BASLER A102k

USER'S MANUAL

Document Number: DA00052205

Release Date: 23 January 2004

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1 Introduction

The **BASLER A102k** high resolution, progressive scan camera is a versatile camera designed for industrial use. Superb image sensing features are combined with a robust, high-precision, machined housing.

Important features are:

- High spatial resolution
- High responsivity, low smear
- Anti-blooming
- Asynchronous full frame shutter via electronic exposure control
- Square sensor cells
- High signal-to-noise ratio
- Programmable via an RS-644 serial port
- Area of Interest (AOI) scanning
- Partial scanning
- Binning
- Correlated double sampling
- Industrial housing manufactured with high planar, parallel, and angular precision
- Compact size
- Complies with the Camera Link standard

1.1 Camera Models

The camera is available in a monochrome model (the **A102k**) and a color model (the **A102kc**). Throughout the manual, the camera will be called the **A102k**. Passages that are only valid for a specific model will be so indicated.

1.2   Performance Specifications

Category	Specification
Sensor	Sony ICX285 Progressive Scan CCD Sensor
Number of Pixels	1392 (H) × 1040 (V)
Pixel Size	6.45 µm (H) × 6.45 µm (V)
Spectral Response	See Figure 1-1
Photo Response Non-uniformity	± 0.17% (typical) @ 95% Vsat (gain = 0 dB)
Dark Signal Non-uniformity	± 0.375 gray values peak to peak (typical) in 8-bit mode, gain = 0 dB
Signal-to-noise Ratio (SNR)	43 dB
Dynamic Range	> 60.9 dB
Anti-blooming	Yes
Pixel Clock Speed	28 MHz
Max. Frame Rate	14.8 Frames/sec. in normal operation 24.8 Frames/sec. with vertical or full binning up to 75 Frames/sec. with area of interest
Video Output Type	Camera Link LVDS (RS-644 when used with the optional Basler Interface Controller)
Video Output Formats	A102k / A102kc: Single 8 bit, single 10 bit, or single 12 bit* A102kc: 3 x 8 bit RGB *Single 12 bit output is not available on all cameras. See Section 2.5.5.2.
Synchronization	Via external ExSync signal or free-run
Exposure Time Control	Level-controlled, programmable, or free-run
Gain and Offset	Programmable via an RS-644 serial connection on the frame grabber
Power Requirements	12 VDC (± 10%), < 3.5 W, < 1% ripple
Lens Adapter	C-mount or F-mount
Housing Size (L x W x H)	without lens adapter: 37.7 mm x 62 mm x 62 mm with C-mount adapter: 40.2 mm x 62 mm x 62 mm with F-mount adapter: 69.2 mm x 62 mm x 62 mm
Weight	without lens adapter: ~ 182 g. with C-mount adapter: ~ 222 g. with F-mount adapter: ~ 292 g.
Conformity	CE, FCC

Table 1-1: **A102k** Performance Specifications

1.3 Spectral Response

The spectral response for the **A102k** monochrome camera is shown in Figure 1-1.
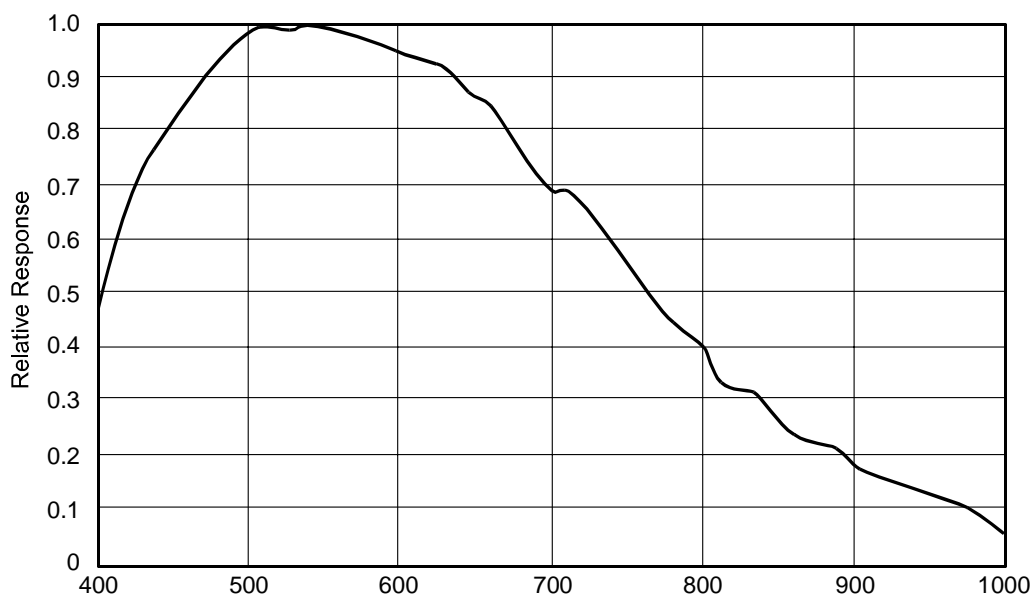
Figure 1-1: **A102k** Spectral Response

