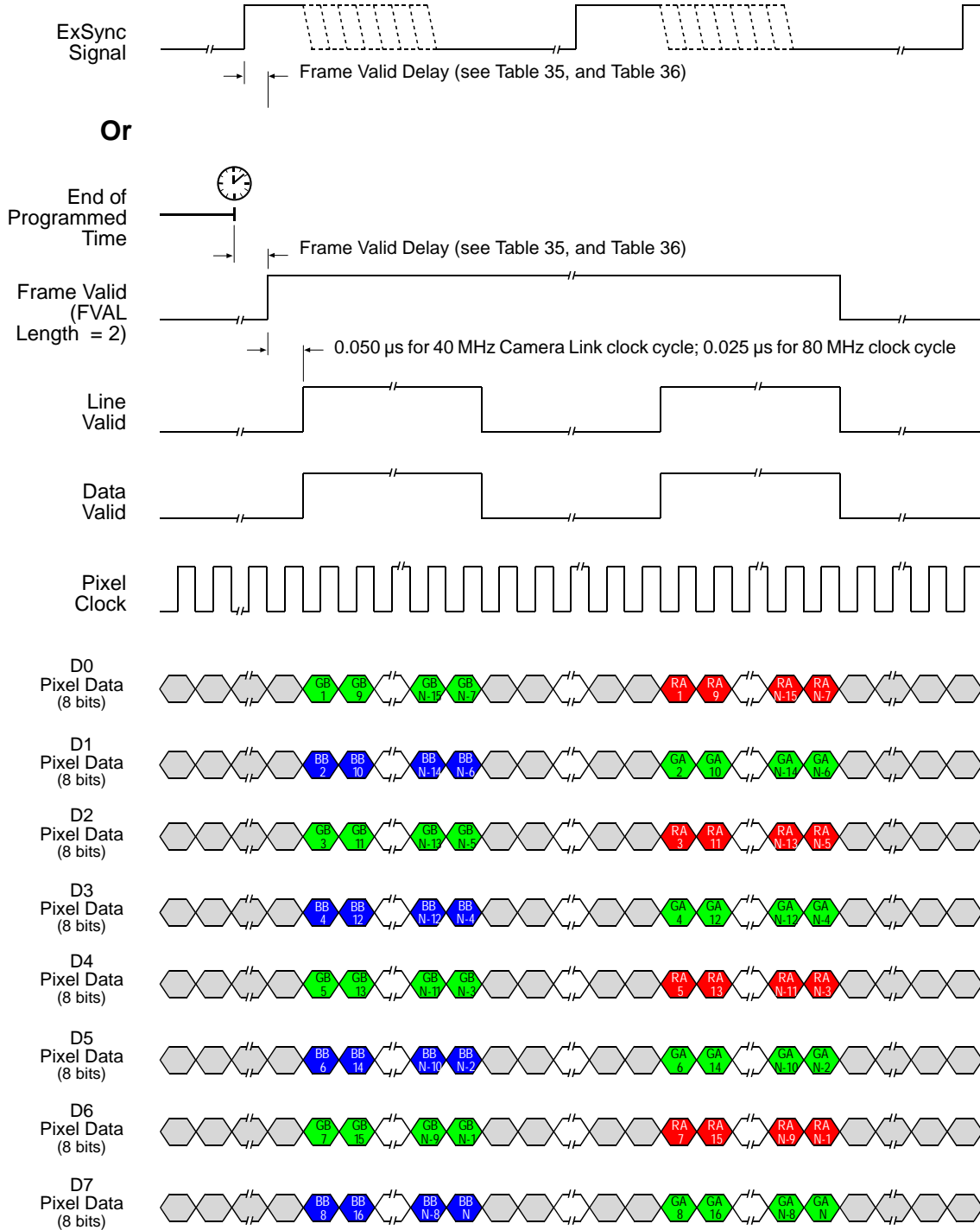


Fig. 50: Eight Tap Mode with Edge/Level Controlled or Programmed Exposure (Enhanced Raw - Line B First)

3.5 Operating Recommendations

3.5.1 Camera Operating Recommendations

To achieve the best results, certain operating requirements should be met.

- Exposure start should be triggered by an ExSync signal (see Chapter 4 on [page 92](#)).
- Use of the programmable exposure mode is recommended to ensure uniform exposure.
- The edge controlled or level controlled exposure modes can be used, but only if the conveyor speed is almost perfectly stable. If the conveyor speed is not stable, unacceptable variations in exposure time will result.

3.5.2 System Design Recommendations

When you are using the RGB or the Raw line acquisition mode, the camera's line rate and the conveyor speed must be attuned to ensure that the object is completely covered and that exposures do not overlap. When you are using the Enhanced Raw line acquisition mode, for a given point on the object to be captured correctly, its image must fall precisely on line A in the sensor and then precisely on line B in the sensor.

Position Encoder

You should use a position encoder to monitor the movement of the system's conveyor. You should also use the encoder output to trigger line acquisition for attuning the camera's line rate and the conveyor speed.

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.

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.

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 to ensure that all of the pixels in the sensor lines view the object at the same magnification.

3.5.3 System Design Calculations

Our recommended approach for calculating system design criteria is tuned to matching the line of view of the sensor to the width of your conveyor. The example below illustrates this approach.

Example

Assume the following conditions:

- A 4k camera is used
- The Enhanced Raw line acquisition is used, requiring the image to move by 10 µm between two successive exposures
- Conveyor width = 850 mm
- Conveyor movement per encoder step = 0.09 mm
- Center-to-center distance between sensor lines = 10 µm
(Each line in the sprint's sensor is 10 µm wide and they are adjacent to one another. Therefore the center-to-center distance is 10 µm.)
- Pixel size = 10 µm
- Length of sensor line = 40.96 mm (4096 pixels/line x 10 µm/pixel)
- **With an objective lens in place**, the direction of travel of the object will cause the image to cross the line B in the sensor first.

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

$$\frac{\text{Sensor Line Length}}{\text{Conveyor Width}} = \frac{40.96 \text{ mm}}{850 \text{ mm}} = 0.048$$

$$\frac{1}{0.048} = 20.83$$

$$\beta = 1 : 20.83$$

(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** 10 µm.

$$10 \text{ µm} \times 20.83 = 0.2083 \text{ mm}$$

Step 3 - Calculate the number of encoder steps needed to move the conveyor 0.2083 mm.

$$\frac{0.2083 \text{ mm}}{0.09 \text{ mm/step}} = 2.31 \text{ steps}$$

Since the encoder only counts in whole steps, we have two options. We can move the conveyor enough to generate 2 encoder steps or we can move the conveyor enough to generate 3 encoder steps. In either of these cases, the movement of the conveyor will not result in the image moving exactly 10 μm . Therefore, we will need to adjust the magnification so that exactly 10 μm of image movement results. And we must also consider that a change in magnification will result in a change in the amount of conveyor width that is viewed by each sensor line.

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

Option 1

Calculate the conveyor movement that will generate 2 encoder steps:

$$2 \text{ steps} \times 0.09 \text{ mm/step} = 0.18 \text{ mm}$$

Calculate the magnification needed to make 0.18 mm of conveyor movement result in 10 μm movement of the image:

$$\frac{10 \mu\text{m}}{0.18 \text{ mm}} = 0.056$$

$$\frac{1}{0.056} = 17.86$$

$$\beta = 1 : 17.86$$

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

$$40.96 \text{ mm} \times 17.86 = 731.55 \text{ mm}$$

Option 2

Calculate the conveyor movement that will generate 3 encoder steps:

$$3 \text{ steps} \times 0.09 \text{ mm/step} = 0.27 \text{ mm}$$

Calculate the magnification needed to make 0.27 mm of conveyor movement result in 10 μm movement of the image:

$$\frac{10 \mu\text{m}}{0.27 \text{ mm}} = 0.037$$

$$\frac{1}{0.037} = 27,03$$

$$\beta = 1 : 27.03$$

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

$$40.96 \text{ mm} \times 27.03 = 1102.92 \text{ mm}$$

If you choose to use 2 encoder steps to move the image 10 μm , you will require a 1 : 17.86 magnification and at this magnification, the field of view of each sensor line will be 731.55 mm. If you choose to use 3 encoder steps to move the image 10 μm , you will require a magnification of 1 : 27.03 and at this magnification, the field of view of each sensor line will be 1102.92 mm. Since our conveyor is 850 mm wide and since it is usually more acceptable to have a field of view slightly larger than the conveyor, assume that we choose option 2.

Step 4 - Select an appropriate lens and determine the mounting distance for your camera. You can contact Basler technical support if you need help with this procedure.

Step 5 - Make sure that the line acquisition mode is set correctly. In this case it would be set to Enhanced Raw - Line A First (B Delayed). This setting is required because the image of the object being imaged will cross line B in the sensor first and each point of the object is imaged twice.

Step 6 - Capture images

4 Exposure Start and Exposure Time Control

This section describes the methods that can be used to trigger the start of exposure and control the length of exposure for each acquisition. Exposure start and exposure time can be controlled via an external trigger signal (ExSync) applied to the camera. The camera can also operate in “free run.” In free run, the camera generates its own internal control signal and does not require an ExSync signal.

4.1 ExSync Controlled Operation

4.1.1 Basics of ExSync Controlled Operation

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

When the camera is operating under the control of an ExSync signal, the length of the ExSync signal period determines the camera’s line rate:

$$\text{Line Rate} = \frac{1}{\text{ExSync Period}}$$

The ExSync signal can be periodic or non-periodic as required.



- For simplicity, no delays related to line acquisition and readout are considered in this section. For more information about delays, see Section 4.1.4 on [page 96](#) and Section 5.2 on [page 110](#).
- Valid for the **spL2048-70kc**, the **spL4096-70kc**, the **spL4096-70kcESC**, and for the **spL4096-140kc only**:
If the enhanced raw line acquisition mode is selected, in ExSync operation the **maximum line rate** for these camera models is 137 kHz.

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

- In **ExSync edge controlled** mode, line acquisition begins on the rising edge of the ExSync signal. 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 pixel values read out of the sensor on the rising edge of ExSync (see Figure 51).

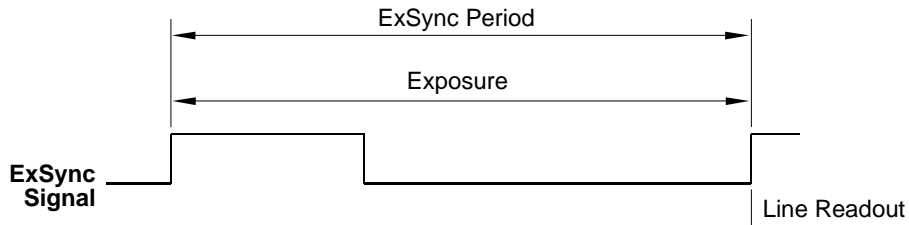


Fig. 51: ExSync Edge Controlled Mode

- In **ExSync level controlled** mode, line acquisition begins on the rising edge of the ExSync signal. 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 pixel values are read out of the sensor on the rising edge of the ExSync signal (see Figure 52).

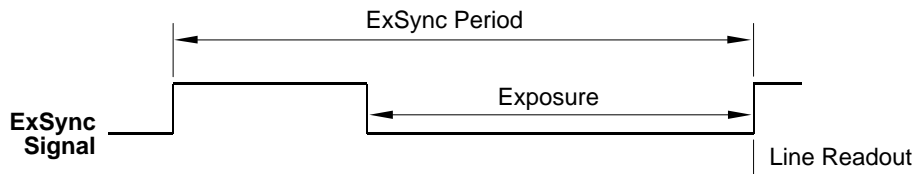


Fig. 52: ExSync Level Controlled Mode

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

A parameter called "Exposure Time" is used to set the length of the pre-programmed exposure period.

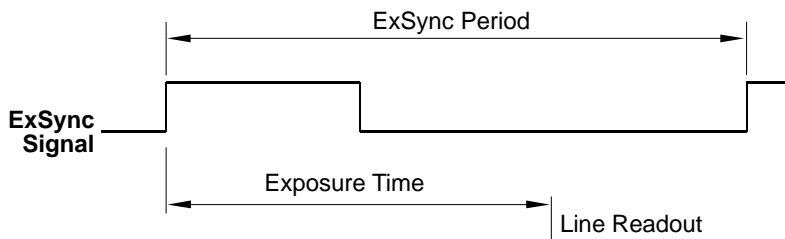


Fig. 53: ExSync Programmable Mode

4.1.2 Selecting an ExSync Exposure Mode and Setting the Exposure Time

You can select an ExSync exposure time control mode and set the exposure time for the ExSync programmable mode with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Exposure Time Control Mode parameter in the Exposure parameters group to select the ExSync edge controlled, ExSync level controlled or ExSync programmable exposure time control mode. If you select the ExSync programmable mode, you can use the Exposure Time parameter to set the exposure time.

By Setting CSRs

You select the exposure time control mode by writing the appropriate value to the Mode field of the Exposure Time Control Mode CSR (see [page 223](#)).

If you select the ExSync programmable mode, you will also need to set the exposure time. You set the exposure time by writing a value to the Absolute Exposure Time field or to the Raw Exposure Time field of the Exposure Time CSR (see [page 224](#)).

Section 7.2.2 on [page 219](#) explains CSRs and the difference between using the “absolute” field and the “raw” field in a CSR. Section 7.3.1 on [page 266](#) explains using read/write commands.



Do **not over-trigger** the camera, because the camera might freeze and might not deliver any images any more.

If you over-trigger the camera, and you change the Exposure Time Control Mode parameter, this has no effect, i.e. the camera may still not deliver any images.

In such a case: Undo the over-triggering of the camera. Afterwards, you can change the Exposure Time Control Mode parameter, if required.

Call Basler technical support for assistance.

4.1.3 Low Line Rate Compensation

The low line rate compensation is used at low line rates to clear retained pixel charges in a sensor line. To achieve this clearance, the low line rate compensation repeatedly reads out the sensor and discards the pixel data to ensure that a completely read out sensor is present before each line acquisition. This is a prerequisite for optimum image quality.

By default the low line rate compensation is enabled.

When low line rate compensation is enabled, low line rate compensation will automatically operate when low line acquisition rates are entered. At higher line rates, low line rate compensation does not operate.

When low line rate compensation operates, a **low line rate compensation delay** of 14.2 μ s precedes each line acquisition, in addition to exposure start delay.

The low line rate compensation starts and stops at different line rates:

- When low line rate gives way to a high line rate, the low line rate compensation stops at a line rate of 3.906 Hz (256 ms line period).
Note that only the first line acquisition of the series acquired at a line rate above 3.906 Hz will be affected by the low line rate compensation delay.
- When low line rate is entered from a high line rate, the low line rate compensation starts at a line rate of 1.953 Hz (512 ms line period).

For more information about configuring the low line rate compensation feature, see "Low Line Rate Compensation CSR" on [page 222](#).



Low line rate compensation is only available for ExSync controlled operation but not for free run controlled operation where relatively high line rates are used.

4.1.4 Guidelines When Using an ExSync Signal

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

- The ExSync signal must toggle.
- In order for the camera to detect a transition from low to high, the ExSync signal must be held high for at least 1.3 μs when the camera is set for the level controlled exposure mode and for at least 100 ns when the camera is set for programmable or edge controlled exposure mode.
- The ExSync signal must be held low for at least 2.0 μs .
- In ExSync edge controlled mode:
The actual exposure time = line period - 1.8 μs (± 100 ns).
- In the ExSync programmable mode:
The maximum allowed programmed exposure time = line period - 1.3 μs (± 100 ns).
(If you set the exposure time to be longer than this allowed maximum, the camera will use the set exposure time and will ignore the new ExSync signal(s) while exposure proceeds. The line rate will accordingly be decreased.)

Exposure Start Delay

In the ExSync edge controlled and ExSync programmable exposure modes, there is a slight delay between the rise of the ExSync signal and the actual start of exposure. In the ExSync level controlled mode, there is a slight delay between the fall of the ExSync signal and the actual start of exposure. This delay is commonly referred to as an exposure start delay.

The exposure start delay for each mode is as shown in the table below.

	Start Delay
ExSync Programmable ExSync Level Controlled	1.21 μs (± 20 ns)
ExSync Edge Controlled	2.51 μs (± 20 ns)

Table 8: Exposure Start Delay

Delay Due to Low Line Rate Compensation

When low line rate compensation operates (see Section 4.1.3 on [page 95](#)), a delay of 14.2 μs precedes each line acquisition, in addition to exposure start delay.

4.2 Free Run

4.2.1 Basics of Free Run Controlled Operation

In free run, an ExSync signal is not required. The camera generates its own internal control signal based on two programmable parameters, “Line Period” and “Exposure Time.” The camera’s internally generated control signal rises and falls in a fashion similar to an ExSync signal.

In free run, the camera exposes and outputs lines continuously and the line period parameter setting determines the camera’s line rate:

$$\text{Line Rate} = \frac{1}{\text{Line Period}}$$

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

- In **free run edge controlled** mode, line acquisition begins on the rising edge of the internal control signal. The pixels are exposed and charge is accumulated over the full line period (from rising edge to rising edge of the internal control signal). The falling edge of the control signal is irrelevant. The pixel values are read out of the sensor on the rising edge of the internal control signal as shown in Figure 54. The line period is determined by the setting for the line period parameter.

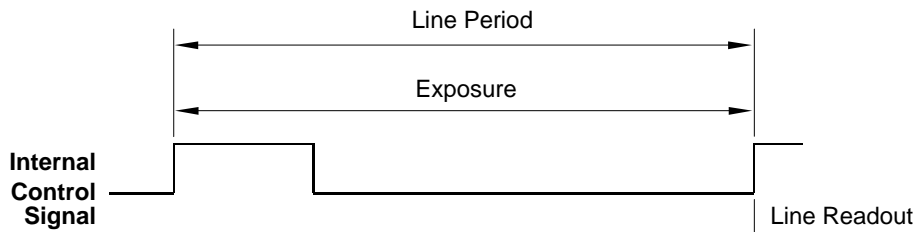


Fig. 54: Free Run, Edge Controlled Mode

- In **free run programmable** mode, line acquisition begins on the rising edge of the ExSync signal. The pixels are exposed and charge is accumulated when the internal control signal is low. The pixel values are read out of the sensor on the rising edge of the internal control signal as shown in Figure 55 on [page 97](#).

In this mode, the line period is determined by the setting for the line period parameter. The exposure time parameter setting determines how long the control signal will be low and thus determines the exposure time.

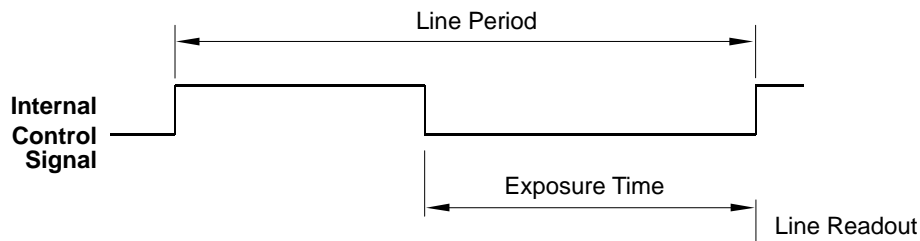


Fig. 55: Free Run, Programmable Mode

4.2.2 Selecting a Free Run Exposure Mode, Setting the Line Period, and Setting the Exposure Time

You can select a free run exposure time control mode, set the line period, and set the exposure time for the free run programmable mode with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Exposure Time Control Mode parameter in the Exposure parameters group to select the free run edge controlled or free run programmable exposure time control mode. The Line Period parameter is used to set the line period. If you select the free run programmable mode, you can use the Exposure Time parameter to set the exposure time.

By Setting CSRs

You select the exposure time control mode by writing the appropriate value to the Mode field of the Exposure Time Control Mode CSR (see [page 223](#)).

You set the line period by writing a value in μs to the Absolute Line Period field or by writing an integer value to the Raw Line Period field of the Line Period CSR (see [page 226](#)).

If you select the free run programmable mode, you will also need to set the exposure time. You set the exposure time by writing a value in μs to the Absolute Exposure Time field or by writing an integer value to the Raw Exposure Time field of the Exposure Time CSR (see [page 224](#)).

Section 7.2.2 on [page 219](#) explains CSRs and the difference between using the "absolute" field and the "raw" field in a CSR. Section 7.3.1 on [page 266](#) explains using read/write commands.

4.2.3 Guidelines When Using Free Run

When using free run mode to control exposure, the following guideline must be followed:

In the free run programmable mode, the minimum exposure time and the maximum exposure time must be within the limits specified in the Exposure Time CSR (see [page 224](#)).

4.3 Maximum Allowed Line Rate / Minimum Line Period



Valid for the spL2048-70 kc, spL4096-70kc, and for the spL4096-70kcESC only:
If the enhanced raw line acquisition mode is selected, in ExSync operation the maximum line rate for these camera models is 137 kHz.

Knowing the maximum allowed line acquisition rate or the minimum line period will be particularly important when you want to operate the camera under the control of an external sync signal (see [page 30](#)).

The formulas given below provide insight into the factors limiting the maximum allowed line rate. For most camera settings, the formulas will allow determining the maximum allowed line acquisition rate. For some camera settings, however, the maximum allowed line acquisition rate may be lower than suggested by the formulas.

We therefore recommend to **generally** determine the maximum allowed line acquisition rate via the CCT+ or the line period CSR.

To determine the maximum allowed line acquisition rate, check the Line Period parameter in the Exposure parameter group of the CCT+ (see Section 7.1 on [page 212](#)) or check the absolute min field of the Line Period CSR (see [page 226](#)) and use the line period value to calculate the maximum allowed line acquisition rate.

Check the line period value before setting the camera to operate under the control of an external sync signal. The line period value will else not be indicated.

In general, the maximum allowed line acquisition rate can be limited by four factors:

- The exposure time for the acquired lines. If you use long exposure times, you can acquire fewer lines per second.
- The amount of time it takes to read an acquired line out of the imaging sensor and into the camera's line buffer. This time can vary depending on the length of the area of interest (AOI) for the acquired lines. Smaller AOIs can take less time to read out.
- The amount of time that it takes to process the pixels before they are ready for transmission. This time varies by camera model.
- The amount of time it takes to transmit the pixel data for an acquired line from the camera to the host computer. This time can vary depending on the length of the area of interest (AOI) for the acquired lines. Smaller AOIs take less time to transmit.

For information about the camera settings to obtain the maximum specified line rate of the camera, see Section 4.3.4 on [page 107](#).

To determine the maximum allowed line acquisition rate with your current camera settings, you must calculate a result for the four formulas that appear below. The formula that returns the lowest value will determine the maximum allowed line rate with the current settings. (In other words, the factor that restricts the line rate the most will determine the maximum allowed line capture rate.)

Formula 1 calculates the maximum line rate based on the exposure time:

$$\text{Max Lines / s} = \frac{1}{\text{Exposure time in s} + .0000013}$$

Formula 2 calculates the maximum line rate based on the sensor readout time:

$$\text{Max Lines / s} = \frac{160000000 \times n}{\text{Max Seg AOI Pixels} + 224}$$

Where: $n = 1$ if the camera is set for the RGB line acquisition mode (see Section 3.2 on [page 36](#))

$n = 2$ if the camera is set for the Raw or Enhanced Raw line acquisition mode (see Chapter 3.3 on [page 44](#) and Chapter 3.4 on [page 63](#))

Max Seg AOI Pixels is the number of AOI pixels in the segment that contains the most AOI pixels (see the explanation of Max Seg AOI Pixels on [page 101](#) for more details)

Formula 3 calculates the maximum line rate based on the amount of time it takes the camera to process the pixels read out from the sensor:

$$\text{Max Lines / s} = \frac{\text{PPR}}{\text{AOI Length} + p}$$

Where: *PPR* is the pixel processing rate for your camera model as stated in the table below:

Model	PPR
spL2048-39kc	80000000
spL2048-50kc spL2048-50kcESC	104000000
spL2048-70kc	320000000

Model	PPR
spL4096-39kc spL4096-39kcESC	160000000
spL4096-50kc	210000000
spL4096-70kc spL4096-70kcESC spL4096-140kc	640000000

Model	PPR
spL8192-39kc spL8192-39kcCI	320000000

AOI Length is the length of the AOI based on the current AOI length setting (see Section 6.3 on [page 152](#))

$p = 0$ if the line stamp feature is not enabled (see Section 6.8 on [page 188](#))

$p = 16$ when the line stamp feature is enabled

Formula 4 calculates the maximum line rate based on the amount of time it takes to transmit the pixel data for an acquired line from the camera to the host computer:

$$\text{Max Lines / s} = \frac{\text{CL Clk} \times \text{Taps}}{(\text{CL Readout Gap} \times \text{Taps}) + \text{AOI Length} + p}$$

Where: *CL Clk* is the Camera Link clock speed for your camera model

Taps is the number of taps being used as determined by the current video data output mode setting (see Chapter 5 on [page 108](#))

CL Readout Gap is the Camera Link readout gap parameter for the camera. This parameter is the minimum time (in Camera Link pixel clocks) between the readouts of two consecutive lines.

This parameter depends on the Camera Link clock speed:

For 40 MHz: 16

For 80 MHz: 24

AOI Length is the length of the AOI based on the current AOI length setting (see Section 6.3 on [page 152](#))

$p = 0$ if the line stamp feature is not enabled (see Section 6.8 on [page 188](#))

$p = 16$ when the line stamp feature is enabled

Section 4.3.2 on [page 104](#) includes an example that illustrates how to use these formulas.

Once you have determined the maximum allowed line rate, you can easily determine the minimum allowed line period:

$$\text{Min Line Period} = \frac{1}{\text{Max Line Rate}}$$

4.3.1 Max Segment AOI Pixels

Each sensor line in a camera is divided into segments with each segment including 2048 pixels.

In cameras equipped with sensors that have 2048 pixels per line, each line has only one segment.

In cameras equipped with sensors that have 4096 pixels per line, each line has two segments as shown in Figure 56.

In cameras equipped with sensors that have 8192 pixels per line, each line has four segments.

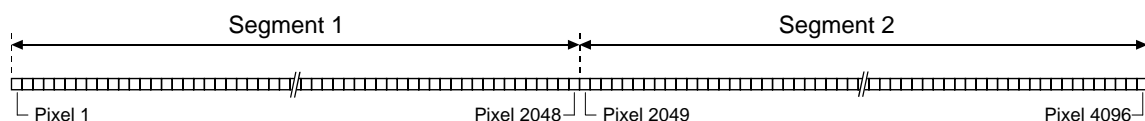


Fig. 56: Segments in Each Line of a 4096 Pixel Sensor

When you are setting up the area of interest (AOI, see Section 6.3 on [page 152](#)) on a camera with only one segment in each line, all of the pixels included in the AOI will fall into that single segment. On these cameras, the Max Seg AOI Pixels is simply the number of pixels included in the AOI. For example, if the AOI starting pixel is set to 33 and the AOI length is set to 512 on an spL2048-39kc, the Max Seg AOI Pixels will be 512.

When you are setting up the AOI on a camera with two segments (4096 pixels) in each line, the pixels within the AOI may all fall into one segment. Or, the AOI could be positioned so that some of the pixels in the AOI fall into segment 1 and some of the pixels in the AOI fall into segment 2. The Max Seg AOI Pixels is defined as the number of AOI pixels included in the segment that contains the largest number of AOI pixels.

When you are setting up the AOI on a camera with four segments (8192 pixels) in each line, the pixels within the AOI may all fall into one segment. Or, the AOI could be positioned so that some of the pixels in the AOI fall into one segment and some of the pixels in the AOI fall into an adjacent segment. The Max Seg AOI Pixels is defined as the number of AOI pixels included in the segment that contains the largest number of AOI pixels. Or, the AOI could be positioned so that the pixels in the AOI fall into three segments so that some of the pixels in the AOI fall into a complete segment and the other pixels into the segments that are adjacent to the completely covered segment. As above, the Max Seg AOI Pixels is defined as the number of AOI pixels included in the segment that contains the largest number of AOI pixels which, in this case, is the completely covered segment. Therefore, the Max Seg AOI Pixels will be 2048.

Consider some examples:

- Suppose that the AOI is set to use the entire line of a 4k camera, i.e., the AOI starting pixel is 1 and the AOI length is 4096. With these settings, the number of AOI pixels in segment 1 is 2048 and the number of AOI pixels in segment 2 is 2048. The Max Seg AOI would be 2048. (In any case where the number of AOI pixels that falls into each segment is the same, the Max Seg AOI Pixels is simply the number of AOI pixels included in one of the segments).
- Suppose that the AOI starting pixel is set to 1 and the AOI length is set to 256. With these settings, all 256 pixels in the AOI would fall into segment 1. The number of AOI pixels in segment 1 is 256 and the number in segment 2 is 0. So the Max Seg AOI Pixels would be 256.
- Suppose that for a 4k camera, the AOI starting pixel is set for 1985 and the length is set for 256. With these settings, the AOI falls across the two sensor segments as shown in Figure 57. Segment 1 includes 64 of the pixels in the AOI and segment 2 includes 192 of the pixels in the AOI. The Max Seg AOI Pixels in this situation would be 192 (because segment 2 contains the largest part of the AOI and the number of AOI pixels in segment 2 is 192).

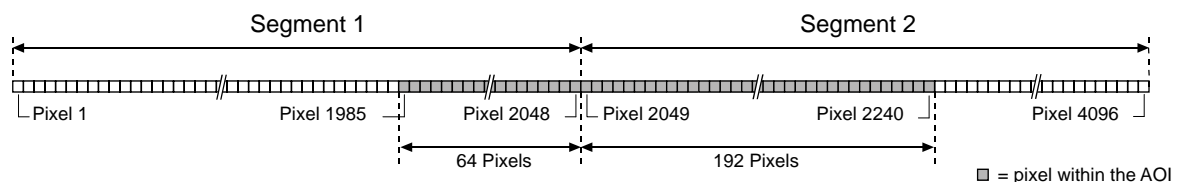


Fig. 57: AOI Falling Across Segments



If you have set an AOI to extend over two adjacent sensor segments and to use each sensor segment only partially, the Max Seg AOI Pixels will be smallest when the AOI is evenly divided across the two segments (i.e., each segment contains the same number of AOI pixels). Positioning the AOI so that it is evenly divided across the two segments will yield the best results from formula two.

The same principle holds, if you have set an AOI to extend over three adjacent sensor segments and use the outer sensor segments only partially. The Max Seg AOI Pixels will be smallest when the AOI is evenly divided across the two outer segments (i.e., each segment contains the same number of AOI pixels).

Positioning the AOI so that it is evenly divided across the two outer segments will yield the best results from formula two.



We recommend using an AOI that is centered on the sensor. When an AOI is centered on the sensor, the number of pixels outside of the AOI will be the same on both sides of the AOI. If an AOI is not centered, the maximum allowed line acquisition rate may be lower than suggested by the formulas given above.

If you are using an AOI that is not centered, determine the maximum allowed line acquisition rate via the CCT+ or the Line Period CSR: Check the Line Period parameter in the Exposure parameter group of the CCT+ or check the absolute min field of the Line Period CSR (see [page 226](#)) and use the line period value to calculate the maximum allowed line acquisition rate.

Knowing the maximum allowed line acquisition rate or the minimum line period will be particularly important when you want to operate the camera under the control of an external sync signal (see [page 30](#)).

Check the line period value before setting the camera to operate under the control of an external sync signal. Otherwise, the line period value will not be indicated.

4.3.2 Example of Calculating the Maximum Allowed Line Rate / Minimum Line Period



The above formulas for determining the maximum allowed line rate will apply to most camera settings. For some camera settings, however, the maximum allowed line acquisition rate may be lower than suggested by the formulas. We therefore recommend to **generally** determine the maximum allowed line acquisition rate via the CCT+ (see Section 7.1 on [page 212](#)) or the line period CSR (see [page 226](#)). Bear these restrictions in mind when considering the following example.

Assume that you are working with an spL4096-70kc. Also assume that the camera is set for the Raw line acquisition mode, 80 MHz Camera Link clock speed, and 8 tap 8 bit video data output mode. The AOI starting pixel is set to 1249, AOI length is set to 2400, and the exposure time is set to 4 μ s. The stamp feature is disabled.

First, you must determine the max segment AOI pixels. With the current settings 800 AOI pixels would be included in segment 1 and 1600 AOI pixels would be included in segment 2. In this case, the max segment AOI pixels is 1600.

Next, use the four formulas to calculate the maximum allowed line rate:

Formula 1:

$$\text{Max Lines / s} = \frac{1}{\text{Exposure time in s} + .0000013}$$

$$\text{Max Lines / s} = \frac{1}{.000004 + .0000013}$$

$$\text{Max Lines / s} = 188679$$

Formula 2:

$$\text{Max Lines / s} = \frac{160000000 \times n}{\text{Max Seg AOI Pixels} + 224}$$

$$\text{Max Lines / s} = \frac{160000000 \times 2}{1600 + 224}$$

$$\text{Max Lines / s} = 175438$$

Formula 3:

$$\text{Max Lines / s} = \frac{\text{PPR}}{\text{AOI Length} + p}$$

$$\text{Max Lines / s} = \frac{290000000}{2400 + 0}$$

$$\text{Max Lines / s} = 120833$$

Formula 4:

$$\text{Max Lines / s} = \frac{\text{CL Clk} \times \text{Taps}}{(\text{CL Readout gap} \times \text{Taps}) + \text{AOI Length} + p}$$

$$\text{Max Lines / s} = \frac{80000000 \times 8}{(24 \times 8) + 2400 + 0}$$

$$\text{Max Lines / s} = 246913$$

Formula 3 returns the lowest value. So with the current camera settings, the maximum allowed line rate would be 120833 lines per second.

The minimum allowed line period in this case would be:

$$\text{Min Line Period} = \frac{1}{120833}$$

$$\text{Min Line Period} = 0.00000827 = 8.3 \mu\text{s}$$

4.3.3 Increasing the Maximum Allowed Line Rate

You may find that you would like to acquire lines at a rate higher than the maximum allowed with your current camera settings. If this is the case, you must first use the four formulas described on [page 104](#) to determine which factor is restricting the maximum line rate the most. Next, you must try to make that factor less restrictive:

- If you find that formula one (exposure time) is the most restrictive factor, you should decrease the exposure time. Decreasing the exposure time will increase the maximum line rate yielded by formula one. If you decrease the exposure time, you may need to compensate for a lower exposure time by using a brighter light source or by increasing the opening of your lens aperture.
- If you find that formula two (sensor readout) is the most restrictive factor, you may be able to adjust your AOI settings to decrease the Max Seg AOI Pixels. Using a smaller AOI can decrease the Max Seg AOI Pixels. Decreasing the Max Seg AOI Pixels will increase the maximum line rate yielded by formula two.

If you are using a camera that has two sensor segments and the AOI is positioned so that many pixels in the AOI fall into one sensor segment and few pixels fall into the other, you can try re-positioning your AOI. The Max Seg AOI Pixels will be smallest when the AOI is evenly divided across the two segments (i.e., each segment contains the same number of AOI pixels).

- If you find that formula three (pixel processing rate) is the most restrictive factor, you can decrease the AOI length. Decreasing the AOI length will increase the maximum line rate yielded by formula three.
- Formula four (transmission time) will not normally be a restricting factor. But if you are using a 2 tap or a 4 tap video data output mode, you may find that the transmission time is restricting the line rate. In this situation, you may be able to switch to an output mode that uses a larger number of taps. Using a larger number of taps will reduce the time it takes to transmit the pixel data and will increase the maximum line rate yielded by formula four. You may be able to decrease the transmission time by selecting a higher Camera Link clock speed, if available.

4.3.4 Camera Settings for the Maximum Specified Line Rate

You can obtain the camera's maximum specified line rate by combining the appropriate settings for the following parameters:

- number of taps of the video data output mode
- Camera Link clock speed
- line acquisition mode.

The combinations listed in this section apply to full resolution.

When using the AOI feature, you may be able to obtain the specified line rates for additional combinations and you may obtain higher line rates than the maximum specified line rates.

The following table lists all combinations of the relevant parameters for all camera models.

Model	Taps	Camera Link Clock Speed	Line Acquisition Mode(s)
spL2048-39kc	2 taps	40 MHz	Raw
	2 taps	80 MHz	RGB, Raw, Enhanced Raw
	3 taps	40 MHz, 80 MHz	RGB
spL2048-50kc, spL2048-50kcESC, spL2048-70kc	2 taps	80 MHz	Raw
	3 taps	40 MHz, 80 MHz	RGB
	4 taps	40 MHz	Raw
	4 taps	80 MHz	RGB, Raw, Enhanced Raw
	6 taps	40 MHz	RGB
	8 taps	40 MHz	RGB, Raw, Enhanced Raw
spL4096-39kc, spL4096-39kcESC	4 taps	40 MHz	Raw
	6 taps	40 MHz	RGB
	8 taps	40 MHz	RGB, Raw, Enhanced Raw
spL4096-50kc, spL4096-70kc, spL4096-70kcESC, spL4096-140kc	4 taps	80 MHz	Raw
	6 taps	80 MHz	RGB
	8 taps	40 MHz	Raw
	8 taps	80 MHz	Raw, RGB, Enhanced Raw
	8 taps	80 MHz	Raw, RGB, Enhanced Raw
spL8192-39kc, spL8192-39kcCI	4 taps	80 MHz	Raw
	6 taps	80 MHz	RGB
	8 taps	40 MHz	Raw
	8 taps	80 MHz	RGB, Raw, Enhanced Raw

Table 9: Combinations of Parameter Settings for the Maximum Specified Line Rates

5 Video Data Output Modes

This section describes the video data output modes available on the camera. The video data output mode will determine the format of the pixel data output from the camera and will affect the camera's maximum allowed line rate.

5.1 Overview

The camera can operate in different video data output modes. The video data output mode will determine the format of the pixel data output from the camera. The video data output modes available vary on each camera model as shown in Table 11 on [page 109](#).

The main difference between the video data output modes is the amount of pixel data that will be output on each cycle of the Camera Link pixel clock.

Tap Mode	Pixel Output on Each Pixel Clock Cycle
2 tap modes	2 pixels
3 tap modes	3 pixels (if the line acquisition mode is set to RGB)
4 tap modes	4 pixels
6 tap modes	6 pixels (if the line acquisition mode is set to Raw)
8 tap modes	8 pixels

Table 10: Tap Modes and Pixel Outputs

The selection of a video data output mode also determines the bit depth of the transmitted pixel data. The video data output modes are described in detail in Section 5.2.1 on [page 111](#) through Section 5.2.5 on [page 136](#).

In general, you can operate the camera at a higher maximum line rate when you use an output mode with more taps. This is true because the modes with more taps output a greater amount of pixel data on each cycle of the pixel clock and therefore require less time to output a given amount of data.

For more information about how the video data output mode will affect the camera's maximum allowed line rate, see Section 4.3 on [page 99](#).

On the camera models the speed can be set to either 40 or 80 MHz. The available clock speeds on each model are also shown in Table 11. For more information about setting the Camera Link pixel clock speed, see Section 2.8.5 on [page 32](#).

For Models	Video Data Outmode Modes	Camera link Clock Speed(s)
spL2048-39kc	2 tap - 8 bit / 10 bit / 12 bit 3 tap - 8 bit	40 MHz or 80 MHz
All other models	2 tap - 8 bit / 10 bit / 12 bit 3 tap - 8 bit / 10 bit 4 tap - 8 bit / 10 bit / 12 bit 6 tap - 8 bit 8 tap - 8 bit	40 MHz or 80 MHz

Table 11: Available Video Data Output Modes and Pixel Clock Speed(s)

For information about the camera settings to obtain the maximum specified line rate of the camera, see Section 4.3.4 on [page 107](#).

5.1.1 Setting the Video Data Output Mode

You can set the video data output mode with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Video Data Output Mode parameter in the Output Mode parameters group to set the output mode.

By Setting CSRs

You select the video data output mode by writing the appropriate value to the Mode field of the Video Data Output Mode CSR (see [page 228](#)).

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.

5.2 Video Data Output Mode Details



The following values for line valid and frame valid delays apply to line acquisitions at full resolution. If a shorter AOI is used, the values for line valid and frame valid delays may be smaller or larger, depending on the size and position of the AOI.



The bit depths of the video data output modes have no effect on the values for line valid and frame valid delays.

The following delays are given in this section:

- Line valid delays for the RGB line acquisition mode (see Figure 14 on [page 39](#) through Figure 18 on [page 43](#))
- Frame valid delays for the Raw and Enhanced Raw line acquisition modes (Figure 23 on [page 51](#) through Figure 25 on [page 53](#), and Figure 39 on [page 73](#) through Figure 41 on [page 75](#)).

After the frame valid signals, the line valid signals will go high with some additional delay. The additional delay will be 0.050 μ s for a Camera Link clock cycle of 40 MHz and 0.025 μ s for a Camera Link clock cycle of 80 MHz (see also the figures referred to above).



When the FVAL Length parameter is set to 0 and the FVAL signal will always stay low, the line valid delay will be the sum of the frame valid delay (in spite of the frame valid signal staying low) plus the additional delay.

For information about the FVAL Length parameter, see Section 2.8.1 on [page 31](#).

5.2.1 2 Tap Output Modes

2 Tap - 12 Bit Output Mode

In 2 tap 12 bit mode, on each pixel clock cycle, the camera transmits data for two pixels at 12 bit depth, a line valid bit, and a data valid bit. In the Raw and Enhanced Raw line acquisition modes, the camera also transmits a frame valid bit, unless the FVAL Length parameter is set to zero. For more information about the frame valid bit, see Section 2.8.1 on [page 31](#).

In the 2 tap output modes, the camera uses the output ports on Camera Link Transmitter X to transmit pixel data, a frame valid bit (in the Raw and Enhanced Raw line acquisition modes only), a line valid bit, a data valid bit, and a pixel clock. The assignment of the bits to the output ports on Camera Link Transmitter X is as shown in Table 12 on [page 113](#).

The Camera Link clock is used to time the transmission of acquired pixel data. As shown in Figure 14 on [page 39](#), Figure 23 on [page 51](#), and Figure 39 on [page 73](#), the camera samples and transmits data on each rising edge of the clock. The Camera Link pixel clock frequency is as stated in Section 2.8.5 on [page 32](#).

The frame valid bit indicates that line A is being transmitted (in the Raw - Line A First and in the Enhanced Raw - Line A First (B Delayed) line acquisition modes only). The line valid bit indicates that a valid line is being transmitted. The data valid bit indicates that valid pixel data is being transmitted. Pixel data is only valid when the frame valid (in the Raw and Enhanced Raw line acquisition modes only), line valid and data valid bits are all high.

2 Tap - 10 Bit Output Mode

Operation in 2 tap 10 bit mode is similar to 2 tap 12 bit mode. In 10 bit mode, however, the two least significant bits output from the camera's ADCs are dropped and only the 10 most significant bits of data per pixel are transmitted.

2 Tap - 8 Bit Output Mode

Operation in 2 tap 8 bit mode is similar to 2 tap 12 bit mode. In 8 bit mode, however, the four least significant bits output from the camera's ADCs are dropped and only the 8 most significant bits of data per pixel are transmitted.



The video data output mode that you select may affect the camera's maximum allowed line rate. See Section 4.3 on [page 99](#).

The data sequence outlined below, along with Figure 14 on [page 39](#), Figure 23 on [page 51](#), and Figure 39 on [page 73](#), describes what is happening at the inputs to the Camera Link transmitters in the camera.

Video Data Sequence for 2 Tap Output Modes

The following assumes that the Raw or Enhanced Raw line acquisition mode is selected where a frame valid signal is transmitted. If the RGB line acquisition mode is selected, the frame valid signal will not be transmitted.

When the camera is not transmitting valid data, the frame valid, line valid and data valid bits sent on each cycle of the pixel clock will be low.

Once the camera has completed an exposure, there will be a delay while data is read out of the sensor. When readout is complete, the camera will begin to transmit pixel data:

- On the clock cycle where valid pixel data transmission begins, the frame valid, line valid and data valid bits all become high. Two data streams, D0 and D1 are transmitted in parallel on this clock cycle. On this clock cycle, data stream D0 will transmit data for pixel 1 in the line. Data stream D1 will transmit data for pixel 2. Depending on the video data output mode selected, the pixel data will be at 12 bit, 10 bit, or 8 bit depth.
- On the next cycle of the pixel clock, the frame valid, line valid and data valid bits will all be high. On this clock cycle, data stream D0 will transmit data for pixel 3 in the line. Data stream D1 will transmit data for pixel 4.
- On the next cycle of the pixel clock, the frame valid, line valid and data valid bits will all be high. On this clock cycle, data stream D0 will transmit data for pixel 5 in the line. Data stream D1 will transmit data for pixel 6.
- This pattern will continue until all of the pixel data for the line has been transmitted.
- After all of the pixel data for the line has been transmitted, the frame valid, line valid and data valid bits all become low indicating that valid pixel data is no longer being transmitted.

Figure 14 on [page 39](#), Figure 23 on [page 51](#), and Figure 39 on [page 73](#) show the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode or in programmable exposure mode.

MDR Conn. 1, Transmitter X					
Port	Camera	Frame Grabber	Bit Assignment		
			2 Tap - 12 Bit	2 Tap - 10 Bit	2 Tap - 8 Bit
Port A0	TxIN0	RxOut0	D0 Bit 0	D0 Bit 0	D0 Bit 0
Port A1	TxIN1	RxOut1	D0 Bit 1	D0 Bit 1	D0 Bit 1
Port A2	TxIN2	RxOut2	D0 Bit 2	D0 Bit 2	D0 Bit 2
Port A3	TxIN3	RxOut3	D0 Bit 3	D0 Bit 3	D0 Bit 3
Port A4	TxIN4	RxOut4	D0 Bit 4	D0 Bit 4	D0 Bit 4
Port A5	TxIN6	RxOut6	D0 Bit 5	D0 Bit 5	D0 Bit 5
Port A6	TxIN27	RxOut27	D0 Bit 6	D0 Bit 6	D0 Bit 6
Port A7	TxIN5	RxOut5	D0 Bit 7	D0 Bit 7	D0 Bit 7 (MSB)
Port B0	TxIN7	RxOut7	D0 Bit 8	D0 Bit 8	D1 Bit 0
Port B1	TxIN8	RxOut8	D0 Bit 9	D0 Bit 9 (MSB)	D1 Bit 1
Port B2	TxIN9	RxOut9	D0 Bit 10	Not Used	D1 Bit 2
Port B3	TxIN12	RxOut12	D0 Bit 11 (MSB)	Not Used	D1 Bit 3
Port B4	TxIN13	RxOut13	D1 Bit 8	D1 Bit 8	D1 Bit 4
Port B5	TxIN14	RxOut14	D1 Bit 9	D1 Bit 9 (MSB)	D1 Bit 5
Port B6	TxIN10	RxOut10	D1 Bit 10	Not Used	D1 Bit 6
Port B7	TxIN11	RxOut11	D1 Bit 11(MSB)	Not Used	D1 Bit 7 (MSB)
Port C0	TxIN15	RxOut15	D1 Bit 0	D1 Bit 0	Not Used
Port C1	TxIN18	RxOut18	D1 Bit 1	D1 Bit 1	Not Used
Port C2	TxIN19	RxOut19	D1 Bit 2	D1 Bit 2	Not Used
Port C3	TxIN20	RxOut20	D1 Bit 3	D1 Bit 3	Not Used
Port C4	TxIN21	RxOut21'	D1 Bit 4	D1 Bit 4	Not Used
Port C5	TxIN22	RxOut22	D1 Bit 5	D1 Bit 5	Not Used
Port C6	TxIN16	RxOut16	D1 Bit 6	D1 Bit 6	Not Used
Port C7	TxIN17	RxOut17	D1 Bit 7	D1 Bit 7	Not Used
LVAL	TxIN24	RxOut24	Line Valid	Line Valid	Line Valid
FVAL	TxIN25	RxOut25	Frame Valid*	Frame Valid*	Frame Valid*
DVAL	TxIN26	RxOut26	Data Valid	Data Valid	Data Valid
Spare	TxIN23	RxOut23	Not Used	Not Used	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock	Pixel Clock	Pixel Clock

Table 12: Bit Assignments for 2 Tap Output Modes (MDR Conn. 1 - Transmitter X)

*: Present for the Raw and Enhanced Raw line acquisition modes only.

The tables below show the following delays when the camera is set for full resolution and 2 tap video data output mode:

- Line valid delays for the RGB line acquisition mode (see Figure 14 on [page 39](#))
- Frame valid delays for the Raw and Enhanced Raw line acquisition modes (Figure 23 on [page 51](#), and Figure 39 on [page 73](#))

Note that the delays depend on the line acquisition mode setting and the camera link clock speed setting. The delays also depend on whether the camera is a 2k, 4k, or 8k camera.

Each delay can vary slightly within the stated minimum and maximum values.

2k Cameras

Line Valid/Frame Valid Delays for 2 Tap Modes - 2k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.08 μ s	3.20 μ s
Edge Controlled Exposure	3.12 μ s	3.25 μ s
Level Controlled Exposure	3.08 μ s	3.20 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.10 μ s	3.25 μ s
Edge Controlled Exposure	3.10 μ s	3.25 μ s
Level Controlled Exposure	3.10 μ s	3.25 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.13 μ s	3.28 μ s
Edge Controlled Exposure	3.13 μ s	3.28 μ s
Level Controlled Exposure	3.13 μ s	3.28 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	2.91 μ s	3.01 μ s
Edge Controlled Exposure	2.96 μ s	3.06 μ s
Level Controlled Exposure	2.91 μ s	3.01 μ s

Table 13: Line Valid/Frame Valid Delays with the 2k Camera Set for 2 Tap Video Data Output Modes

Line Valid/Frame Valid Delays for 2 Tap Modes - 2k Cameras		
	Frame Valid Delay for the Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	2.97 μ s	3.09 μ s
Edge Controlled Exposure	2.97 μ s	3.09 μ s
Level Controlled Exposure	2.97 μ s	3.09 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	2.99 μ s	3.11 μ s
Edge Controlled Exposure	2.99 μ s	3.11 μ s
Level Controlled Exposure	2.99 μ s	3.11 μ s

Table 13: Line Valid/Frame Valid Delays with the 2k Camera Set for 2 Tap Video Data Output Modes

4k Cameras

Line Valid/Frame Valid Delays for 2 Tap Modes - 4k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.10 μ s	3.23 μ s
Edge Controlled Exposure	3.15 μ s	3.28 μ s
Level Controlled Exposure	3.10 μ s	3.23 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.15 μ s	3.30 μ s
Edge Controlled Exposure	3.15 μ s	3.30 μ s
Level Controlled Exposure	3.15 μ s	3.30 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.17 μ s	3.33 μ s
Edge Controlled Exposure	3.17 μ s	3.33 μ s

Table 14: Line Valid/Frame Valid Delays with the 4k Camera Set for 2 Tap Video Data Output Modes

Line Valid/Frame Valid Delays for 2 Tap Modes - 4k Cameras		
Level Controlled Exposure	3.18 μ s	3.33 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	2.93 μ s	3.03 μ s
Edge Controlled Exposure	2.98 μ s	3.08 μ s
Level Controlled Exposure	2.93 μ s	3.03 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	3.02 μ s	3.13 μ s
Edge Controlled Exposure	3.02 μ s	3.13 μ s
Level Controlled Exposure	3.02 μ s	3.13 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	3.04 μ s	3.16 μ s
Edge Controlled Exposure	3.04 μ s	3.16 μ s
Level Controlled Exposure	3.04 μ s	3.16 μ s

Table 14: Line Valid/Frame Valid Delays with the 4k Camera Set for 2 Tap Video Data Output Modes

8k Camera

Line Valid/Frame Valid Delays for 2 Tap Modes - 8k Camera		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.08 μ s	3.22 μ s
Edge Controlled Exposure	3.13 μ s	3.27 μ s
Level Controlled Exposure	3.08 μ s	3.22 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.21 μ s	3.36 μ s

Table 15: Line Valid/Frame Valid Delays with the 8k Camera Set for 2 Tap Video Data Output Modes

Line Valid/Frame Valid Delays for 2 Tap Modes - 8k Camera		
Edge Controlled Exposure	3.21 μ s	3.36 μ s
Level Controlled Exposure	3.21 μ s	3.36 μ s
Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz		
	Min.	Max.
Programmable	3.23 μ s	3.39 μ s
Edge Controlled Exposure	3.23 μ s	3.39 μ s
Level Controlled Exposure	3.23 μ s	3.39 μ s
Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz		
	Min.	Max.
Programmable	2.91 μ s	3.01 μ s
Edge Controlled Exposure	2.96 μ s	3.06 μ s
Level Controlled Exposure	2.91 μ s	3.01 μ s
Frame Valid Delay for the Raw Line Acquisition Mode - 80 MHz		
	Min.	Max.
Programmable	3.07 μ s	3.19 μ s
Edge Controlled Exposure	3.07 μ s	3.19 μ s
Level Controlled Exposure	3.07 μ s	3.19 μ s
Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 80 MHz		
	Min.	Max.
Programmable	3.10 μ s	3.21 μ s
Edge Controlled Exposure	3.10 μ s	3.21 μ s
Level Controlled Exposure	3.10 μ s	3.21 μ s

Table 15: Line Valid/Frame Valid Delays with the 8k Camera Set for 2 Tap Video Data Output Modes

5.2.2 3 Tap Output Modes

3 Tap - 10 Bit Output Mode

In 3 tap 10 bit mode, on each pixel clock cycle, the camera transmits data for three pixels at 10 bit depth, a line valid bit, and a data valid bit.

In the 3 tap output modes, the camera uses the output ports on Camera Link Transmitter X and Y to transmit pixel data, a line valid bit, a data valid band, and a pixel clock. The assignment of the bits to the output ports on Camera Link Transmitter X and Y are as shown in Table 16 on [page 120](#) and Table 17 on [page 121](#) respectively.

The Camera Link clock is used to time the transmission of acquired pixel data. As shown in Figure 15 on [page 40](#), the camera samples and transmits data on each rising edge of the clock. The Camera Link pixel clock frequency is as stated in Section 2.8.5 on [page 32](#).

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

3 Tap - 8 Bit Output Mode

Operation in 3 tap 8 bit mode is similar to 3 tap 10 bit mode. In 8 bit mode, however, the two least significant bits output from the camera's ADCs are dropped and only the 8 most significant bits of data per pixel are transmitted.



The video data output mode that you select may affect the camera's maximum allowed line rate. See Section 4.3 on [page 99](#).

The data sequence outlined below, along with Figure 15 on [page 40](#), describes what is happening at the inputs to the Camera Link transmitters in the camera.

Video Data Sequence for 3 Tap Output Modes

When the camera is not transmitting valid data, the line valid and data valid bits sent on each cycle of the pixel clock will be low.

Once the camera has completed an exposure, there will be a delay while data is read out of the sensor. When readout is complete, the camera will begin to transmit pixel data:

- On the clock cycle where valid pixel data transmission begins, the line valid and data valid bits both become high. Three data streams, D0, D1, and D2 are transmitted in parallel on this clock cycle. On this clock cycle, data stream D0 will transmit data for pixel 1 in the line. Data stream D1 will transmit data for pixel 2. And data stream D2 will transmit data for pixel 3. Depending on the video data output mode selected, the pixel data will be at 10 bit, or 8 bit depth.
- On the next cycle of the pixel clock, the line valid and data valid bits will both be high. On this clock cycle, data stream D0 will transmit data for pixel 4 in the line. Data stream D1 will transmit data for pixel 5. And data stream D2 will transmit data for pixel 6.
- On the next cycle of the pixel clock, the line valid and data valid bits will be high. On this clock cycle, data stream D0 will transmit data for pixel 7 in the line. Data stream D1 will transmit data for pixel 8. And data stream D2 will transmit data for pixel 9.
- This pattern will continue until all of the pixel data for the line has been transmitted.
- After all of the pixel data for the line has been transmitted, the line valid and data valid bits both become low indicating that valid pixel data is no longer being transmitted.

Figure 15 on [page 40](#) shows the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode or in programmable exposure mode.

MDR Conn. 1, Transmitter X				
Port	Camera	Frame Grabber	Bit Assignment	
			3 Tap - 10 Bit	3 Tap - 8 Bit
Port A0	TxIN0	RxOut0	D0 Bit 0	D0 Bit 0
Port A1	TxIN1	RxOut1	D0 Bit 1	D0 Bit 1
Port A2	TxIN2	RxOut2	D0 Bit 2	D0 Bit 2
Port A3	TxIN3	RxOut3	D0 Bit 3	D0 Bit 3
Port A4	TxIN4	RxOut4	D0 Bit 4	D0 Bit 4
Port A5	TxIN6	RxOut6	D0 Bit 5	D0 Bit 5
Port A6	TxIN27	RxOut27	D0 Bit 6	D0 Bit 6
Port A7	TxIN5	RxOut5	D0 Bit 7	D0 Bit 7 (MSB)
Port B0	TxIN7	RxOut7	D0 Bit 8	D1 Bit 0
Port B1	TxIN8	RxOut8	D0 Bit 9 (MSB)	D1 Bit 1
Port B2	TxIN9	RxOut9	Not Used	D1 Bit 2
Port B3	TxIN12	RxOut12	Not Used	D1 Bit 3
Port B4	TxIN13	RxOut13	D2 Bit 8	D1 Bit 4
Port B5	TxIN14	RxOut14	D2 Bit 9 (MSB)	D1 Bit 5
Port B6	TxIN10	RxOut10	Not Used	D1 Bit 6
Port B7	TxIN11	RxOut11	Not Used	D1 Bit 7 (MSB)
Port C0	TxIN15	RxOut15	D2 Bit 0	D2 Bit 0
Port C1	TxIN18	RxOut18	D2 Bit 1	D2 Bit 1
Port C2	TxIN19	RxOut19	D2 Bit 2	D2 Bit 2
Port C3	TxIN20	RxOut20	D2 Bit 3	D2 Bit 3
Port C4	TxIN21	RxOut21'	D2 Bit 4	D2 Bit 4
Port C5	TxIN22	RxOut22	D2 Bit 5	D2 Bit 5
Port C6	TxIN16	RxOut16	D2 Bit 6	D2 Bit 6
Port C7	TxIN17	RxOut17	D2 Bit 7	D2 Bit 7 (MSB)
LVAL	TxIN24	RxOut24	Line Valid	Line Valid
FVAL	TxIN25	RxOut25	Frame Valid	Not used
DVAL	TxIN26	RxOut26	Data Valid	Data Valid
Spare	TxIN23	RxOut23	Not Used	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock	Pixel Clock

Table 16: Bit Assignments for 3 Tap Output Modes (MDR Conn. 1 - Transmitter X)

MDR Conn 2, Transmitter Y			
Port	Camera	Frame Grabber	Bit Assignment
			3 Tap - 10 Bit
Port D0	TxIN0	RxOut0	not used
Port D1	TxIN1	RxOut1	not used
Port D2	TxIN2	RxOut2	not used
Port D3	TxIN3	RxOut3	not used
Port D4	TxIN4	RxOut4	not used
Port D5	TxIN6	RxOut6	not used
Port D6	TxIN27	RxOut27	not used
Port D7	TxIN5	RxOut5	not used
Port E0	TxIN7	RxOut7	D1 Bit 0
Port E1	TxIN8	RxOut8	D1 Bit 1
Port E2	TxIN9	RxOut9	D1 Bit 2
Port E3	TxIN12	RxOut12	D1 Bit 3
Port E4	TxIN13	RxOut13	D1 Bit 4
Port E5	TxIN14	RxOut14	D1 Bit 5
Port E6	TxIN10	RxOut10	D1 Bit 6
Port E7	TxIN11	RxOut11	D1 Bit 7
Port F0	TxIN15	RxOut15	D1 Bit 8
Port F1	TxIN18	RxOut18	D1 Bit 9 (MSB)
Port F2	TxIN19	RxOut19	Not used
Port F3	TxIN20	RxOut20	Not used
Port F4	TxIN21	RxOut21'	not used
Port F5	TxIN22	RxOut22	not used
Port F6	TxIN16	RxOut16	Not used
Port F7	TxIN17	RxOut17	Not used
LVAL	TxIN24	RxOut24	Line Valid
FVAL	TxIN25	RxOut25	Not Used
DVAL	TxIN26	RxOut26	Data Valid
Spare	TxIN23	RxOut23	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock

Table 17: Bit Assignments for 3 Tap Output Modes (MDR Conn 2 - Transmitter Y)

The tables below show the line valid delays for the RGB line acquisition mode (see Figure 15 on page 40) when the camera is set for full resolution and 3 tap video data output mode.

Note that the delays depend on the line acquisition mode setting and the camera link clock speed setting. The delays also depend on whether the camera is a 2k, 4k, or 8k camera.

Each delay can vary slightly within the stated minimum and maximum values.

2k Cameras

Line Valid Delays for 3 Tap Modes - 2k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.08 μ s	3.20 μ s
Edge Controlled Exposure	3.13 μ s	3.25 μ s
Level Controlled Exposure	3.08 μ s	3.20 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	2.91 μ s	3.01 μ s
Edge Controlled Exposure	2.96 μ s	3.04 μ s
Level Controlled Exposure	2.91 μ s	3.01 μ s

Table 18: Line Valid Delays with the 2k Camera Set for 3 Tap Video Data Output Modes

4k Cameras

Line Valid Delays for 3 Tap Modes - 4k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.10 μ s	3.23 μ s
Edge Controlled Exposure	3.15 μ s	3.28 μ s
Level Controlled Exposure	3.10 μ s	3.23 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	2.94 μ s	3.04 μ s
Edge Controlled Exposure	2.99 μ s	3.09 μ s
Level Controlled Exposure	2.94 μ s	3.04 μ s

Table 19: Line Valid Delays with the 4k Camera Set for 3 Tap Video Data Output Modes

8k Camera

Line Valid Delays for 3 Tap Modes - 8k Camera		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.08 μ s	3.21 μ s
Edge Controlled Exposure	3.13 μ s	3.26 μ s
Level Controlled Exposure	3.08 μ s	3.21 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	6.45 μ s	6.55 μ s
Edge Controlled Exposure	6.80 μ s	6.90 μ s
Level Controlled Exposure	6.45 μ s	6.55 μ s

Table 20: Line Valid Delays with the 8k Camera Set for 3 Tap Video Data Output Modes

5.2.3 4 Tap Output Modes

4 Tap - 12 Bit Output Mode

In 4 tap 12 bit mode, on each pixel clock cycle, the camera transmits data for four pixels at 12 bit depth, a line valid bit and a data valid bit. In the Raw and Enhanced Raw line acquisition modes, the camera also transmits a frame valid bit, unless the FVAL Length parameter is set to zero. For more information about the frame valid bit, see Section 2.8.1 on [page 31](#).

In the 4 tap output modes, the camera uses the output ports on Camera Link Transmitters X and Y to transmit pixel data, a frame valid bit (in the Raw and Enhanced Raw line acquisition modes only), a line valid bit, a data valid bit, and the Camera Link pixel clock. The assignment of the bits to the output ports on Camera Link Transmitters X and Y is as shown in Table 21 on [page 126](#) and Table 22 on [page 127](#) respectively.

The Camera Link clock is used to time the transmission of acquired pixel data. As shown in Figure 16 on [page 41](#), Figure 24 on [page 52](#) and Figure 40 on [page 74](#), the camera samples and transmits data on each rising edge of the Camera Link clock. The Camera Link pixel clock frequency is as stated in Section 2.8.5 on [page 32](#).

The frame valid bit indicates that line A is being transmitted (in the Raw - Line A First and in the Enhanced Raw - Line A First (B Delayed) line acquisition modes only). The line valid bit indicates that a valid line is being transmitted. The data valid bit indicates that valid pixel data is being transmitted. Pixel data is only valid when the frame valid (in the Raw and Enhanced Raw line acquisition modes only), line valid and data valid bits are all high.

4 Tap - 10 Bit Output Mode

Operation in 4 tap 10 bit mode is similar to 4 tap 12 bit mode. In 10 bit mode, however, the two least significant bits output from the camera's ADCs are dropped and only the 10 most significant bits of data per pixel are transmitted.

4 Tap - 8 Bit Output Mode

Operation in 4 tap 8 bit mode is similar to 4 tap 12 bit mode. In 8 bit mode, however, the four least significant bits output from the camera's ADCs are dropped and only the 8 most significant bits of data per pixel are transmitted.



The video data output mode that you select may affect the camera's maximum allowed line rate. See Section 4.3 on [page 99](#).

The data sequence outlined below, along with Figure 16 on [page 41](#), Figure 24 on [page 52](#), and Figure 40 on [page 74](#), describes what is happening at the inputs to the Camera Link transmitters in the camera.

Video Data Sequence for 4 Tap Modes

The following assumes that the Raw or Enhanced Raw line acquisition mode is selected where a frame valid signal is transmitted. If the RGB line acquisition mode is selected, the frame valid signal will not be transmitted.

When the camera is not transmitting valid data, the frame valid, line valid and data valid bits sent on each cycle of the pixel clock will be low.

Once the camera has completed an exposure, there will be a delay while data is read out of the sensor. When readout is complete, the camera will begin to transmit pixel data:

- On the clock cycle where valid pixel data transmission begins, the frame valid, line valid and data valid bits all become high. Four data streams, D0, D1, D2, and D3 are transmitted in parallel on this clock cycle. On this clock cycle, data stream D0 will transmit data for pixel 1 in the line. Data stream D1 will transmit data for pixel 2. Data stream D2 will transmit data for pixel 3. And data stream D3 will transmit data for pixel 4. Depending on the video data output mode selected, the pixel data will be at either 12 bit, 10 bit, or 8 bit depth.
- On the next cycle of the pixel clock, the frame valid, line valid and data valid bits will all be high. On this clock cycle, data stream D0 will transmit data for pixel 5 in the line. Data stream D1 will transmit data for pixel 6. Data stream D2 will transmit data for pixel 7. And data stream D3 will transmit data for pixel 8.
- On the next cycle of the pixel clock, the frame valid, line valid and data valid bits will all be high. On this clock cycle, data stream D0 will transmit data for pixel 9 in the line. Data stream D1 will transmit data for pixel 10. Data stream D2 will transmit data for pixel 11. And data stream D3 will transmit data for pixel 12.
- This pattern will continue until all of the pixel data for the line has been transmitted.
- After all of the pixel data for the line has been transmitted, frame valid, the line valid and data valid bits all become low indicating that valid pixel data is no longer being transmitted.

Figure 16 on [page 41](#), Figure 24 on [page 52](#), and Figure 40 on [page 74](#) show the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode or in programmable exposure mode.

MDR Conn. 1, Transmitter X					
Port	Camera	Frame Grabber	Bit Assignment		
			4 Tap - 12 Bit	4 Tap - 10 Bit	4 Tap - 8 Bit
Port A0	TxIN0	RxOut0	D0 Bit 0	D0 Bit 0	D0 Bit 0
Port A1	TxIN1	RxOut1	D0 Bit 1	D0 Bit 1	D0 Bit 1
Port A2	TxIN2	RxOut2	D0 Bit 2	D0 Bit 2	D0 Bit 2
Port A3	TxIN3	RxOut3	D0 Bit 3	D0 Bit 3	D0 Bit 3
Port A4	TxIN4	RxOut4	D0 Bit 4	D0 Bit 4	D0 Bit 4
Port A5	TxIN6	RxOut6	D0 Bit 5	D0 Bit 5	D0 Bit 5
Port A6	TxIN27	RxOut27	D0 Bit 6	D0 Bit 6	D0 Bit 6
Port A7	TxIN5	RxOut5	D0 Bit 7	D0 Bit 7	D0 Bit 7 (MSB)
Port B0	TxIN7	RxOut7	D0 Bit 8	D0 Bit 8	D1 Bit 0
Port B1	TxIN8	RxOut8	D0 Bit 9	D0 Bit 9 (MSB)	D1 Bit 1
Port B2	TxIN9	RxOut9	D0 Bit 10	Not used	D1 Bit 2
Port B3	TxIN12	RxOut12	D0 Bit 11 (MSB)	Not used	D1 Bit 3
Port B4	TxIN13	RxOut13	D1 Bit 8	D1 Bit 8	D1 Bit 4
Port B5	TxIN14	RxOut14	D1 Bit 9	D1 Bit 9 (MSB)	D1 Bit 5
Port B6	TxIN10	RxOut10	D1 Bit 10	Not used	D1 Bit 6
Port B7	TxIN11	RxOut11	D1 Bit 11 (MSB)	Not used	D1 Bit 7 (MSB)
Port C0	TxIN15	RxOut15	D1 Bit 0	D1 Bit 0	D2 Bit 0
Port C1	TxIN18	RxOut18	D1 Bit 1	D1 Bit 1	D2 Bit 1
Port C2	TxIN19	RxOut19	D1 Bit 2	D1 Bit 2	D2 Bit 2
Port C3	TxIN20	RxOut20	D1 Bit 3	D1 Bit 3	D2 Bit 3
Port C4	TxIN21	RxOut21'	D1 Bit 4	D1 Bit 4	D2 Bit 4
Port C5	TxIN22	RxOut22	D1 Bit 5	D1 Bit 5	D2 Bit 5
Port C6	TxIN16	RxOut16	D1 Bit 6	D1 Bit 6	D2 Bit 6
Port C7	TxIN17	RxOut17	D1 Bit 7	D1 Bit 7	D2 Bit 7 (MSB0)
LVAL	TxIN24	RxOut24	Line Valid	Line Valid	Line Valid
FVAL	TxIN25	RxOut25	Frame Valid*	Frame Valid*	Frame Valid*
DVAL	TxIN26	RxOut26	Data Valid	Data Valid	Data Valid
Spare	TxIN23	RxOut23	Not Used	Not Used	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock	Pixel Clock	Pixel Clock

Table 21: Bit Assignments for 4 Tap Output Modes (MDR Conn. 1 - Transmitter X)

*: Present for the Raw and Enhanced Raw line acquisition modes only.

MDR Conn 2, Transmitter Y					
Port	Camera	Frame Grabber	Bit Assignment		
			4 Tap - 12 Bit	4 Tap - 10 Bit	4 Tap - 8 Bit
Port D0	TxIN0	RxOut0	D3 Bit 0	D3 Bit 0	D3 Bit 0
Port D1	TxIN1	RxOut1	D3 Bit 1	D3 Bit 1	D3 Bit 1
Port D2	TxIN2	RxOut2	D3 Bit 2	D3 Bit 2	D3 Bit 2
Port D3	TxIN3	RxOut3	D3 Bit 3	D3 Bit 3	D3 Bit 3
Port D4	TxIN4	RxOut4	D3 Bit 4	D3 Bit 4	D3 Bit 4
Port D5	TxIN6	RxOut6	D3 Bit 5	D3 Bit 5	D3 Bit 5
Port D6	TxIN27	RxOut27	D3 Bit 6	D3 Bit 6	D3 Bit 6
Port D7	TxIN5	RxOut5	D3 Bit 7	D3 Bit 7	D3 Bit 7 (MSB)
Port E0	TxIN7	RxOut7	D2 Bit 0	D2 Bit 0	Not used
Port E1	TxIN8	RxOut8	D2 Bit 1	D2 Bit 1	Not used
Port E2	TxIN9	RxOut9	D2 Bit 2	D2 Bit 2	Not used
Port E3	TxIN12	RxOut12	D2 Bit 3	D2 Bit 3	Not used
Port E4	TxIN13	RxOut13	D2 Bit 4	D2 Bit 4	Not used
Port E5	TxIN14	RxOut14	D2 Bit 5	D2 Bit 5	Not used
Port E6	TxIN10	RxOut10	D2 Bit 6	D2 Bit 6	Not used
Port E7	TxIN11	RxOut11	D2 Bit 7	D2 Bit 7	Not used
Port F0	TxIN15	RxOut15	D2 Bit 8	D2 Bit 8	Not used
Port F1	TxIN18	RxOut18	D2 Bit 9	D2 Bit 9 (MSB)	Not used
Port F2	TxIN19	RxOut19	D2 Bit 10	Not used	Not used
Port F3	TxIN20	RxOut20	D2 Bit 11 (MSB)	Not used	Not used
Port F4	TxIN21	RxOut21'	D3 Bit 8	D3 Bit 8	Not used
Port F5	TxIN22	RxOut22	D3 Bit 9	D3 Bit 9 (MSB)	Not used
Port F6	TxIN16	RxOut16	D3 Bit 10	Not used	Not used
Port F7	TxIN17	RxOut17	D3 Bit 11 (MSB)	Not used	Not used
LVAL	TxIN24	RxOut24	Line Valid	Line Valid	Line Valid
FVAL	TxIN25	RxOut25	Frame Valid*	Frame Valid*	Frame Valid*
DVAL	TxIN26	RxOut26	Data Valid	Data Valid	Data Valid
Spare	TxIN23	RxOut23	Not Used	Not Used	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock	Pixel Clock	Pixel Clock

Table 22: Bit Assignments for 4 Tap Output Modes (MDR Conn 2 - Transmitter Y)

*: Present for the Raw and Enhanced Raw line acquisition modes only.

The tables below show the following delays when the camera is set for full resolution and 4 tap video data output mode:

- Line valid delays for the RGB line acquisition mode (see Figure 16 on [page 41](#))
- Frame valid delays for the Raw and Enhanced Raw line acquisition modes (see Figure 24 on [page 52](#) and Figure 40 on [page 74](#))

Note that the delays depend on the line acquisition mode setting and the camera link clock speed setting. The delays also depend on whether the camera is a 4k, or an 8k camera.

Each delay can vary slightly within the stated minimum and maximum values.

2k Cameras

Line Valid/Frame Valid Delays for 4 Tap Modes - 2k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.07 μ s	3.20 μ s
Edge Controlled Exposure	3.12 μ s	3.24 μ s
Level Controlled Exposure	3.07 μ s	3.20 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.09 μ s	3.24 μ s
Edge Controlled Exposure	3.09 μ s	3.24 μ s
Level Controlled Exposure	3.09 μ s	3.24 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.12 μ s	3.27 μ s
Edge Controlled Exposure	3.12 μ s	3.27 μ s
Level Controlled Exposure	3.12 μ s	3.27 μ s

Table 23: Line Valid/Frame Valid Delays with the 2k Camera Set for 4 Tap Video Data Output Modes

4k Cameras

Line Valid/Frame Valid Delays for 4 Tap Modes - 4k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.10 μ s	3.23 μ s
Edge Controlled Exposure	3.15 μ s	3.28 μ s
Level Controlled Exposure	3.10 μ s	3.23 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.15 μ s	3.30 μ s
Edge Controlled Exposure	3.15 μ s	3.30 μ s
Level Controlled Exposure	3.15 μ s	3.30 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.17 μ s	3.33 μ s
Edge Controlled Exposure	3.17 μ s	3.33 μ s
Level Controlled Exposure	3.17 μ s	3.33 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	2.94 μ s	3.04 μ s
Edge Controlled Exposure	2.99 μ s	3.09 μ s
Level Controlled Exposure	2.94 μ s	3.04 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	9.43 μ s	9.55 μ s
Edge Controlled Exposure	9.43 μ s	9.55 μ s
Level Controlled Exposure	9.43 μ s	9.54 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.

Table 24: Line Valid/Frame Valid Delays with the 4k Camera Set for 4 Tap Video Data Output Modes

Line Valid/Frame Valid Delays for 4 Tap Modes - 4k Cameras		
Programmable	9.45 μ s	9.57 μ s
Edge Controlled Exposure	9.45 μ s	9.57 μ s
Level Controlled Exposure	9.45 μ s	9.57 μ s

Table 24: Line Valid/Frame Valid Delays with the 4k Camera Set for 4 Tap Video Data Output Modes

8k Camera

Line Valid/Frame Valid Delays for 4 Tap Modes - 8k Camera		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.08 μ s	3.21 μ s
Edge Controlled Exposure	3.13 μ s	3.26 μ s
Level Controlled Exposure	3.08 μ s	3.21 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.21 μ s	3.36 μ s
Edge Controlled Exposure	3.21 μ s	3.36 μ s
Level Controlled Exposure	3.21 μ s	3.36 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.23 μ s	3.39 μ s
Edge Controlled Exposure	3.23 μ s	3.39 μ s
Level Controlled Exposure	3.23 μ s	3.39 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	6.45 μ s	6.55 μ s
Edge Controlled Exposure	6.80 μ s	6.90 μ s
Level Controlled Exposure	6.45 μ s	6.55 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 80 MHz	

Table 25: Line Valid/Frame Valid Delays with the 8k Camera Set for 4 Tap Video Data Output Modes

Line Valid/Frame Valid Delays for 4 Tap Modes - 8k Camera		
	Min.	Max.
Programmable	9.47 μ s	9.59 μ s
Edge Controlled Exposure	9.47 μ s	9.59 μ s
Level Controlled Exposure	9.47 μ s	9.59 μ s
Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 80 MHz		
	Min.	Max.
Programmable	9.50 μ s	9.61 μ s
Edge Controlled Exposure	9.50 μ s	9.61 μ s
Level Controlled Exposure	9.50 μ s	9.61 μ s

Table 25: Line Valid/Frame Valid Delays with the 8k Camera Set for 4 Tap Video Data Output Modes

5.2.4 6 Tap Output Mode

6 Tap - 8 Bit Output Mode

In 6 tap 8 bit mode, on each pixel clock cycle, the camera transmits data for six pixels at 8 bit depth, a line valid bit, and a data valid bit.

In the 6 tap output mode, the camera uses the output ports on Camera Link Transmitters X and Y to transmit pixel data, a line valid bit, a data valid bit, and a pixel clock. The assignment of the bits to the output ports on Camera Link Transmitters X and Y is as shown in Table 26 on [page 133](#) and Table 27 on [page 134](#) respectively.

The Camera Link clock is used to time the transmission of acquired pixel data. As shown in Figure 17 on [page 42](#), the camera samples and transmits data on each rising edge of the clock. The Camera Link pixel clock frequency is as stated in Section 2.8.5 on [page 32](#).

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



The video data output mode that you select may affect the camera's maximum allowed line rate. See Section 4.3 on [page 99](#).

The data sequence outlined below, along with Figure 17 on [page 42](#), describes what is happening at the inputs to the Camera Link transmitters in the camera.

Video Data Sequence for 6 Tap Output Mode

When the camera is not transmitting valid data, the line valid and data valid bits sent on each cycle of the pixel clock will be low.

Once the camera has completed an exposure, there will be a delay while data is read out of the sensor. When readout is complete, the camera will begin to transmit pixel data:

- On the clock cycle where valid pixel data transmission begins, the line valid and data valid bits both become high. Six data streams, D0 through D5 are transmitted in parallel on this clock cycle. On this clock cycle, data stream D0 will transmit data for pixel 1 in the line. Data stream D1 will transmit data for pixel 2. Data stream D2 will transmit data for pixel 3. Data stream D3 will transmit data for pixel 4. Data stream D4 will transmit data for pixel 5. And data stream D5 will transmit data for pixel 6. Depending on the video data output mode selected, the pixel data will be at 8 bit depth.
- On the next cycle of the pixel clock, the line valid and data valid bits will both be high. On this clock cycle, data stream D0 will transmit data for pixel 7 in the line. Data stream D1 will transmit data for pixel 8. Data stream D2 will transmit data for pixel 9. Data stream D3 will transmit data for pixel 10. Data stream D4 will transmit data for pixel 11. And data stream D5 will transmit data for pixel 12.
- On the next cycle of the pixel clock, the line valid and data valid bits will be high. On this clock cycle, data stream D0 will transmit data for pixel 13 in the line. Data stream D1 will transmit data for pixel 14. Data stream D2 will transmit data for pixel 15. Data stream D3 will transmit data for pixel 16. Data stream D4 will transmit data for pixel 17. And data stream D5 will transmit data for pixel 18.
- This pattern will continue until all of the pixel data for the line has been transmitted.
- After all of the pixel data for the line has been transmitted, the line valid and data valid bits both become low indicating that valid pixel data is no longer being transmitted.

Figure 17 on [page 42](#) shows the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode or in programmable exposure mode.

MDR Conn. 1, Transmitter X			
Port	Camera	Frame Grabber	Bit Assignment
			6 Tap - 8 Bit
Port A0	TxIN0	RxOut0	D0 Bit 0
Port A1	TxIN1	RxOut1	D0 Bit 1
Port A2	TxIN2	RxOut2	D0 Bit 2
Port A3	TxIN3	RxOut3	D0 Bit 3
Port A4	TxIN4	RxOut4	D0 Bit 4
Port A5	TxIN6	RxOut6	D0 Bit 5
Port A6	TxIN27	RxOut27	D0 Bit 6
Port A7	TxIN5	RxOut5	D0 Bit 7 (MSB)
Port B0	TxIN7	RxOut7	D1 Bit 0
Port B1	TxIN8	RxOut8	D1 Bit 1
Port B2	TxIN9	RxOut9	D1 Bit 2
Port B3	TxIN12	RxOut12	D1 Bit 3
Port B4	TxIN13	RxOut13	D1 Bit 4
Port B5	TxIN14	RxOut14	D1 Bit 5
Port B6	TxIN10	RxOut10	D1 Bit 6
Port B7	TxIN11	RxOut11	D1 Bit 7 (MSB)
Port C0	TxIN15	RxOut15	D2 Bit 0
Port C1	TxIN18	RxOut18	D2 Bit 1
Port C2	TxIN19	RxOut19	D2 Bit 2
Port C3	TxIN20	RxOut20	D2 Bit 3
Port C4	TxIN21	RxOut21'	D2 Bit 4
Port C5	TxIN22	RxOut22	D2 Bit 5
Port C6	TxIN16	RxOut16	D2 Bit 6
Port C7	TxIN17	RxOut17	D2 Bit 7 (MSB)
LVAL	TxIN24	RxOut24	Line Valid
FVAL	TxIN25	RxOut25	Not Used
DVAL	TxIN26	RxOut26	Data Valid
Spare	TxIN23	RxOut23	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock

Table 26: Bit Assignments for 6 Tap Output Mode (MDR Conn 1 - Transmitter X)

MDR Conn 2, Transmitter Y			
Port	Camera	Frame Grabber	Bit Assignment
			6 Tap - 8 Bit
Port D0	TxIN0	RxOut0	D3 Bit 0
Port D1	TxIN1	RxOut1	D3 Bit 1
Port D2	TxIN2	RxOut2	D3 Bit 2
Port D3	TxIN3	RxOut3	D3 Bit 3
Port D4	TxIN4	RxOut4	D3 Bit 4
Port D5	TxIN6	RxOut6	D3 Bit 5
Port D6	TxIN27	RxOut27	D3 Bit 6
Port D7	TxIN5	RxOut5	D3 Bit 7 (MSB)
Port E0	TxIN7	RxOut7	D4 Bit 0
Port E1	TxIN8	RxOut8	D4 Bit 1
Port E2	TxIN9	RxOut9	D4 Bit 2
Port E3	TxIN12	RxOut12	D4 Bit 3
Port E4	TxIN13	RxOut13	D4 Bit 4
Port E5	TxIN14	RxOut14	D4 Bit 5
Port E6	TxIN10	RxOut10	D4 Bit 6
Port E7	TxIN11	RxOut11	D4 Bit 7 (MSB)
Port F0	TxIN15	RxOut15	D5 Bit 0
Port F1	TxIN18	RxOut18	D5 Bit 1
Port F2	TxIN19	RxOut19	D5 Bit 2
Port F3	TxIN20	RxOut20	D5 Bit 3
Port F4	TxIN21	RxOut21'	D5 Bit 4
Port F5	TxIN22	RxOut22	D5 Bit 5
Port F6	TxIN16	RxOut16	D5 Bit 6
Port F7	TxIN17	RxOut17	D5 Bit 7 (MSB)
LVAL	TxIN24	RxOut24	Line Valid
FVAL	TxIN25	RxOut25	Not Used
DVAL	TxIN26	RxOut26	Data Valid
Spare	TxIN23	RxOut23	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock

Table 27: Bit Assignments for 6 Tap Output Mode (MDR Conn 2 - Transmitter Y)

The tables below show the line valid delays for the RGB line acquisition mode (see Figure 17 on page 42) when the camera is set for full resolution and 6 tap video data output mode.

Note that the delays depend on the line acquisition mode setting and the camera link clock speed setting. The delays also depend on whether the camera is a 4k, or an 8k camera.

Each delay can vary slightly within the stated minimum and maximum values.

2k Cameras

Line Valid/Frame Valid Delays for 6 Tap Mode - 2k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.07 μ s	3.19 μ s
Edge Controlled Exposure	3.12 μ s	3.24 μ s
Level Controlled Exposure	3.07 μ s	3.19 μ s

Table 28: Line Valid/Frame Valid Delays with the 2k Camera Set for 6 Tap Video Data Output Mode

4k Cameras

Line Valid Delays for 6 Tap Mode - 4k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.10 μ s	3.23 μ s
Edge Controlled Exposure	3.15 μ s	3.28 μ s
Level Controlled Exposure	3.10 μ s	3.23 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	9.33 μ s	9.43 μ s
Edge Controlled Exposure	9.68 μ s	9.78 μ s
Level Controlled Exposure	9.33 μ s	9.43 μ s

Table 29: Line Valid Delays with the 4k Camera Set for 6 Tap Video Data Output Mode

8k Camera

Line Valid Delays for 6 Tap Mode - 8k Camera		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	6.63 μ s	6.76 μ s
Edge Controlled Exposure	6.98 μ s	7.11 μ s
Level Controlled Exposure	6.63 μ s	6.76 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	11.10 μ s	11.20 μ s
Edge Controlled Exposure	11.45 μ s	11.55 μ s
Level Controlled Exposure	11.10 μ s	11.20 μ s

Table 30: Line Valid Delays with the 8k Camera Set for 6 Tap Video Data Output Mode

5.2.5 8 Tap Output Mode

8 Tap - 8 Bit Output Mode

In 8 tap 8 bit output mode, on each pixel clock cycle, the camera transmits data for eight pixels at 8 bit depth, a line valid bit and a data valid bit. In the Raw and Enhanced Raw line acquisition modes, the camera also transmits a frame valid bit, unless the FVAL Length parameter is set to zero. For more information about the frame valid bit, see Section 2.8.1 on [page 31](#).

In the 8 tap output mode, the camera uses the output ports on Camera Link Transmitters X, Y and Z to transmit pixel data, a frame valid bit (in the Raw and Enhanced Raw line acquisition modes only), a line valid bit, a data valid bit, and the Camera Link pixel clock. The assignment of the bits to the output ports on Camera Link Transmitters X, Y and Z is as shown in [Table 31 on page 138](#), [Table 32 on page 139](#), and [Table 33 on page 140](#) respectively.

The Camera Link clock is used to time the transmission of acquired pixel data. As shown in [Figure 18 on page 43](#), [Figure 25 on page 53](#), and [Figure 41 on page 75](#), the camera samples and transmits data on each rising edge of the Camera Link clock. The Camera Link pixel clock frequency is as stated in [Section 2.8.5 on page 32](#).

The frame valid bit indicates that line A is being transmitted (in the Raw - Line A First and in the Enhanced Raw - Line A First (B Delayed) line acquisition modes only). The line valid bit indicates that a valid line is being transmitted. The data valid bit indicates that valid pixel data is being transmitted. Pixel data is only valid when the frame valid (in the Raw and Enhanced Raw line acquisition modes only), line valid and data valid bits are all high.



The video data output mode that you select may affect the camera's maximum allowed line rate. See Section 4.3 on [page 99](#).

The data sequence outlined below, along with Figure 18 on [page 43](#), Figure 25 on [page 53](#), and Figure 41 on [page 75](#), describes what is happening at the inputs to the Camera Link transmitters in the camera.

Video Data Sequence for 8 Tap 8 Bit Mode

The following assumes that the Raw or Enhanced Raw line acquisition mode is selected where a frame valid signal is transmitted. If the RGB line acquisition mode is selected, the frame valid signal will not be transmitted.