ⓘ The spectral response curve excludes lens characteristics and light source characteristics.

To obtain best performance regarding the camera's blooming, smearing and dark signal non-uniformity characteristics, use of a dielectric IR cut-off filter is recommended. The filter should transmit in a range of 400 nm to 700...720 nm, and it should cut off from 700...720 nm to 1100 nm.

A suitable filter is included in the C-mount adapter.

The F-mount adapter does not include the filter. A suitable filter type is the B+W486, for example.

⚠ **Caution!**

A102k cameras shipped with a C-mount lens adapter are equipped with an IR cut filter as standard equipment. The filter is mounted in the lens adapter. The location of the filter limits the thread length of the lens that can be used on the camera. The thread length on your lens must be less than 7.5 mm. If a lens with a longer thread length is used, the camera will be damaged and will no longer operate. See Section 5.5 for more details.

Cameras without an IR cut filter in the C-mount lens adapter are available on request.

The spectral response for the **A102kc** color camera is shown in Figure 1-2.

Figure 1-2: **A102kc** Spectral Response

ⓘ	The spectral response curve excludes lens characteristics and light source characteristics.
	To obtain best performance regarding the camera's blooming, smearing and dark signal non-uniformity characteristics, use of a dielectric IR cut-off filter is recommended. The filter should transmit in a range of 400 nm to 700...720 nm, and it should cut off from 700...720 nm to 1100 nm.
	A suitable filter is included in the C-mount adapter.
	The F-mount adapter does not include the filter. A suitable filter type is the B+W486, for example.

⚠	**Caution!**
	A102kc cameras shipped with a C-mount lens adapter are equipped with an IR cut filter as standard equipment. The filter is mounted in the lens adapter. The location of the filter limits the thread length of the lens that can be used on the camera. The thread length on your lens must be less than 7.5 mm. If a lens with a longer thread length is used, the camera will be damaged and will no longer operate. See Section 5.5 for more details.
	Cameras without an IR cut filter in the C-mount lens adapter are available on request.

1.4 Precautions

Power

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

Read the manual

Read the manual carefully before using the camera.

Keep foreign matter outside of the camera

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

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

Electromagnetic Fields

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

Transporting

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

Cleaning

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

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

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

1.5 Environmental Requirements

1.5.1 Temperature and Humidity

Housing temperature during operation: 0° C ... + 50° C (+ 32° F ... + 122° F)

Humidity during operation: 20 % ... 80 %, relative, non-condensing

1.5.2 Ventilation

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

2   Camera Interface

2.1   Connections

2.1.1 General Description

The **A102k** is interfaced to external circuitry via two connectors located on the back of the camera:

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

A status LED located on the back of the camera is used to indicate power present and signal integrity. Figure 2-1 shows the connectors and the LED.
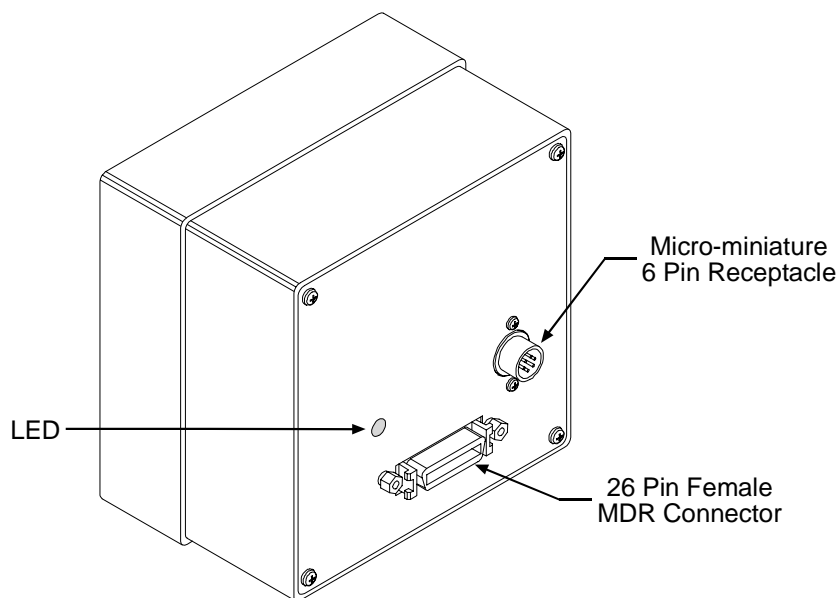
Figure 2-1: **A102k** Connectors and LED