When the camera is not transmitting valid data, the frame valid, line valid and data valid bits sent on each cycle of the pixel clock will be low. After the camera has completed an exposure, there will be a delay while data is read out of the sensor. When readout is complete, the camera will begin to transmit pixel data:

- On the clock cycle where valid pixel data transmission begins, the frame valid, line valid and data valid bits all become high. Eight data streams, D0 through D7 are transmitted in parallel on this clock cycle. On this clock cycle, data stream D0 will transmit data for pixel 1 in the line. Data stream D1 will transmit data for pixel 2. Data stream D2 will transmit data for pixel 3. Data stream D3 will transmit data for pixel 4. Data stream D4 will transmit data for pixel 5. Data stream D5 will transmit data for pixel 6. Data stream D6 will transmit data for pixel 7. And data stream D7 will transmit data for pixel 8. The pixel data will be at 8 bit depth.
- On the next cycle of the pixel clock, the frame valid, line valid and data valid bits will all be high. On this clock cycle, data stream D0 will transmit data for pixel 9 in the line. Data stream D1 will transmit data for pixel 10. Data stream D2 will transmit data for pixel 11. Data stream D3 will transmit data for pixel 12. Data stream D4 will transmit data for pixel 13. Data stream D5 will transmit data for pixel 14. Data stream D6 will transmit data for pixel 15. And data stream D7 will transmit data for pixel 16. The pixel data will be at 8 bit depth.
- On the next cycle of the pixel clock, the frame valid, line valid and data valid bits will all be high. On this clock cycle, data stream D0 will transmit data for pixel 17 in the line. Data stream D1 will transmit data for pixel 18. Data stream D2 will transmit data for pixel 19. Data stream D3 will transmit data for pixel 20. Data stream D4 will transmit data for pixel 21. Data stream D5 will transmit data for pixel 22. Data stream D6 will transmit data for pixel 23. And data stream D7 will transmit data for pixel 24. The pixel data will be at 8 bit depth.
- This pattern will continue until all of the pixel data for line one has been transmitted.
- After all of the pixel data for the line has been transmitted, the frame valid, line valid and data valid bits all become low indicating that valid pixel data is no longer being transmitted.

Figure 18 on [page 43](#), Figure 25 on [page 53](#), and Figure 41 on [page 75](#) shows the data sequence when the camera is operating in edge-controlled or level-controlled exposure mode or in programmable exposure mode.

MDR Conn. 1, Transmitter X			
Port	Camera	Frame Grabber	Bit Assignment
			8 Tap - 8 Bit
Port A0	TxIN0	RxOut0	D0 Bit 0
Port A1	TxIN1	RxOut1	D0 Bit 1
Port A2	TxIN2	RxOut2	D0 Bit 2
Port A3	TxIN3	RxOut3	D0 Bit 3
Port A4	TxIN4	RxOut4	D0 Bit 4
Port A5	TxIN6	RxOut6	D0 Bit 5
Port A6	TxIN27	RxOut27	D0 Bit 6
Port A7	TxIN5	RxOut5	D0 Bit 7 (MSB)
Port B0	TxIN7	RxOut7	D1 Bit 0
Port B1	TxIN8	RxOut8	D1 Bit 1
Port B2	TxIN9	RxOut9	D1 Bit 2
Port B3	TxIN12	RxOut12	D1 Bit 3
Port B4	TxIN13	RxOut13	D1 Bit 4
Port B5	TxIN14	RxOut14	D1 Bit 5
Port B6	TxIN10	RxOut10	D1 Bit 6
Port B7	TxIN11	RxOut11	D1 Bit 7 (MSB)
Port C0	TxIN15	RxOut15	D2 Bit 0
Port C1	TxIN18	RxOut18	D2 Bit 1
Port C2	TxIN19	RxOut19	D2 Bit 2
Port C3	TxIN20	RxOut20	D2 Bit 3
Port C4	TxIN21	RxOut21'	D2 Bit 4
Port C5	TxIN22	RxOut22	D2 Bit 5
Port C6	TxIN16	RxOut16	D2 Bit 6
Port C7	TxIN17	RxOut17	D2 Bit 7 (MSB)
LVAL	TxIN24	RxOut24	Line Valid
FVAL	TxIN25	RxOut25	Frame Valid*
DVAL	TxIN26	RxOut26	Data Valid
Spare	TxIN23	RxOut23	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock

Table 31: Bit Assignments for 8 Tap Output Mode (MDR Conn 1 - Transmitter X)

*: Present for the Raw and Enhanced Raw line acquisition modes only.

MDR Conn 2, Transmitter Y			
Port	Camera	Frame Grabber	Bit Assignment
			8 Tap - 8 Bit
Port D0	TxIN0	RxOut0	D3 Bit 0
Port D1	TxIN1	RxOut1	D3 Bit 1
Port D2	TxIN2	RxOut2	D3 Bit 2
Port D3	TxIN3	RxOut3	D3 Bit 3
Port D4	TxIN4	RxOut4	D3 Bit 4
Port D5	TxIN6	RxOut6	D3 Bit 5
Port D6	TxIN27	RxOut27	D3 Bit 6
Port D7	TxIN5	RxOut5	D3 Bit 7 (MSB)
Port E0	TxIN7	RxOut7	D4 Bit 0
Port E1	TxIN8	RxOut8	D4 Bit 1
Port E2	TxIN9	RxOut9	D4 Bit 2
Port E3	TxIN12	RxOut12	D4 Bit 3
Port E4	TxIN13	RxOut13	D4 Bit 4
Port E5	TxIN14	RxOut14	D4 Bit 5
Port E6	TxIN10	RxOut10	D4 Bit 6
Port E7	TxIN11	RxOut11	D4 Bit 7 (MSB)
Port F0	TxIN15	RxOut15	D5 Bit 0
Port F1	TxIN18	RxOut18	D5 Bit 1
Port F2	TxIN19	RxOut19	D5 Bit 2
Port F3	TxIN20	RxOut20	D5 Bit 3
Port F4	TxIN21	RxOut21'	D5 Bit 4
Port F5	TxIN22	RxOut22	D5 Bit 5
Port F6	TxIN16	RxOut16	D5 Bit 6
Port F7	TxIN17	RxOut17	D5 Bit 7 (MSB)
LVAL	TxIN24	RxOut24	Line Valid
FVAL	TxIN25	RxOut25	Frame Valid*
DVAL	TxIN26	RxOut26	Data Valid
Spare	TxIN23	RxOut23	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock

Table 32: Bit Assignments for 8 Tap Output Mode (MDR Conn 2 - Transmitter Y)

*: Present for the Raw and Enhanced Raw line acquisition modes only.

MDR Conn 2, Transmitter Z			
Port	Camera	Frame Grabber	Bit Assignment
			8 Tap - 8 Bit
Port G0	TxIN0	RxOut0	D6 Bit 0
Port G1	TxIN1	RxOut1	D6 Bit 1
Port G2	TxIN2	RxOut2	D6 Bit 2
Port G3	TxIN3	RxOut3	D6 Bit 3
Port G4	TxIN4	RxOut4	D6 Bit 4
Port G5	TxIN6	RxOut6	D6 Bit 5
Port G6	TxIN27	RxOut27	D6 Bit 6
Port G7	TxIN5	RxOut5	D6 Bit 7 (MSB)
Port H0	TxIN7	RxOut7	D7 Bit 0
Port H1	TxIN8	RxOut8	D7 Bit 1
Port H2	TxIN9	RxOut9	D7 Bit 2
Port H3	TxIN12	RxOut12	D7 Bit 3
Port H4	TxIN13	RxOut13	D7 Bit 4
Port H5	TxIN14	RxOut14	D7 Bit 5
Port H6	TxIN10	RxOut10	D7 Bit 6
Port H7	TxIN11	RxOut11	D7 Bit 7
Spare	TxIN15	RxOut15	Not Used
Spare	TxIN18	RxOut18	Not Used
Spare	TxIN19	RxOut19	Not Used
Spare	TxIN20	RxOut20	Not Used
Spare	TxIN21	RxOut21'	Not Used
Spare	TxIN22	RxOut22	Not Used
Spare	TxIN16	RxOut16	Not Used
Spare	TxIN17	RxOut17	Not Used
LVAL	TxIN24	RxOut24	Line Valid
FVAL	TxIN25	RxOut25	Frame Valid*
DVAL	TxIN26	RxOut26	Data Valid
Spare	TxIN23	RxOut23	Not Used
Strobe	TxINCLK	RxOutClk	Pixel Clock

Table 33: Bit Assignments for 8 Tap Output Mode (MDR Conn 2 - Transmitter Z)

*: Present for the Raw and Enhanced Raw line acquisition modes only.

The tables below show the following delays when the camera is set for full resolution and 8 tap video data output mode:

- Line valid delays for the RGB line acquisition mode (see Figure 14 on [page 39](#) through Figure 18 on [page 43](#))
- Frame valid delays for the Raw and Enhanced Raw line acquisition modes (Figure 23 on [page 51](#) through Figure 25 on [page 53](#), and Figure 39 on [page 73](#) through Figure 41 on [page 75](#)).

Note that the delays depend on the line acquisition mode setting and the Camera Link clock speed setting. The delays also depend on whether the camera is a 4k, or an 8k camera.

Each delay can vary slightly within the stated minimum and maximum values.

2k Cameras

Line Valid/Frame Valid Delays for 8 Tap Mode - 2k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.07 μ s	3.20 μ s
Edge Controlled Exposure	3.12 μ s	3.24 μ s
Level Controlled Exposure	3.07 μ s	3.19 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	9.49 μ s	9.64 μ s
Edge Controlled Exposure	9.49 μ s	9.64 μ s
Level Controlled Exposure	9.49 μ s	9.64 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	9.51 μ s	9.67 μ s
Edge Controlled Exposure	9.52 μ s	9.67 μ s
Level Controlled Exposure	9.52 μ s	9.67 μ s

Table 34: Line Valid/Frame Valid Delays with the 2k Camera Set for 8 Tap Video Data Output Mode

4k Cameras

Line Valid/Frame Valid Delays for 8 Tap Mode - 4k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	3.10 μ s	3.23 μ s
Edge Controlled Exposure	3.15 μ s	3.28 μ s
Level Controlled Exposure	3.10 μ s	3.23 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	9.55 μ s	9.70 μ s
Edge Controlled Exposure	9.55 μ s	9.70 μ s
Level Controlled Exposure	9.55 μ s	9.70 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	9.57 μ s	9.73 μ s
Edge Controlled Exposure	9.57 μ s	9.73 μ s
Level Controlled Exposure	9.57 μ s	9.73 μ s

Table 35: Line Valid/Frame Valid Delays with the 4k Camera Set for 8 Tap Video Data Output Mode

Line Valid/Frame Valid Delays for 8 Tap Mode - 4k Cameras		
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	9.33 μ s	9.43 μ s
Edge Controlled Exposure	9.68 μ s	9.78 μ s
Level Controlled Exposure	9.33 μ s	9.43 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	12.62 μ s	12.73 μ s
Edge Controlled Exposure	12.62 μ s	12.73 μ s
Level Controlled Exposure	12.62 μ s	12.73 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	12.64 μ s	12.76 μ s
Edge Controlled Exposure	12.64 μ s	12.76 μ s
Level Controlled Exposure	12.64 μ s	12.76 μ s

Table 35: Line Valid/Frame Valid Delays with the 4k Camera Set for 8 Tap Video Data Output Mode

8k Camera

Line Valid/Frame Valid Delays for 8 Tap Mode - 8k Camera		
	Line Valid Delay for the RGB Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	6.63 μ s	6.76 μ s
Edge Controlled Exposure	6.98 μ s	7.11 μ s
Level Controlled Exposure	6.63 μ s	6.76 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	9.61 μ s	9.76 μ s
Edge Controlled Exposure	9.61 μ s	9.76 μ s

Table 36: Line Valid/Frame Valid Delays with the 8k Camera Set for 8 Tap Video Data Output Mode

Line Valid/Frame Valid Delays for 8 Tap Mode - 8k Camera		
Level Controlled Exposure	9.61 μ s	9.76 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 40 MHz	
	Min.	Max.
Programmable	9.63 μ s	9.79 μ s
Edge Controlled Exposure	9.63 μ s	9.79 μ s
Level Controlled Exposure	9.63 μ s	9.79 μ s
	Line Valid Delay for the RGB Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	11.11 μ s	11.21 μ s
Edge Controlled Exposure	11.46 μ s	11.56 μ s
Level Controlled Exposure	11.11 μ s	11.21 μ s
	Frame Valid Delay for the Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	12.66 μ s	12.78 μ s
Edge Controlled Exposure	12.66 μ s	12.78 μ s
Level Controlled Exposure	12.66 μ s	12.78 μ s
	Frame Valid Delay for the Enhanced Raw Line Acquisition Mode - 80 MHz	
	Min.	Max.
Programmable	12.68 μ s	12.80 μ s
Edge Controlled Exposure	12.68 μ s	12.80 μ s
Level Controlled Exposure	12.68 μ s	12.80 μ s

Table 36: Line Valid/Frame Valid Delays with the 8k Camera Set for 8 Tap Video Data Output Mode

6 Features

6.1 Gain and Offset

6.1.1 Gain

Gain is adjustable. As shown in Figure 58, increasing the gain setting increases the slope of the camera's response curve and results in higher camera output for a given amount of light input. Decreasing the gain setting decreases the slope of the response curve and results in lower output for a given amount of light.

Gain is a global adjustment and affects the red, green, and blue pixels equally. Additional color-specific gain can be used for white balancing (see Section 6.2 on [page 148](#)). The total gain for each color will be the sum of the global Gain (this section) and the additional color-specific gain:

Gain is adjustable on an integer scale. The minimum gain setting for all video data output modes is 2731. The default setting is 4096 which results in 0 dB of gain.

By default, the maximum setting is 8192 for all bit depths of the video data output modes. However, the maximum can be increased to 16383 by setting the additional color-specific gain to 0 (see Section 6.2 on [page 148](#)).

Table 37 shows the dB of gain that will be achieved at various integer settings.

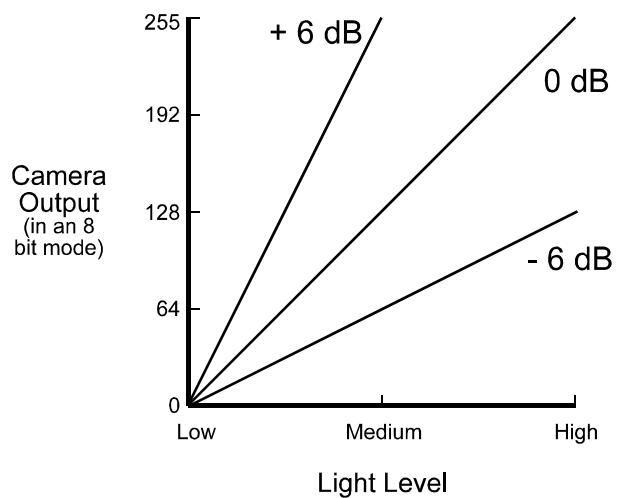


Fig. 58: Various Levels of Gain

Gain Setting	dB of Gain
2731 (minimum allowed for all output modes)	- 3.5
4096 (default)	0
8192 (default maximum allowed)	+ 6.0
16383 (maximum allowed if additional color-specific gain is set to 0)	+ 12.0

Table 37: dB of Gain at Various Settings

If you know the integer setting for the gain, you can calculate the resulting dB of gain that the camera will achieve by using the following formula:

$$\text{Gain in dB} = 20 \times \log_{10} \left(\frac{\text{setting}}{4096} \right)$$

The maximum allowed of +12.0 dB not only applies to Gain but also to the total gain for each color, i.e. global Gain plus the additional color-specific gain **must not exceed** +12.0 dB.



High gain settings will degrade the image quality and high settings of the global Gain will limit your ability for white balancing.

We therefore **strongly recommend** using settings that will keep the **sum of the global gain and the color-specific gain distinctly below 12.0 dB**. This recommendation applies particularly to 10-bit and 12-bit video data output modes.

For details and information how to avoid high gain settings, see Section 6.2 on [page 148](#).

Setting the Gain

You can set the gain with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Gain parameter in the Gain & Offset parameters group to set the gain.

By Setting CSRs

You set the gain by writing a value in dB to the Absolute Gain field or by writing an integer value to the Raw Gain field of the Gain CSR (see [page 228](#)).

Section 7.2.2 on [page 219](#) explains CSRs and the difference between using the “absolute” field and the “raw” field in a CSR. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.1.2 Offset

Depending on the video data output mode, the offset is adjustable on an integer scale in the following ranges:

- For an **8 bit** video data output mode: from -255 to +255.
If the camera is set for an 8 bit video data output mode:
 - increasing the integer offset setting by 16 will increase the digital pixel values output from the camera by 1.
 - decreasing the integer offset setting by 16 will decrease the digital pixel values output from the camera by 1.
- For a **10 bit** video data output mode: from -1023 to +1023.
If the camera is set for a 10 bit video data output mode:
 - increasing the integer offset setting by 4 will increase the digital pixel values output from the camera by 1.
 - decreasing the integer offset setting by 4 will decrease the digital pixel values output from the camera by 1.
- For a **12 bit** video data output mode: from -4095 to +4095.
If the camera is set for a 12 bit video data output mode:
 - increasing the integer offset setting by 1 will increase the digital pixel values output from the camera by 1.
 - decreasing the integer offset setting by 1 will decrease the digital pixel values output from the camera by 1.

Setting the Offset

You can set the offset with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Offset parameter in the Gain & Offset parameters group to set the offset.

By Setting CSRs

You set the offset by writing a value in digital numbers to the Absolute Offset field or by writing an integer value to the Raw Offset field of the Offset CSR (see [page 229](#)).

Section 7.2.2 on [page 219](#) explains CSRs and the difference between using the "absolute" field and the "raw" field in a CSR. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.2 White Balance

White balancing can be achieved by individually adjusting gain settings for the red, green and blue pixels. The total gain for each color will be the sum of the global Gain (see Section 6.1 on [page 145](#)) and the additional color-specific gain:

- Gain Red sets an additional amount of gain for the red pixels. The total gain for the red pixels will be the sum of Gain and Gain Red.
- Gain Green sets an additional amount of gain for all green pixels (in line A and line B). If Gain Green 2 is disabled, the total gain for the green pixels will be the sum of Gain and Gain Green. If Gain Green 2 is enabled:
Gain Green sets an additional amount of gain only for the green pixels in line A.
Gain Green 2 sets an additional amount of gain only for the green pixels in line B.
For more information about gain green 2, see "Gain Green 2" on [page 151](#).
- Gain Blue sets an additional amount of gain for the blue pixels. The total gain for the blue pixels will be the sum of Gain and Gain Blue.

The following default settings apply to the additional color-specific gains:

Additional Color-specific Gain Setting	dB of Color-specific Gain
Gain Red: 4096	0
Gain Green: 6144	+ 3.5
Gain Blue: 8192	+ 6.0

Table 38: Default Settings of Additional Color-specific Gain

By default, Gain Green 2 is disabled.


The additional color-specific gain used for white balancing works like the global Gain (see Section 6.1 on [page 145](#)) and the same formula applies for calculating the dB from the integer settings:

$$\text{Additional Color-specific Gain in dB} = 20 \times \log_{10} \left(\frac{\text{additional color-specific setting}}{4096} \right)$$

The following minimum and maximum settings apply to the additional color-specific gain **and** to the total gain, i.e. global Gain plus the additional color-specific gain must not exceed +12.0 dB:

Gain Setting	dB of Gain
2731 (minimum allowed)	- 3.5
16383 (maximum allowed)	+ 12.0


Table 39: dB of Gain at Various Settings


	<p>High gain settings will degrade the image quality and high settings of the global Gain will limit your ability for white balancing.</p> <p>We therefore strongly recommend using settings that will keep the sum of the global gain and the color-specific gain distinctly below 12.0 dB. This recommendation applies particularly to 10 bit and 12 bit video data output modes (see Table 40).</p>
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For good image quality, the following maximum settings should not be exceeded by total gain:

Gain Setting	dB of Gain
12 bit video data output modes: 6144	+ 3.5
10 bit video data output modes: 8192	+ 6.0
8 bit video data output modes: 16383	+ 12.0

Table 40: Values for Total Gain That Should Not Be Exceeded

	<p>It may be difficult to keep the total gain below the values given in Table 40 and obtaining optimum white balance at the same time. This will be particularly true when a halogen lamp is used for illumination, where the blue pixel values will require strong correction.</p> <p>We recommend to generally use a blue conversion filter which will prevent the need for high additional color-specific gain settings.</p>
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	<p>Make sure color adjustment is disabled before carrying out white balance.</p> <p>For more information about color adjustment, see Section 6.6.1 on page 166.</p>
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6.2.1 Setting the Additional Color-specific Gain

You can set the white balance with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Gain Red, Gain Green, Gain Green 2 (if Gain Green 2 is enabled) and Gain Blue parameters in the Gain & Offset parameters group to set the additional color-specific gain for the red, green, blue pixels, and to enable Gain Green 2.

By Setting CSRs

Red

You set the additional color-specific gain for the red pixels by writing a value in dB to the Absolute Gain Red field or by writing an integer value to the Raw Gain Red field of the Gain Red CSR (see [page 231](#)).

Green

- If Gain Green 2 is **disabled**:

You set the additional color-specific gain for all green pixels (in **line A** and **line B**) by writing a value in dB to the Absolute Gain Green field or by writing an integer value to the Raw Gain Green field of the Gain Green CSR (see [page 232](#)).

- If Gain Green 2 is **enabled**:

- You set the additional color-specific gain for the green pixels in **line A** by writing a value in dB to the Absolute Gain Green field or by writing an integer value to the Raw Gain Green field of the Gain Green CSR (see [page 232](#)).
- You set the additional color-specific gain for the green pixels in **line B** by writing a value in dB to the Absolute Gain Green 2 field or by writing an integer value to the Raw Gain Green 2 field of the Gain Green 2 CSR (see [page 235](#)).

Blue

You set the additional color-specific gain for the blue pixels by writing a value in dB to the Absolute Gain Blue field or by writing an integer value to the Raw Gain Blue field of the Gain Blue CSR (see [page 234](#)).

Section 7.2.2 on [page 219](#) explains CSRs and the difference between using the “absolute” field and the “raw” field in a CSR. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.2.2 Gain Green 2

The camera's sensor includes two different lines with green pixels: Line A with red and green pixels and line B with green and blue pixels.

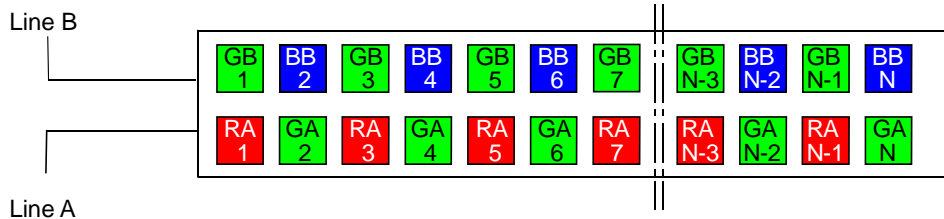


Fig. 59: Green Pixels in Line A and Line B

Gain Green 2

- in combination with Gain Green lets you specify the gain settings for the green pixels in Line A and for the green pixels in Line B separately.
- can be enabled or disabled via the Gain Green 2 Enable CSR (see [page 236](#)).

By default, Gain Green 2 is disabled.

If the Gain Green 2 feature is **enabled**,

- the Gain Green parameter is used to set the color-specific gain of the green pixels in Line A. The total gain for the green pixels in Line A will be the sum (in dB) of the global Gain and Gain Green.
- the Gain Green 2 parameter is used to set the color-specific gain of the green pixels in Line B. The total gain for the green pixels in Line B will be the sum (in dB) of the global Gain and Gain Green 2.
- the Gain Green 2 parameter is by default set to the current value of the Gain Green parameter. If you change the Gain Green 2 parameter afterwards, these new Gain Green 2 setting will be valid
 - as long as the Gain Green 2 feature stays enabled and
 - until the camera is turned off. Every time you turn off the camera and on again, the Gain Green 2 parameter will return to the default setting.

If the Gain Green 2 feature is **disabled**, the total gain for the green pixels in Lines A and B will be the sum (in dB) of the global Gain and Gain Green.

The maximum value for the total gain being fixed, the maximum Gain setting will be limited by the settings of any of the color-specific gains Gain Red, Gain Green, Gain Blue, and Gain Green 2.

6.3 Area of Interest

The area of interest feature lets you specify a portion of the sensor lines. During operation, only the pixel information from the specified portion of the lines is read out of the sensor and transmitted from the camera to the frame grabber.

The size of the area of interest is defined by declaring a starting pixel and a length in pixels. For example, if you specify the starting pixel as 33 and the length in pixels as 256, the camera will readout and transmit pixel values for pixels 33 through 288 as shown in Figure 60.

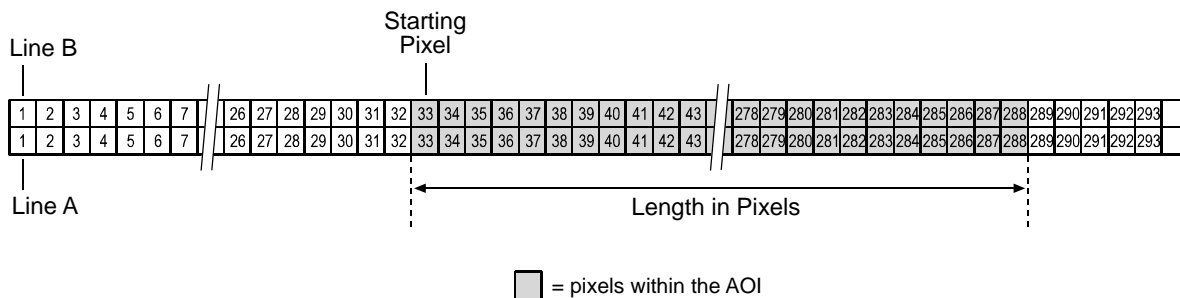


Fig. 60: Area of Interest

The AOI applies to both line A and line B.

When setting the AOI, the following guidelines apply:

- The AOI starting pixel can be set to a minimum of 1.
- If the RGB line acquisition mode is selected, the area of interest starting pixel can be set in increments of 16 for cameras that have 2048 or 4096 pixels and in increments of 32 for cameras that have 8192 pixels.
- If a Raw line acquisition mode or an Enhanced Raw line acquisition mode is selected, the area of interest starting pixel can be set in increments of 32 for cameras that have 2048 or 4096 pixels and in increments of 64 for cameras that have 8192 pixels.
- For all sprint 2k and 4k cameras:
The AOI length must be a minimum of 256 pixels and can be increased in increments of 32.
- For all sprint 8k cameras:
 - The AOI length must be a minimum of 2048 pixels.
 - If the Raw line acquisition mode is active, the AOI length can be increased in increments of 64.
- For all sprint cameras:
The AOI starting pixel number + AOI length must be less than or equal to the number of pixels in each sensor line + 1.

For example, if a Raw line acquisition mode is selected and if you are working with a camera that has 2048 pixels in each sensor line:

The AOI starting pixel can be set to 1, 33, 65, 97, etc.

The AOI length can be set to 256, 288, 320, 352, etc.

AOI starting pixel + AOI length \leq 2049.

If you are working with a camera that has 4096 pixels in each sensor line:

The AOI starting pixel can be set to 1, 33, 65, 97, etc.

The AOI length can be set to 256, 288, 320, 352, etc.

AOI starting pixel + AOI length \leq 4097.

If you are working with a camera that has 8192 pixels in each sensor line:

The AOI starting pixel can be set to 1, 65, 129, 193, etc.

The AOI length can be set to 2048, 2112, 2176, 2240, etc.

AOI starting pixel + AOI length \leq 8193.

When the area of interest feature is used, the maximum allowed line rate may increase. For more information about the impact of the AOI settings on the maximum allowed line rate, see Section 4.3 on [page 99](#).

6.3.1 Setting the AOI

You can set the AOI with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the AOI Starting Pixel parameter and the AOI Length parameter in the AOI parameters group to set the AOI.

By Setting CSRs

You set the AOI starting pixel by writing a value to the Starting Pixel field of the AOI Starting Pixel CSR (see [page 237](#)).

You set the AOI length by writing a value to the Length field of the AOI Length CSR (see [page 238](#)).

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.

6.4 Shading Correction

6.4.1 Standard Shading Correction

In theory, when a digital camera captures an image of a uniform object, the pixel values output from the camera should be uniform. In practice, however, variations in optics and lighting and small variations in the sensor's performance can cause the camera output to be non-uniform even when it is capturing images of a uniform object. The camera is equipped with a shading correction feature that allows it to correct the captured image for variations caused by optics, lighting, and sensor variations.

The standard shading correction feature can correct variations down to 66 % of the maximum intensity, i.e. light variations that go down to 66 % of the maximum intensity can be corrected (maximum correction factor: 1.5).

6.4.2 Enhanced Shading Correction (ESC) (For Certain Models Only)

The enhanced shading correction has the same working principle as the standard shading correction. The enhanced shading correction can correct variations down to 25 % of the maximum intensity, light variations that go down to 25 % of the maximum intensity can be corrected (maximum correction factor: 4.0).

As a consequence of the increased range of correction the resolution of the shading correction parameter is decreased.

Camera models with enhanced shading correction include the letters ESC in their name (e.g. spL4096-39kcESC).

The effect of ESC is schematically shown in the following figure:

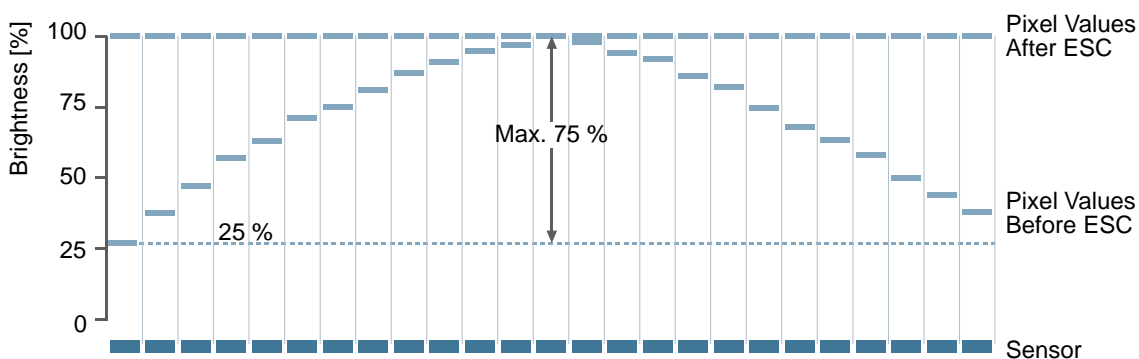


Fig. 61: Pixel Value Adjustment (Example) Due to Enhanced Shading Correction (ESC)

The file format of the user shading value file for a Basler sprint ESC camera is different from the file format for a standard Basler sprint camera. Accordingly, a file generated by a Basler sprint ESC camera can not be used in a standard Basler sprint camera and vice versa. Therefore note:



When uploading a user shading value file

- to a Basler sprint ESC camera, make sure the file was generated using a Basler sprint ESC camera.
- to a standard Basler sprint camera, make sure the file was generated using a standard Basler sprint camera.

6.4.3 Types of Shading Correction

There are two types of shading correction available on the camera, DSNU shading correction and PRNU shading correction. You can set the camera to do only DSNU correction, to do only PRNU correction, or to do both types of correction.

DSNU Shading Correction

When a line scan camera with a digital sensor captures a line in complete darkness, all of the pixel values in the line should be near zero and they should be equal. In practice, slight variations in the performance of the pixels in the sensor will cause some variation in the pixel values output from the camera when the camera is capturing lines in darkness. This type of variation is known as Dark Signal Non-uniformity (DSNU). DSNU shading correction corrects for the variations caused by DSNU.

PRNU Shading Correction

When a line scan camera with a digital sensor captures a line with the camera viewing a uniform light-colored target in bright light, all of the pixel values in the line should be near their maximum gray value and they should be equal. In practice, slight variations in the performance of the pixels in the sensor, variations in the optics, and variations in the lighting will cause some variation in the pixel values output from the camera. This type of variation is known as Photo Response Non-uniformity (PRNU). The PRNU shading correction feature on the camera can correct for the variations caused by PRNU.

The Factory Shading Value File and the User Shading Value File

To perform DSNU and PRNU shading correction, the camera needs a set of DSNU and PRNU shading correction values. The camera has two files in its nonvolatile memory where it stores the values that it needs to perform shading correction.

The first shading values file is called the "factory shading" file. This file contains a complete collection of the values needed to perform both DSNU shading correction and PRNU shading correction. The values in this file are generated during the camera's factory setup procedure and they essentially serve as default shading values. The values in the factory file are optimized for performing shading correction with "standard" optics and lighting. Using the factory settings will give you reasonable DSNU and PRNU shading correction performance in most situations. The factory shading values file is in a protected area of the camera's memory and can't be changed. One advantage of the factory values is that they serve as a good default.

The second shading values file is called the "user shading" file. This file can also hold a complete collection of the values needed to perform both DSNU and PRNU shading correction. The values stored in this file must be generated by the camera user while the camera is operating under its real world conditions. This file contains the shading values that will normally be used for day-to-day camera operation. A procedure describing how to generate the values in this file appears on the next page.)

Guidelines When Using Shading Correction

When using the shading correction feature, make sure to take the following guidelines into account:

Any time you make a change to the optics or lighting or if you change the camera's exposure mode or exposure time, you must generate a new set of user PRNU shading values and a new set of DSNU shading values. Using out of date shading values can result in poor image quality.

6.4.4 Enabling Shading Correction

You can enable shading correction with the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Shading Mode parameter in the DSNU and PRNU Shading Correction parameters group to enable shading correction. You can enable, DSNU correction only, PRNU correction only, or both DSNU and PRNU correction.

By Setting CSRs

You enable shading correction by writing the appropriate value to the Mode field of the Shading Mode CSR (see [page 239](#)).

Section 7.2.2 on [page 219](#) explains CSRs and Section 7.3.1 on [page 266](#) explains using read/write commands.

6.4.5 Generating and Saving User Shading Correction Values

This section includes procedures for generating the user DSNU and PRNU shading correction values that will be stored in the user shading correction values file. If you will be setting the camera to do DSNU correction only, then you only need to perform the DSNU procedure. If you will be setting the camera to do PRNU correction only, then you only need to perform the PRNU procedure. And if you will be setting the camera to do both DSNU and PRNU correction, you must follow both procedures.

Generating and Saving User DSNU Shading Correction Values

The procedure below describes how to generate user DSNU shading correction values. When you generate the values, they will automatically be stored in the camera's user shading value file.

You should be aware that the camera uses one set of DSNU values when it is operating in single line acquisition mode and a different set of values when it is operating in any one of the other line acquisition modes (see Chapter 3 on [page 35](#) for more information about line acquisition modes). This means that:

- If you will always be operating the camera in single line acquisition mode, you should set the camera for single line acquisition mode and then follow the steps below one time.
- If you will never be operating the camera in single line acquisition mode, you should set the camera for any one of the other acquisition modes and then follow the steps below one time.
- If you will sometimes operate the camera in single line acquisition mode and other times operate the camera in one of the other modes, you should first set the camera for single line acquisition mode and follow the steps below. You should then, set the camera for any one of the other acquisition modes and you should go through the steps a second time.

(The camera's user shading values file has one area where it holds the DSNU values it uses for single line mode and another area where it stores the values for all of the other modes.)

To generate a set of user DSNU values:

1. Set the camera for the desired line acquisition mode.
2. Make sure the area of interest parameters are set so that the camera will use the full length of the sensor (see Section 6.3 on [page 152](#)).

It is possible to generate shading values when the AOI is set to a smaller value than the full length of the sensor. In this case only the shading values inside the AOI will be calculated, but the full shading file will be written. Values that are outside of the current AOI will be copied from the previously activated shading file.

3. Ensure that the camera will be capturing lines in complete darkness by covering the camera lens, closing the iris in the lens, or darkening the room.
4. Begin acquiring lines either by generating an ExSync signal to trigger line acquisition or by setting the camera for a free run exposure time control mode.
5. Signal the camera to generate a set of DSNU values:
 - a. You can start the generation of a set of DSNU values with the Camera Configuration Tool

Plus (see Section 7.1 on [page 212](#)). With the CCT+, set the value of the Generate parameter in the DSNU & PRNU Shading Correction parameters group to Generate DSNU Values.

- b. You can also start the generation of a set of DSNU values by using a binary write command (see Section 7.3 on [page 265](#)) to write a value to the Generate field of the Shading Value Generate CSR (see [page 240](#)).
6. The camera must make at least 64 acquisitions to create a set of DSNU shading correction values. If your camera is set to control exposure with an ExSync signal, you must generate at least 64 ExSync signal cycles after you signal the camera to begin generating the values. If you are running the camera in a free run exposure time control mode, you must wait long enough for the camera to complete at least 64 acquisitions.
- a. When the camera is acquiring the lines it needs to create the DSNU shading values, the line valid and data valid signals will go high and low as you would normally expect. However, the data in these lines is not useful to you and should be ignored.



If you started the generation of the shading values using the CCT+, you are using an ExSync signal to trigger acquisitions, and you are operating the camera at a line period greater than approximately 300 ms, you should be aware of a potential problem. Under these conditions, the CCT+ may time out while it is waiting for the camera to complete 64 acquisitions and you may see a "Camera is not responding ..." error message. This error is not fatal to the shading value creation process. If you close the error message window, wait several seconds and then click the Refresh button on the CCT+, the shading values will be properly created.

If you started the generation of the shading values using binary commands, you are using an ExSync signal to trigger acquisitions, and you are operating the camera at very low line rates, you should be aware of a restriction. The camera will not acknowledge or respond to binary commands while it is performing the 64 acquisitions needed to create a set of shading values. Once you have issued the binary command to start generating shading values, you should wait until the generation process is complete before you issue any further binary commands. The time needed to complete the generation process will be equal to 64 times the line period.

7. Once 64 acquisitions have been completed, the camera calculates the DSNU values:
- a. The camera uses the data from the 64 acquisitions to calculate an average gray value for the pixels in each line.
 - b. The camera finds the pixel with the highest average gray value in each line.
 - c. For each of the other pixels in the line, the camera determines the offset that would be needed to make the pixel's average value equal to the average value for the highest pixel.
 - d. The camera generates a set of DSNU shading values that contains the calculated offsets.
8. The generated set of DSNU values is automatically saved in the user shading values file in the camera's non-volatile memory. Existing values in the file will be overwritten.
9. The user shading value file is automatically "activated." See Section 6.4.6 on [page 161](#) for more information about what it means to activate a shading file.

Generating and Saving User PRNU Shading Correction Values

The procedure below describes how to generate user PRNU shading correction values. When you generate the values, they will automatically be stored in the camera's user shading value file.

You should be aware that the camera uses one set of PRNU values when it is operating in single line acquisition mode and a different set of values when it is operating in any one of the other line acquisition modes (see Chapter 3 on [page 35](#) for more information about line acquisition modes). This means that:

- If you will always be operating the camera in single line acquisition mode, you should set the camera for single line acquisition mode and then follow the steps below one time.
- If you will never be operating the camera in single line acquisition mode, you should set the camera for any one of the other acquisition modes and then follow the steps below one time.
- If you will sometimes operate the camera in single line acquisition mode and other times operate the camera in one of the other modes, you should first set the camera for single line acquisition mode and follow the steps below. You should then, set the camera for any one of the other acquisition modes and you should go through the steps a second time.

(The camera's user shading values file has one area where it holds the PRNU values it uses for single line mode and another area where it stores the values for all of the other modes.)


To generate a set of user PRNU values:

1. Place a uniform white or light colored target in the field of view of the camera. Adjust your lighting, optics, line rate, exposure mode, exposure time, gain and camera temperature as you would for normal system operation.
2. Set the camera for the desired line acquisition mode.
3. Make sure the area of interest parameters are set so that the camera will use the full length of the sensor (see Section 6.3 on [page 152](#)).

It is possible to generate shading values when the AOI is set to a smaller value than the full length of the sensor. In this case only the shading values inside the AOI will be calculated, but the full shading file will be written. Values that are outside of the current AOI will be copied from the previously activated shading file.

4. Perform several acquisitions and examine the pixel values returned from the camera. The pixel values for the brightest pixels should be about 80 to 85% of maximum.
 - a. If the pixel values for the brightest pixels are at 80 to 85% of maximum, go on to step 3.
 - b. If the pixel values for the brightest pixels are not at 80 to 85% of maximum adjust your lighting and/or lens aperture setting to achieve 80 to 85%.
5. Perform several acquisitions and examine the pixel values in each line. In each line, the values for the darkest pixels must be at least 67% of the values for the lightest pixels in the line. (If the values for the darkest pixels are less than 67% of the value for the lightest pixels, the camera will not be able to fully correct for shading variations.)
 - a. If the values for the darkest pixels are at least 67% of the value for the lightest pixels, go on to step 6.
 - b. If the values for the darkest pixels are less than 67% of the value for the lightest pixels, it usually indicates extreme variations in lighting or poor quality optics. Return to step 4. Make corrections as required.

6. Begin acquiring lines either by generating an ExSync signal to trigger line capture or by setting the camera for a free run exposure time control mode.

	<p>When you generate the PRNU values in the step below, you will have two options:</p> <ol style="list-style-type: none">1. You can generate the PRNU values without using DSNU shading correction. If you do this the pixel values used to calculate the PRNU correction values will not be corrected for DSNU.2. You can generate the PRNU values with using DSNU shading correction. If you do this the pixel values used to calculate the PRNU correction values will be corrected for DSNU. (For this option to work correctly, you must have already generated DSNU values before you generate the PRNU values.) <p>For optimum correction results, we strongly recommend to generate both DSNU and PRNU shading correction values.</p>
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7. Signal the camera to generate a set of PRNU values:
 - a. You can start the generation of a set of PRNU values with the Camera Configuration Tool Plus (see Section 7.1 on [page 212](#)). With the CCT+, set the value of the Generate parameter in the DSNU & PRNU Shading Correction parameters group to Generate PRNU Values or to Generate PRNU Values with DSNU.
 - b. You can also start the generation of a set of PRNU values by using a binary write command (see Section 7.3 on [page 265](#)) to write a value to the Generate field of the Shading Value Generate CSR (see [page 240](#)).
8. The camera must make at least 128 acquisitions to generate a set of PRNU values. If your camera is set to control exposure with an ExSync signal, you must generate at least 128 ExSync signal cycles after you signal the camera to begin generating the values. If you are running the camera in a free run exposure time control mode, you must wait long enough for the camera to complete at least 128 acquisitions.
 - a. When the camera is capturing the lines it needs to create the PRNU shading values, the line valid and data valid signals will go high and low as you would normally expect. However, the data in these lines is not useful to you and should be ignored.



If you started the generation of the shading values using the CCT+, you are using an ExSync signal to trigger acquisitions, and you are operating the camera at a line period greater than approximately 300 ms, you should be aware of a potential problem. Under these conditions, the CCT+ may time out while it is waiting for the camera to complete 128 acquisitions and you may see a "Camera is not responding ..." error message. This error is not fatal to the shading value creation process. If you close the error message window, wait several seconds and then click the Refresh button on the CCT+, the shading values will be properly created.

If you started the generation of the shading values using binary commands, you are using an ExSync signal to trigger acquisitions, and you are operating the camera at very low line rates, you should be aware of a restriction. The camera will not acknowledge or respond to binary commands while it is performing the 128 acquisitions needed to create a set of shading values. Once you have issued the binary command to start generating shading values, you should wait until the generation process is complete before you issue any further binary commands. The time needed to complete the generation process will be equal to 128 times the line period.

9. Once 128 acquisitions have been completed, the camera calculates the PRNU values:
 - a. The camera uses the data from the 128 acquisitions to calculate an average gray value for the pixels in each line.
 - b. The camera finds the pixel with the highest average gray value in the line.
 - c. For each of the other pixels in the line, the camera determines the additional gain that would be needed to make the pixel's average value equal to the average value for the highest pixel.
 - d. The camera generates a set of PRNU values that contains the calculated gain adjustments.
10. The generated set of PRNU values is automatically stored in the user shading values file in the camera's non-volatile memory. Existing values in the file will be overwritten.
11. The user shading value file is automatically "activated." See Section 6.4.6 on [page 161](#) for more information about what it means to activate a shading file.

6.4.6 Activating a Shading Values File

As explained in Section 6.4 on [page 154](#), the camera contains a set of factory determined shading correction values in a file in its non-volatile memory. As explained in Section 6.4.5 on [page 157](#), you can also generate a set of "user" shading values and save them to a separate file in the non-volatile memory.

Assuming that you have generated user shading values, you can choose to “activate” either the user shading values file or the factory shading values file. When you activate a shading values file, two things happen:

- The values from the activated file are immediately copied into the camera’s volatile memory. When you have shading correction enabled, the camera uses the shading values in the volatile memory to perform shading correction.
- A link is created between the activated file and the volatile memory. The shading values from the activated file will automatically be copied into the volatile memory whenever the camera is powered up or reset. (Assume, for example, that the user shading values file is the activated file. In this case, when the camera is powered on or reset, the values from the user shading values file will be copied into the volatile memory of the camera and will be used to perform shading correction.)

Activating a Shading Values File

You can activate a shading values file with the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera’s bulk data control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the File Name Select parameter to select a shading values file and the Activate button in the Shading Files parameters group to activate the selected file.

By Setting CSRs

You can activate a shading values file by writing values to the shading values bulk data CSR.

Section 7.2.3 on [page 257](#) explains bulk data CSRs and using the bulk data activate process. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.4.7 Copying the Factory Shading Values into the User Shading Values File

As explained in Section 6.4 on [page 154](#), the camera contains a set of factory determined shading correction values in a file in its non-volatile memory. As explained in Section 6.4.5 on [page 157](#), you can also generate a set of “user” shading values and save them to a separate file in the non-volatile memory.

In some situations, it may be advantageous for you to be able to simply copy the contents of the factory shading values files into the file for user shading values

You can copy the values from the factory file into the user file with the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera’s bulk data control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the File Name Select parameter and the Copy button in the Shading Files parameters group to copy the data in the factory shading values file to the user shading values file.

By Setting CSRs

You can copy the data in the factory shading values file to the user shading values file by writing values to the shading values bulk data CSR.

Section 7.2.3 on [page 257](#) explains bulk data CSRs and using the bulk data copy process. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.4.8 Downloading a Shading Values File to Your Computer

Once you have generated a set of user shading values in the user shading values file as described in Section 6.15.1 on [page 207](#), you can download the user shading values file to your computer. You can also download the factory shading values file to your computer.

Using the download function together with the upload function that is described on the next page is useful if you want to transfer a user shading values file from one camera to another camera of the same type.

You can download the user or the factory shading values file by using the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the File Name Select parameter in the Shading Files parameters group to select the user shading values file or the factory shading values file and use the Download button to download the selected file.

By Setting CSRs

You can download the user or the factory shading values file by writing values to the shading values bulk data CSR. Section 7.2.3 on [page 257](#) explains the bulk data CSRs and Section 7.2.3.3 on [page 260](#) explains how to use the CSRs to download a file. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.4.9 Uploading a Shading Values File to Your Camera

Once you have downloaded a user shading value file to your computer as described on the previous page, you can upload the file from your computer to a camera.

Using the download function together with the upload function is useful if you want to transfer a user shading values file from one camera to another camera of the same type.

You can upload a user shading values file by using the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera's control and status registers (CSRs).

Note that when you upload a user shading values file to your camera, you will overwrite any existing values in the camera's user shading values file.

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Upload button in the Shading Files parameters group to upload a user shading values file. When you click the button, the CCT+ will open a window that lets you navigate to your computer and select a file.

By Setting CSRs

You can upload a user shading values files by writing values to the shading values bulk data CSR. Section 7.2.3 on [page 257](#) explains the bulk data CSRs and Section 7.2.3.3 on [page 260](#) explains how to use the CSRs to upload a file. Section 7.3.1 on [page 266](#) explains using read/write commands.



The factory shading values file can be downloaded from the camera to the computer. The factory shading values file can't be uploaded from the computer to the camera because the factory shading values file in the camera is protected and can't be overwritten.

6.5 Gamma Correction

The gamma correction feature lets you modify the brightness of the pixel values output by the camera's sensor to account for a non-linearity in the human perception of brightness. To accomplish the correction, a gamma correction factor (γ) is applied to the brightness value (Y) of each pixel according to the following formula:

$$Y_{\text{corrected}} = \left(\frac{Y_{\text{uncorrected}}}{Y_{\text{max}}} \right)^{\gamma} \times Y_{\text{max}}$$

The formula uses uncorrected and corrected pixel brightnesses that are normalized by the maximum pixel brightness. The maximum pixel brightness equals 255 for 8 bit output, and is constrained for technical reasons to 1020 for 10 bit output and 4080 for 12 bit output.

When the gamma correction factor is set to 1, the output pixel brightness will not be corrected.

A gamma correction factor between 0 and 1 will result in increased overall brightness, and a gamma correction factor greater than 1 will result in decreased overall brightness.

In all cases, black (output pixel brightness equals 0) and white (output pixel brightness equals 255 for 8 bit output, 1020 for 10 bit output, and 4080 for 12 bit output) will not be corrected.

Enabling Gamma Correction and Setting the Gamma



The gamma correction feature will only operate when the lookup table feature is enabled. Make sure to enable the lookup table feature before setting the gamma correction feature.

For more information about enabling the lookup table feature, see Section 6.9 on [page 198](#).

You can set the gamma correction feature with the Camera Configuration Tool Plus (CCT+, see Section 7.1 on [page 212](#)) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

Gamma correction is enabled, when the value of the Gamma parameter is set to >0. The correction is determined by the value of the Gamma parameter which can be set in a range from 0 to 3.99902. So if the value is set to 1.2, for example, the gamma used for the correction will be 1.2.

By Setting CSRs

You set the gamma by writing a value to the Absolute Gamma or the Raw Gamma field of the Gamma CSR (see [page 240](#)).

Section 7.2.2 on [page 219](#) explains CSRs and Section 7.3.1 on [page 266](#) explains using read/write commands.

6.6 Color Enhancement

6.6.1 Color Adjustment

The color adjustment feature lets you modify the colors output by the camera to best suit your needs.

The color adjustment feature can be used in combination with all line acquisition modes, i. e. with the RGB, Raw, and Enhanced Raw line acquisition modes.

For more information about the line acquisition modes, see Section 3 on [page 35](#).



Note on the availability of the color adjustment and line stamp features (Basler spL8192-39 only)

On the initial wake-up after delivery, the camera loads the factory configuration set into the work set.

It depends **on the firmware version** in the corresponding camera model which feature is **available** and which is **not**:

- For **spL8192-39kc**: The firmware of this camera model wakes up with the line stamp feature.
- For **spL8192-39kcCI**: The firmware of this camera model wakes up with the color adjustment feature.

If you want your camera to wake up with the feature that is not included in the currently installed firmware, please contact Basler Technical Support.

Additional information:

All other features are available for the spL8192-39kc and spL8192-39kcCI (exceptions, see single feature sections).

6.6.1.1 The RGB Color Space

As explained in Section 1.6 on [page 16](#), color creation involves the use of a color separation filter above each pixel of the sensor. This allows only red, green or blue light to strike a pixel. Accordingly, red (R), green (G), and blue (B) will be the primary colors for representing the colors of an image and R, G, and B will be the primary colors of the RGB color space.

This color space includes light with the **primary colors** R, G, B, and all of their combinations: When red, green, and blue light are combined and when the intensities of R, G, and B are allowed to vary independently between 0% and 100%, all colors within the RGB color space can be formed. Combining colored light is referred to as additive mixing.

When two primary colors are mixed at equal intensities, the **secondary colors** will result. The mixing of red and green light produces yellow light (Y), the mixing of green and blue light produces cyan light (C), and the mixing of blue and red light produces magenta light (M).

When the three primary colors are mixed at maximum intensities, white will result. In the absence of light, black will result.

The color space can be represented as a color cube (see Figure 62) where the primary colors R, G, B, the secondary colors C, M, Y, and black and white define the corners. All shades of gray are represented by the line connecting the black and the white corner.

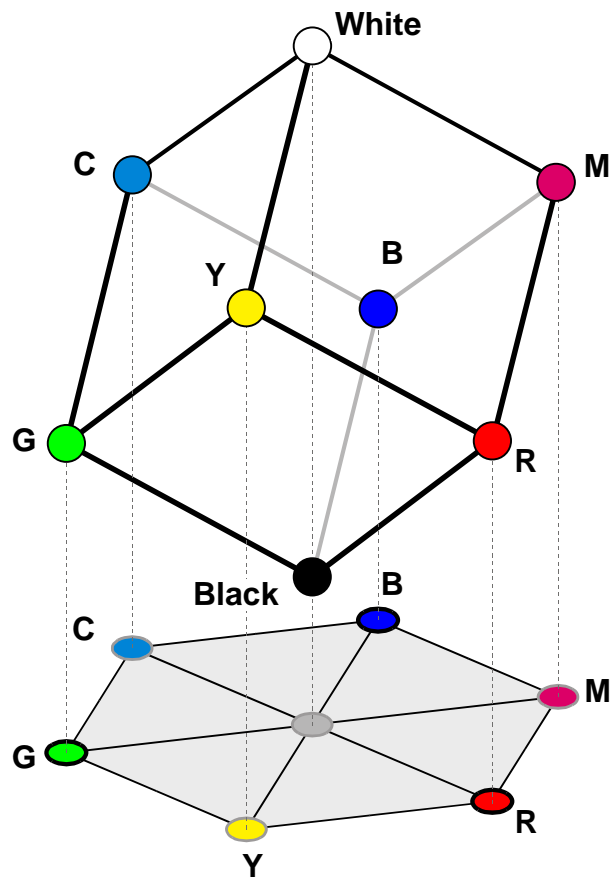


Fig. 62: RGB Color Cube With YCM Secondary Colors, Black, and White, Projected On a Plane

For ease of imagination, the color cube can be projected onto a plane such that a color hexagon is formed: The primary and secondary colors define the corners of the color hexagon in an alternating fashion. The edges of the color hexagon represent the colors resulting from mixing the primary and secondary colors. The center of the color hexagon represents all shades of gray including black and white.

The representation of any arbitrary color of the RGB color space will lie within the color hexagon. The color will be characterized by its hue and saturation.

- **Hue** specifies the kind of coloration, whether e.g. the color is red, yellow, orange etc.
- **Saturation** expresses the colorfulness of a color. At maximum saturation no shade of gray is present. At minimum saturation no "color" but only some shade of gray (including black and white) is present.

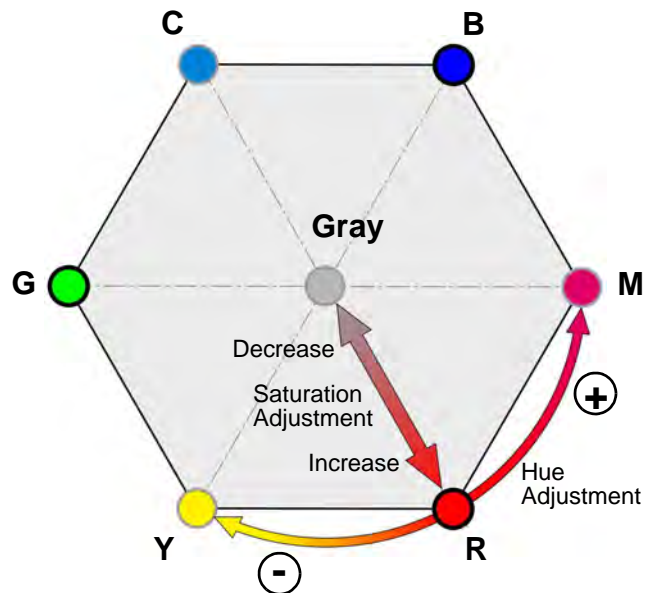


Fig. 63: Hue and Saturation Adjustment In the Color Hexagon.

[Adjustments Are Indicated for Red as an Example]

6.6.1.2 Hue and Saturation Adjustment

The color adjustment feature lets you adjust **hue** and **saturation** for the primary and the secondary colors. Each adjustment affects those areas in the image where the adjusted color predominates. For example, the adjustment of red affects the colors in the image with a predominantly red component.

When you adjust a color, the colors on each side of it in the color hexagon will also be affected to some degree. For example, when you adjust red, yellow and magenta will also be affected.

In the color hexagon, the adjustment of **hue** can be considered as a rotation between hues.

Primary colors can be rotated towards, and as far as, their neighboring secondary colors.

Secondary colors can be rotated towards, and as far as, their neighboring primary colors.

Example: When red is rotated in negative direction towards yellow, then, for example, purple in the image can be changed to red and red in the image can be changed to orange.

Red can be rotated as far as yellow, where red will be completely transformed into yellow.

Adjusting **saturation** changes the colorfulness (intensity) of a color.

Example: If saturation for red is increased, the colorfulness for red colors in the image will increase. If red is set to minimum saturation, red will be replaced by gray for "red" colors in the image.

You can set the hue and saturation adjustment either with the **CCT+** (Camera Configuration Tool Plus) or by using binary write commands to set the camera's control and status register (**CSRs**).

	With CCT+ [Color Adjustment group]	With CSRs	Used for...
	Hue <i>Color Name</i> parameter (*)	Hue <i>Color Name</i> field (*)	Hue adjustment of the selected primary or secondary color.
	Saturation <i>Color Name</i> parameter (*)	Saturation <i>Color Name</i> field (*)	Saturation adjustment of the selected primary or secondary color.
For more information about...	the CCT+, see Section 7.1 on page 212	on CSRs, see Section 7.2 on page 212	--
(*) <i>Color Name</i> stands for the chosen color			

Table 41: Setting Hue and Saturation Adjustment Parameters via CCT+ or via CSRs

6.6.2 Adapting the Color Adjustment Settings to Different Light Sources

On the initial wake-up after delivery, the Basler sprint color camera loads the factory configuration set into the work set. The color enhancement feature is deactivated in the factory configuration set. This factory set contains neutral values concerning color settings (see values without correction in Table 42 on [page 173](#)).

Depending on what you want to achieve by adapting the color adjustment settings, you have the following possibilities:

(A)

If a **high color accuracy** is important to you, i.e. you want the camera to capture an object and you want the monitor to display the colors of an object as seen under a standard light source (i.e. the **exact numerical values** of the object's pixels), make sure that you use a standard color chart within your camera's field of view when you adjust the color enhancements.

(B)

If you want to rely on your visual impression, i.e. you want to achieve that the monitor you use displays the colors of the captured object as you perceive them, you require a high-end, calibrated monitor.

- Use a high-end, calibrated monitor for displaying your acquired images.
- Use a standard color chart within your camera's field of view when you adjust the color enhancements.



You can only obtain good color enhancements with a well-adjusted monitor (e.g. brightness etc.).

You can find information about

- how to adjust the color performance of the camera to a specific light source in Section 6.6.2.1 on [page 170](#). The procedure describes the (B) scenario mentioned above.
- specific parameter settings for different light sources in Section 6.6.2.2 on [page 173](#).

6.6.2.1 A Procedure for Setting the Color Enhancements

In the following procedure we assume that you select the CCT+ for adjusting the color enhancement parameters.

Required Tools/Materials:

- We recommend including a standard color chart within your camera's field of view when you are adjusting the color enhancements. This will make it much easier to know when the colors are properly adjusted.
One widely used chart is the ColorChecker® chart (also known as the Macbeth chart). If you order a color checker chart, the target values for red, green and blue will be indicated on the chart for each color field.

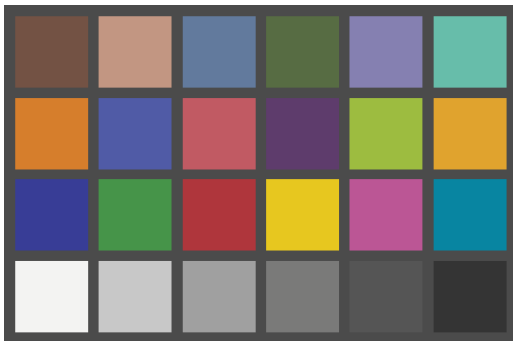


Fig. 64: ColorChecker® Image (sRGB)

- Make sure that a tool is installed on your computer that helps you to identify the color value of any pixel in an image.
The tool should be able to display the colors as RGB values and as HSB/HSV values.
Example tool: Just Color Picker.

To adjust the color performance of the Basler sprint color camera:

1. Make sure that you use an IR cut filter on the camera lens.
The filter should transmit in a range from 400 nm to 650 nm, and it should cut off from 650...680 nm to at least 1100 nm (e.g. B + W 486 filter).
2. Arrange your camera so that it is viewing a scene similar to what it will view during actual operation.
3. Make sure that the lighting for the scene is as close as possible to the actual lighting you will be using during normal operation.
4. Set the exposure time and gain so that you are acquiring good quality images.
It is important to make sure that the images are not over-exposed. Over exposure can have a significant negative effect on the fidelity of the color in the acquired images.

5. Carry out DSNU and PRNU **shading correction**:
 - a. Close the lens of the camera (e.g. with a cap).
 - b. In CCT+:
 - a. Set **Exposure: Exposure Time Control Mode <Free-run, programmable>**.
 - b. In the **DSNU & PRNU Shading Correction** group: Select **Generate DSNU Values**.
If the generation is successful, **Last Shading Generation Failed** is <0> is displayed.
 - c. Remove the cover from the camera lens.
 - d. Capture an image of a homogeneous surface (e.g. white sheet of paper).
The gray values in the image should be as bright as possible, but they should not be saturated (i.e. for 8 bit: gray values < 255).
 - e. In CCT+:
In the **DSNU & PRNU Shading Correction** group: Select **Generate PRNU Values with DSNU Values**.
If the generation is successful, **Last Shading Generation Failed** is <0>.

The shading values will be saved automatically in the user shading values file. Make sure the shading mode is selected.

See Section 6.4.6 on [page 161](#) for more information about activating user shading values files.

6. Depending on your light source, set the corresponding Offset [DN] and color-specific gain parameters for **white balance** in the [**Gain & Offset**] section. Table 42 on [page 173](#) shows you the values for different light sources.



Fig. 65: Checking White Balance

- a. Capture images of the gray fields of the color chart (see example in Figure 65).
The brightest (white field) should be in the focus area of the camera and it must not be saturated (i.e. not too bright).
Preferably you should start with a gain value of 1 for the brightest color. A small value means less noise.
 - b. Check whether the white balance in the image is correct, i.e. if the values of the colors red, green and blue inside a segment (preferably the brightest, the white segment) are the same.

Via the white balance parameters you adapt the three color channels of the camera (red, green and blue) to the light source in such a way that you obtain a basic gray value.
For more information about the white balance feature, see Section 6.2 on [page 148](#).
 - c. Set the gain value of the color with the highest gain value as low as possible. Thus you obtain the lowest noise.
 - If the white balance is correct, proceed with step 8.
 - If the white balance is not correct, go to the following step.
7. If the white balance is not correct, adjust the corresponding color gain parameter in the [**Gain & Offset**] section.

8. Adjust the **gamma correction** parameters (for detailed information, see Section 6.5 on [page 164](#)):

- a. Make sure that gamma correction is enabled ([**Lookup Table**] section > Lookup Table Enable parameter).
- b. Set the gamma parameter:

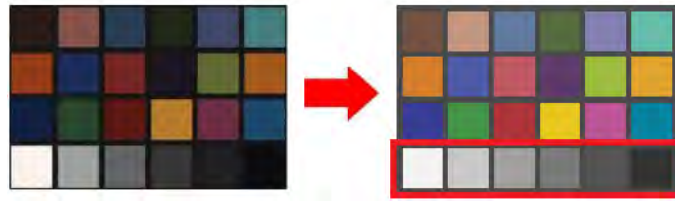


Fig. 66: Setting the Gamma Value

The standard value for gamma is 0.42. An incorrect gamma value means that the saturation of the colors will change with the brightness.

Gamma = 1 means no adaptation. **Only** set gamma to 1, if image evaluations later on include this step or if you want to obtain a higher contrast. The higher contrast can only be obtained by simultaneously losing details in the dark areas of the image.

If you use another color space, set the gamma value to the corresponding value.

When gamma is set correctly, the intensity difference between adjacent gray values (i.e. white - bright gray - etc.) should be equal (see example in Figure 66).

9. Save the current settings as a user set. This will reflect the status before the color adjustment. This user set will include the results from white balance and gamma correction.
10. Depending on your light source, set the corresponding color enhancement parameters in the [**Color Adjustment**] section. Table 42 on [page 173](#) shows you the values for different light sources.
11. Take again an image of the white and gray fields of the color chart (see example in Figure 65). The displayed image on the monitor should look like the image in Figure 65. If the displayed image does not correspond to the captured line, check whether the monitor is correctly adjusted.
12. Capture images of the blue, green, red, yellow, magenta and cyan line of the color chart (see example in Figure 67).

13. Check whether the colors are correct.

- If the colors are correctly displayed, the color enhancement is complete. Go to step a.
- If the colors are not correctly set, proceed with the next step.



Fig. 67: Checking the Colors

- a. Depending on what color is not correctly displayed, adjust the corresponding **color enhancement** parameters in the [**Color Adjustment**] section (see Figure 68).
- b. Set the viewing tool (e.g. Just Color Picker) to HSB/HSV mode.
- c. Capture a new image of the ColorChecker[®].
- d. Compare the values of the captured image to the reference image on your computer.

- Color Adjustment	
Color Adjustment Enable	Enabled
Saturation Red	
Hue Red	
Saturation Yellow	
Hue Yellow	
Saturation Green	
Hue Green	
Saturation Cyan	
Hue Cyan	
Saturation Blue	
Hue Blue	
Saturation Magenta	
Hue Magenta	

Fig. 68: Color Adjustment Parameters in CCT+

- e. Adjust the primary and secondary colors as close as possible to the values of the reference image by adjusting the corresponding saturation and hue color parameter. See
- parameters for the different light sources in Table 42 on [page 173](#) and
 - hue and saturation adjustment in Section 6.6.1.2 on [page 168](#).



Each of the six primary and secondary colors can be separately adjusted in the HSB color space. Neighboring colors will influence each other, e.g. changes for yellow may also slightly change red and green.

14. Save the settings (i.e. with the modified color enhancement parameters) to a separate user set.

If not saved in a separate user set, the settings made for color adjustment will be lost when the camera is reset or switched off and back on.

6.6.2.2 List of Color Settings for Different Light Sources


In Table 42 different possible color and gain settings for three different light sources are displayed.

Parameter Name in CCT+	Values Without Correction	Tungsten 2800 K	Daylight 5000 K	Daylight 6500 K
[Color Adjustment]				
Color Adjustment Enable	0	1	1	1
Saturation Red	64	91	69	70
Hue Red	0	8	15	13
Saturation Yellow	64	139	104	104
Hue Yellow	0	18	- 4	- 4
Saturation Green	64	203	152	147
Hue Green	0	127	69	54
Saturation Cyan	64	91	89	91
Hue Cyan	0	115	46	42
Saturation Blue	64	105	89	91
Hue Blue	0	- 24	- 26	-27
Saturation Magenta	64	115	125	117
Hue Magenta	0	127	127	127
[Gain & Offset]				
... Gain Red [dB]	0	1	1	1.0344
... Gain Green [dB] *	3.5	2.1669	1.1499	1

Table 42: Specific Settings for Different Light Sources

Parameter Name in CCT+	Values Without Correction	Tungsten 2800 K	Daylight 5000 K	Daylight 6500 K
... Gain Blue [dB]	6	6.2717	1.8924	1.513
Offset [DN]	0	0	0	0
Gamma	1	0.416667	0.416667	0.416667
[Lookup Table]				
Lookup Table Enable (i.e. Gamma Enable)	1	1	1	1
* By default Gain Green 2 is disabled. If enabled, the gain value would be as the Gain Green value.				

Table 42: Specific Settings for Different Light Sources

	<p>LED light source</p> <p>As the variety of light emitting diodes is very large, e.g. varying temperature and color ranges etc., no values for an LED light source are indicated in this table. If you want to use an LED, we recommend to check the color and temperature values for the selected LED type and take the values of a light source that is close to the LED color temperature. This can be a starting point for your color enhancement.</p>
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6.7 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 cables. Test images are especially useful for service purposes and for failure diagnostics. In test mode, the image is generated with a software program and the camera's digital devices and does not use the optics or the imaging sensor. Nonetheless, the test image generation takes account of the fact, that the sensor includes two different pixel lines, providing either "red" and "green" or "green" and "blue" pixel values.

Guidelines When Using Test Images

- When using a test image, 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 e.g. in Figure 71 on [page 177](#) or

Figure 77 on [page 181](#).

- 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.
- The length of the exposure time has no effect on test images.
- The detailed descriptions of the test patterns assume that the AOI feature is set to use the full area of the sensor.
- The test images will look different, depending on the line acquisition mode:
 - Test images generated with the RGB line acquisition mode (see Section 3.2 on [page 36](#)) will include RGB pixel values of virtual pixels.



The test images presented here for the RGB line acquisition mode assume that a 3 tap or 6 tap output mode was selected, relieving oneself of handling dummy data which are transmitted in the 2 tap, 4 tap, and 8 tap output modes.

- Test images generated with the Raw or Enhanced Raw line acquisition modes (see Chapter 3.3 on [page 44](#) and Chapter 3.4 on [page 63](#)) will
 - discriminate between sensor lines A and B,
 - will be characterized by the sequence of transmission of lines A and B (A first, B second or B first, A second).

Enabling Test Images

You can enable a test image with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Test Image Mode parameter in the Output Mode parameters group to enable a test image.

By Setting CSRs

You enable a test image by writing the appropriate value to the Mode field of the Test Image Mode CSR (see [page 250](#)).

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.

6.7.1 Test Image Two (Moving Gray Gradient)

6.7.1.1 Test Image Two Generated with the RGB Line Acquisition Mode

When the camera is set for RGB line acquisition mode (see Section 3.2 on [page 36](#)) and test image two, a test image is formed with a gray scale gradient. When e.g. an 8 bit output mode is selected, the gray scale gradient ranges from 0 to 255 and repeats every 256 pixels as shown in Figure 70.

The starting pixel values for red, green, and blue are not defined. In the following description, however, they are assumed to be 0 for the first line. The pixel values refer to virtual pixels (Section 3.2 on [page 36](#)). Therefore, each line of the test image includes 1024 pixels for 2k cameras, 2048 pixels for 4k cameras, and 4096 pixels for 8k cameras.

The lines of the test image for e.g. 8 bit output modes are generated in the following way (see also Figure 69):

- On the first cycle of the ExSync signal or the camera's internal control signal, the first pixel has a red value (R) of 0, a green value (G) of 0, and a blue (B) value of 0, the second pixel has a red value of 1, a green value of 1, and a blue value of 1, the third pixel has a red value of 2, a green value of 2, and a blue value of 2, and so on.
- On the second cycle, the first pixel has 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, the third pixel has a red value of 3, a green value of 3, and a blue value of 3, and so on.
- The following lines are generated in an analogous way.
- On the 256th cycle, the first pixel has a red value of 255, a green value of 255, and a blue value of 255, the second pixel has a red value of 0, a green value of 0, and a blue value of 0, the third pixel has a red value of 1, a green value of 1, and a blue value of 1, and so on.

R=0 G=0 B=0	R=1 G=1 B=1	R=2 G=2 B=2	R=3 G=3 B=3	R=4 G=4 B=4	R=5 G=5 B=5
R=1 G=1 B=1	R=2 G=2 B=2	R=3 G=3 B=3	R=4 G=4 B=4	R=5 G=5 B=5	R=6 G=6 B=6
R=2 G=2 B=2	R=3 G=3 B=3	R=4 G=4 B=4	R=5 G=5 B=5	R=6 G=6 B=6	R=7 G=7 B=7
R=3 G=3 B=3	R=4 G=4 B=4	R=5 G=5 B=5	R=6 G=6 B=6	R=7 G=7 B=7	R=8 G=8 B=8

Fig. 69: Pixel Values in the Upper Left Corner of Test Image Two Generated with RGB Line Acquisition Mode

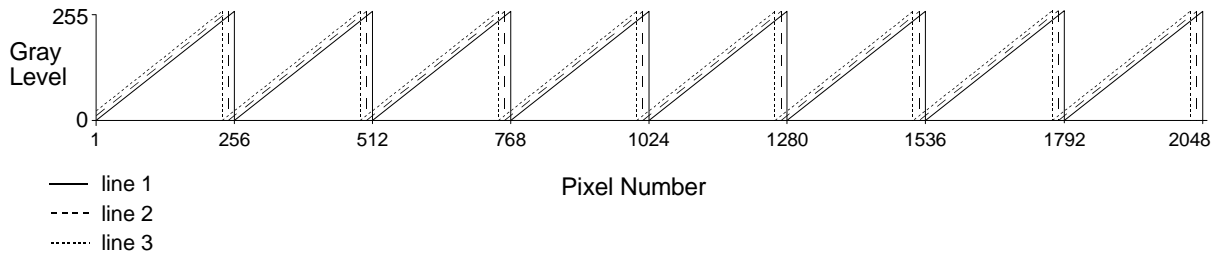


Fig. 70: Formation of Test Image Two for 8 bit Output Modes Generated with RGB Line Acquisition Mode on a Camera with 4096 Pixels Per Line (2048 Virtual Pixels)

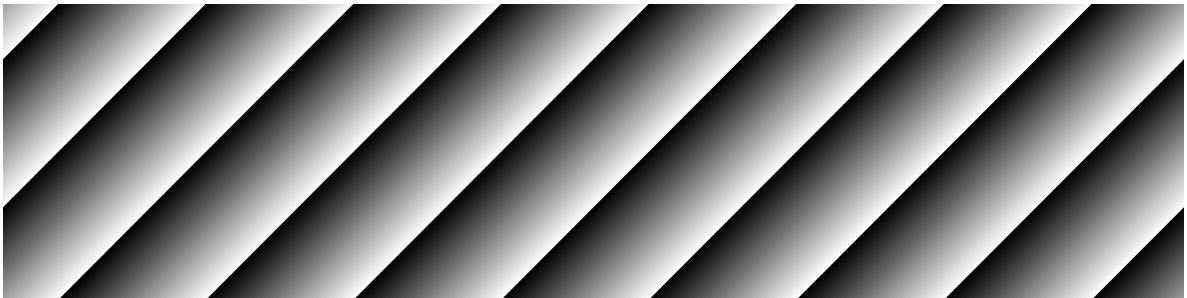


Fig. 71: Test Image Two Generated with RGB Line Acquisition Mode

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

Test image two is useful for checking the integrity of the data transmitted by the camera. If you capture lines and examine the pixel values in the captured lines, the values should be exactly as described above.



When the camera is set for an 8 bit output mode, the pixel values in test image two range from 0 to 255 as described above.

If the camera is set for a 10 bit output, the pixel values will range from 0 to 1023.

If the camera is set for a 12 bit output, the pixel values will range from 0 to 4095.

6.7.1.2 Test Image Two Generated with the Raw and Enhanced Raw Line Acquisition Modes

When the camera is set to a Raw or Enhanced Raw line acquisition mode (see Section 3.3 on [page 44](#) and Section 3.4 on [page 63](#)) and test image two, a test image is formed with a gray scale gradient. When e.g. an 8 bit output mode is selected, the gray scale gradient ranges from 0 to 255 and repeats every 512 pixels as shown in Figure 73.

The odd lines in the test image refer to the sensor lines transmitted first by the selected line acquisition mode and the even lines refer to the sensor lines transmitted second (see Section 1.6 on [page 16](#)):

- In Raw - Line A First and Enhanced Raw - Line A First line acquisition mode line A is transmitted first and line B second. Accordingly, the odd lines in the test image refer to lines A and the even lines refer to lines B.
- In Raw - Line B First and Enhanced Raw - Line B First line acquisition mode line B is transmitted first and line A second. Accordingly, the odd lines in the test image refer to lines B and the even lines refer to lines A.

The starting pixel value is not defined. In the following description, however, it is assumed to be 0 for the first line.

The lines of the test image for e.g. 8 bit output modes and Raw - Line A First or Enhanced Raw - Line A First line acquisition mode are generated in the following way (see also Figure 72, left):

- On the first cycle of the ExSync signal or the camera's internal control signal, the pixel values refer to line A. The first pixel has a red value (RA) of 0, the second pixel has a green value (GA) of 0, the third pixel has a red value of 1, the fourth pixel has a green value of 1, the fifth pixel has a red value of 2, the sixth pixel has a green value of 2, and so on.
- On the second cycle, the pixel values refer to line B. The first pixel has a green value (GB) of 0, the second pixel has a blue value (BB) of 0, the third pixel has a green value of 1, the fourth pixel has a blue value of 1, the fifth pixel has a green value of 2, the sixth pixel has a blue value of 2, and so on.
- On the third cycle, the pixel values refer to line A. The first pixel has a red value of 1, the second pixel has a green value of 1, the third pixel has a red value of 2, the fourth pixel has a green value of 2, the fifth pixel has a red value of 3, the sixth pixel has a green value of 3, and so on.
- On the fourth cycle, the pixel values refer to line B. The first pixel has a green value of 1, the second pixel has a blue value of 1, the third pixel has a green value of 2, the fourth pixel has a blue value of 2, the fifth pixel has a green value of 3, the sixth pixel has a blue value of 3, and so on.
- The following lines are generated in an analogous way.
- On the 511th cycle, the pixel values refer to line A. The first pixel has a red value of 255, the second pixel has a green value of 255, the third pixel has a red value of 0, the fourth pixel has a green value of 0, the fifth pixel has a red value of 1, the sixth pixel has a green value of 1, and so on.
- On the 512th cycle, the pixel values refer to line B. The first pixel has a green value of 255, the second pixel has a blue value of 255, the third pixel has a green value of 0, the fourth pixel has a blue value of 0, the fifth pixel has a green value of 1, the sixth pixel has a blue value of 1, and so on.

RA=0	GA=0	RA=1	GA=1	RA=2	GA=2
GB=0	BB=0	GB=1	BB=1	GB=2	BB=2
RA=1	GA=1	RA=2	GA=2	RA=3	GA=3
GB=1	BB=1	GB=2	BB=2	GB=3	BB=3
RA=2	GA=2	RA=3	GA=3	RA=4	GA=4
GB=2	BB=2	GB=3	BB=3	GB=4	BB=4

GB=0	BB=0	GB=1	BB=1	GB=2	BB=2
RA=0	GA=0	RA=1	GA=1	RA=2	GA=2
GB=1	BB=1	GB=2	BB=2	GB=3	BB=3
RA=1	GA=1	RA=2	GA=2	RA=3	GA=3
GB=2	BB=2	GB=3	BB=3	GB=4	BB=4
RA=2	GA=2	RA=3	GA=3	RA=4	GA=4

Raw - Line A First and Enhanced Raw - Line A First

Raw - Line B First and Enhanced Raw - Line B First

Fig. 72: Pixel Values in the Upper Left Corner of Test Image Two Generated with a Raw or Enhanced Raw Line Acquisition Mode

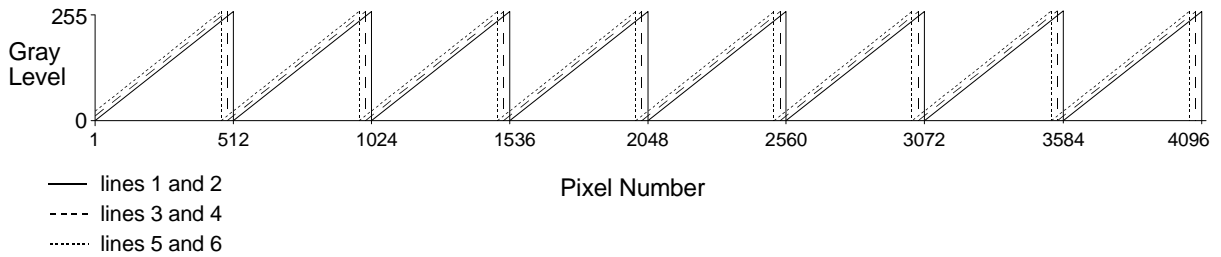


Fig. 73: Formation of Test Image Two for 8 bit Output Modes Generated with a Raw or Enhanced Raw Line Acquisition Mode on a Camera with 4096 Pixels Per Line



Fig. 74: Test Image Two Generated with a Raw or Enhanced Raw Line Acquisition Mode

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

Test image two is useful for checking the integrity of the data transmitted by the camera. If you capture lines and examine the pixel values in the captured lines, the values should be exactly as described above.



When the camera is set for an 8 bit output mode, the pixel values in test image two range from 0 to 255 as described above.

If the camera is set for a 10 bit output, the pixel values will range from 0 to 1023.

If the camera is set for a 12 bit output, the pixel values will range from 0 to 4095.

6.7.2 Test Image Seven (Fixed Red Gradient)

6.7.2.1 Test Image Seven Generated with the RGB Line Acquisition Mode

When the camera is set for RGB line acquisition mode (see Section 3.2 on [page 36](#)) and test image seven, a test image is formed with a fixed horizontal red gradient. When e.g. an 8 bit output mode is selected, the red gradient ranges from 0 to 255 and repeats every 256 pixels as shown in Figure 76.

The pixel values refer to virtual pixels (Section 3.2 on [page 36](#)). Therefore, each line of the test image includes 1024 pixels for 2k cameras, 2048 pixels for 4k cameras, and 4096 pixels for 8k cameras.

The lines of the test image for e.g. 8 bit output modes are generated in the following way (see also Figure 75):

- On the first cycle of the ExSync signal or the camera's internal control signal, the first pixel has a red value (R) of 0, a green value (G) of 0, and a blue (B) 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.
- The following lines are identical to the first line.

R=0	R=1	R=2	R=3	R=4	R=5	
G=0	G=0	G=0	G=0	G=0	G=0	
B=0	B=0	B=0	B=0	B=0	B=0	
R=0	R=1	R=2	R=3	R=4	R=5	
G=0	G=0	G=0	G=0	G=0	G=0	
B=0	B=0	B=0	B=0	B=0	B=0	
R=0	R=1	R=2	R=3	R=4	R=5	
G=0	G=0	G=0	G=0	G=0	G=0	
B=0	B=0	B=0	B=0	B=0	B=0	
R=0	R=1	R=2	R=3	R=4	R=5	
G=0	G=0	G=0	G=0	G=0	G=0	
B=0	B=0	B=0	B=0	B=0	B=0	

Fig. 75: Pixel Values in the Upper Left Corner of Test Image Seven Generated with RGB Line Acquisition Mode

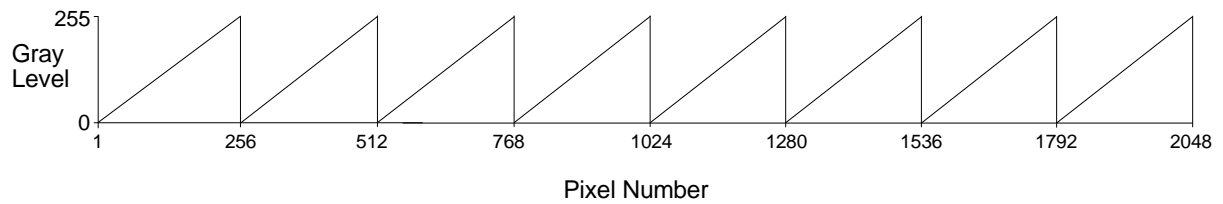


Fig. 76: Formation of Test Image Seven for 8 bit Output Modes Generated with RGB Line Acquisition Mode on a Camera with 4096 Pixels Per Line (2048 Virtual Pixels)

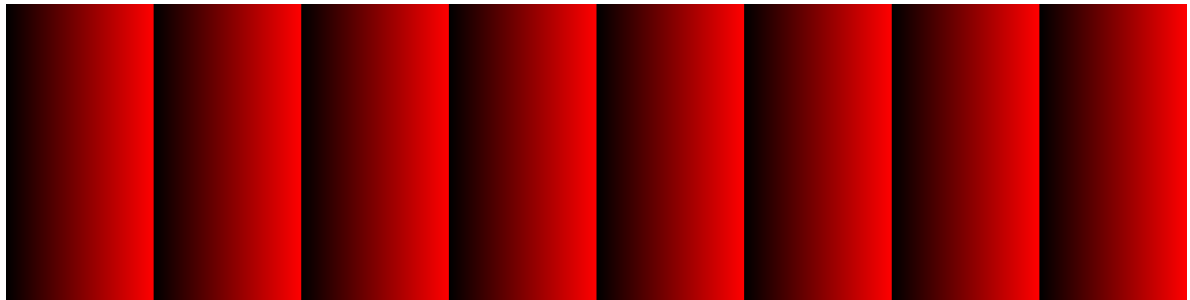


Fig. 77: Test Image Seven for 8 bit Output Modes Generated with RGB Line Acquisition Mode on a Camera with 4096 Pixels Per Line (2048 Virtual Pixels)

Test image two is useful for checking the integrity of the data transmitted by the camera. If you capture lines and examine the pixel values in the captured lines, the values should be exactly as described above.



When the camera is set for an 8 bit output mode, the pixel values in test image seven range from 0 to 255 as described above.

If the camera is set for a 10 bit output, the pixel values will range from 0 to 1023.

If the camera is set for a 12 bit output, the pixel values will range from 0 to 4095.

6.7.2.2 Test Image Seven Generated with the Raw and Enhanced Raw Line Acquisition Modes

When the camera is set for a Raw or Enhanced Raw line acquisition mode (see Section 3.3 on [page 44](#) and Section 3.4 on [page 63](#)) and test image seven, a test image is formed with a fixed horizontal gray scale gradient derived from the "red" pixels. When e.g. an 8 bit output mode is selected, the gray scale gradient ranges from 0 to 255 and repeats every 512 pixels as shown in Figure 79.

The odd lines in the test image refer to the sensor lines transmitted first by the selected line acquisition mode and the even lines refer to the sensor lines transmitted second (see Section 1.6 on [page 16](#)):

- In Raw - Line A First and Enhanced Raw - Line A First line acquisition mode line A is transmitted first and line B second. Accordingly, the odd lines in the test image refer to lines A and the even lines refer to lines B.
- In Raw - Line B First and Enhanced Raw - Line B First line acquisition mode line B is transmitted first and line A second. Accordingly, the odd lines in the test image refer to lines B and the even lines refer to lines A.

In Raw - Line A First and Enhanced Raw - Line A First line acquisition mode, the gray scale gradient is restricted to the odd lines, while the even lines stay black. In Raw - Line B First and Enhanced Raw - Line B First line acquisition mode, the gray scale gradient is restricted to the even lines, while the odd lines stay black.

The lines of the test image for e.g. 8 bit output modes and Raw - Line A First or Enhanced Raw - Line A First line acquisition mode are generated in the following way (see also Figure 78, left):

- On the first cycle of the ExSync signal or the camera's internal control signal, the pixel values refer to line A. The first pixel has a red value (RA) of 0, the second pixel has a green value (GA) of 0, the third pixel has a red value of 1, the fourth pixel has a green value of 0, the fifth pixel has a red value of 2, the sixth pixel has a green value of 0, and so on.
- On the second cycle, the pixel values refer to line B. The first pixel has a green value (GB) of 0, the second pixel has a blue value (BB) of 0, the third pixel has a green value of 0, the fourth pixel has a blue value of 0, the fifth pixel has a green value of 0, the sixth pixel has a blue value of 0, and so on.
- The following odd lines are identical to the first line.
- The following even lines are identical to the second line.

RA=0	GA=0	RA=1	GA=0	RA=2	GA=0
GB=0	BB=0	GB=0	BB=0	GB=0	BB=0
RA=0	GA=0	RA=1	GA=0	RA=2	GA=0
GB=0	BB=0	GB=0	BB=0	GB=0	BB=0

GB=0	BB=0	GB=0	BB=0	GB=0	BB=0
RA=0	GA=0	RA=1	GA=0	RA=2	GA=0
GB=0	BB=0	GB=0	BB=0	GB=0	BB=0
RA=0	GA=0	RA=1	GA=0	RA=2	GA=0

Raw - Line A First and Enhanced Raw - Line A First **Raw - Line B First and Enhanced Raw - Line B First**

Fig. 78: Pixel Values in the Upper Left Corner of Test Image Seven Generated with a Raw or Enhanced Raw Line Acquisition Mode

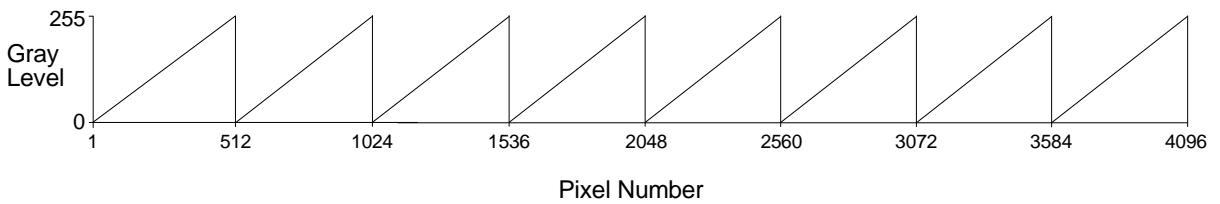



Fig. 79: Gray Scale Gradients of Test Image Seven for 8 bit Output Modes Formed by the "Red" Pixels and Generated with a Raw or Enhanced Raw Line Acquisition Mode on a Camera with 4096 Pixels Per Line



Fig. 80: Test Image Seven for 8 bit Output Modes Generated with a Raw or Enhanced Raw Line Acquisition Mode (Raw - Line A First and Enhanced Raw - Line A First as an Example) on a Camera with 4096 Pixels Per Line

Test image one is useful for checking the integrity of the data transmitted by the camera. If you capture lines and examine the pixel values in the captured lines, the values should be exactly as described above.

	<p>When the camera is set for an 8 bit output mode, the pixel values in test image seven range from 0 to 255 as described above.</p> <p>If the camera is set for a 10 bit output, the pixel values will range from 0 to 1023.</p> <p>If the camera is set for a 12 bit output, the pixel values will range from 0 to 4095.</p>
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6.7.3 Test Image Eight (Fixed Green Gradient)

6.7.3.1 Test Image Eight Generated with the RGB Line Acquisition Mode

Test image eight generated with the RGB line acquisition mode, displays a fixed horizontal green gradient. The test image is identical to test image seven generated with the RGB line acquisition mode, apart from the fact that green is shown instead of red.

6.7.3.2 Test Image Eight Generated with the Raw and Enhanced Raw Line Acquisition Modes

When the camera is set to a Raw or Enhanced Raw line acquisition mode (see Section 3.3 on [page 44](#) and Section 3.4 on [page 63](#)) and test image eight, a test image is formed with a fixed horizontal gray scale gradient derived from all "green" pixels. When e.g. an 8 bit output mode is selected, the gray scale gradient ranges from 0 to 255 and repeats every 512 pixels as shown in Figure 82.

The odd lines in the test image refer to the sensor lines transmitted first by the selected line acquisition mode and the even lines refer to the sensor lines transmitted second (see Section 1.6 on [page 16](#)):

- In Raw - Line A First and Enhanced Raw - Line A First line acquisition mode line A is transmitted first and line B second. Accordingly, the odd lines in the test image refer to lines A and the even lines refer to lines B.
- In Raw - Line B First and Enhanced Raw - Line B First line acquisition mode line B is transmitted first and line A second. Accordingly, the odd lines in the test image refer to lines B and the even lines refer to lines A.

The lines of the test image for e.g. 8 bit output modes and Raw - Line A First or Enhanced Raw - Line A First line acquisition mode are generated in the following way (see also Figure 81, left):

- On the first cycle of the ExSync signal or the camera's internal control signal, the pixel values refer to line A. The first pixel has a red value (RA) of 0, the second pixel has a green value (GA) of 0, the third pixel has a red value of 0, the fourth pixel has a green value of 1, the fifth pixel has a red value of 0, the sixth pixel has a green value of 2, and so on.
- On the second cycle, the pixel values refer to line B. The first pixel has a green value (GB) of 0, the second pixel has a blue value (BB) of 0, the third pixel has a green value of 1, the fourth pixel has a blue value of 0, the fifth pixel has a green value of 2, the sixth pixel has a blue value of 0, and so on.
- The following odd lines are identical to the first line.
- The following even lines are identical to the second line.

RA=0	GA=0	RA=0	GA=1	RA=0	GA=2
GB=0	BB=0	GB=1	BB=0	GB=2	BB=0
RA=0	GA=0	RA=0	GA=1	RA=0	GA=2
GB=0	BB=0	GB=1	BB=0	GB=2	BB=0

GB=0	BB=0	GB=1	BB=0	GB=2	BB=0
RA=0	GA=0	RA=0	GA=1	RA=0	GA=2
GB=0	BB=0	GB=1	BB=0	GB=2	BB=0
RA=0	GA=0	RA=0	GA=1	RA=0	GA=2

Raw - Line A First and Enhanced Raw - Line A First **Raw - Line B First and Enhanced Raw - Line B First**

Fig. 81: Pixel Values in the Upper Left Corner of Test Image Eight, Generated with a Raw or Enhanced Raw Line Acquisition Mode

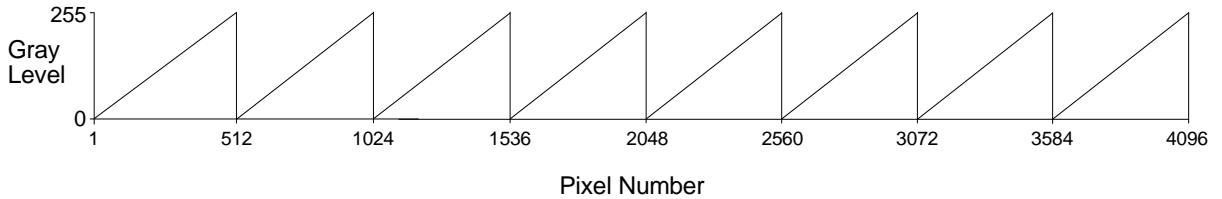



Fig. 82: Gray Scale Gradients for Test Image Eight for 8 bit Output Modes Formed by the "Green" Pixels and Generated with a Raw or Enhanced Raw Line Acquisition Mode on a Camera with 4096 Pixels Per Line



Fig. 83: Test Image Eight for 8 bit Output Modes, Generated with a Raw or Enhanced Raw Line Acquisition Mode on a Camera with 4096 Pixels Per Line

Test image one is useful for checking the integrity of the data transmitted by the camera. If you capture lines and examine the pixel values in the captured lines, the values should be exactly as described above.

	<p>When the camera is set for an 8 bit output mode, the pixel values in test image eight range from 0 to 255 as described above.</p> <p>If the camera is set for a 10 bit output, the pixel values will range from 0 to 1023.</p> <p>If the camera is set for a 12 bit output, the pixel values will range from 0 to 4095.</p>
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6.7.4 Test Image Nine (Fixed Blue Gradient)

6.7.4.1 Test Image Nine Generated with the RGB Line Acquisition Mode

Test image nine generated with the RGB line acquisition mode, displays a fixed horizontal blue gradient. The test image is identical to test image seven generated with the RGB line acquisition mode, apart from the fact that blue is shown instead of red.

6.7.4.2 Test Image Nine Generated with the Raw and Enhanced Raw Line Acquisition Modes

When the camera is set to a Raw or Enhanced Raw line acquisition mode (see Section 3.3 on [page 44](#) and Section 3.4 on [page 63](#)), and test image nine, a test image is formed with a fixed horizontal gray scale gradient derived from the "blue" pixels. When e.g. an 8 bit output mode is selected, the gray scale gradient ranges from 0 to 255 and repeats every 512 pixels as shown in Figure 85.

The odd lines in the test image refer to the sensor lines transmitted first by the selected line acquisition mode and the even lines refer to the sensor lines transmitted second (see Section 1.6 on [page 16](#)):

- In Raw - Line A First and Enhanced Raw - Line A First line acquisition mode line A is transmitted first and line B second. Accordingly, the odd lines in the test image refer to lines A and the even lines refer to lines B.
- In Raw - Line B First and Enhanced Raw - Line B First line acquisition mode line B is transmitted first and line A second. Accordingly, the odd lines in the test image refer to lines B and the even lines refer to lines A.

In Raw - Line A First and Enhanced Raw - Line A First line acquisition mode, the gray scale gradient is restricted to the even lines, while the odd lines stay black. In Raw - Line B First and Enhanced Raw - Line B First line acquisition mode, the gray scale gradient is restricted to the odd lines, while the even lines stay black.

The lines of the test image for e.g. 8 bit output modes and Raw - Line A First or Enhanced Raw - Line A First line acquisition mode are generated in the following way (see also Figure 84, left):

- On the first cycle of the ExSync signal or the camera's internal control signal, the pixel values refer to line A. The first pixel has a red value (RA) of 0, the second pixel has a green value (GA) of 0, the third pixel has a red value of 0, the fourth pixel has a green value of 0, the fifth pixel has a red value of 0, the sixth pixel has a green value of 0, and so on.
- On the second cycle, the pixel values refer to line B. The first pixel has a green value (GB) of 0, the second pixel has a blue value (BB) of 0, the third pixel has a green value of 0, the fourth pixel has a blue value of 1, the fifth pixel has a green value of 0, the sixth pixel has a blue value of 2, and so on.
- The following odd lines are identical to the first line.
- The following even lines are identical to the second line.

RA=0	GA=0	RA=0	GA=0	RA=0	GA=0
GB=0	BB=0	GB=0	BB=1	GB=0	BB=2
RA=0	GA=0	RA=0	GA=0	RA=0	GA=0
GB=0	BB=0	GB=0	BB=1	GB=0	BB=2

GB=0	BB=0	GB=0	BB=1	GB=0	BB=2
RA=0	GA=0	RA=0	GA=0	RA=0	GA=0
GB=0	BB=0	GB=0	BB=1	GB=0	BB=2
RA=0	GA=0	RA=0	GA=0	RA=0	GA=0

Raw - Line A First and Enhanced Raw - Line A First **Raw - Line B First and Enhanced Raw - Line B First**

Fig. 84: Pixel Values in the Upper Left Corner of Test Image Nine Generated with a Raw or Enhanced Raw Line Acquisition Mode

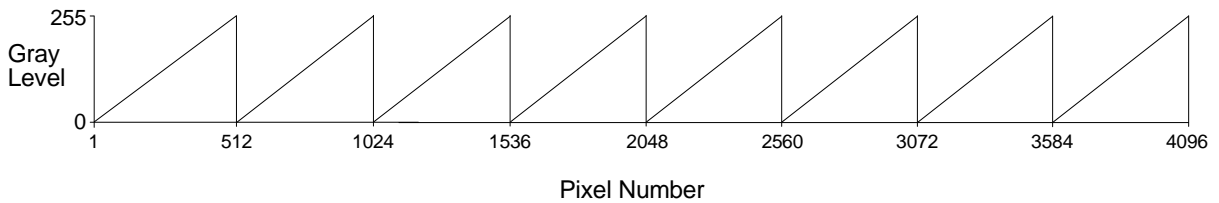



Fig. 85: Gray Scale Gradients of Test Image Nine Formed by the "Blue" Pixels for 8 bit Output Modes and Generated with a Raw or Enhanced Raw Line Acquisition Mode on a Camera with 4096 Pixels Per Line



Fig. 86: Test Image Nine for 8 bit Output Modes Generated with a Raw or Enhanced Raw Line Acquisition Mode (Raw - Line A First and Enhanced Raw - Line A First as an Example) on a Camera with 4096 Pixels Per Line

Test image one is useful for checking the integrity of the data transmitted by the camera. If you capture lines and examine the pixel values in the captured lines, the values should be exactly as described above.

	<p>When the camera is set for an 8 bit output mode, the pixel values in test image nine range from 0 to 255 as described above.</p> <p>If the camera is set for a 10 bit output, the pixel values will range from 0 to 1023.</p> <p>If the camera is set for a 12 bit output, the pixel values will range from 0 to 4095.</p>
---	---

6.8 Line Stamp

The line stamp feature provides you with information about each acquired line. For each color individually, the information includes e.g. the line counter value, the sum of the pixel values in the line, and the contrast value of the line. When the line stamp feature is enabled, 16 extra "stamp pixel" values are added for each color to the end of each transmitted line.

If the line stamp feature is used together with the AOI feature (see Section 6.3 on [page 152](#)), the stamp pixels are transmitted immediately after the last pixel in the AOI.

Each stamp pixel carries an 8, 10, or 12 bit value that conveys information about the transmitted line.



When the camera is operating in an 8 bit output mode, the stamp pixels will be 8 bit values.

When the camera is operating in a 10 bit output mode, the stamp pixels will be 10 bit values but only the 8 MSBs will carry information. The 2 LSBs will be packed with zeros.

When the camera is operating in a 12 bit output mode, the stamp pixels will be 12 bit values but only the 8 MSBs will carry information. The 4 LSBs will be packed with zeros.



Note on availability of color adjustment and line stamp features (spL8192-39kc only)

On the initial wake-up after delivery, the camera loads the factory configuration set into the work set.

In the spL8192-39kc, it depends **on the firmware version** in the camera which feature is **available** and which is **not**:

- One firmware version includes the line stamp feature.
- The other firmware version includes the color adjustment feature.

If you want your camera to wake up with the feature that is not included in the currently installed firmware, please contact Basler Technical Support.

Additional information:

All other features are available for the spL8192-39kc (exceptions, see single feature sections).

The table below lists the function of each stamp pixel. A more detailed explanation of how to interpret the pixel values follows the table.

Position	Function
S1	A fixed value of 0xAA
S2	A fixed value of 0x55 (RGB line acquisition mode: stamps relate to the red, (averaged) green or blue pixels; Raw/Enhanced Raw line acquisition mode: stamps relate to the red pixels) A fixed value of 0x56 (Raw/Enhanced Raw line acquisition mode: stamps relate to the green pixels from line A) A fixed value of 0x57 (Raw/Enhanced Raw line acquisition mode: stamps relate to the green pixels from line B) A fixed value of 0x58 (Raw/Enhanced Raw line acquisition mode: stamps relate to the blue pixels)
S3	Line Counter (LSByte)
S4	Line Counter (MSByte)
S5	Line Sum (LSByte)
S6	Line Sum (lower MidByte)
S7	Line Sum (higher MidByte)
S8	Line Sum (MSByte)
S9	Total High Pixels (LSByte)
S10	Total High Pixels (MSByte)
S11	Total Low Pixels (LSByte)
S12	Total Low Pixels (MSByte)
S13	Contrast Value (LSByte)
S14	Contrast Value (lower MidByte)
S15	Contrast Value (higher MidByte)
S16	Contrast Value (MSByte)

Table 43: Stamp Pixel Functions

Stamp Pixels S1 and S2

Stamp pixel S1 always has a fixed value of 0xAA.

If the camera is set for the RGB line acquisition mode, stamp pixel S2 will have a fixed value of 0x55. The reference of the stamp data to either red, (averaged) green or blue is obvious from the stamp pixel sequence (see above).

If the camera is set for a Raw or Enhanced Raw line acquisition mode and if the pixel values are from the red pixels (line A), stamp pixel S2 will have a fixed value of 0x55.

If the camera is set for a Raw or Enhanced Raw line acquisition mode and if the pixel values are from the green pixels from line A, stamp pixel S2 will have a fixed value of 0x56.

If the camera is set for a Raw or Enhanced Raw line acquisition mode and if the pixel values are from the green pixels from line B, stamp pixel S2 will have a fixed value of 0x57.

If the camera is set for a Raw or Enhanced Raw line acquisition mode and if the pixel values are from the blue pixels (line B), stamp pixel S2 will have a fixed value of 0x58.

S1 and S2 can be used as a data integrity check. They can also be used to find the start of the stamp pixels.

For more information about line acquisition modes, see Section 3 on [page 35](#).

Stamp Pixels S3 and S4

Stamp pixels S3 and S4 represent the least significant and most significant bytes (respectively) of the line counter. The line counter increments by one for each line captured by the camera. The counter starts at 0 and wraps at 65535 (decimal). The line counter is reset to 0 whenever the camera is switched off or reset.

Stamp Pixels S5, S6, S7, and S8

Stamp pixels S5, S6, S7, and S8 represent the least significant, lower middle, upper middle, and most significant bytes (respectively) of the line sum. The line sum is simply the total of all of the pixel values of the related color in the line.

The line sum does not include the 16 added “stamp pixels.” If the AOI feature is being used, the line sum is based only on the pixels within the AOI.

Stamp Pixels S9 and S10

Stamp pixels S9 and S10 represent the least significant and most significant bytes (respectively) of the Total High Pixels of the related color. The Total High Pixels indicates the number of pixels of the color that are above a camera parameter called the “High Pixel Threshold” (see Section 6.8.3 on [page 198](#) for information about setting this parameter).

As an example, assume that the High Pixel Threshold is set to 200. Also assume that the camera has captured a line and that 56 of the pixels of the related color in that line have a value greater than 200. In this case, the Total High Pixels in the line would be 56.

The total high pixels does not include any of the 16 added “stamp pixels.” If the AOI feature is being used, the total high pixels is based only on the pixels within the AOI.

Stamp Pixels S11 and S12

Stamp pixels S11 and S12 represent the least significant and most significant bytes (respectively) of the Total Low Pixels of the related color. The Total Low Pixels indicates the number of pixels of the color that are below a camera parameter called the “Low Pixel Threshold” (see Section 6.8.3 on [page 198](#) for information about setting this parameter).

As an example, assume that the Low Pixel Threshold is set to 100. Also assume that the camera has captured a line and that 22 of the pixels of the related color in that line have a value less than 100. In this case, the Total Low Pixels in the line would be 22.

The total low pixels does not include any of the 16 added “stamp pixels.” If the AOI feature is being used, the total low pixels is based only on the pixels within the AOI.

The total high pixel and total low pixel values are useful if you want to perform automatic gain control from within your camera control software application. If you find that the total low pixel values are increasing over a period of time, an increase in the gain setting would be appropriate. If you find that the total high pixel values are increasing over a period of time, a decrease in the gain setting would be appropriate.

Stamp Pixels S13, S14, S15, and S16

Stamp pixels S13, S14, S15, and S16 represent the least significant, lower middle, upper middle, and most significant bytes (respectively) of the line contrast. The line contrast is the sum of the difference in pixel values for each pair of successive pixels in the line for the related color. For example, for the red pixel values acquired with the RGB line acquisition mode, pairs of neighboring pixels are considered. And e.g. for the red pixel values acquired with a Raw or Enhanced Raw line acquisition mode, pairs of successive, odd-numbered pixels from line A are considered.

In mathematical terms, the line contrast is expressed in the following ways:

- Line contrast for each color, acquired with the RGB line acquisition mode. (The pixel values refer to virtual pixels.)

$$\text{Line Contrast} = \sum_{i = \text{first pixel in AOI}}^{\text{last pixel in AOI} - 1} | \text{Pixel Value}_{i+1} - \text{Pixel Value}_i |$$

- Line contrast for the red pixel values (RA) in Line A and for the green pixel values (GB) in line B (i.e. for the pixel values of odd-numbered pixels in lines A and B), acquired with a Raw or Enhanced Raw line acquisition mode:

$$\text{Line Contrast} = \sum_{i = (\text{first pixel in AOI} + 1) / 2}^{(\text{last pixel in AOI} / 2) - 1} | \text{Pixel Value}_{2i+1} - \text{Pixel Value}_{2i-1} |$$

- Line contrast for the green pixels (GA) in Line A and for the blue pixels (BB) in line B (i.e. for the pixel values of even-numbered pixels in lines A and B), acquired with a Raw or Enhanced Raw line acquisition mode:

$$\text{Line Contrast} = \sum_{i = (\text{first pixel in AOI}+1)/2}^{(\text{last pixel in AOI}/2)-1} \left| \text{Pixel Value}_{2i+2} - \text{Pixel Value}_{2i} \right|$$

The line contrast does not include any of the 16 added “stamp pixels.” The line contrast is based only on the pixels within the current AOI (see Section 6.3.1 on [page 153](#)).

Line contrast values are useful when you are adjusting the camera’s focus. Generally, the higher the line contrast value, the better the focus. Generally, the contrast value(s) for green will serve as the best measure of contrast. We recommend using the contrast value for red if red predominates in the image and using the contrast value for blue if blue predominates in the image.

6.8.1 Line Stamp with RGB Line Acquisition Mode

With RGB line acquisition mode, the transmission sequence of the stamp pixel values mimics the transmission sequence of the pixel values for the related colors. This is illustrated in Figure 87 through Figure 89.

- Stamp pixel values are transmitted on the same taps as the pixel values for the related colors. For example, when red pixel values (R) are only transmitted on the D0 tap, the related stamp pixel values (RS) will also only be transmitted on the D0 tap (see Figure 87 through Figure 89).
- When dummy pixel data are transmitted with the pixel values, the stamp pixel values will also be transmitted with dummy pixels in the same transmission pattern (see Figure 87 and Figure 89).
- When the pixel values for two colors alternate on one tap, the related stamp pixel values will alternate as well (see Figure 89 where red (R) and blue (B) pixel values alternate, as do the red (RS) and blue (BS) stamp pixel values).

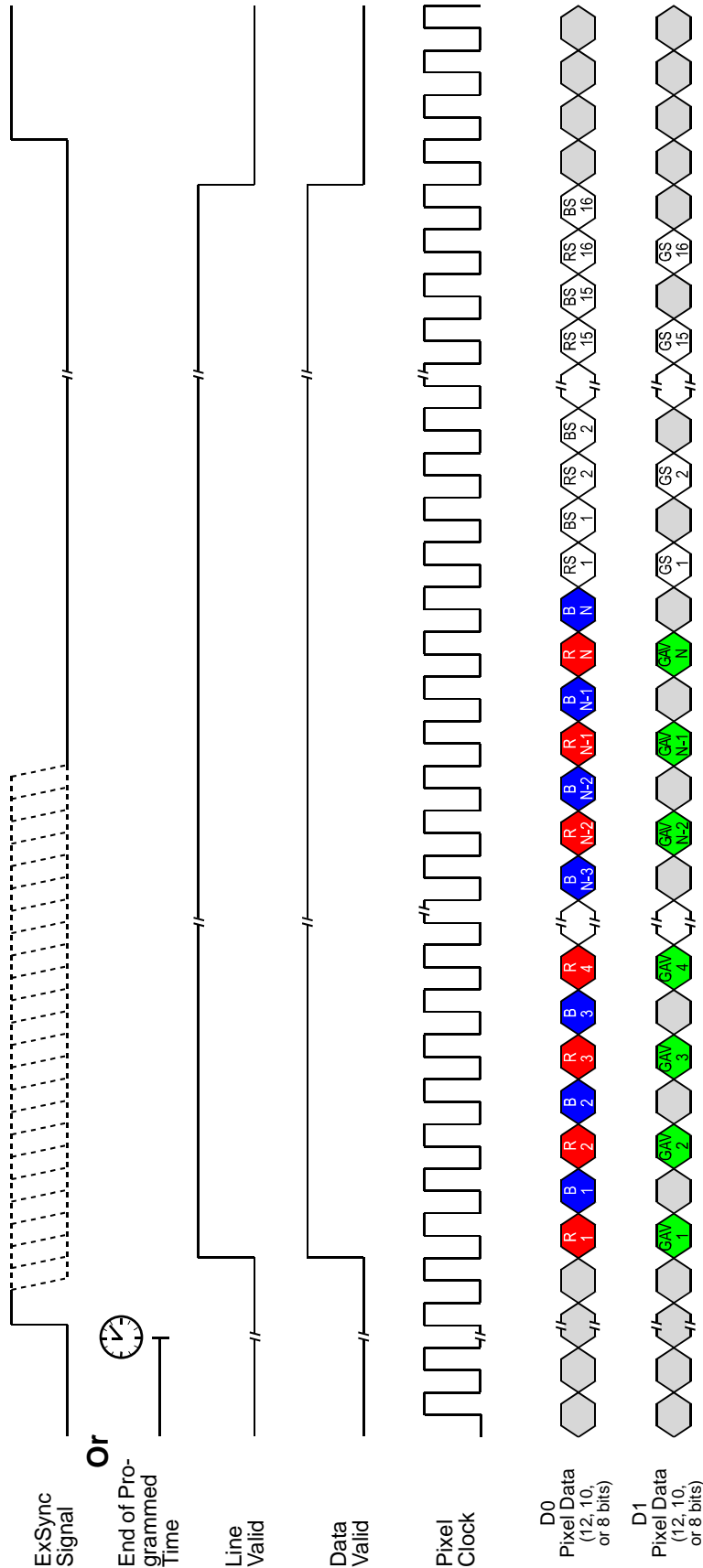


Fig. 87: Stamp Pixel Transmission with RGB Line Acquisition Mode and 2 Tap Video Data Output Mode (with Edge/Level Controlled or Programmed Exposure)

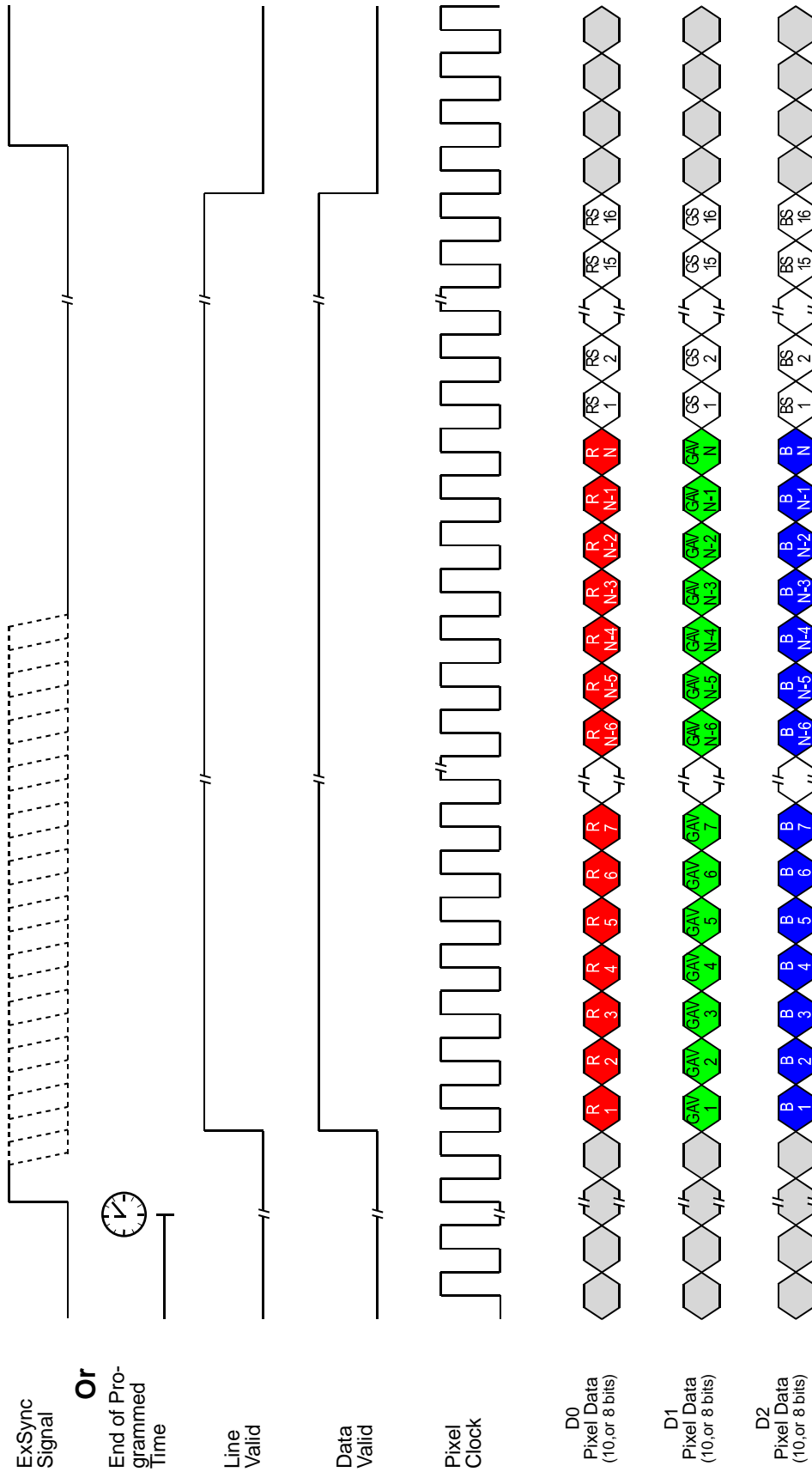


Fig. 88: Stamp Pixel Transmission with RGB Line Acquisition Mode and 3 Tap Video Data Output Mode (with Edge/Level Controlled or Programmed Exposure)

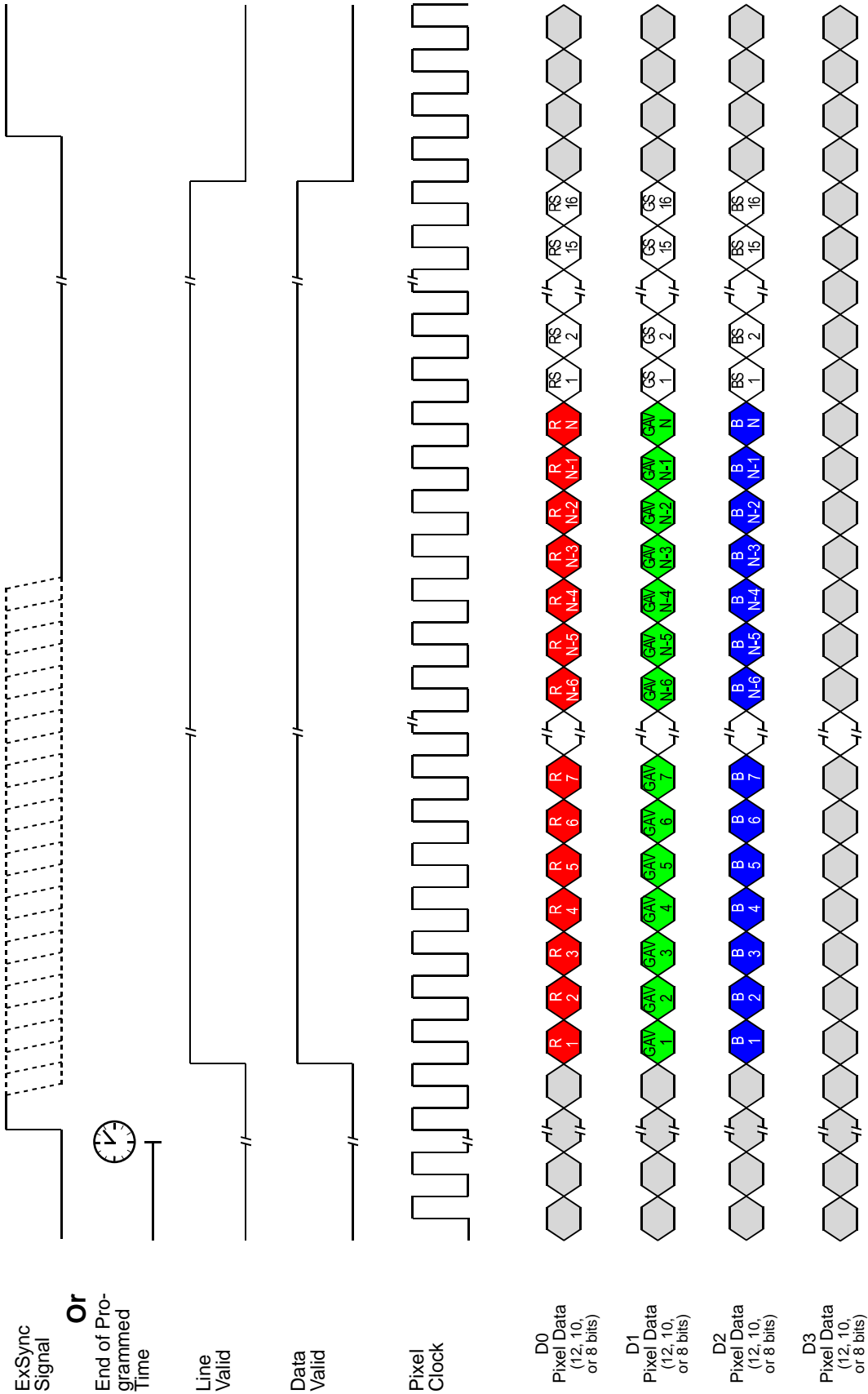


Fig. 89: Stamp Pixel Transmission with RGB Line Acquisition Mode and 4 Tap Video Data Output Mode (with Edge/Level Controlled or Programmed Exposure)

6.8.2 Line Stamp with Raw/Enhanced Raw Line Acquisition Mode

With Raw or Enhanced Raw line acquisition mode, the stamp pixel values are transmitted for each related color separately, as contiguous data streams on all available taps. This is illustrated in Figure 90 for e.g. Raw - Line A First and Enhanced Raw - Line A First line acquisition modes.

- When stamp pixel values are transmitted for line A, the stamp pixel values (RS) related to the red pixel values (RA) are transmitted on all available taps first, and the stamp pixel values (GS) related to the green pixel values (GA) are transmitted on all available taps second.
- When stamp pixel values are transmitted for line B, the stamp pixel values (GS) related to the green pixel values (GB) are transmitted on all available taps first, and the stamp pixel values (BS) related to the blue pixel values (BB) are transmitted on all available taps second.

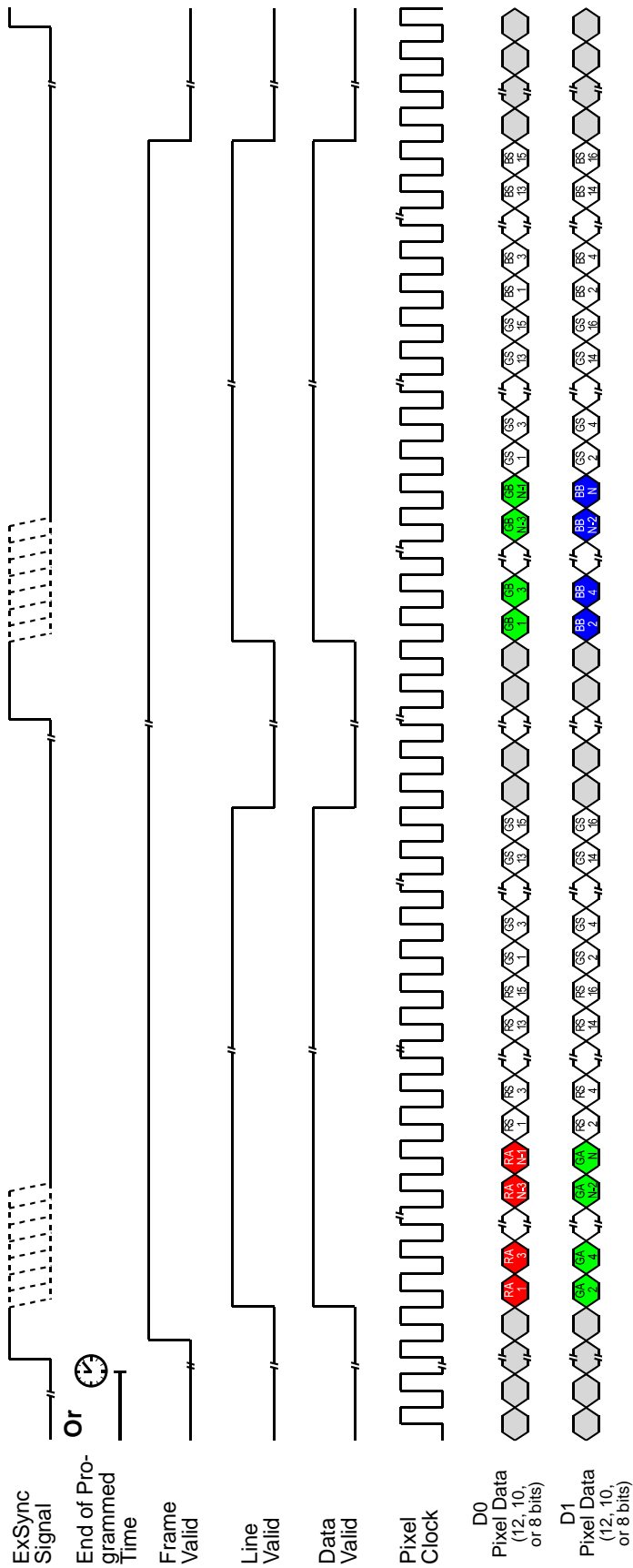


Fig. 90: Stamp Pixel Transmission with Raw - Line A First/Enhanced Raw - Line A First Line Acquisition Mode as an Example and 2 Tap Video Data Output Mode (with Edge/Level Controlled or Programmed Exposure)

6.8.3 Enabling and Setting the Line Stamp

You can enable and set the stamp feature with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Stamp Mode parameter in the Stamp parameters group to enable the stamp. You use the Stamp Low Pixel Threshold parameter and the Stamp High Pixel Threshold parameter to set the low pixel threshold and the high pixel threshold.

By Setting CSRs

You enable the stamp feature by writing the appropriate value to the Mode field of the Line Stamp Mode CSR (see Section [on page 250](#)).

You set the low pixel threshold by writing a value to the Low Pixel Threshold field in the Line Stamp Low Pixel Threshold CSR (see [page 251](#)). The set value will apply to all colors.

You set the high pixel threshold by writing a value to the High Pixel Threshold field in the Line Stamp High Pixel Threshold CSR (see [page 252](#)). The set value will apply to all colors.

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.

6.9 Lookup Table

The sensor circuitry in the camera acquires pixel data at 12 bit depth. However, when the camera is set for an 8 bit video data output format, pixel data is only output at 8 bit depth. With the camera set for an 8 bit format, it normally converts the 12 bit data output from the sensor to 8 bit data by simply truncating the least significant 4 bits.

The lookup table feature lets you create three customized tables, one each for red, green, and blue. The lookup tables can be used to map the 12 bit values output from the sensor to 8 bit values that will be transmitted from the camera. Once you have entered values into the lookup table, you can use the table to control 12 bit to 8 bit conversion rather than relying on simple truncation.



When the camera is operating in an 10 bit or 12 bit output mode and when the lookup table feature is enabled, only the 8 MSBs of the transmitted data will carry information. The 2 or 4 LSBs, respectively, will be packed with zeros.

The lookup table has 1025 indexed locations with an 8 bit value stored at each index like this:

Index	Data
0	User defined 8 bit value
4	User defined 8 bit value
8	User defined 8 bit value
12	User defined 8 bit value
16	User defined 8 bit value
•	
•	
•	
4080	User defined 8 bit value
4084	User defined 8 bit value
4088	User defined 8 bit value
4092	User defined 8 bit value
4096	User defined 8 bit value

Table 44: Lookup Table

When the lookup table feature is enabled, the camera will operate for each color in this manner:

- If the sensor reports that a pixel has a 12 bit value of 0, the 8 bit value stored at index 0 will be transmitted.
- If the sensor reports that a pixel has a 12 bit value of 4, the 8 bit value stored at index 4 will be transmitted.
- If the sensor reports that a pixel has a 12 bit value of 8, the 8 bit value stored at index 8 will be transmitted.
-
-
-
-
- If the sensor reports that a pixel has a 12 bit value of 4084, the 8 bit value stored at index 4084 will be transmitted.
- If the sensor reports that a pixel has a 12 bit value of 4088, the 8 bit value stored at index 4088 will be transmitted.
- If the sensor reports that a pixel has a 12 bit value of 4092, the 8 bit value stored at index 4092 will be transmitted.
- The value stored at index 4096 is used for interpolation.

As you can see, the table does not include a user defined 8 bit value for every 12 bit value that the sensor can report. If the sensor reports a 12 bit pixel value that does not have a corresponding defined 8 bit value, it does a straight line interpolation between the two nearest defined values. For

example, assume that the sensor reported that a certain pixel had a 12 bit value of 9. In this case, the camera would perform an interpolation between the values stored at index 8 and index 12 in the table. The result of the interpolation would then be transmitted out of the camera as an 8 bit value.

The value stored at index 4096 is only used for interpolation purposes when the sensor reports a 12 bit pixel value of 4093, 4094, or 4095.



When the lookup table feature is enabled, the lookup tables for red, green, and blue will all be active.



In the Raw and Enhanced Raw output modes, the same "green" lookup table will apply to the green pixel values from lines A and B.



If you want to use the lookup table feature, make sure to know the status of the lookup tables:

- If you entered new lookup table values for all three colors, the new values will be applied to the colors.
- If you entered new lookup table values for only one or two colors, make sure you know the kind of values residing in the unchanged lookup table(s):
 - If you are using the factory configuration set, the values output from the sensor for the color with the unchanged lookup table will be transmitted unchanged.
 - If you are using a user configuration set, the lookup table values previously stored for the user configuration set will be applied to the values output from the sensor for the color with the unchanged lookup table.

For more information about the factory configuration set and the user configuration sets, see Section 6.15 on [page 206](#).

Entering Values Into the Lookup Table

You can enter 8 bit values into the lookup table with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), entering an 8 bit value at an index in the lookup table for a color is a three step process:

1. Use the Lookup Table Selector parameter in the Lookup Table parameters group to select the lookup table that relates to the color.
2. Use the Lookup Table Index parameter in the Lookup Table parameters group to select an index in the lookup table.
3. Enter a value into the Lookup Table Value parameter in the Lookup Table parameters group. The value will be written to the index you selected in step one.

Repeat steps two and three to enter values for each index in the table.

Repeat from step one if you want to enter values for a different color.

By Setting CSRs

Entering an 8 bit value at an index in the lookup table for a color is a three step process:

1. Select the lookup table that relates to the color by writing the appropriate value to the Mode field of the Lookup Table Selector CSR (see [page 253](#)).
2. Select an index in the lookup table by writing a value to the Index field of the Lookup Table Index CSR (see [page 254](#)).
3. Write an 8 bit value to the Value field of the Lookup Table Value CSR (see [page 255](#)). The 8 bit value will be written to the lookup table index you selected in step one.

Repeat steps one and two to enter values for each index in the table.

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.

Enabling the Lookup Table Feature

You can enable the lookup table feature with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Lookup Table Enable parameter in the Lookup Table parameters group to enable the lookup table feature.

By Setting CSRs

You enable the lookup table feature by writing the appropriate value to the Mode field of the Lookup Table Mode CSR (see [page 253](#)).

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.

6.10 Imaging Sensor Temperature

The camera is equipped with a temperature sensor that lets you monitor the temperature of the imaging sensor. You can check the temperature of the imaging sensor with the Camera Configuration Tool Plus (CCT+) or by using binary read commands from within your own application to read the camera's inquiry registers.

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Sensor Temperature parameter in the Camera Information parameters group to check the temperature of the imaging sensor.

By Reading Inquiry Registers

You check the temperature of the imaging sensor by reading the Temperature field of the Imaging Sensor Temperature Inquiry Register (see [page 218](#)).

See Section 7.2.2 on [page 219](#) for an explanation of Inquiry Registers and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.



If the temperature of the imaging sensor rises above 75° C, an overtemperature error will be declared. See Section 6.12.1 on [page 203](#) for more information about overtemperature error detection.

6.11 Camera Power Undervoltage and Overvoltage Protection

The camera's nominal camera power voltage is 12 VDC ($\pm 10\%$). Do not apply a voltage less than 10.8 VDC or greater than 13.2 VDC.

The camera has camera power undervoltage protection:

- If the camera power voltage is less than but close to 9.8 VDC, a camera voltage error may be detected and if the camera voltage decreases further, the camera's internal power regulator will automatically disconnect, and the camera will no longer operate.
- When the camera power voltage is returned to the normal range, the camera will return to normal operation.

The camera also has camera power overvoltage protection up to 25 VDC:

- If the camera power voltage is between 14 and 18 VDC, a camera power voltage error will be detected (see Section 6.12.2 on [page 204](#)). The LED on the back of the camera will begin to flash red.
- If a camera power voltage between 18 and 25 VDC is applied to the camera, the camera's internal power regulator will automatically disconnect, and the camera will no longer operate.
- When the camera power voltage is returned to the normal range, the camera will return to normal operation.

Applying a camera power voltage greater than 25 VDC can seriously damage the camera.

6.12 Error Condition Detection

6.12.1 Imaging Sensor Overtemperature Condition Detected

As described in Section 6.10 on [page 202](#), the camera includes a temperature sensor that is used to monitor the temperature of the imaging sensor.

The camera also has imaging sensor overtemperature protection. If the temperature of the camera's imaging sensor rises above 75° C, an overtemperature condition will be detected and the circuitry for the imaging sensor will switch off. In this situation, you will still be able to communicate with the camera and the camera will still be able to transmit test images, however, no live images can be generated. The imaging sensor circuitry will remain off until its temperature falls below 60° C. Once the sensor temperature falls below 60° C, the error condition will clear and the camera will begin to operate normally.

You can check to see if the camera has detected an overtemperature condition with the Camera Configuration Tool Plus (CCT+) or by using binary read commands from within your own application to read the camera's inquiry registers.

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Overtemperature parameter in the Camera Information parameters group to determine if an overtemperature condition has been detected. If the value is 1, an overtemperature condition is present.

By Reading Inquiry Registers

You check for an overtemperature condition by reading the value of bit 20 in the Camera Status field of the Camera Status Inquiry Register (see [page 215](#)). If the bit is set to 1, an overtemperature condition is present.

See Section 7.2.1 on [page 213](#) for an explanation of Inquiry Registers and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.



The Overtemperature parameter in the CCT+ and bit 20 in the Camera Status field of the Camera Status Inquiry Register will be set to 1 when the camera detects an overtemperature condition. They will remain set to 1 until the condition is corrected and a reset or a power off/on is performed.

6.12.2 Camera Power Undervoltage or Overvoltage Condition Detected

The required camera power voltage for the camera is 12 VDC \pm 10%.

If a camera power voltage below but close to 9.8 VDC is applied to the camera, a camera power undervoltage condition may be detected. Similarly, if a camera power voltage between 14 and 18 VDC is applied to the camera, a camera power overvoltage condition will be detected. The LED on the back of the camera will begin to flash red. When the camera power voltage is returned to its normal range, the error condition will clear and the LED will stop flashing.

(Note that if the camera power voltage rises above 18 VDC, the camera's internal power will switch off as described in Section 6.11 on [page 202](#).)

You can check to see if the camera has detected a camera power undervoltage or overvoltage condition with the Camera Configuration Tool Plus (CCT+) or by using binary read commands from within your own application to read the camera's inquiry registers.

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Voltage Error parameter in the Camera Information parameters group to determine if a camera power undervoltage or overvoltage condition has been detected. If the value is 1, a camera power undervoltage or overvoltage condition is present.

By Reading Inquiry Registers

You check for a camera power overvoltage condition by reading the value of bit 6 in the Camera Status field of the Camera Status Inquiry Register (see [page 215](#)). If the bit is set to 1, a camera power overvoltage condition is present.

See Section 7.2.1 on [page 213](#) for an explanation of Inquiry Registers and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.



The Voltage Error parameter in the CCT+ and bit 6 in the Camera Status field of the Camera Status Inquiry Register will be set to 1 when the camera detects a camera power undervoltage or overvoltage condition. They will remain set to 1 until the condition is corrected, i.e., the camera power voltage is returned to its normal range.

Applying a camera power voltage greater than 25 VDC may seriously damage the camera. See Section 6.11 on [page 202](#) for more information.

6.13 Camera Status Checks

During operation, the camera performs a continuous series of self checks. You can view the current camera status in several ways:

- by using the Camera Configuration Tool Plus (see Section 7.1 on [page 212](#)). Check the Camera Status parameter in the Camera Information parameters group to see if any error codes are present.
- by using binary read/write commands from within your own application to read the value in the Camera Status field of the Camera Status inquiry register (see [page 215](#)).
Section 7.2.1 on [page 213](#) explains inquiry registers and Section 7.3.1 on [page 266](#) explains using read/write commands.
- by checking the LED on the back of the camera. If certain error conditions are present, the LED will flash (see Section 8.3 on [page 275](#)).

6.14 Camera Reset

You can initiate a camera reset with the Camera Configuration Tool Plus (CCT+) or by using binary write commands from within your own application to set the camera's control and status registers (CSRs). A reset is the equivalent of switching off power to the camera and switching power back on.

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), click on "Camera" in the menu at the top of the CCT+ window and a drop down list will appear. Click on "Reset Camera" in the drop down list to initiate a reset.

By Setting CSRs

You can initiate a reset by writing the appropriate value to the Reset field of the Camera Reset CSR (see [page 255](#)).

See Section 7.2.2 on [page 219](#) for an explanation of CSRs and Section 7.3.1 on [page 266](#) for an explanation of using read/write commands.



Whenever the camera is powered on or when a camera reset is performed, your computer may receive one random character on the serial interface. We recommend clearing the serial input buffers in your computer after a camera power on or reset.

6.15 Configuration Sets

A configuration set is a group of values that contains all of the parameter settings needed to control the camera. There are three basic types of configuration sets: the work configuration set, the factory configuration set, and user configuration sets.

Work Configuration Set

The work configuration set contains the camera's current parameter settings and thus determines the camera's performance. If you use the CCT+ to change the camera settings or if you change settings by writing to the camera's registers, you are making changes to the work configuration set. The work configuration set resides in the camera's volatile memory and the settings are lost if the camera is reset or if power is switched off. The work configuration set is usually just called the "work set" for short.

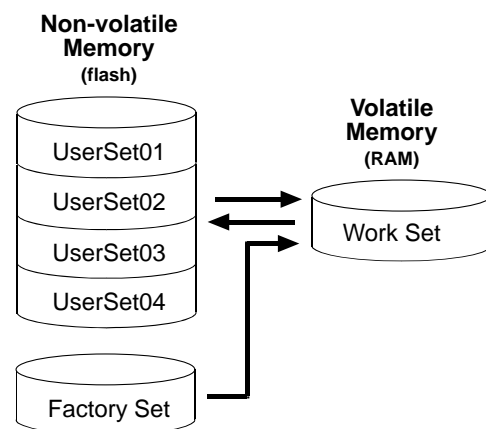


Fig. 91: Configuration Sets

Factory Configuration Set

When a camera is manufactured, a test setup is performed on the camera and an optimized configuration is determined. The factory configuration set contains the camera's factory optimized parameter settings. The factory set is saved in a permanent file in the camera's non-volatile memory. The factory set can not be altered by the user and since it is stored in non-volatile memory, it is not lost when the camera is reset or switched off. The factory configuration set is usually just called the "factory set" for short and is named *FactorySet*.

User Configuration Sets

As mentioned above, the work configuration set resides in the camera's volatile memory, and the parameters settings in the work set are lost if the camera is reset or is switched off. The camera can save the parameter settings from the current work set to a file in the camera's non-volatile memory. Files in the non-volatile memory are not lost when the camera is reset or switched off. There are four files in the camera's non-volatile memory available for holding a saved configuration set. A configuration set saved in one of these files is commonly referred to as a "user configuration set" or "user set" for short.

The four files available for holding a saved user configuration set are called UserSet01, UserSet02, UserSet03, and UserSet04. For the 8k camera, only two user sets (*UserSet01* and *UserSet02*) are available.



The configuration sets described in this section only include parameter settings and the values stored in the lookup table (see Section 6.9 on [page 198](#)).

Configuration sets do not include the values used for shading correction. Values for shading correction are stored in a different file. For more information about shading correction and shading correction values, see Section 6.4 on [page 154](#).

6.15.1 Saving the Work Set to a User Set File

As mentioned above, the work configuration set is stored in the camera's volatile memory and the parameter settings in the work set are lost if the camera is reset or if power is switched off. The camera can save the current work set values in the volatile memory to files in the camera's non-volatile memory. Files in the non-volatile memory are not lost at reset or power off. There are four files available for holding a saved user configuration set: UserSet01, UserSet02, UserSet03, and UserSet04. Saved configuration sets are commonly referred to as "user configuration sets" or "user sets."



For the 8k camera, only two user sets (*UserSet01* and *UserSet02*) are available.

Saving a User Configuration Set

You can save the current work set to one of the files in the non-volatile memory by using the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera's control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the File Name Select parameter and the Copy button in the User Set Files parameters group. Clicking the copy button will copy the work set settings to the selected user set file in the non-volatile memory.

By Setting CSRs

You can save the current work set settings to a file in the non-volatile memory by writing values to the bulk data CSR for configuration sets.

Section 7.2.3 on [page 257](#) explains the bulk data CSRs and explains how to use the CSRs to save the work set to a user set file. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.15.2 “Activating” a User Set File or the Factory Set File

As explained on [page 206](#), a factory configuration set containing an optimized set of parameters is created when the camera is manufactured. The factory set is saved in a permanent file in the camera’s non-volatile memory.

As explained on [page 207](#), you can also save up to four different "user" configuration sets to files in the camera’s non-volatile memory.

Assuming that you have saved one or more user set files, you can choose to make one of the saved user set files or the factory set file the “activated” file. When you activate a file, two things happen:

- The values from the activated file are immediately copied into the work set in the camera’s volatile memory. The camera will now actively use the configuration values that were copied into the work set.
- A link is created between the activated file and the camera’s volatile memory. The values in the activated file will automatically be copied into the work set whenever the camera is powered up or reset. (Assume, for example, that the UserSet01 file is the activated file. In this case, when the camera is powered on or reset, the values from the UserSet01 file will be copied into the volatile memory of the camera and will be the actively used parameter settings.)

You can activate a saved user set file or the factory set file by using the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera’s bulk data control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the File Name Select parameter and the Activate button in the User Set Files parameters group to activate a saved user set file or the factory set file.

By Setting CSRs

You can activate a saved user set file or the factory set file by writing values to the bulk data CSR for configuration sets. The bulk data “activate” process is used to activate a stored file.

Section 7.2.3 on [page 257](#) explains bulk data CSRs and using the bulk data activate process. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.15.3 Which Configuration Set File Will Load at Startup or at Reset?

On the initial wake-up after delivery, the camera loads the factory configuration set into the work set.

At each subsequent power on or reset, the configuration set file that was last activated is loaded into the work set.

If there is no activated file, the factory set file will be loaded into the work set.

6.15.4 Downloading Configuration Set Files to Your Computer

Once you have saved user sets to the user set files in your camera, you can download the user set files to your computer. You can also download the factory set file to your computer.

Using the download function together with the upload function that is described on the next page is useful if you want to transfer a user set file from one camera to another camera of the same type.

You can download a user set file or the factory set file by using the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera’s control and status registers (CSRs).

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the File Name Select parameter in the Configuration Set Files parameters group to select a user set file or the factory set file and use the Download button to download the selected file.

By Setting CSRs

You can download a user set file or the factory set file by writing values to the configuration set bulk data CSR. Section 7.2.3 on [page 257](#) explains the bulk data CSRs and Section 7.2.3.3 on [page 260](#) explains how to use the CSRs to download a file. Section 7.3.1 on [page 266](#) explains using read/write commands.

6.15.5 Uploading Configuration Set Files to Your Camera

Once you have downloaded user configuration set files to your computer as described on the previous page, you can upload the files from your computer to a camera.

Using the download function together with the upload function is useful if you want to transfer a user set file from one camera to another camera of the same type.

You can upload a user set file by using the Camera Configuration Tool Plus (CCT+) or by using binary read/write commands from within your own application to set the camera's control and status registers (CSRs).

Note that when you upload a user set file to your camera, you will overwrite any existing values in the camera's user set file of the same name.

With the CCT+

With the CCT+ (see Section 7.1 on [page 212](#)), you use the Upload button in the Configuration Set Files parameters group to upload a user set file. When you click the button, the CCT+ will open a window that lets you navigate to your computer and select a file.

By Setting CSRs

You can upload a user set file by writing values to the configuration set bulk data CSR. Section 7.2.3 on [page 257](#) explains the bulk data CSRs and Section 7.2.3.3 on [page 260](#) explains how to use the CSRs to upload a file. Section 7.3.1 on [page 266](#) explains using read/write commands.



The factory configuration set file can be downloaded from the camera to the computer. The factory configuration set file can't be uploaded from the computer to the camera because the factory configuration set file in the camera is protected and can't be overwritten.

7 Configuring the Camera

The camera comes with a factory set of parameters that will work properly for most applications with only minor changes. For normal operation, the following parameters are usually configured by the user:

- Video data output mode
- Line acquisition mode
- Exposure time control mode
- Exposure time (for ExSync programmable or free run programmable exposure modes)
- Line period (for free run exposure modes)

To customize operation for your particular application, the following parameters may e.g. also need to be configured:

- Gain
- Offset
- White Balance
- Area of Interest
- Stamp
- Shading correction

The camera is programmable via the RS-644 serial connection that is integrated into the Camera Link interface between the frame grabber and the camera. Two methods can be used to change the camera's parameters:

- The first and easier approach is to change the parameters using the Camera Configuration Tool Plus (CCT+). The CCT+ is especially useful during initial camera testing and the camera design in process. See Section 7.1 on [page 212](#) for more information about the configuration tool.
- You can also change the parameters directly from within your application software by using binary read/write commands to set values in the camera's registers (see Section 7.2 on [page 212](#)).

7.1 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 parameter settings. The CCT+ is especially useful during initial camera testing and the camera design in process.

The CCT+ communicates via the RS-644 serial connection that is integrated into the Camera Link interface between the frame grabber and the camera. The tool automatically generates the binary programming commands that are described in Section 7.2 on [page 212](#).

The Installation and Setup Guide for Camera Link Cameras includes detailed information about installing the CCT+ and includes instructions that describe how to use the CCT+ to change the camera's parameters. The guide is available in the downloads section of the Basler website: www.baslerweb.com.



In demo mode, the CCT+ does not cover the full functionality of the camera. We therefore recommend not to use the CCT+ in demo mode.

7.2 Configuring the Camera By Setting Registers

The camera has blocks of mapped memory space known as registers. By reading values from the registers, you can determine basic information about the camera and information about the camera's current parameter settings. By writing values to the registers, you can set camera parameters and control how the camera's features will operate. There are three types of registers in the camera:

Inquiry Registers - these registers provide basic information about the camera. Section 7.2.1 on [page 213](#) explains inquiry registers in more detail, lists the inquiry registers in the camera, and describes the function of each register.

Feature Control and Status Registers - these registers let you set the parameters associated with the camera's features. Section 7.2.2 on [page 219](#) explains feature control and status registers in more detail, lists the feature control and status registers in the camera, and describes the function of each register.

Bulk Data Control and Status Registers - these registers let you store and recall sets of values that the camera uses as a group. Section 7.2.3 on [page 257](#) explains bulk data and the bulk data control and status registers in more detail. It also lists the bulk data registers in the camera and describes the function of each register.

A special binary read/write command protocol is used to read from and write to the registers in the camera. Read and write commands are sent to the camera via the RS-644 serial link between the camera and the frame grabber. Section 7.3.1 on [page 266](#) describes the binary read/write command protocol in detail and also provides information about using the serial link. Sample code that illustrates how to use the read/write commands is available from Basler (see Section 7.4 on [page 273](#)).

7.2.1 Inquiry Registers

Inquiry registers contain basic information about the camera and information about the camera's current status. Each inquiry register contains one or more fields and each field has an assigned address within the camera's memory space. By using a binary read command, you can read the data in a field and get information about the camera.

The address for any field within a register is equal to the register base address plus the offset for the field. For example, the Vendor Information Inquiry Register (see below) has a Vendor Name field with an address of 0x0101 (the base address of 0x0100 plus an offset of 0x0001). By reading the data at address 0x0101, you can get information about the camera vendor's name.

The section starting below lists the inquiry registers in the camera and shows detailed information about the use of each field within the registers.

7.2.1.1 Inquiry Register Details

Vendor Information Inquiry

Register Base Address: 0x0100			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Vendor Name	Offset: 0x0001	Size: 20 Bytes	Type: Read only
Description: String containing the camera vendor's name. The string is zero terminated if less than 20 bytes are needed and unterminated if all 20 bytes are needed.			

Model Information Inquiry

Register Base Address: 0x0200			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Model Info	Offset: 0x0001	Size: 20 Bytes	Type: Read only
Description: String containing the camera's model number. The string is zero terminated if less than 20 bytes are needed and unterminated if all 20 bytes are needed.			

Product ID Inquiry

Register Base Address: 0x0300			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Product ID	Offset: 0x0001	Size: 20 Bytes	Type: Read only
Description: String containing the camera's product ID number. The string is zero terminated if less than 20 bytes are needed and unterminated if all 20 bytes are needed.			

Serial Number Inquiry

Register Base Address: 0x0400			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Serial Number	Offset: 0x0001	Size: 20 Bytes	Type: Read only
Description: String containing the camera's serial number. The string is zero terminated if less than 20 bytes are needed and unterminated if all 20 bytes are needed.			

Camera Version Inquiry

Register Base Address: 0x0500			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Camera Version	Offset: 0x0001	Size: 3 Bytes	Type: Read only
Description: The value in this field indicates the camera's version information. The bytes in the field are interpreted as follows: Byte 1 = Low byte of the camera version (BCD coded) Byte 2 = High byte of the camera version (BCD coded) Byte 3 = Register layout ID (BCD coded)			

Firmware Version Inquiry

Register Base Address: 0x0510			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Firmware Version	Offset: 0x0001	Size: 128 Bytes	Type: Read only
Description: String containing the camera's firmware version. The string is zero terminated if less than 128 bytes are needed and unterminated if all 128 bytes are needed.			

Camera Status Inquiry

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

Register Base Address: 0x0C00			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			

Register Base Address: 0x0C00	
Field Name: Camera Status	Offset: 0x0001 Size: 4 Bytes Type: Read only
Description: Each bit in this field specifies an error condition (see table below). Bit 0 is the least significant bit. 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.	
Bit	Description
0	Reserved
1	The camera is busy performing an internal operation (such as generating shading values).
2	A reset has occurred.
3	Parameter error. For example, a parameter has been set to a value that is out of range or not allowed. A black image is produced (all pixel values are equal to zero).
4	A user set load has failed.
5	A file operation has failed.
6	A camera power undervoltage or overvoltage condition is present (see Section 6.12.2 on page 204).
7	A binary read/write command protocol error has been detected. For more information about the error, read the Binary Command Protocol Status Inquiry Register (see page 218). This bit is auto-cleared on read.
8 ... 15	Reserved
16	An FPGA not ready error has occurred. For more information about the error, read the FPGA Status Inquiry register (see page 217). This bit clears when you read the FPGA Status Inquiry register.
17	A trigger error has occurred. Either the maximum allowed line rate has been exceeded or the ExSync signal is missing. For more information about the error, read the FPGA Status Inquiry register (see page 217). This bit clears when you read the FPGA Status inquiry register.
18	Reserved
19	The last shading value generation process failed. The DSNU shading value generation process can fail if the pixel values in the lines captured during the generation process are too high. (This process should be performed in darkness or in very low light conditions.) The PRNU shading value generation process can fail if the values for the darkest pixels in the captured lines are less than 1/2 of the values for the highest pixels. This problem is often caused by extremely non-uniform lighting or by poor quality optics. This bit will clear when you perform a successful shading value generation process.
20	An overtemperature condition is present (see Section 6.12.1 on page 203).
21	Low line rate compensation activity (1=active, 0=inactive, see Section 4.1.3 on page 95).
22	An internal overvoltage condition is present (see Section 8.3 on page 275).
23 ... 31	Reserved

FPGA Status Inquiry

The camera has been programmed to detect several error conditions in its field programmable gate array (FPGA). When an error condition is detected, a flag is set. The FPGA status inquiry register allows you to read the error flags.

Register Base Address: 0x0C10			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: FPGA Status	Offset: 0x0001	Size: 1 Byte	Type: Read only
Description: Each bit in this field (except bit 7) specifies an error condition (see table below). Bit 0 is the least significant bit. 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.			
Bit	Description		
0	No FPGA firmware available.		
1	FPGA firmware is available, but the firmware has failed to load.		
2	The camera's maximum line rate has been exceeded. (Note: If you are operating the camera in ExSync programmable mode and you trigger the camera faster than allowed, the camera will automatically ignore any trigger signals that would cause a max line rate exceeded condition and this bit will not be set.)		
3	There is no ExSync signal.		
4	Reserved		
5	Reserved		
6	Reserved		
7	Reserved		
	Low line rate compensation activity (1=active, 0=inactive, see Section 4.1.3 on page 95).		

Binary Command Protocol Status Inquiry

The camera has been programmed to detect several errors in the format of any binary commands received by the camera. When an error condition is detected, a flag is set. The binary command status inquiry register allows you to read the error flags.

Register Base Address: 0x0C30			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Binary Command Status	Offset: 0x0001	Size: 1 Byte	Type: Read only
Description: Each bit in this field specifies an error condition (see table below). Bit 0 is the least significant bit. 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.			
Bit	Description		
0	A binary command with no BFS was received (see Section 7.3.1 on page 266).		
1	A byte timeout has occurred (see Section 7.3.1.1 on page 269).		
2	A binary command with an invalid OpCode was received (see Section 7.3.1 on page 266).		
3	A binary command with no BFE was received (see Section 7.3.1 on page 266).		
4	A binary command with an incorrect BCC was received (see Section 7.3.1 on page 266).		
5	A binary command with an address error was received (see Section 7.3.1 on page 266).		
6	Reserved		
7	An unknown error has occurred.		

Imaging Sensor Temperature Inquiry

Register Base Address: 0x2710			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this inquiry register: 0x00 = The register is not available 0x01 = The register is available			
Field Name: Temperature	Offset: 0x0001	Size: 4 Bytes	Type: Read only
Description: The value in this field indicates the temperature of the imaging sensor in °C. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			

7.2.2 Feature Control and Status Registers

The feature control and status registers (CSRs) let you set the parameters for camera features such as exposure mode, gain, offset, and the AOI. These registers also let you check the current parameter settings and the status for each feature.

Each feature has one or more CSRs associated with it. The fields within a feature's CSR(s) are used to control how the feature operates. By using binary write commands to write to fields within a feature's CSR(s), you can change the parameter settings for the feature. By using binary read commands, you can determine the current setting for the parameters and get information about the feature's status.

The address for any field within a register is equal to the register base address plus the offset for the field. Look at the Video Data Output Mode CSR on [page 228](#) as an example. The Mode field of this register has an address of 0x1701 (the base address of 0x1700 plus the offset of 0x0001). By writing a value to this address, you can set the video data output mode. By reading the value at this address, you can determine the current output mode setting.

The Video Data Output Mode CSR is a simple CSR with only two fields. Most of the other feature CSRs have several read/write fields that let you set the parameters associated with the feature. They may also have read only fields that contain information about the minimum and maximum allowed setting for each parameter. Section 7.2.2.2 on [page 220](#) lists the feature CSRs in the camera and shows detailed information about the use of each field within the register.

7.2.2.1 “Raw” Value Fields vs. “Absolute” Value Fields

As you look through the descriptions of the feature CSRs, you will notice that some CSRs have a parameter that can be set by writing a value to a “raw” field or by writing a value to an “absolute” field. You will find this to be true for the Exposure Time, Line Period, Gain, and Offset parameters. The common characteristic among these parameters is that they are “scalar”, i.e., they can be set to a value within a continuous scale rather than just a small set of individually defined values. Any one of these scalar parameters can be set on a “raw” scale or on an “absolute” scale. A raw scale is simply a range of integer values that has no defined units. An absolute scale is a range of floating point values that has defined units.

Consider the Gain parameter as an example:

Setting the Raw Gain

If you set the gain by writing a value to the Raw Gain field of the Gain CSR, you can write any integer value from 2731 to 16383 (decimal). Writing an integer value to the raw register sets the gain, but it doesn't directly tell you how many dB of gain you will be getting from the camera at that setting. To determine the dB of gain you are getting at a particular raw gain setting, you must use the formula:

$$\text{Gain in dB} = 20 \times \log_{10} \left(\frac{\text{setting}}{4096} \right)$$

Setting the Absolute Gain

If you set the gain by writing a value to the Absolute Gain field of the Gain CSR, you can write a floating point value from -3.5 to +12.04 (decimal) in increments of 0.01. Writing a floating point value to the absolute register sets the gain directly in dB. For example, if the absolute gain field is set to 3.42, then the camera would be set for 3.42 dB of gain.



You do not need to set both the raw field and the absolute field. Setting just one of the fields is sufficient and you can choose to set whichever field best suits your needs.

7.2.2.2 Feature Control and Status Register Details

Camera Link Clock Speed CSR

Register Base Address: 0x3900			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Clock Speed	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the clock speed for the Camera Link interface: 0x06 = 40 MHz clock speed 0x0e = 80 MHz clock speed See Section 2.8.5 on page 32 for more information about the camera link clock speed.			

Video Data Output Mode CSR

Register Base Address: 0x1700			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the video data output mode: 0x01 = 2 Tap 8 Bit Mode 0x03 = 2 Tap 10 Bit Mode 0x05 = 2 Tap 12 Bit Mode 0x08 = 3 Tap 8 Bit Mode 0x10 = 4 Tap 8 Bit Mode 0x11 = 8 Tap 8 Bit Mode 0x12 = 4 Tap 10 Bit Mode 0x13 = 4 Tap 12 Bit Mode 0x30 = 6 Tap 8 Bit Mode 0x32 = 3 Tap 10 Bit Mode See Chapter 5 on page 108 for a description of the video data output modes.			

Line Acquisition Mode CSR

Register Base Address: 0x3600			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the line acquisition mode: 0x10 = RGB 0x16 = Raw - Line A First 0x17 = Raw - Line B First 0x18 = Enhanced Raw - Line B First (A Delayed) 0x19 = Enhanced Raw - Line A First (B Delayed) See Chapter 3 on page 35 for a description of the line acquisition modes.			

Low Line Rate Compensation CSR

Register Base Address: 0x4500			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the low line rate compensation mode: 0x00 = Low line rate compensation disabled 0x01 = Low line rate compensation enabled See Section 4.1.3 on page 95 for more information about the low line rate compensation mode.			

FVAL Length CSR

Register Base Address: 0x4200			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Length	Offset: 0x0001	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer to this field sets a number of consecutive lines and during the transmission of those lines the frame valid (FVAL) signal will remain high. The value can be set to 0 or to an even integer, e.g. 2, 4, 6, and so on. For example, if the value is set to 2, the FVAL signal will stay high during the transmission of two consecutive lines. If the value is set to 0, the FVAL signal will stay low throughout. The allowed range for this value can vary depending on how the camera is configured. You should check the min, max, and increment fields of this register to determine the allowed range and increment with the current configuration. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the length setting Byte 2 = High byte of the length setting See Section 2.8.1 on page 31 for more information about the FVAL signal.			
Field Name: Min	Offset: 0x0003	Size: 2 Bytes	Type: Read only
Description: Minimum allowed integer value for the FVAL length setting. This field is updated to reflect limitations caused by the way any related features are set. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the min value Byte 2 = High byte of the min value			

Register Base Address: 0x4200			
Field Name: Max	Offset: 0x0005	Size: 2 Bytes	Type: Read only
Description: Maximum allowed integer value for the FVAL length setting. This field is updated to reflect limitations caused by the way any related features are set. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the max value Byte 2 = High byte of the max value			
Field Name: Increment	Offset: 0x0007	Size: 2 Bytes	Type: Read only
Description: An integer value indicating the increment for the FVAL length setting. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the increment Byte 2 = High byte of the increment			

Exposure Time Control Mode CSR

Register Base Address: 0x1400			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the exposure time control mode: 0x00 = Free run, programmable 0x02 = Free run, edge controlled 0x04 = ExSync. level controlled 0x05 = ExSync, programmable 0x06 = ExSync, edge controlled See Section 4.1 on page 92 for a description of the exposure time control modes.			

Exposure Time CSR

Note: The exposure time can be set by writing a floating point value to the Absolute Exposure Time field or by writing an integer value to the Raw Exposure Time field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

Register Base Address: 0x1500			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Exposure Time	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the exposure time in μs . For example, if the value in this field is set to 5.2, the exposure time will be 5.2 μs . The allowed range for the exposure time can vary depending on the camera model and how the camera is configured. You should check the absolute min and absolute max fields of this register to determine the allowed range with the current configuration. The increment is 0.1. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Chapter 4 on page 92 for more information about exposure time.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute exposure time setting. This field is updated to reflect limitations caused by the way that any related features are set. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute exposure time setting. This field is updated to reflect limitations caused by the way that any related features are set. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Raw Exposure Time	Offset: 0x000D	Size: 4 Bytes	Type: Read/Write
Description: Writing an integer value to this field sets the exposure time. The allowed range for this value can vary depending on the camera model and how the camera is configured. You should check the raw min and raw max fields of this register to determine the allowed range with the current configuration. The integer value represents a multiplier, and the actual exposure time is equal to the value in this field times 0.1 μs . For example, if the value in this field is set to 1200, then: Exposure Time = 1200 x 0.1 μs Exposure Time = 120 μs The bytes in this field are interpreted as follows: Byte 1 = Low byte of the raw value Byte 2 = Mid byte of the raw value Byte 3 = High byte of the raw value Byte 4 = Always 0 (not used)			

Field Name: Raw Min	Offset: 0x0011	Size: 4 Bytes	Type: Read only
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Description: Minimum allowed integer value for the raw exposure time setting. This field is updated to reflect limitations caused by the way that any related fields are set.

The bytes in this field are interpreted as follows:

- Byte 1 = Low byte of the min value
- Byte 2 = Mid byte of the min value
- Byte 3 = High byte of the min value
- Byte 4 = Always 0 (not used)

Field Name: Raw Max	Offset: 0x0015	Size: 4 Bytes	Type: Read only
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Description: Maximum allowed integer value for the raw exposure time setting. This field is updated to reflect limitations caused by the way that any related fields are set.

The bytes in this field are interpreted as follows:

- Byte 1 = Low byte of the max value
- Byte 2 = Mid byte of the max value
- Byte 3 = High byte of the max value
- Byte 4 = Always 0x00 (not used)

Line Period CSR

Note: The line period can be set by writing a floating point value to the Absolute Line Period field or by writing an integer value to the Raw Line Period field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

Register Base Address: 0x1600			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Line Period	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the line period in μs . For example, if the value in this field is set to 180.6, the line period will be 180.6 μs . The allowed range for the absolute line period can vary depending on the camera model and how the camera is configured. You should check the absolute min and absolute max fields of this register to determine the allowed range with the current configuration. The increment is 0.1. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Section 4.2 on page 97 for more information about the line period.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute line period setting. This field is updated to reflect limitations caused by the way that any related features are set. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute line period setting. This field is updated to reflect limitations caused by the way that any related features are set. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Raw Line Period	Offset: 0x000D	Size: 4 Bytes	Type: Read/Write
Description: Writing an integer value to this field sets the line period. The allowed range for this value can vary depending on the camera model and how the camera is configured. You should check the raw min and raw max fields of this register to determine the allowed range with the current configuration. The integer value represents a multiplier, and the line period is equal to the value in this field times 0.1 μs . For example, if the value in this field is set to 1500, then: Line Period = 1500 x 0.1 μs Exposure Time = 150 μs The bytes in this field are interpreted as follows: Byte 1 = Low byte of the raw value Byte 2 = Mid byte of the raw value Byte 3 = High byte of the raw value Byte 4 = Always 0 (not used)			

Field Name: Raw Min	Offset: 0x0011	Size: 4 Bytes	Type: Read only
Description: Minimum allowed integer value for the raw line period setting. This field is updated to reflect limitations caused by the way that any related fields are set.			
The bytes in this field are interpreted as follows:			
Byte 1 = Low byte of the min value			
Byte 2 = Mid byte of the min value			
Byte 3 = High byte of the min value			
Byte 4 = Always 0 (not used)			
Field Name: Raw Max	Offset: 0x0015	Size: 4 Bytes	Type: Read only
Description: Maximum allowed integer value for the raw line period setting. This field is updated to reflect limitations caused by the way that any related fields are set.			
The bytes in this field are interpreted as follows:			
Byte 1 = Low byte of the max value			
Byte 2 = Mid byte of the max value			
Byte 3 = High byte of the max value			
Byte 4 = Always 0x00 (not used)			

Gain CSR

Note: The gain can be set by writing a floating point value to the Absolute Gain field or by writing an integer value to the Raw Gain field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

Register Base Address: 0x0E00			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Gain	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the gain in dB. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Section 6.1 on page 145 for more information about gain.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute gain setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute gain setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Raw Gain	Offset: 0x000D	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer value to this field sets the gain. The dB of gain that the camera will achieve at a given setting is determined by the formula shown in Section 6.1 on page 145 . The bytes in this field are interpreted as follows: Byte 1 = Low byte of the raw value Byte 2 = High byte of the raw value			
Field Name: Raw Min	Offset: 0x000F	Size: 2 Bytes	Type: Read only
Description: Minimum allowed integer value for the raw gain setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the min value Byte 2 = High byte of the min value			
Field Name: Raw Max	Offset: 0x0011	Size: 2 Bytes	Type: Read only
Description: Maximum allowed integer value for the raw gain setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the max value Byte 2 = High byte of the max value			

Offset CSR

Note: The offset can be set by writing a floating point value to the Absolute Offset field or by writing an integer value to the Raw Offset field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

Register Base Address: 0x0F00			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Offset	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field directly sets the offset in DN (digital numbers). For example, if you set this value to +5.00, you would increase the digital values output from the camera by 5. The allowed range for the absolute offset can vary depending on how the camera is configured. You should check the absolute min and absolute max fields of this register to determine the allowed range with the current configuration. The increment is 0.01. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Section 6.1 on page 145 for more information about offset.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute offset setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute offset setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			

Field Name: Raw Offset	Offset: 0x000D	Size: 2 Bytes	Type: Read/Write
<p>Description: Writing an integer value to this field sets the offset.</p> <p>The allowed range for this value can vary depending on how the camera is configured. You should check the raw min and raw max fields of this register to determine the allowed range with the current configuration.</p> <p>The DN of offset that the camera will apply is determined as follows:</p> <p>If the camera is set for an 8 bit video data output mode, increasing the integer value by 16 will increase the digital values output from the camera by 1 and decreasing the integer value by 16 will decrease the digital values output from the camera by 1.</p> <p>If the camera is set for a 10 bit video data output mode, increasing the integer value by 4 will increase the digital values output from the camera by 1 and decreasing the integer value by 4 will decrease the digital values output from the camera by 1.</p> <p>If the camera is set for a 12 bit video data output mode, increasing the integer value by 1 will increase the digital values output from the camera by 1 and decreasing the integer value by 1 will decrease the digital values output from the camera by 1.</p> <p>The bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the raw value</p> <p>Byte 2 = High byte of the raw value</p>			
Field Name: Raw Min	Offset: 0x000F	Size: 2 Bytes	Type: Read only
<p>Description: Minimum allowed integer value for the raw gain setting.</p> <p>The bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the min value</p> <p>Byte 2 = High byte of the min value</p>			
Field Name: Raw Max	Offset: 0x0011	Size: 2 Bytes	Type: Read only
<p>Description: Maximum allowed integer value for the raw gain setting.</p> <p>The bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the max value</p> <p>Byte 2 = High byte of the max value</p>			

Gain Red CSR

Note: The gain specifically for the red pixels can be set by writing a floating point value to the Absolute Gain Red field or by writing an integer value to the Raw Gain Red field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

Register Base Address: 0x0E80			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Gain Red	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the gain in dB. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Section 6.1 on page 145 for more information about gain red.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute gain red setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute gain red setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Raw Gain Red	Offset: 0x000D	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer value to this field sets the gain for the red pixels. The dB of gain red that the camera will achieve at a given setting is determined by the formula shown in Section 6.2 on page 148 . The bytes in this field are interpreted as follows: Byte 1 = Low byte of the raw value Byte 2 = High byte of the raw value			
Field Name: Raw Min	Offset: 0x000F	Size: 2 Bytes	Type: Read only
Description: Minimum allowed integer value for the raw gain red setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the min value Byte 2 = High byte of the min value			
Field Name: Raw Max	Offset: 0x0011	Size: 2 Bytes	Type: Read only
Description: Maximum allowed integer value for the raw gain red setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the max value Byte 2 = High byte of the max value			

Gain Green CSR

Note: The gain specifically for the green pixels can be set by writing a floating point value to the Absolute Gain Green field or by writing an integer value to the Raw Gain Green field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

If Gain Green 2 is

- not enabled, the register settings relate to sensor lines A **and** B.
- enabled, register settings relate **only** to sensor line A.

Register Base Address: 0x0EA0			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Gain Green	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the gain in dB. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Section 6.2 on page 148 for more information about gain green.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute gain green setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute gain green setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Raw Gain Green	Offset: 0x000D	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer value to this field sets the gain for the green pixels. The dB of gain green that the camera will achieve at a given setting is determined by the formula shown in Section 6.2 on page 148 . The bytes in this field are interpreted as follows: Byte 1 = Low byte of the raw value Byte 2 = High byte of the raw value			
Field Name: Raw Min	Offset: 0x000F	Size: 2 Bytes	Type: Read only

Register Base Address: 0x0EA0

Description: Minimum allowed integer value for the raw gain green setting.

The bytes in this field are interpreted as follows:

Byte 1 = Low byte of the min value

Byte 2 = High byte of the min value

Field Name: Raw Max

Offset: 0x0011

Size: 2 Bytes

Type: Read only

Description: Maximum allowed integer value for the raw gain green setting.

The bytes in this field are interpreted as follows:

Byte 1 = Low byte of the max value

Byte 2 = High byte of the max value

Gain Blue CSR

Note: The gain specifically for the blue pixels can be set by writing a floating point value to the Absolute Gain Blue field or by writing an integer value to the Raw Gain Blue field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

Register Base Address: 0x0EC0			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Gain Blue	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the gain in dB. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Section 6.2 on page 148 for more information about gain blue.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute gain blue setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute gain blue setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Raw Gain Blue	Offset: 0x000D	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer value to this field sets the gain for the blue pixels. The dB of gain blue that the camera will achieve at a given setting is determined by the formula shown in Section 6.2 on page 148 . The bytes in this field are interpreted as follows: Byte 1 = Low byte of the raw value Byte 2 = High byte of the raw value			
Field Name: Raw Min	Offset: 0x000F	Size: 2 Bytes	Type: Read only
Description: Minimum allowed integer value for the raw gain blue setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the min value Byte 2 = High byte of the min value			
Field Name: Raw Max	Offset: 0x0011	Size: 2 Bytes	Type: Read only
Description: Maximum allowed integer value for the raw gain blue setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the max value Byte 2 = High byte of the max value			

Gain Green 2 CSR

Note: The gain specifically for the green pixels of sensor line B can be set by writing a floating point value to the Absolute Gain Green 2 field or by writing an integer value to the Raw Gain Green 2 field. See Section 7.2.2.1 on [page 219](#) for an explanation of the difference between these two fields.

If Gain Green 2 is enabled (using the Gain Green 2 Enable CSR), the settings in the Gain Green CSR will only relate to sensor line A.

Register Base Address: 0x4600			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Gain Green 2	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the gain for the green pixels in line B in dB. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Section 6.2 on page 148 for more information about gain green.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute gain green 2 setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute gain green 2 setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Raw Gain Green 2	Offset: 0x000D	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer value to this field sets the gain for the green pixels in line B. The dB of gain green 2 that the camera will achieve at a given setting is determined by the formula shown in Section 6.2 on page 148 . The bytes in this field are interpreted as follows: Byte 1 = Low byte of the raw value Byte 2 = High byte of the raw value			
Field Name: Raw Min	Offset: 0x000F	Size: 2 Bytes	Type: Read only
Description: Minimum allowed integer value for the raw gain green 2 setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the min value Byte 2 = High byte of the min value			
Field Name: Raw Max	Offset: 0x0011	Size: 2 Bytes	Type: Read only
Description: Maximum allowed integer value for the raw gain green 2 setting. The bytes in this field are interpreted as follows: Byte 1 = Low byte of the max value Byte 2 = High byte of the max value			

Gain Green 2 Enable CSR

Register Base Address: 0x4613			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1Byte	Type: Read/Write
Description: Writing an integer to this field sets the gain green 2. 0x00 = Gain Green 2 is disabled (default). 0x01 = Gain Green 2 is enabled.			

Area of Interest Starting Pixel CSR

Register Base Address: 0x1000			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
<p>Description: The integer value in this field indicates the status of this control and status register:</p> <p>0x00 = The register is not available</p> <p>0x01 = The register is available and all related settings are OK</p> <p>0x80 = A value in the register is set out of range</p>			
Field Name: Starting Pixel	Offset: 0x0001	Size: 2 Bytes	Type: Read/Write
<p>Description: Writing an integer to this field sets the starting pixel for the area of interest (AOI) feature. The area of interest starting pixel can be set to a minimum of 1.</p> <p>If the RGB line acquisition mode is selected, the area of interest starting pixel can be set in increments of 16.</p> <p>If the Raw line acquisition mode or the Enhanced Raw line acquisition mode is selected, the area of interest starting pixel can be set in increments of 32.</p> <p>If the value for the area of interest starting pixel is set to 1, the starting pixel for the AOI will be 1. If the value is set to 33, the starting pixel for the AOI will be 33. And so on.</p> <p>The allowed range for this value can vary depending on how the area of interest length parameter is set. You should check the raw min and raw max fields of this register to determine the allowed range with the current configuration.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the starting pixel value</p> <p>Byte 2 = High byte of the starting pixel value</p> <p>See Section 6.3 on page 152 for more information about the AOI feature.</p>			
Field Name: Min	Offset: 0x0003	Size: 2 Bytes	Type: Read only
<p>Description: Minimum allowed integer value for the starting pixel setting. This field is updated to reflect limitations caused by the way any related features are set.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the min value</p> <p>Byte 2 = High byte of the min value</p>			
Field Name: Max	Offset: 0x0005	Size: 2 Bytes	Type: Read only
<p>Description: Maximum allowed integer value for the starting pixel setting. This field is updated to reflect limitations caused by the way any related features are set.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the max value</p> <p>Byte 2 = High byte of the max value</p>			
Field Name: Increment	Offset: 0x0007	Size: 2 Bytes	Type: Read only
<p>Description: An integer value indicating the increment for the starting pixel setting.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the increment</p> <p>Byte 2 = High byte of the increment</p>			

Area of Interest Length CSR

Register Base Address: 0x100A			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
<p>Description: The integer value in this field indicates the status of this control and status register:</p> <ul style="list-style-type: none"> 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range 			
Field Name: Length	Offset: 0x0001	Size: 2 Bytes	Type: Read/Write
<p>Description: Writing an integer to this field sets the length in pixels for the area of interest (AOI) feature. The area of interest length can be set to a minimum of 256 and increased in increments of 32. If the value is set to 256, the length of the AOI will be 256. If the value is set to 288, the length of the AOI will be 288. And so on.</p> <p>The allowed range for this value can vary depending on how the area of interest starting pixel parameter is set. You should check the raw min and raw max fields of this register to determine the allowed range with the current configuration.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <ul style="list-style-type: none"> Byte 1 = Low byte of the length setting Byte 2 = High byte of the length setting <p>See Section 6.3 on page 152 for more information about the AOI feature.</p>			
Field Name: Min	Offset: 0x0003	Size: 2 Bytes	Type: Read only
<p>Description: Minimum allowed integer value for the AOI length setting. This field is updated to reflect limitations caused by the way any related features are set.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <ul style="list-style-type: none"> Byte 1 = Low byte of the min value Byte 2 = High byte of the min value 			
Field Name: Max	Offset: 0x0005	Size: 2 Bytes	Type: Read only
<p>Description: Maximum allowed integer value for the AOI length setting. This field is updated to reflect limitations caused by the way any related features are set.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <ul style="list-style-type: none"> Byte 1 = Low byte of the max value Byte 2 = High byte of the max value 			
Field Name: Increment	Offset: 0x0007	Size: 2 Bytes	Type: Read only
<p>Description: An integer value indicating the increment for the AOI length setting.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <ul style="list-style-type: none"> Byte 1 = Low byte of the increment Byte 2 = High byte of the increment 			

Shading Value Generate CSR

Register Base Address: 0x2100			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x02 = The generation process failed 0x80 = A value in the register is set out of range			
Field Name: Generate	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the shading correction mode: 0x00 = No generation 0x01 = Generate DSNU correction values 0x02 = Generate PRNU correction values and do not use DSNU correction during generation 0x03 = Generate PRNU correction values and use DSNU correction during generation See Section 6.4 on page 154 for more information about the shading correction feature.			

Gamma CSR

Register Base Address: 0x4300			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Absolute Gamma	Offset: 0x0001	Size: 4 Bytes	Type: Read/Write
Description: Writing a floating point value to this field sets the gamma correction value. For example, if the value in this field is set to 1.5259, the gamma correction value will be 1.5259. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number. See Chapter 6.5 on page 164 for more information about gamma correction.			
Field Name: Absolute Min	Offset: 0x0005	Size: 4 Bytes	Type: Read only
Description: Minimum allowed floating point value for the absolute gamma setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			
Field Name: Absolute Max	Offset: 0x0009	Size: 4 Bytes	Type: Read only
Description: Maximum allowed floating point value for the absolute gamma setting. The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.			

Register Base Address: 0x4300			
Field Name: Raw Gamma	Offset: 0x000D	Size: 4 Bytes	Type: Read/Write
<p>Description: Writing an integer value to this field sets the gamma correction value.</p> <p>The value represents a multiplier, and the actual gamma correction value is equal to the value in this field times 65536 (i.e. 0x10000). For example, if the value in this field is set to 2, then:</p> <p style="padding-left: 40px;">Gamma = 65536 x 2</p> <p style="padding-left: 40px;">Gamma = 131072</p> <p>The bytes in this field are interpreted as follows:</p> <p style="padding-left: 40px;">Byte 1 = Low byte of the raw value</p> <p style="padding-left: 40px;">Byte 2 = Mid byte of the raw value</p> <p style="padding-left: 40px;">Byte 3 = High byte of the raw value</p> <p style="padding-left: 40px;">Byte 4 = Always 0 (not used)</p> <p>The value in this field is a standard IEEE-754 single precision (32 bit) floating point number.</p>			
Field Name: Raw Min	Offset: 0x0011	Size: 4 Bytes	Type: Read only
<p>Description: Minimum allowed integer value for the raw gamma setting.</p> <p>The bytes in this field are interpreted as follows:</p> <p style="padding-left: 40px;">Byte 1 = Low byte of the min value</p> <p style="padding-left: 40px;">Byte 2 = Mid byte of the min value</p> <p style="padding-left: 40px;">Byte 3 = High byte of the min value</p> <p style="padding-left: 40px;">Byte 4 = Always 0 (not used)</p>			
Field Name: Raw Max	Offset: 0x0015	Size: 4 Bytes	Type: Read only
<p>Description: Maximum allowed integer value for the raw gamma setting.</p> <p>The bytes in this field are interpreted as follows:</p> <p style="padding-left: 40px;">Byte 1 = Low byte of the max value</p> <p style="padding-left: 40px;">Byte 2 = Mid byte of the max value</p> <p style="padding-left: 40px;">Byte 3 = High byte of the max value</p> <p style="padding-left: 40px;">Byte 4 = Always 0x00 (not used)</p>			

Color Adjustment CSR

Register Base Address: 0x4400			
Field Name: Enable Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the color adjustment CSR. 0x00 = Color adjustment is not available 0x01 = Color adjustment is available			
Field Name: Enable Value	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this enable enumeration field sets the Enable Value: 0x00 = Color adjustment disabled 0x01 = Color adjustment enabled See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Enable Bitmap Size	Offset: 0x0002	Size: 1 Byte	Type: Read only
Description: An integer value indicating the size of the Enable Bitmap field in bytes.			
Field Name: Enable Bitmap	Offset: 0x0003	Size: 1 Byte	Type: Read only
Description: The bit positions in this field indicate the available values for the enable enumeration field.			
Field Name: Saturation Red Status	Offset: 0x0005	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the saturation adjustment for red: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Saturation Red Value	Offset: 0x0006	Size: 1 Byte	Type: Read/Write
Description: Writing an integer value to this field sets the saturation value of red for predominantly red colors in the image. If the saturation red value is set to 64 the saturation of red will not be changed. Setting the value to less than 64 will decrease the saturation. If, for example the value is set to 32 the saturation of red will be halved. If the value is set to 0, the saturation of red is zero and red will not be present in the image. Setting the value to greater than 64 will increase the saturation. If, for example the value is set to 128 the saturation of red will be doubled. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Saturation Red Min	Offset: 0x0007	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the saturation red value setting.			
Field Name: Saturation Red Max	Offset: 0x0008	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the saturation red value setting.			
Field Name: Saturation Red Increment	Offset: 0x0009	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the saturation red value setting.			

Register Base Address: 0x4400			
Field Name: Hue Red Status	Offset: 0x000A	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the hue adjustment for red: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Hue Red Value	Offset: 0x000B	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the hue value of red for predominantly red colors in the image. The hue red value can be set to a minimum of -128 and can be increased to a maximum of +127. If the hue red value is set to a negative number, red will be mixed with yellow. If the hue red value is set to a positive number, red will be mixed with magenta. If the hue red value is set to -128 (corresponding to a rotation in negative direction by 60° in the color hexagon), red will be completely transformed into yellow. If the value is set to +127 (corresponding to a rotation in positive direction by 60° in the color hexagon), red will be completely transformed into magenta. If the value is set to 0, red will not be changed. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Hue Red Min	Offset: 0x000C	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the hue red value setting.			
Field Name: Hue Red Max	Offset: 0x000D	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the hue red value setting.			
Field Name: Hue Red Increment	Offset: 0x000E	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the hue red value setting.			
Field Name: Saturation Yellow Status	Offset: 0x000F	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the saturation adjustment for yellow: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Saturation Yellow Value	Offset: 0x0010	Size: 1 Byte	Type: Read/Write
Description: Writing an integer value to this field sets the saturation value of yellow for predominantly yellow colors in the image. If the saturation yellow value is set to 64 the saturation of yellow will not be changed. Setting the value to less than 64 will decrease the saturation. If, for example the value is set to 32 the saturation of yellow will be halved. If the value is set to 0, the saturation of yellow is zero and yellow will not be present in the image. Setting the value to greater than 64 will increase the saturation. If, for example the value is set to 128 the saturation of yellow will be doubled. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Saturation Yellow Min	Offset: 0x0011	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the saturation yellow value setting.			
Field Name: Saturation Yellow Max	Offset: 0x0012	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the saturation yellow value setting.			

Register Base Address: 0x4400			
Field Name: Saturation Yellow Increment	Offset: 0x0013	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the saturation yellow value setting.			
Field Name: Hue Yellow Status	Offset: 0x0014	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the hue adjustment for yellow: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Hue Yellow Value	Offset: 0x0015	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the hue value of yellow for predominantly yellow colors in the image. The hue yellow value can be set to a minimum of -128 and can be increased to a maximum of +127. If the hue yellow value is set to a negative number, yellow will be mixed with green. If the hue yellow value is set to a positive number, yellow will be mixed with red. If the hue yellow value is set to -128 (corresponding to a rotation in negative direction by 60° in the color hexagon), yellow will be completely transformed into green. If the value is set to +127, yellow will be completely transformed into red. If the value is set to 0, yellow will not be changed. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Hue Yellow Min	Offset: 0x0016	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the hue yellow value setting.			
Field Name: Hue Yellow Max	Offset: 0x0017	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the hue yellow value setting.			
Field Name: Hue Yellow Increment	Offset: 0x0018	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the hue yellow value setting.			
Field Name: Saturation Green Status	Offset: 0x0019	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the saturation adjustment for green: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Saturation Green Value	Offset: 0x001A	Size: 1 Byte	Type: Read/Write
Description: Writing an integer value to this field sets the saturation value of green for predominantly green colors in the image. If the saturation green value is set to 64 the saturation of green will not be changed. Setting the value to less than 64 will decrease the saturation. If, for example the value is set to 32 the saturation of green will be halved. If the value is set to 0, the saturation of green is zero and green will not be present in the image. Setting the value to greater than 64 will increase the saturation. If, for example the value is set to 128 the saturation of green will be doubled. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Saturation Green Min	Offset: 0x001B	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the saturation green value setting.			

Register Base Address: 0x4400			
Field Name: Saturation Green Max	Offset: 0x001C	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the saturation green value setting.			
Field Name: Saturation Green Increment	Offset: 0x001D	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the saturation green value setting.			
Field Name: Hue Green Status	Offset: 0x001E	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the hue adjustment for green: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Hue Green Value	Offset: 0x001F	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the hue value of green for predominantly green colors in the image. The hue green value can be set to a minimum of -128 and can be increased to a maximum of +127. If the hue green value is set to a negative number, green will be mixed with cyan. If the hue green value is set to a positive number, green will be mixed with yellow. If the hue green value is set to -128 (corresponding to a rotation in negative direction by 60° in the color hexagon), green will be completely transformed into cyan. If the value is set to +127 (corresponding to a rotation in positive direction by 60° in the color hexagon), green will be completely transformed into yellow. If the value is set to 0, green will not be changed. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Hue Green Min	Offset: 0x0020	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the hue green value setting.			
Field Name: Hue Green Max	Offset: 0x0021	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the hue green value setting.			
Field Name: Hue Green Increment	Offset: 0x0022	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the hue green value setting.			
Field Name: Saturation Cyan Status	Offset: 0x0023	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the saturation adjustment for cyan: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			

Register Base Address: 0x4400			
Field Name: Saturation Cyan Value	Offset: 0x0024	Size: 1 Byte	Type: Read/Write
<p>Description: Writing an integer value to this field sets the saturation value of cyan for predominantly cyan colors in the image.</p> <p>If the saturation cyan value is set to 64 the saturation of cyan will not be changed.</p> <p>Setting the value to less than 64 will decrease the saturation. If, for example the value is set to 32 the saturation of cyan will be halved. If the value is set to 0, the saturation of cyan is zero and cyan will not be present in the image.</p> <p>Setting the value to greater than 64 will increase the saturation. If, for example the value is set to 128 the saturation of cyan will be doubled.</p> <p>See Section 6.6.1 on page 166 for more information about the color adjustment feature.</p>			
Field Name: Saturation Cyan Min	Offset: 0x0025	Size: 1 Byte	Type: Read only
<p>Description: Minimum allowed integer value for the saturation cyan value setting.</p>			
Field Name: Saturation Cyan Max	Offset: 0x0026	Size: 1 Byte	Type: Read only
<p>Description: Maximum allowed integer value for the saturation cyan value setting.</p>			
Field Name: Saturation Cyan Increment	Offset: 0x0027	Size: 1 Byte	Type: Read only
<p>Description: An integer value indicating the increment for the saturation cyan value setting.</p>			
Field Name: Hue Cyan Status	Offset: 0x0028	Size: 1 Byte	Type: Read only
<p>Description: The integer value in this field indicates the status of the hue adjustment for cyan:</p> <p>0x00 = The adjustment is not available</p> <p>0x01 = The adjustment is available and all related settings are OK</p>			
Field Name: Hue Cyan Value	Offset: 0x0029	Size: 1 Byte	Type: Read/Write
<p>Description: Writing an integer to this field sets the hue value of cyan for predominantly cyan colors in the image.</p> <p>The hue cyan value can be set to a minimum of -128 and can be increased to a maximum of +127.</p> <p>If the hue cyan value is set to a negative number, cyan will be mixed with blue. If the hue cyan value is set to a positive number, cyan will be mixed with green.</p> <p>If the hue cyan value is set to -128 (corresponding to a rotation in negative direction by 60° in the color hexagon), cyan will be completely transformed into blue. If the value is set to +127 (corresponding to a rotation in positive direction by 60° in the color hexagon), cyan will be completely transformed into green. If the value is set to 0, cyan will not be changed.</p> <p>See Section 6.6.1 on page 166 for more information about the color adjustment feature.</p>			
Field Name: Hue Cyan Min	Offset: 0x002A	Size: 1 Byte	Type: Read only
<p>Description: Minimum allowed integer value for the hue cyan value setting.</p>			
Field Name: Hue Cyan Max	Offset: 0x002B	Size: 1 Byte	Type: Read only
<p>Description: Maximum allowed integer value for the hue cyan value setting.</p>			
Field Name: Hue Cyan Increment	Offset: 0x002C	Size: 1 Byte	Type: Read only
<p>Description: An integer value indicating the increment for the hue cyan value setting.</p>			

Register Base Address: 0x4400			
Field Name: Saturation Blue Status	Offset: 0x002D	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the saturation adjustment for blue: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Saturation Blue Value	Offset: 0x002E	Size: 1 Byte	Type: Read/Write
Description: Writing an integer value to this field sets the saturation value of blue for predominantly blue colors in the image. If the saturation blue value is set to 64 the saturation of blue will not be changed. Setting the value to less than 64 will decrease the saturation. If, for example the value is set to 32 the saturation of blue will be halved. If the value is set to 0, the saturation of blue is zero and blue will not be present in the image. Setting the value to greater than 64 will increase the saturation. If, for example the value is set to 128 the saturation of blue will be doubled. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Saturation Blue Min	Offset: 0x002F	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the saturation blue value setting.			
Field Name: Saturation Blue Max	Offset: 0x0030	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the saturation blue value setting.			
Field Name: Saturation Blue Increment	Offset: 0x0031	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the saturation blue value setting.			
Field Name: Hue Blue Status	Offset: 0x0032	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the hue adjustment for blue: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Hue Blue Value	Offset: 0x0033	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the hue value of blue for predominantly blue colors in the image. The hue blue value can be set to a minimum of -128 and can be increased to a maximum of +127. If the hue blue value is set to a negative number, blue will be mixed with magenta. If the hue blue value is set to a positive number, blue will be mixed with cyan. If the hue blue value is set to -128 (corresponding to a rotation in negative direction by 60° in the color hexagon), blue will be completely transformed into magenta. If the value is set to +127 (corresponding to a rotation in positive direction by 60° in the color hexagon), blue will be completely transformed into cyan. If the value is set to 0, blue will not be changed. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Hue Blue Min	Offset: 0x0034	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the hue blue value setting.			
Field Name: Hue Blue Max	Offset: 0x0035	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the hue blue value setting.			

Register Base Address: 0x4400			
Field Name: Hue Blue Increment	Offset: 0x0036	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the hue blue value setting.			
Field Name: Saturation Magenta Status	Offset: 0x0037	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the saturation adjustment for magenta: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Saturation Magenta Value	Offset: 0x0038	Size: 1 Byte	Type: Read/Write
Description: Writing an integer value to this field sets the saturation value of magenta for predominantly magenta colors in the image. If the saturation magenta value is set to 64 the saturation of magenta will not be changed. Setting the value to less than 64 will decrease the saturation. If, for example the value is set to 32 the saturation of magenta will be halved. If the value is set to 0, the saturation of magenta is zero and magenta will not be present the image. Setting the value to greater than 64 will increase the saturation. If, for example the value is set to 128 the saturation of magenta will be doubled. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			
Field Name: Saturation Magenta Min	Offset: 0x0039	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the saturation magenta value setting.			
Field Name: Saturation Magenta Max	Offset: 0x003A	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the saturation magenta value setting.			
Field Name: Saturation Magenta Increment	Offset: 0x003B	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the saturation magenta value setting.			
Field Name: Hue Magenta Status	Offset: 0x003C	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of the hue adjustment for magenta: 0x00 = The adjustment is not available 0x01 = The adjustment is available and all related settings are OK			
Field Name: Hue Magenta Value	Offset: 0x003D	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the hue value of magenta for predominantly magenta colors in the image. The hue magenta value can be set to a minimum of -128 and can be increased to a maximum of +127. If the hue magenta value is set to a negative number, magenta will be mixed with red. If the hue magenta value is set to a positive number, magenta will be mixed with blue. If the hue magenta value is set to -128 (corresponding to a rotation in negative direction by 60° in the color hexagon), magenta will be completely transformed into red. If the value is set to +127 (corresponding to a rotation in positive direction by 60° in the color hexagon), magenta will be completely transformed into blue. If the value is set to 0, magenta will not be changed. See Section 6.6.1 on page 166 for more information about the color adjustment feature.			

Register Base Address: 0x4400			
Field Name: Hue Magenta Min	Offset: 0x003E	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for the hue magenta value setting.			
Field Name: Hue Magenta Max	Offset: 0x003F	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for the hue magenta value setting.			
Field Name: Hue Magenta Increment	Offset: 0x0040	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for the hue magenta value setting.			

Test Image Mode CSR

Register Base Address: 0x1800			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the test image mode: 0x00 = Test images disabled 0x02 = Test image 2 enabled (moving gray gradient) 0x07 = Test image 7 enabled (fixed red gradient) 0x08 = Test image 8 enabled (fixed green gradient) 0x09 = Test image 9 enabled (fixed blue gradient) See Section 6.7 on page 174 for more information about the test image feature.			

Line Stamp Mode CSR

Register Base Address: 0x2B00			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the line stamp mode: 0x00 = Line stamp off 0x01 = Line stamp on See Section 6.8 on page 188 for more information about the line stamp feature.			

Line Stamp Low Pixel Threshold CSR

Register Base Address: 0x2B20			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Low Pixel Threshold	Offset: 0x0001	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer to this field sets the low pixel threshold for the line stamp feature. The set low pixel threshold will apply to all colors. When the camera is set for 8 bit output, you should set the low pixel threshold within a range from 0 (0x0000) to 255 (0x00FF). When the camera is set for 10 bit output, you should set the low pixel threshold within a range from 0 (0x0000) to 1023 (0x03FF). When the camera is set for 12 bit output, you should set the low pixel threshold within a range from 0 (0x0000) to 4095 (0x0FFF). The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the low pixel threshold Byte 2 = High byte of the low pixel threshold See Section 6.8 on page 188 for more information about the line stamp feature and the low pixel threshold.			
Field Name: Min	Offset: 0x0003	Size: 2 Bytes	Type: Read only
Description: Minimum allowed integer value for the low pixel threshold. This field is updated to reflect limitations caused by the way any related features are set. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the min value Byte 2 = High byte of the min value			
Field Name: Max	Offset: 0x0005	Size: 2 Bytes	Type: Read only
Description: Maximum allowed integer value for the low pixel threshold. This field is updated to reflect limitations caused by the way any related features are set. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the max value Byte 2 = High byte of the max value			
Field Name: Increment	Offset: 0x0007	Size: 2 Bytes	Type: Read only
Description: An integer value indicating the increment for the low pixel threshold setting. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the increment Byte 2 = High byte of the increment			

Line Stamp High Pixel Threshold CSR

Register Base Address: 0x2B40			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
<p>Description: The integer value in this field indicates the status of this control and status register:</p> <p>0x00 = The register is not available</p> <p>0x01 = The register is available and all related settings are OK</p> <p>0x80 = A value in the register is set out of range</p>			
Field Name: High Pixel Threshold	Offset: 0x0001	Size: 2 Bytes	Type: Read/Write
<p>Description: Writing an integer to this field sets the high pixel threshold for the line stamp feature. The set high pixel threshold will apply to all colors.</p> <p>When the camera is set for 8 bit output, you should set the high pixel threshold within a range from 0 (0x0000) to 255 (0x00FF).</p> <p>When the camera is set for 10 bit output, you should set the high pixel threshold within a range from 0 (0x0000) to 1023 (0x03FF).</p> <p>When the camera is set for 12 bit output, you should set the high pixel threshold within a range from 0 (0x0000) to 4095 (0x0FFF).</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the high pixel threshold</p> <p>Byte 2 = High byte of the high pixel threshold</p> <p>See Section 6.8 on page 188 for more information about the line stamp feature and the high pixel threshold.</p>			
Field Name: Min	Offset: 0x0003	Size: 2 Bytes	Type: Read only
<p>Description: Minimum allowed integer value for the high pixel threshold. This field is updated to reflect limitations caused by the way any related features are set.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the min value</p> <p>Byte 2 = High byte of the min value</p>			
Field Name: Max	Offset: 0x0005	Size: 2 Bytes	Type: Read only
<p>Description: Maximum allowed integer value for the high pixel threshold. This field is updated to reflect limitations caused by the way any related features are set.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the max value</p> <p>Byte 2 = High byte of the max value</p>			
Field Name: Increment	Offset: 0x0007	Size: 2 Bytes	Type: Read only
<p>Description: An integer value indicating the increment for the high pixel threshold setting.</p> <p>The 2 bytes in this field are interpreted as follows:</p> <p>Byte 1 = Low byte of the increment</p> <p>Byte 2 = High byte of the increment</p>			

Lookup Table Mode CSR

Register Base Address: 0x4100			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the lookup table mode: 0x00 = Lookup tables disabled 0x01 = Lookup tables enabled See Section 6.9 on page 198 for more information about the lookup table feature.			

Lookup Table Selector CSR

Register Base Address: 0x4104			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Mode	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field selects either the red, green or blue lookup table: 0x01 = Red lookup table enabled for entering values at selected indices 0x02 = Green lookup table enabled for entering values at selected indices 0x03 = Blue lookup table enabled for entering values at selected indices See Section 6.9 on page 198 for more information about the lookup table feature.			

Lookup Table Index CSR

Register Base Address: 0x4108			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Lookup Table Index	Offset: 0x0001	Size: 2 Bytes	Type: Read/Write
Description: Writing an integer to this field selects an index in the lookup table currently selected in the lookup table selector CSR. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the lookup table index Byte 2 = High byte of the lookup table index See Section 6.9 on page 198 for more information about the lookup table feature.			
Field Name: Min	Offset: 0x0003	Size: 2 Bytes	Type: Read only
Description: Minimum allowed integer value for the index of the currently selected lookup table. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the min value Byte 2 = High byte of the min value			
Field Name: Max	Offset: 0x0005	Size: 2 Bytes	Type: Read only
Description: Maximum allowed integer value for the index of the currently selected lookup table. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the max value Byte 2 = High byte of the max value			
Field Name: Increment	Offset: 0x0007	Size: 2 Bytes	Type: Read only
Description: An integer value indicating the increment for the index of the currently selected lookup table. The 2 bytes in this field are interpreted as follows: Byte 1 = Low byte of the increment Byte 2 = High byte of the increment			

Lookup Table Value CSR

Register Base Address: 0x4111			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Lookup Table Value	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field enters a value into the currently selected lookup table at the index currently specified by the lookup table index CSR. See Section 6.9 on page 198 for more information about the lookup table feature.			
Field Name: Min	Offset: 0x0002	Size: 1 Byte	Type: Read only
Description: Minimum allowed integer value for a value of the currently selected lookup table.			
Field Name: Max	Offset: 0x0003	Size: 1 Byte	Type: Read only
Description: Maximum allowed integer value for a value of the currently selected lookup table.			
Field Name: Increment	Offset: 0x0004	Size: 1 Byte	Type: Read only
Description: An integer value indicating the increment for a value of the selected currently lookup table.			

Camera Reset CSR

Register Base Address: 0x0B00			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Reset	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer value of 1 (0x01) to this field will initiate a camera reset. The reset behavior of the camera is similar to power up behavior.			

Serial Communication CSR

An RS-644 serial connection is integrated into the Camera Link interface between the frame grabber installed in your computer and the camera. The serial connection is used to issue commands to the camera for changing modes and parameters. You can use the serial communication CSR to set the bitrate for the camera's RS-644 serial port.

The default setting is 9600 bps.

The setting is changed immediately after the successful receipt of this command.

Register Base Address: 0x0D00			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Bitrate	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field sets the bit rate: 0x0F = 9600 bps (default) 0x11 = 19200 bps 0x12 = 38400 bps 0x13 = 57600 bps 0x14 = 115200 bps See Section 2.9.1 on page 34 and Section 7.3 on page 265 for more information about serial communication.			



When changing a setting for serial communication, use the following procedure:

1. Issue the write command with the new setting.
2. Wait one second.
3. Change the setting on the frame grabber's RS-644 serial port.
4. Resume communication.

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.

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

7.2.3 Bulk Data and the Bulk Data Control and Status Registers

The term “bulk data” refers to a collection of values used by the camera as a block. A configuration set (see Section 6.15 on [page 206](#)) is an example of one type of bulk data. A single configuration set contains values for all of the normal parameter settings needed to configure the camera and the values within a configuration set are used by the camera as a block. A set of shading values (see Section 6.4 on [page 154](#)) is an examples of another type of bulk data. The set of shading values contains all of the values needed to do shading correction, and the camera uses the shading values as a block.

The camera has a file system similar to the file system used on computers. The camera can store blocks of bulk data such as a configuration set or the set of shading values in named files within the camera’s non-volatile memory. The camera’s bulk data control and status registers (CSRs) are used to save blocks of bulk data to files in the non-volatile memory. For example, you can use the configuration set bulk data control register to store the settings from the current work configuration set in a named file.

For sprint cameras, there are two types of bulk data: configuration sets and shading values. There is a separate bulk data control and status register for each type of bulk data. The configuration set bulk data CSR is used to work with configuration sets, the shading value CSR is used to work with shading values.

By writing to fields within a bulk data CSR you can do things such as saving a block of bulk data to a file in the non-volatile memory, copying a saved bulk data file from the camera to a computer and creating a list of existing saved bulk data files. Section 7.2.3.4 on [page 263](#) lists the bulk data CSRs and provides a general description of the use of each field within the registers.

The best way to understand the use of the bulk data CSRs is to read about the different tasks that you can perform with them. Section 7.2.3.1 on [page 258](#) describes the tasks and procedures that are normally performed by manipulating the Configuration Set Bulk Data CSR. Section 7.2.3.2 on [page 259](#) describes the tasks and procedures that are normally performed by manipulating the Shading Values Bulk Data CSR.

7.2.3.1 Using the Configuration Set Bulk Data CSR

Saving the Work Configuration Set to a User Set File

As described in Section 6.15 on [page 206](#), the work configuration set resides in the camera's volatile memory. Assume that you want to save the parameter values in the current work set to the *UserSet01* file in the camera's non-volatile memory. To do so, you would follow this procedure:

1. Use a binary write command to write the file name *UserSet01* to the Name field of the configuration set bulk data CSR (see [page 263](#)).
2. Use a binary write command to set the value of the Control field of the configuration set bulk data CSR to 0x06. Setting the value to 0x06 initiates a copy function.

This procedure will copy the current work set settings from the camera's volatile memory into a file called *UserSet01* in the non-volatile memory. Note that any existing data in the file will be overwritten.

Sample code that illustrates how to save a bulk data file is available from Basler (see [Section 7.4 on page 273](#)).



There are four files available in the non-volatile memory to hold saved user configuration sets: *UserSet01*, *UserSet02*, *UserSet03*, or *UserSet04*. You must use one of these file names when you save a user configuration set.

Activating a User Set File or the Factory Set File

The process of “activating” a user set file or the factory set file, accomplishes two things:

- The values from the activated file are immediately copied into the work set in the camera's volatile memory. The camera will now actively use the configuration values that were copied into the work set.
- A link is created between the activated file and the camera's volatile memory. The values in the activated file will automatically be copied into the work set whenever the camera is powered up or reset.

As an example, assume that you have saved a configuration set to the *UserSet01* file and that you want to activate this file. To do so, you would follow this procedure:

1. Use a binary write command to write the file name *UserSet01* to the Name field of the configuration set bulk data CSR (see [page 263](#)).
2. Use a binary write command to set the value of the Control field in the configuration set bulk data CSR to 0x05. Setting the value to 0x05 initiates an activate function.

This procedure would find the *UserSet01* file in the non-volatile memory and would copy the values in the file into the camera's volatile memory. It would also create a link to the file so that the values in the file would be loaded into volatile memory after a reset or a power up.

If you want to activate the factory set, you would follow a similar procedure but use *FactorySet* as the file name.

Sample code that illustrates how to activate a saved bulk data file is available from Basler (see Section 7.4 on [page 273](#)).

7.2.3.2 Using the Shading Values Bulk Data CSR

Activating the User Shading Values File or the Factory Shading Values File

The process of “activating” the user shading value file or the factory shading value file, accomplishes two things:

- It copies the values from the file into the camera’s volatile memory. This means that the values will now be actively used by the camera.
- It creates a link to the activated file. If the camera is reset or if it is powered off and then back on, the shading values from the activated file will be loaded into volatile memory of the camera and actively used by the camera when shading correction is enabled.

As an example, assume that you have generated user shading values and that you want to activate the user shading values file. To do so, you would follow this procedure:

1. Use a binary write command to write the file name *UserShading* to the Name field of the shading value bulk data CSR (see [page 264](#)).
2. Use a binary write command to set the value of the Control field in the shading value bulk data CSR to 0x05. Setting the value to 0x05 initiates an activate function.

This procedure would find the *Usershading* file in the non-volatile memory and would copy the values in the file into the camera’s volatile memory. It would also create a link to the file so that the values in the file would be loaded into volatile memory after a reset or a power up.

If you want to activate the factory shading value file, you would follow a similar procedure but use *FactoryShading* as the file name.

Sample code that illustrates how to activate a saved bulk data file is available from Basler (see Section 7.4 on [page 273](#)).

Copying the Factory Shading Values File into the User Shading Values File

Assume that you want to copy the shading values in the factory shading values file into the user shading values file. To do so, you would follow this procedure:

1. Use a binary write command to write the file name *UserShading* to the Name field of the shading value bulk data CSR (see [page 264](#)).
2. Use a binary write command to set the value of the Control field of the configuration set bulk data CSR to 0x06. Setting the value to 0x06 initiates a copy function.

This procedure will copy the contents of the factory shading values file into the user shading values file. Note that any existing data in the user shading values file will be overwritten.

Sample code that illustrates how to create a bulk data file is available from Basler (see Section 7.4 on [page 273](#)).

7.2.3.3 General Procedures for Working with Bulk Data CSRs

Enumerating Bulk Data Files

Bulk data file enumeration allows you to look through a list of the bulk data files that currently contain saved parameters.

As an example, assume that you want to see a list of all of the configuration set files that currently contains saved parameters. To do so, you would follow this procedure:

1. Use a binary write command to set the value of the Control field in the configuration set bulk data CSR (see [page 263](#)) to 0x00. Setting the value to 0x00 initiates an enumerate function.
2. Use a binary read command to read the Name field of the configuration set bulk data CSR. This is the name of a configuration set file that contains saved data.
3. Use a binary read command to read the value in the Info field of the configuration set bulk data CSR.
 - a. If the value is 0x00, it means that the file contains saved parameters and it is not an activated file. Continue to step 4.
 - b. If the value is 0x04, it means that the file contains saved parameters and it is an activated file. Continue to step 4.
 - c. If the value is 0x01 no more configuration set files with saved parameters exist. Exit the procedure.
4. Use a binary write command to set the value of the Control field in the configuration set bulk data CSR to 0x01. Setting the value to 0x01 initiates an enumerate next function.
5. Return to step 2.

This procedure would list all of the configuration set bulk data files that contain a saved parameter set.

If you wanted to enumerate the existing saved shading value file, you would use a similar procedure but you would write to and read from the shading value bulk data CSR instead.

Sample code that illustrates how to enumerate bulk data files is available from Basler (see [Section 7.4 on page 273](#)).

Downloading a Bulk Data File from the Camera to a Computer

You can download a bulk data file from the camera's non-volatile memory to your host computer.

As an example, assume that you have saved a configuration set to the *UserSet02* file and that you want to download this file from the camera to your host computer. To do so, you would follow this procedure:

Use a binary write command to write the file name *UserSet02* to the Name field of the configuration set bulk data CSR.

1. Use a binary read command to read the Size field of the configuration set bulk data CSR.
 2. If the file contains saved data, this field will tell you the file size. If the file does not contain saved data, this field will be 0.
 3. Use a binary write command to set the value of the Control field in the configuration set bulk data CSR to 0x02. Setting the value to 0x02 places the camera in read mode.
 4. Use a binary command to do a bulk data read from the camera. The binary command must have the following characteristics:
 - OpCode = 0x05 (This OpCode makes the binary command a bulk data read)
 - DataLen = the number of bytes to be read (Max is 255 characters*)
 - Address = 0x281B (Base address for the configuration set bulk data CSR plus the offset for the Data field)
 - Data = none
 5. You will receive a bulk data response frame from the camera. (The amount of data in the response will be as specified by the DataLen in step 4.)
 6. Use a binary read command to read the value in the Info field of the configuration set bulk data CSR.
 - a. If the value is 0x01 no more data exists in the file. Exit the procedure.
 - b. If the value is 0x00, more data exists and this is not an activated file. Return to step 4.
 - c. If the value is 0x04, more data exists and this is an activated file. Return to step 4.
- * Up to 255 characters can be read with a single binary bulk data read command. If the file is larger than 255 characters, repeated binary bulk data read commands are required. When repeated bulk data read commands are required, the file is read sequentially with each read command starting where the previous read stopped.

This procedure will download the data in the file to the host computer.

If you want to download a shading values bulk data file to the host computer, you would use a similar procedure but you would use the shading values bulk data CSR instead.

Sample code that illustrates how to download a bulk data file is available from Basler (see Section 7.4 on [page 273](#)).

Uploading a Bulk Data File from a Computer to the Camera

You can upload a bulk data file from your host computer to the camera's non-volatile memory.

As an example, assume that you previously downloaded a saved configuration set file named *UserSet02* to your computer. Also assume that you now want to upload this file from your host computer to a camera. To do so, you would follow this procedure:

1. Use a binary write command to write the file name *UserSet02* to the Name field of the configuration set bulk data CSR.
 2. Use a binary write command to set the value of the Control field in the configuration set bulk data CSR to 0x03. Setting the value to 0x03 places the camera in write mode.
 3. Use a binary command to do a bulk data write to the camera. The binary write command must have the following characteristics:
 - OpCode = 0x04 (This OpCode makes the command a bulk data write)
 - DataLen = the number of bytes to be written (Max is 255 characters*)
 - Address = 0x281B (Base address for the configuration set bulk data CSR plus the offset for the Data field)
 - Data = Bytes to be written
 4. Repeat step 3 as many times as needed to write all of the data from the computer to the camera.
 5. Close the bulk data file in the camera. To close the file, use a binary write command to set the value of the Control field in the configuration set bulk data CSR to 0x02. Setting the value to 0x02 places the camera in read mode and closes the file.
- * Up to 255 characters can be written with a single binary bulk data write command. If the file is larger than 255 characters, repeated binary bulk data write commands are required. When repeated bulk data write commands are required, the file is written sequentially with each write command starting where the previous write stopped.

This procedure will upload the data in the file to the camera.

If you want to upload a user shading value bulk data file from a computer to a camera, you would use a similar procedure but you would use the shading value bulk data CSR instead.

Sample code that illustrates how to upload a bulk data file is available from Basler (see Section 7.4 on [page 273](#)).



When you upload a bulk data file from the computer to the camera, it will overwrite any existing data in the camera file with the same name. For example, if you upload a configuration set file called *UserSet02* from a computer to a camera, it will overwrite the existing contents of the *UserSet2* file in the camera.

You can download the factory configuration set file from the camera to the computer, but you can't upload the factory configuration set from the computer to the camera. The factory configuration set in the camera is protected and can't be overwritten.

7.2.3.4 Bulk Data Control and Status Register Details

Configuration Set CSR

See Section 7.2.3.1 on [page 258](#) for information about using the configuration set bulk data control register.

Register Base Address: 0x2800			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Control	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field selects a bulk data control function: 0x00 = Enumerate 0x01 = ENext 0x02 = Read 0x03 = Write 0x04 = Erase 0x05 = Activate 0x06 = Copy			
Field Name: Info	Offset: 0x0002	Size: 1 Byte	Type: Read only
Description: If you are performing a bulk read or write operation, this field will indicate when no more data exists: 0x00 = More data exists 0x01 = No more data exists 0x02 = File operation error 0x04 = This is an activated file			
Field Name: File Name	Offset: 0x0003	Size: 20 Bytes	Type: Read/Write
Description: Character string indicating the name of the bulk data file. The field contains 20 characters (left aligned and zero padded) Only the following names are allowed: FactorySet, UserSet01, UserSet02, UserSet03, and UserSet04. UserSet03 and UserSet04 are not allowed for the 8k camera.			
Field Name: Size	Offset: 0x0017	Size: 4 Bytes	Type: Read only
Description: If the file name refers to an already existing bulk data file, this field will contain the file size in bytes. Otherwise, the field contains zeros.			
Field Name: Data	Offset: 0x001B	Size: Variable	Type: Read/Write
Description: Byte sized register that is used to sequentially write to or read from a bulk data file.			

Shading Values CSR

See Section 7.2.3.2 on [page 259](#) for information about using the shading values bulk data control registers.

Register Base Address: 0x2A00			
Field Name: Register Status	Offset: 0x0000	Size: 1 Byte	Type: Read only
Description: The integer value in this field indicates the status of this control and status register: 0x00 = The register is not available 0x01 = The register is available and all related settings are OK 0x80 = A value in the register is set out of range			
Field Name: Control	Offset: 0x0001	Size: 1 Byte	Type: Read/Write
Description: Writing an integer to this field selects a bulk data control function: 0x00 = Enumerate 0x01 = ENext 0x02 = Read 0x03 = Write 0x04 = Erase 0x05 = Activate 0x06 = Copy			
Field Name: Info	Offset: 0x0002	Size: 1 Byte	Type: Read only
Description: If you are performing a bulk read or write operation, this field will indicate when no more data exists: 0x00 = More data exists 0x01 = No more data exists 0x02 = File operation error 0x04 = This is an activated file			
Field Name: File Name	Offset: 0x0003	Size: 20 Bytes	Type: Read/Write
Description: Character string indicating the name of the bulk data file. The field contains 20 characters (left aligned and zero padded). Only the following names are allowed: FactoryShading, UserShading.			
Field Name: Size	Offset: 0x0017	Size: 4 Bytes	Type: Read only
Description: If the file name refers to an already existing bulk data file, this field will contain the file size in bytes. Otherwise, the field contains zeros.			
Field Name: Data	Offset: 0x001B	Size: Variable	Type: Read/Write
Description: Byte sized register that is used to sequentially write to or read from a bulk data file.			

7.3 Using Binary Read/Write Commands

As explained in Section 7.2 on [page 212](#), each camera has control and status registers with one or more fields that are used to set the values for parameters associated with a camera feature. For example, the gain control and status register has two fields that can be used to set the camera's gain (see Section 6.1 on [page 145](#)). By writing values to fields in the control registers, you configure the camera and control how it operates. By reading values from fields in the control registers, you can determine how the camera is currently configured.

Each camera also has inquiry registers with fields that contain basic information such as the camera's serial number and software version numbers. By reading values in the inquiry register fields, you can determine some basic information about the camera.

A "binary read/write command" protocol has been developed for use with the camera.

You can read the data in a register field by sending a binary read command to the camera. For example, you can use a read command to determine the current value of the Mode field of the Test Image Mode control and status register (see [page 250](#)). When you issue a read command to the camera, the camera responds by sending the requested data back to the host computer.

You can write data to a register field by sending a write command to the camera. For example, you can use a write command to change the value of the Mode field of the Test Image control register. When you issue a write command to the camera, the value in the register field will be replaced and the camera will send a write response back to the host computer.

Each field within a control register or an inquiry register has a specific memory address. When you issue a binary read or a binary write command, the address for the field you want to work with is included as part of the command. Section 7.3.1 on [page 266](#) describes the binary read/write command format in detail. Sample code that illustrates how to use binary read and write commands is available from Basler (see Section 7.4 on [page 273](#)).

Binary read/write commands are issued to the camera via the RS-644 serial connection in the Camera Link interface between the frame grabber and the camera. 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 exported by that DLL:

- `clSerialInit` - 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 call up the functions exported by the DLL.



When the camera is powered on or when a camera reset is performed, your computer may receive one random character on the serial interface. We recommend clearing the serial input buffers in your computer after a camera power on or reset.

7.3.1 The Binary Read/Write Command Protocol

With the binary read/write command protocol, data is placed into a “frame” and sent to the camera. When the frame is received, it is checked for validity. If valid, the data is extracted from the frame and the command is executed.

This section describes the basic layout of a binary command frame. Figure 92 shows a graphical representation of the fields within a binary command frame. The text below the graphic describes each field of the command frame in detail.

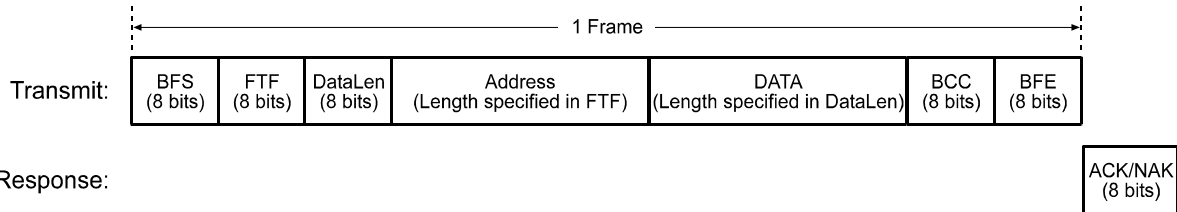


Fig. 92: Representation of a Command Frame and Response

BFS Binary Frame Start field
 Identifies the start of a binary frame.
 Size = 1 byte
 The value of the BFS byte is always 0x01.

FTF Frame Type and Format field
 Identifies the frame type and format.
 Size = 1 byte
 The bits in the FTF field are assigned as follows:

7	6	5	4	3	2	1	0
OpCode					BCC-Code	AddrLen	

The MSB of the FTF field is on the left (highest bit of the opcode) and the LSB of the field is on the right (lowest bit of the address length).

The value in the OpCode portion of the FTF field defines the function of the binary command, that is, whether it is a read command or a write command. The following OpCodes are available:

OpCode	Function
0b00000	This is a write command used to write a single setting to the camera.
0b00001	This is a read command used to read a single setting from the camera.
0b00010	This is a read response frame without an address field. (The AddrLen bits are "don't care").
0b00100	This is a bulk write command used to upload a file into the camera.
0b00101	This is a bulk read command used to download a file from the camera.
0b00110	This is a bulk read response frame without an address field. (The AddrLen bits are "don't care")

The BCC-Code portion of the FTF field indicates the presence of a Block Check Character (BCC). (The use of a BCC is optional.)

BCC-Code	Function
0b0	This frame (and also the response frame) contains no BCC field.
0b1	This frame (and also the response frame) contains a BCC field.

The AddrLen portion of the FTF field indicates the size of the command and status register (CSR) address to which the command is being sent.

AddrLen	Length of the Address Field
0b00	16 bits (= 2 bytes)
0b01	32 bits (= 4 bytes)
0b10	48 bits (= 6 bytes)
0b11	64 bits (= 8 bytes)

All CSR addresses are 16 bits.

Example of an FTF field:

Assume that you are issuing a write command, that you are using a BCC and that the CSR address you are writing to is a 16 bit address. In this case, the OpCode bits would be 0b00000, the BCC-Code bit would be 0b1 and the AddrLen bits would be 0b00. This would result in a binary value of 0b00000100, which translates to a hex value of 0x04 for the FTF field.

DataLen	<p>Data Length field</p> <p>For read commands, the DataLen field indicates the number of bytes to read from the given CSR address.</p> <p>For write commands, the DataLen field indicates the number of bytes contained in the Data field.</p> <p>Size = 1 byte</p> <p>Range of possible settings: 0 to 255.</p> <p>DataLen = 0 will result in an ACK, but no further command will be executed.</p>
Address	<p>Address field</p> <p>For read commands, indicates the CSR address for the read.</p> <p>For write commands, indicates the CSR address for the write.</p> <p>Size = Number of bytes indicated in the AddrLen portion of the FTF field</p>
Data	<p>Data field</p> <p>For read commands, this field contains no data.</p> <p>For write commands, this field contains the data to be written to the CSR.</p> <p>Size for read commands = 0 bytes.</p> <p>Size for write commands = the number of bytes indicated in the DataLen field of the frame.</p>
BCC	<p>Block Check Character field</p> <p>The use of a block check character in read/write commands is optional.</p> <p>If bit 2 of the FTF field is 0, the BCC is not used and the BCC field will contain no data.</p> <p>If bit 2 of the FTF field is 1, the BCC field will contain the block check character.</p> <p>Size = 0 bytes if bit 2 of the FTF field is 0 1 byte if bit 2 of the FTF field is 1</p> <p>The block check character is the exclusive-or sum (XOR sum) of the bytes in the FTF, DataLen, Address and Data fields (see Section 7.3.2.3 on page 272).</p>
BFE	<p>Binary Frame End field</p> <p>Identifies the end of a binary frame.</p> <p>Size = 1 byte</p> <p>The value of the BFE byte is always 0x03.</p>
ACK/NAK Response	<p>Positive frame acknowledge/negative frame acknowledge</p> <p>Size = 1 byte</p> <p>The value for a positive frame acknowledgement (ACK) is 0x06 and for a negative frame acknowledgement (NAK) is 0x15.</p>



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

7.3.1.1 Error Checking and Responses

ACK/NAK

When the camera receives a frame, it checks to see if the order of the bytes in the frame is correct. If the FTF field indicates that the frame includes a BCC, the camera checks to see if the XOR sum of the relevant frame 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 DataLen field.

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

Byte Timeouts

The camera checks the time between the receipt of each byte in the frame. If the time between any two bytes exceeds 0.5 seconds, the camera enters a “garbage state” and discards any more incoming bytes. The camera remains in this state until it sees a new BFS.

Read Commands

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

If the camera receives a read command with an unknown or invalid address in the Address field of the frame, it will respond with an ACK but will send no frame.

If the host sends a read command and gets no ACK/NAK, the host can assume that no camera is present or the camera is in a “garbage state” for some reason.

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.

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 or invalid address in the Address field of the frame, 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 (unless the address is “write-only”). The host can read the Camera Status fields in the Camera Status inquiry register (see [page 217](#)) 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 [page 220](#) through [page 256](#), only data within a specified range or a specified group of vales is valid. If the data in a write command is not within the allowed range or specified group of allowed values, the camera **will not** execute the write command.

7.3.2 Basic Read/Write Command Explanations

7.3.2.1 Read Command

This section includes a text description the hex digits included in a command message used to read the Status field of the Test Image Mode CSR (see [page 250](#)). The intent of this section is to give you a basic understanding of the elements included in a read command. Sample code that illustrates how to send a read command is available from Basler (see Section 7.4 on [page 273](#)).

The hex digits included in the read command are:

0x01, 0x0C, 0x01, 0x00, 0x18, 0x01, 0x03

0x01 is the BFS field.

The value in the BFS field is always 0x01.

0x0C is the FTF field.

The hex value of 0x0C in the FTF field converts to a binary value of 0b00001100.

Bits 7 through 3 of the binary value indicate the OpCode. As shown in the OpCode table on [page 267](#), an OpCode value of 0b00001 indicates that this is a read command frame.

Bit 2 indicates the presence or absence of a BCC in the frame. As shown in the OpCode table, when this bit is set to 0b1, it indicates that a BCC is present.

Bits 1 and 0 indicate the AddrLen. As shown in the OpCode table, a value of 0b00 for the AddrLen indicates that the address portion of this frame contains a 16-bit address. If you check the table on [page 250](#), you will find that the address for the Status field of the Test Image Mode CSR is 0x1800, a 16-bit address. (You are free to use any supported AddrLen as long as the CSR address will fit into it.)

0x01 is the DataLen field.

This field indicates the data size in bytes that will be transferred by using this read command. As shown in the table on [page 250](#), the data size for the Status field of the Test Image Mode CSR is 1 byte.

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

0x00, 0x18 is the Address field (in little endian).

This field indicates the CSR address from which the data bytes will be read.

The little endian values of 0x00, 0x18 in the address field translate to an address of 0x1800. If you check the table on [page 250](#), you will find that 0x1800 is the address for the Status field of the Test Image Mode CSR.

0x15 is the BCC field.

See Section 7.3.2.3 on [page 272](#) for instructions on calculating a BCC.

(Note that the use of a BCC is optional. In this example, we assume that a BCC is used.)

0x03 is the BFE.

The value in the BFE field is always 0x03.

7.3.2.2 Write Command

This section includes a text description the hex digits included in a command message used to write a value of 0x01 to the Mode field of the Test Image Mode CSR (see [page 250](#)). The intent of this section is to give you a basic understanding of the elements included in a write command. Sample code that illustrates how to send a write command is available from Basler (see Section 7.4 on [page 273](#)).

The hex digits included in the write command are:

0x01, 0x04, 0x01, 0x01, 0x18, 0x01, 0x1D, 0x03

0x01 is the BFS field.

The value in the BFS field is always 0x01.

0x04 is the FTF field.

The hex value of 0x04 in the FTF field converts to a binary value of 0b00000100.

Bits 7 through 3 of the binary value indicate the OpCode. As shown in the OpCode table on [page 267](#), an OpCode value of 0b00000 indicates that this is a write command frame.

Bit 2 indicates the presence or absence of a BCC in the frame. As shown in the OpCode table, when this bit is set to 0b1, it indicates that a BCC is present.

Bits 1 through 0 indicate the AddrLen. As shown in the OpCode table, a value of 0b00 for the AddrLen indicates that the Address field in this frame contains a 16-bit address. If you check the table on [page 250](#), you will find that the address for the Mode field of the Test Image Mode CSR is 0x1801, a 16-bit address. (You are free to use any supported AddrLen as long as the CSR address will fit into it.)

0x01 Is the DataLen field.

This field indicates the data size in bytes that will be transferred by using this write command. As shown in the table on [page 250](#), the data size for the Mode field of the Test Image Mode CSR is 1 byte.

0x01, 0x18 is the Address field in little endian.

This field indicates the CSR address to which the data bytes will be written.

The little endian values of 0x01, 0x18 in the address field translate to an address of 0x1801. If you check the table on [page 250](#), you will find that 0x1801 is the address for the Mode field the Test Image Mode CSR. (The address for any field within a CSR is equal to the base address for the CSR plus the offset for the CSR field. In this case, the base address of the Test Image Mode CSR is 1800 and the offset for the Mode field is 0001. This results in an address of 1801 for the Mode field.)

0x01 is the Data field.

This field contains the data that must be written to the register in order to activate Test Image One (see the table on [page 250](#)).

0x1D is the BCC field.

See Section 7.3.2.3 on [page 272](#) for instructions on calculating a BCC.

(Note that the use of a BCC is optional. In this example, we assume that a BCC is used.)

0x03 is the BFE field.

The value in the BFE field is always 0x03.

7.3.2.3 Calculating the Block Check Character

The use of a block check character (BCC) in camera commands is optional (see Section 7.3.1 on [page 266](#)). If you choose to use a BCC, the BCC will be the exclusive-or sum (XOR sum) of the bytes in the FTF field, the DataLen field, the Address field and the Data field of the command frame. For the write command example shown in Section 7.3.2.2 on [page 271](#), the block check character is 0x18. Let's consider how this block check character was calculated.

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

To find the XOR sum of two binary numbers, you 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 check digit for the write command shown in Section 7.3.2.2 on [page 271](#) would be calculated:

0 0 0 0 0 1 0 0 = the binary representation of 0x04 (FTF)

0 0 0 0 0 0 0 1 = the binary representation of 0x01 (DataLen)

0 0 0 0 0 1 0 1 = XOR sum

0 0 0 0 0 1 0 1 = Previous XOR Sum

0 0 0 0 0 0 0 1 = the binary representation of 0x01 (Address Byte 1)

0 0 0 0 0 1 0 0 = New XOR sum

0 0 0 0 0 1 0 0 = Previous XOR sum

0 0 0 1 1 0 0 0 = the binary representation of 0x18 (Address Byte 2)

0 0 0 1 1 1 0 0 = New XOR sum

0 0 0 1 1 1 0 0 = Previous XOR Sum

0 0 0 0 0 0 0 1 = the binary representation of 0x01 (Data)

0 0 0 1 1 1 0 1 = Final XOR sum

0 0 0 1 1 1 0 1 = 0x1D = the block check character

7.4 Binary Command Sample Code

Sample code that illustrates how to use binary commands with sprint cameras is available at the Basler web site. Please look for the Binary Protocol II programming sample at: www.baslerweb.com

8 Troubleshooting and Support

This section outlines the resources available to you if you need help working with your camera. It also provides some basic troubleshooting information that you can use to solve problems.

8.1 Tech Support Resources

The troubleshooting resources in this section of the manual will help you to find the cause of many common problems. If you need more assistance, you can contact the Basler technical support team for your area. Technical support contact information is located in the title pages of this manual.

You will also find helpful information such as frequently asked questions, downloads, and application notes on the Basler website at: www.baslerweb.com

If you do decide to contact Basler technical support, please take a look at the form that starts on [page 284](#) before you call. Filling out this form will help make sure that you have all of the information the technical support team needs to help you with your problem.

8.2 Obtaining an RMA Number

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

You can find detailed information about how to obtain an RMA number on the Basler website at: www.baslerweb.com

8.3 Fault Finding Using the Camera LED

During bootup, the camera loads firmware and performs initial self checks. Once bootup is complete, the camera performs a continuous series of self checks. If an error condition is detected, the LED will begin to flash. The number of flashes indicate the detected error as shown in Table 45.

If several error states are present, the LED outputs the error code that has the highest priority.

To get more information about the camera's current condition, you can check the camera status as described in Section 6.13 on [page 205](#).

LED	Description	Priority
LED is not lit	Power to the camera is not present or the input voltage is too low (see Section 2.5 on page 26 and Section 6.11 on page 202).	
LED is solid green for several seconds, flashes orange and then becomes solid orange	This is the normal LED sequence at power on or after a camera reset.	
Solid orange	The camera has power and is OK.	-
LED flashes with gradually increasing frequency	Indicates that the camera is busy performing a normal operation such as generating shading tables. When the operation is complete, the flashing stops.	-
Continuous red flashing	An undervoltage or overvoltage condition has been detected (see Section 6.11 on page 202).	1 (highest)
Solid red	An internal overvoltage condition has been detected. <ul style="list-style-type: none"> ■ Check whether camera power is supplied with the correct voltage of 12 VDC. ■ If the LED is solid red despite correct camera power, you must return the camera for repair. To do so, follow the RMA process (see Section 8.2 on page 274). You can check for an internal overvoltage condition by reading the value of bit 22 in the Camera Status field of the Camera Status Inquiry Register (see Section on page 215). If the bit is set to 1, an internal overvoltage condition is present.	2
Continuous fast orange flashing	General error. Please contact Basler technical support.	3
Continuous slow orange flashing	An FPGA related error is present: Please contact Basler technical support.	4
Repeated pattern of 6 slow orange flashes	An erroneous parameter set has been loaded. Load another parameter set.	5
Repeated pattern of 5 slow orange flashes	Parameter error. For example, a parameter is set out of range or to a value that is not valid.	6

Table 45: Camera Status Indicators

LED	Description	Priority
Repeated pattern of 4 slow orange flashes	<p>One of the following errors is present:</p> <ul style="list-style-type: none"> ■ A byte time-out has occurred (see Section 7.3.1.1 on page 269). ■ Invalid OpCode in a read or write command (see Section 7.3.1 on page 266). ■ Incoming data has been discarded since no BFS was included (see Section 7.3.1 on page 266). ■ Invalid BCC in a read or write command (see Section 7.3.1 on page 266). ■ Invalid address in a read or write command (see Section 7.3.1 on page 266). ■ Invalid data length in a read or write command (see Section 7.3.1 on page 266). ■ An unknown error with the binary read/write command format has occurred. 	7
Repeated pattern of 3 slow orange flashes	The last shading table generation process failed. The flashing will stop when you successfully complete a generation process or you reset the camera.	8
Repeated pattern of 2 slow orange flashes	<p>One of the following errors is present:</p> <p>The maximum allowed line rate has been exceeded (see Section Section 4.3 on page 99).</p> <p>ExSync has not changed state for 5 seconds or longer. Check the cable and the ExSync generating device.</p>	9 (lowest)

Table 45: Camera Status Indicators

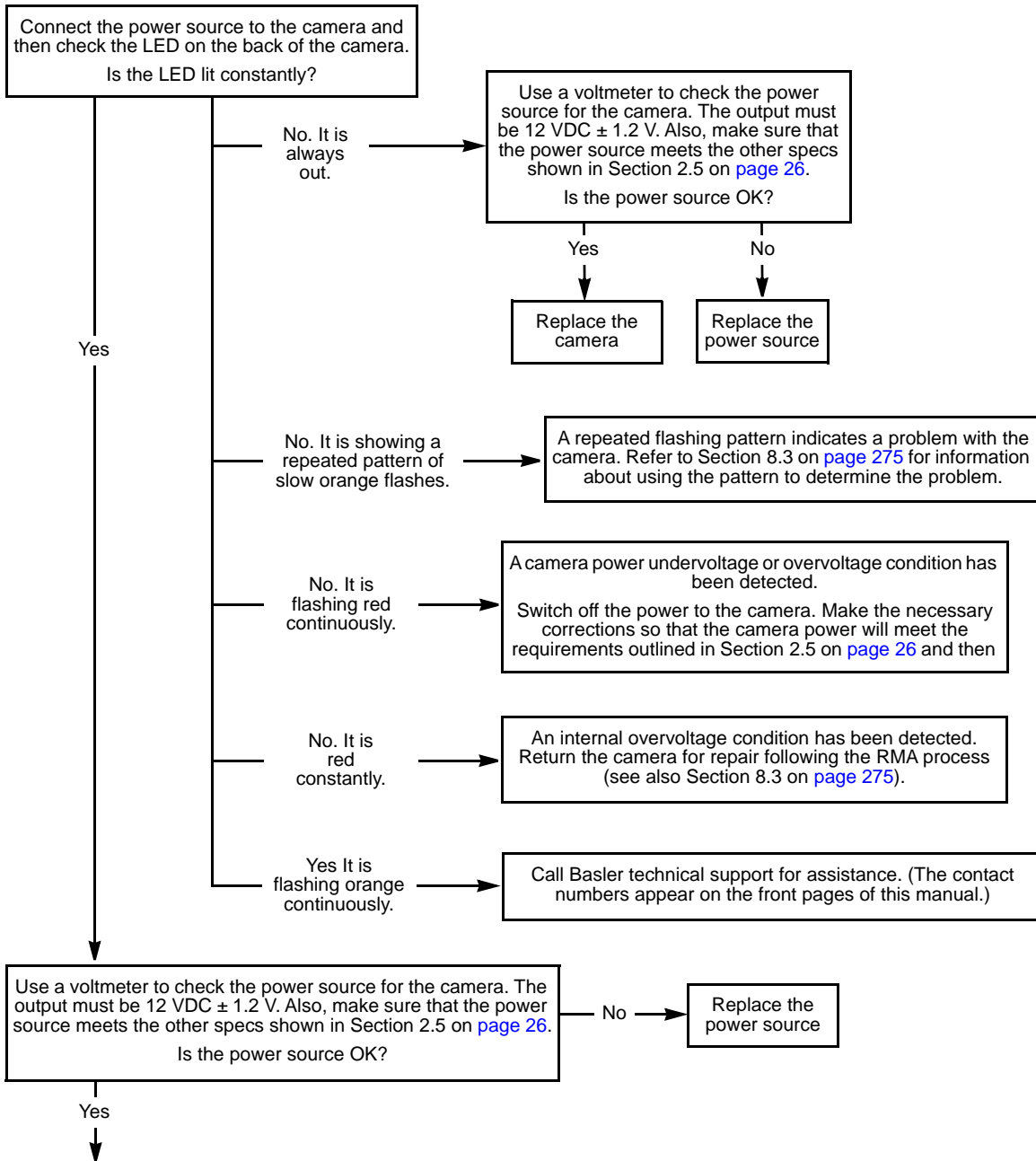
8.4 Troubleshooting Charts

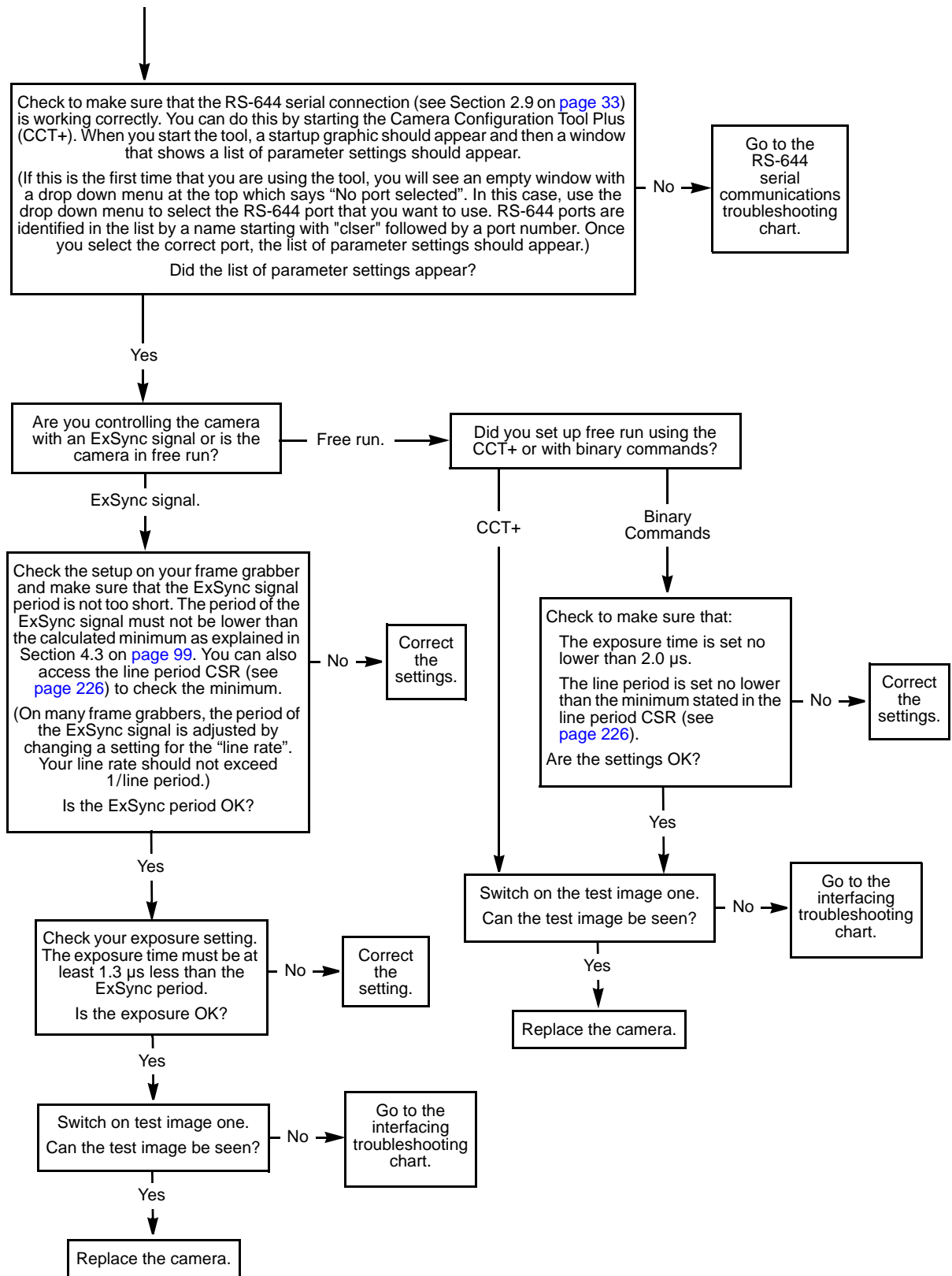
The following pages contain several troubleshooting charts that can help you find the cause of problems users sometimes encounter. The charts assume that you are familiar with the camera's features and settings and with the settings for your frame grabber. If you are not, we suggest you review the manuals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

8.4.1 No Image

Use this chart if you see no image at all when you attempt to capture an image with your frame grabber (in this situation, you will usually get a message from the frame grabber such as “time-out”). If you see a poor quality image, a completely black image, or a completely white image, use the chart in Section 8.4.2 on [page 280](#).

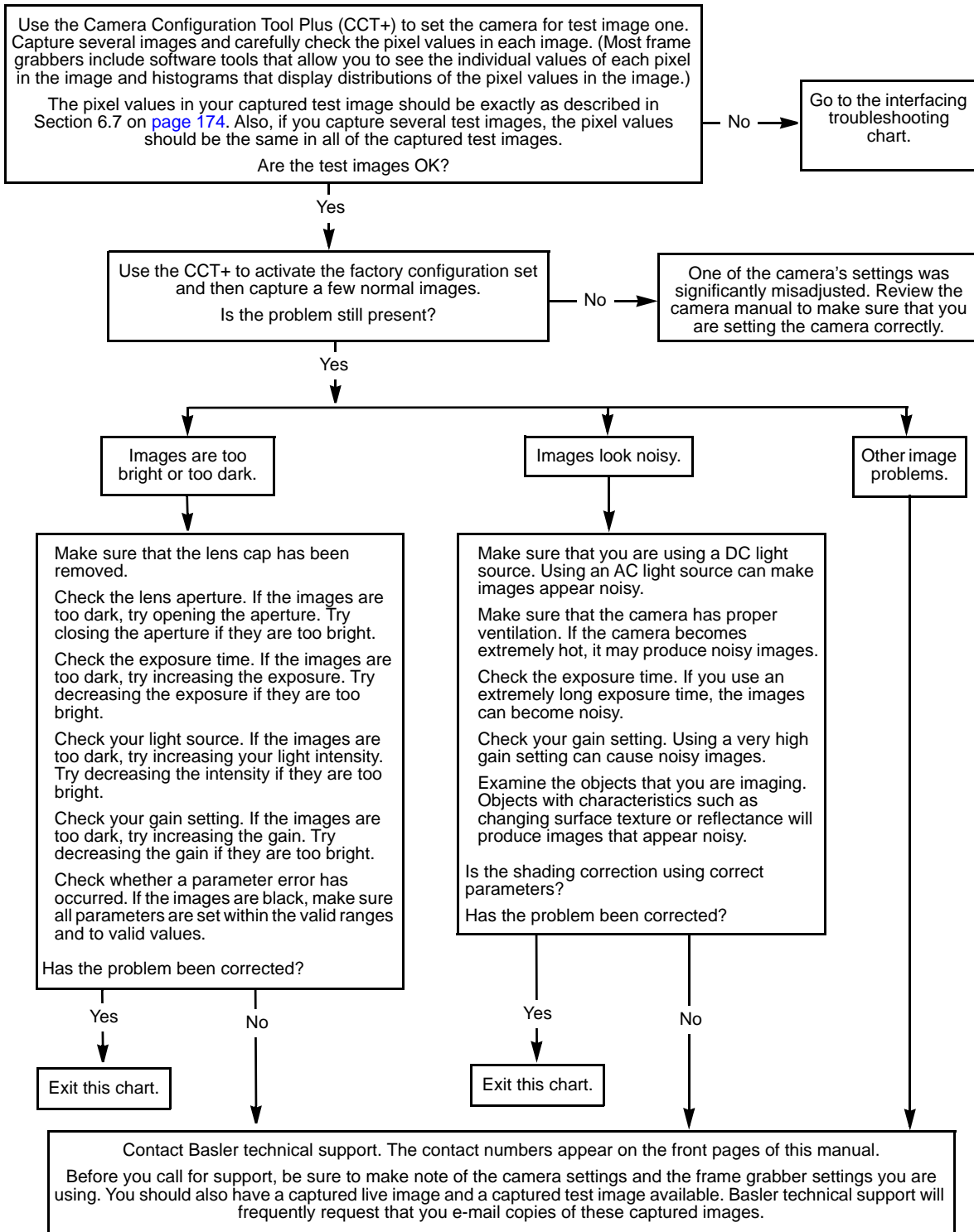
Before making or breaking any camera connections, always switch off power to the system (camera and host computer).





8.4.2 Poor Quality Image

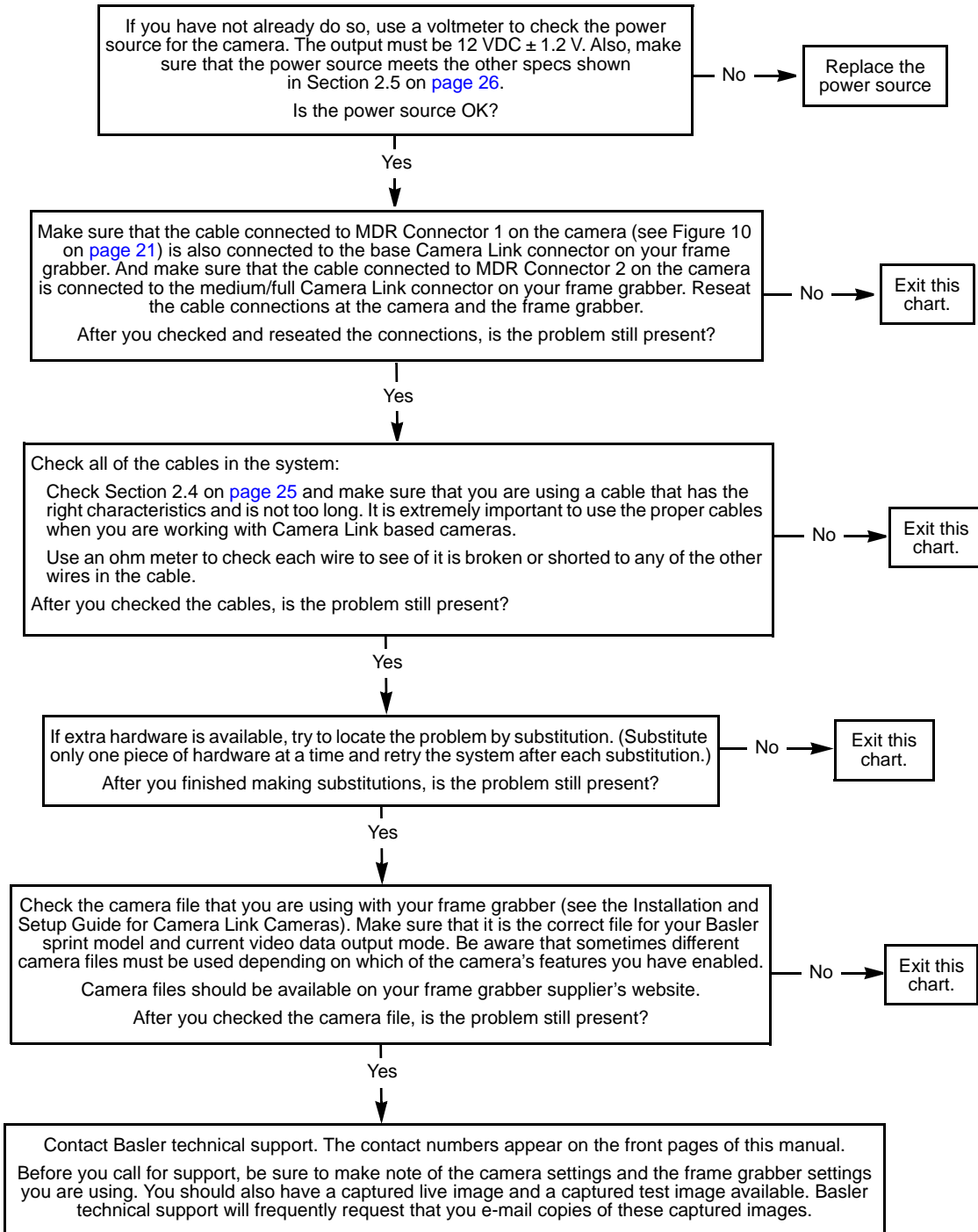
Use this chart if the image is poor quality, is completely white, or is completely black. If you get no image at all when you attempt to capture an image with the frame grabber, use the chart that appears in Section 8.4.1 on [page 278](#).



8.4.3 Interfacing

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

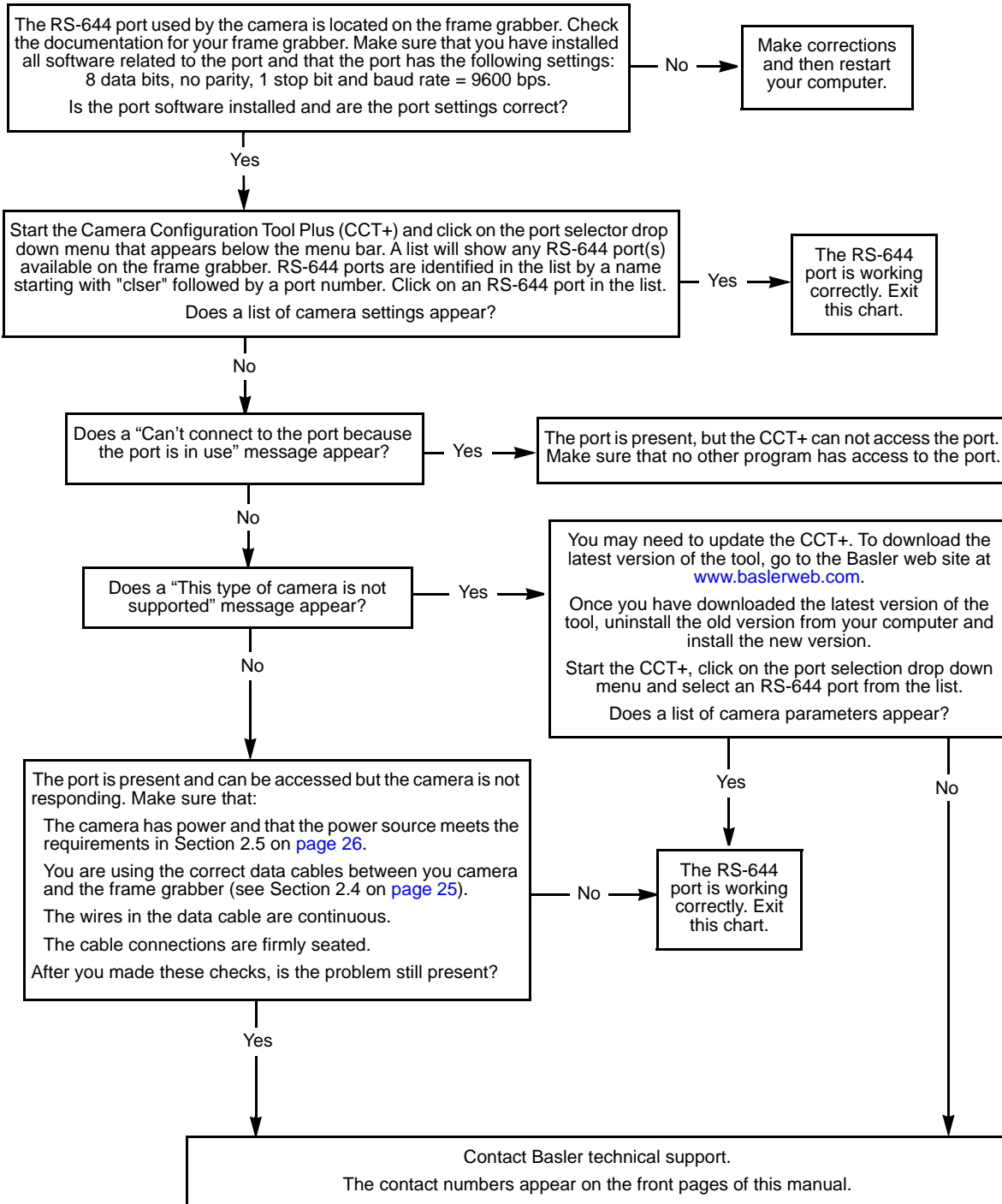
Before making or breaking any camera connections, always switch off power to the system (camera and host computer).



8.4.4 RS-644 Serial Communication

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

Before making or breaking any camera connections, always switch off power to the system (camera and host computer).



8.4.5 Before Calling Basler Technical Support

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

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

- 1 The camera's product ID: _____
- 2 The camera's serial number: _____
- 3 The operating system: _____
- 4 Frame grabber that you use with the camera: _____
- 5 CCT+ version that you use with the camera: _____
- 6 Describe the problem in as much detail as possible:
(If you need more space, use an extra sheet of paper.)

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

- 8 When did the problem occur? After start. While running.
 After a certain action (e.g., a change of parameters):

- 9 How often did/does the problem occur? Once. Every time.
 Regularly when:

 Occasionally when:

- 10 How severe is the problem? Camera can still be used.
- Camera can be used after I take this action:

- Camera can no longer be used.

- 11 Did your application ever run without problems? Yes No

12 Parameter set

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

To make a copy of the parameters, 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: _____

Offset: _____

Line rate: _____

13 Live image/test image

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

Revision History

Doc. ID Number	Date	Changes
AW00069901000	7 Aug 2008	Initial Release. Preliminary version of the document.
AW00069902000	13 Sep 2008	<p>First release for 4k series cameras. Contents relating to 2k and 8k cameras, and section 3.5. are preliminary and subject to change.</p> <p>Added sections Section 4.3.4 on page 114 "Camera Settings for the Maximum Specified Line Rate", Section 6.8 on page 204 "Line Stamp", and Section 6.9 on page 215 "Lookup Table".</p> <p>Modified and added material as necessary.</p>
AW00069903000	9 Apr 2009	<p>Added references to the table with parameter settings for achieving the maximum line rates in Section 1.2 on page 2.</p> <p>Updated the quantum efficiency curves in Figure 1 on page 8.</p> <p>Added information about the set screws for attaching lens mounts in Figure 2 on page 10 and Figure 6 on page 14.</p> <p>Corrected the tolerances for the distance between the CMOS sensor and the front surface of the lens adapter mount for 2k and 4k cameras in Figure 2 on page 10 and Figure 3 on page 11.</p> <p>Improved the indications of the reference planes for the camera housings in Figure 2 on page 10 through Figure 4 on page 12 and Figure 6 on page 14 through Figure 8 on page 16.</p> <p>Corrected Section 4.3.2 on page 111 to indicate that formula 3 returns the maximum allowed line rate.</p> <p>Modified explanations in Figure 22 through Figure 25 in Section 3.3 and in Figure 36 through Figure 41 in Section 3.4 for improved clarity.</p> <p>Removed explanations related to haloing from Section 3.5 on page 94.</p> <p>Corrected the minimum hight time for the ExSync signat in level controlled mode in Section 4.1.4 on page 103.</p> <p>Changed the jitter related to exposure times to 100 ns in Section 4.1.4 on page 103.</p> <p>Modified the explanation related to using a loo long exposure time for ExSync programmable mode in Section 4.1.4 on page 103.</p> <p>Added advice for increasing the line rate in Section 4.3.3 on page 113.</p> <p>Corrected the frame valid delay values for enhanced raw line acquisition mode - 40 MHz for 4k cameras in Section 5.2 on page 118.</p> <p>Added line valid/frame valid delay values for 2k and 8k cameras in Section 5.2 on page 118.</p> <p>Indicated the increments of the AOI starting pixel settings, depending on the line acquisition mode in Section 6.3 on page 163 and on page 260.</p> <p>Indicated on page 238 that a black image results if a parameter error has occurred.</p> <p>Corrected the minimum gain value in Section 7.2.2.1 on page 242.</p> <p>Removed the references to binning in the descriptions of the AOI starting pixel CSR on page 260 and of the AOI length CSR on page 261.</p>

Doc. ID Number	Date	Changes
AW00069903000	9 Apr 2009	Expanded Section 8.1 on page 297 and added Section 8.2 on page 297 describing how to obtain an RMA number. Added the parameter error to Section 8.4.2 on page 303. Minor corrections throughout the manual.
AW00069904000	29 Sep 2009	Updated the telephone number for the European technical support on the contact page. Corrected the default setting for cameras with settable clock speed in Section 2.8.5 on page 38. Removed all information related to these cameras throughout the manual: spL2048-20kc, spL4096-20 kc, spL8192-20kc.
AW00069905000	13 Jul 2010	Updated U.S. contact address and phone number. Updated the camera version ID number in Section 1.1 on page 1. Removed the requirement of a minimum line rate (1 kHz) in Section 1.2 on page 2. Changed maximum line rates from 70 kHz to 140 kHz in Section 1.2 on page 2 and Section 4.3.4 on page 114. Added the instruction to have color adjustment enabled for white balance in Section 6.2 on page 159. Added the "Gamma Correction" section on page 177. Added the "Color Adjustment" section on page 179. Added the recommendation to generate DSNU and PRNU shading correction values in Section 6.4.5 on page 168. Added the Gamma CSR on page 263. Added the Color Adjustment CSR on page 265. Minor corrections in Section 7 on page 233.
AW00069906000	6 Aug 2010	Modified the explanation of color adjustment in Section 6.6.1.2 on page 184 and on page 264.
AW00069907000	4 Jul 2011	Updated the camera version ID number in Section 1.1 on page 1. Added 80 MHz pixel clock speed for the spL4096-39kc in Section 1.2.2 on page 4, Section 2.8.5 on page 38, and Section 5.1 on page 115. Modified the representation of the UNIFOC 76 in Figure 2 and added information about choosing a suitable lens and assembling optical components in Section 1.3.2.2 on page 10. Added line acquisition modes in Section 3.1 on page 41: <ul style="list-style-type: none"> ■ Raw - Line B First ■ Enhanced Raw - Line B First (A Delayed) Added a note about delays in Section 4.1.1 on page 99. Added low line rate compensation in Section 4.1.3 on page 102, Section 4.1.4 on page 103, and in the register descriptions on page 238 and page 240. Corrected the increments for starting pixels and AOI lengths applicable to setting AOIs for cameras with 8192 pixels in Section 6.3 on page 163. Corrected the maximum brightness values for 10 bit and 12 bit output when gamma correction is enabled in Section 6.5 on page 177.

Doc. ID Number	Date	Changes
AW00069907000	4 Jul 2011	<p>Modified the Section 6.7 on page 189 and Section 6.8 on page 204 to take account of the added line acquisition modes.</p> <p>Modified the camera power undervoltage condition and renamed the overvoltage error as voltage error in Section 6.11 on page 220 and adjusted Section 6.12.2 on page 222, Section 8.3 on page 298, and Section 8.4.1 on page 301.</p> <p>Modified the camera power voltage entry in the Camera Status Inquiry register on page 238.</p> <p>Added the internal overvoltage condition in Section 8.3 on page 298, in the Camera Status Inquiry register on page 238, and in Section 8.4.1 on page 301.</p> <p>Modified description for the error indicated by continuous slow orange flashing in Section 8.3 on page 298.</p> <p>Adjusted priority levels in Section 8.3 on page 298.</p> <p>Removed the feedback page.</p>
AW00069908000	8 Nov 2012	<ul style="list-style-type: none"> ■ New front cover image. ■ Renamed Basler Vision Technologies as Basler AG. <p>Chapter 1</p> <ul style="list-style-type: none"> ■ Added note box on camera versions on page 1. ■ Adapted minimum line rates for raw line acquisition mode and enhanced raw line acquisition mode in Sections 1.2.1, 1.2.2 and 1.2.3. ■ Modified wavelength ranges for transmission and cut off for a IR cut filter in Section 1.4 on page 8 ■ Corrected mm to nm in the note box in Section 1.4 on page 8. ■ Updated the spectral response figures of the sprint color cameras. <p>Chapter 2</p> <ul style="list-style-type: none"> ■ Deleted paragraph "A power supply ...is available from Basler. Contact your Basler sales representative..." in Section 2.4.2 on page 31. ■ Corrected the differential line receiver names in Section 2.6 on page 33. <p>Chapter 4</p> <ul style="list-style-type: none"> ■ Adapted Section 4.1.3 on page 102 "Low Line Rate Compensation" to the fact that the low line rate compensation mode can now be enabled/ disabled. ■ Added camera link clock speeds and line acquisition modes for the spL2048-70kc in Table 9 on page 114. <p>Chapter 5</p> <ul style="list-style-type: none"> ■ Entered Table 10 on page 115 instead of text. ■ Simplified Table 11 on page 116. <p>Chapter 6</p> <ul style="list-style-type: none"> ■ Integrated Gain Green 2 in "Setting the Additional Color-specific Gain" on page 161. ■ Added new section on Gain Green 2 feature on page 162. ■ Integrated information in Section 6.4.5 on page 168 about the possibility to generate shading values when the AOI is set to a smaller value than the full length of the sensor.

Doc. ID Number	Date	Changes
AW00069908000	8 Nov 2012	<ul style="list-style-type: none"> ■ Added new section on adjusting the color performance of the camera on page 184. ■ Added new section on special color settings for different light sources on page 187. <p>Chapter 7</p> <ul style="list-style-type: none"> ■ Added note box on camera versions on page 233. ■ Added to the "Feature Control and Status Registers" section: <ul style="list-style-type: none"> ■ "Low Line Rate Compensation CSR" on page 245. ■ "Gain Green 2 CSR" on page 258. ■ "Gain Green 2 Enable CSR" on page 259.
AW00069909000	31 May 2013	<p>Updated the mail addresses on the back of the front page.</p> <p>Entered for 2k and 4k that a V-mount lens adapter is also available (Section 1.3.1 on page 7).</p> <p>Entered restriction for 2048-70kc and spL4096-70kc: 137 kHz line rate for ExSync operation</p> <ul style="list-style-type: none"> ■ Section 1.2 on page 2 ■ Section 2.7.2 on page 35 ■ Section 4.1.1 on page 99 <p>Inserted note on cable length limitations for 80 MHz cameras in Section 2.4.1 on page 31.</p> <p>Inserted note on Exposure Time Control Mode parameter and camera over-triggering in Section 4.1.2 on page 101.</p> <p>Updated formula 4 in Section 4.1.2 on page 101 and Section 4.3 on page 106: new value for camera link readout gap parameter.</p> <p>Removed restriction "(2k and 4k Cameras Only)" in the title of the following sections because the feature is now available in the new spL8192-39kc camera (depending on the firmware version):</p> <ul style="list-style-type: none"> ■ 'Color Adjustment' Section 6.6.1 on page 179 ■ 'Adapting the Color Adjustment Settings to Different Light Sources' Section 6.6.2 on page 183. <p>Integrated enhanced shading correction (ESC) in Section 6.4.2 on page 165.</p> <p>Added note on availability of line stamp and color adjustment features for the spL8192-39kc in Section 6.6.1 on page 179 and Section 6.8 on page 204.</p> <p>Updated the procedure description for setting the color enhancement feature in Section 6.6.2.1 on page 184.</p>

Doc. ID Number	Date	Changes
AW00069910000	23 Jan 2015	<p>Updated the contact information on the back of the front page.</p> <p>Updated the specification tables in Section 1.2 on page 2 to include physical sensor widths and new 2k and 4k 50 kHz camera models (spL2048-50kc and spL4096-50kc).</p> <p>Added ADC bit depth and conformity in Section 1.2 on page 2.</p> <p>Renamed "V-Basler helical mount" to "V-Basler mount" in Section 1.3.2.1 on page 8.</p> <p>Added information in Figure 3 in Section 1.3.2.2 on page 10.</p> <p>Updated mechanical drawings in the following sections:</p> <ul style="list-style-type: none"> ■ Section 1.5.1 on page 9 ■ Section 1.5.2 on page 11 ■ Section 1.5.3 on page 12 ■ Section 1.5.5 on page 13 ■ Section 1.5.6 on page 15 ■ Section 1.5.7 on page 16 <p>Added information to the "Avoid dust on the Sensor" notice in Section 1.8 on page 19.</p> <p>Integrated the spL4096-39kcESC and spL4096-70kcESC in the following sections:</p> <ul style="list-style-type: none"> ■ Section 1.2 on page 2 ■ Table 4 on page 26 ■ Section 2.7.2 on page 35 ■ Section 4.1.1 on page 99 ■ Tables on page 107 ■ Table 9 on page 114 ■ Table 11 on page 116 <p>Integrated the spL8192-39kcCI (Color Improvement) in the following sections:</p> <ul style="list-style-type: none"> ■ Section 1.2 on page 2 ■ Table 4 on page 26 ■ Table for spL8192 on page 107 ■ Table 9 on page 114 ■ Table 11 on page 116 <p>Integrated the spL2048-50kc and spL4096-50kc in the following sections of the user's manual:</p> <ul style="list-style-type: none"> ■ Table 4 on page 26 ■ Section 4.3 on page 106 ■ Table 9 on page 114 ■ Table 11 on page 116 <p>Entered new PPR values for the spL2048-70kc and for the spL4096-70kc in Section 4.3 on page 106.</p> <p>Modified Section 6.1 on page 105 to point out the difference between default maximum gain and total maximum gain settings.</p>

Doc. ID Number	Date	Changes
AW00069910000	23 Jan 2015	<p>Added the gain offset ranges for the different video data output modes in Section 6.1.2 on page 157.</p> <p>Added that the minimum AOI length for the spL8192 cameras must be 2048 pixels (page 163).</p> <p>Updated the "Note on the availability ..." notice in Section 6.6.1 on page 179.</p> <p>Adapted Table 10 on page 115.</p> <p>Modified the AOI lengths that can be set for the 8k camera.</p>
AW00069911000	17 Jul 2017	<p>Updated front page photo.</p> <p>Updated support addresses page.</p> <p>Updated warranty section and moved it to the third page.</p> <p>Removed information on C-mount and V-mount lens adapters in Chapter 1 on page 1.</p> <p>Removed information on Basler-specific adapters and further optical components for 8k cameras.</p> <p>Updated warning and note signs throughout the manual.</p>

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