2.1.2 Pin Assignments

26-Pin MDR Connector

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

Pin Number	Signal Name	Direction	Level	Function
15	Tx X0+	Output	Camera Link LVDS	Data from Camera Link Transmitter
2	Tx X0-			
16	Tx X1+	Output	Camera Link LVDS	Data from Camera Link Transmitter
3	Tx X1-			
17	Tx X2+	Output	Camera Link LVDS	Data from Camera Link Transmitter
4	Tx X2-			
19	Tx X3+	Output	Camera Link LVDS	Data from Camera Link Transmitter
6	Tx X3-			
18	Tx Clk+	Output	Camera Link LVDS	Clock from Camera Link Transmitter
5	Tx Clk-			
12	CC4+	Input	RS-644 LVDS	Reserved for Future Use
25	CC4-			
24	CC3+	Output	RS-644 LVDS	Integrate Enabled
11	CC3-			
10	CC2+	Input	RS-644 LVDS	Reserved for Future Use
23	CC2-			
22	CC1+	Input	RS-644 LVDS	External Trigger
9	CC1-			
21	SerTFG+	Output	RS-644 LVDS	Serial Communication Data Transmit
8	SerTFG-			
7	SerTC+	Input	RS-644 LVDS	Serial Communication Data Receive
20	SerTC-			
1, 13, 14, 26 [1]	DC Gnd	Input	Ground	DC Ground

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

Table 2-1: **A102k** Pin Assignments for the 26-pin MDR Connector

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

6-Pin Micro-miniature Receptacle

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

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

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

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

Table 2-2: **A102k** Pin Assignments for the 6-pin Micro-miniature Receptacle
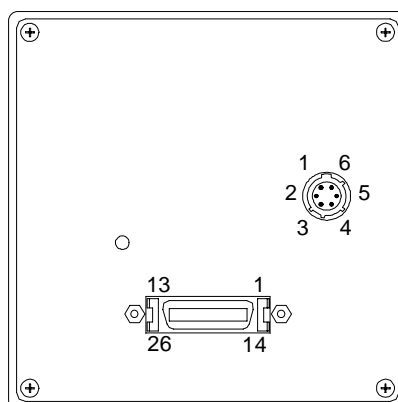
Figure 2-2: **A102k** Pin Numbering

2.1.3 Connector Types

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

The 6 pin connector on the camera will be a Hirose micro-miniature locking receptacle (part # HR10-7R-6PA) or the equivalent. The recommended mating connector is the Hirose micro-miniature locking plug (part # HR10-7P-6S). A Hirose locking plug will be shipped with each camera. This plug should be used to terminate the cable on the power supply for the camera.

2.2 Cable Information

2.2.1 Camera Link Cable

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

The maximum recommended length for the MDR cable used with an **A102k** is 10 meters. It will decrease when used in an area with severe ambient electromagnetic interference.

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

2.2.2 Power Cable

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

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

2.3   Camera Link Implementation in the A102k

The **A102k** uses a National Semiconductor DS90CR287 as a Camera Link transmitter. For a Camera Link receiver, we recommend that you use the National Semiconductor DS90CR288, the National Semiconductor DS90CR288A or an equivalent. Detailed data sheets for these components are available at the National Semiconductor web site (www.national.com). The data sheets contain all of the information that you need to implement Camera Link, including application notes.

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

The **A102k** uses a National Semiconductor DS90LV048A differential line receiver to receive the RS-644 camera control input signals and the serial communication input signal defined in the Camera Link specification. A DS90LV047A differential line transmitter is used to transmit the serial communication output signal defined in the specification. Detailed spec sheets for these devices are available at the National Semiconductor web site (www.national.com).

The schematic in Figure 2-3 shows the interface for **A102k** and a typical implementation for the frame grabber interface.
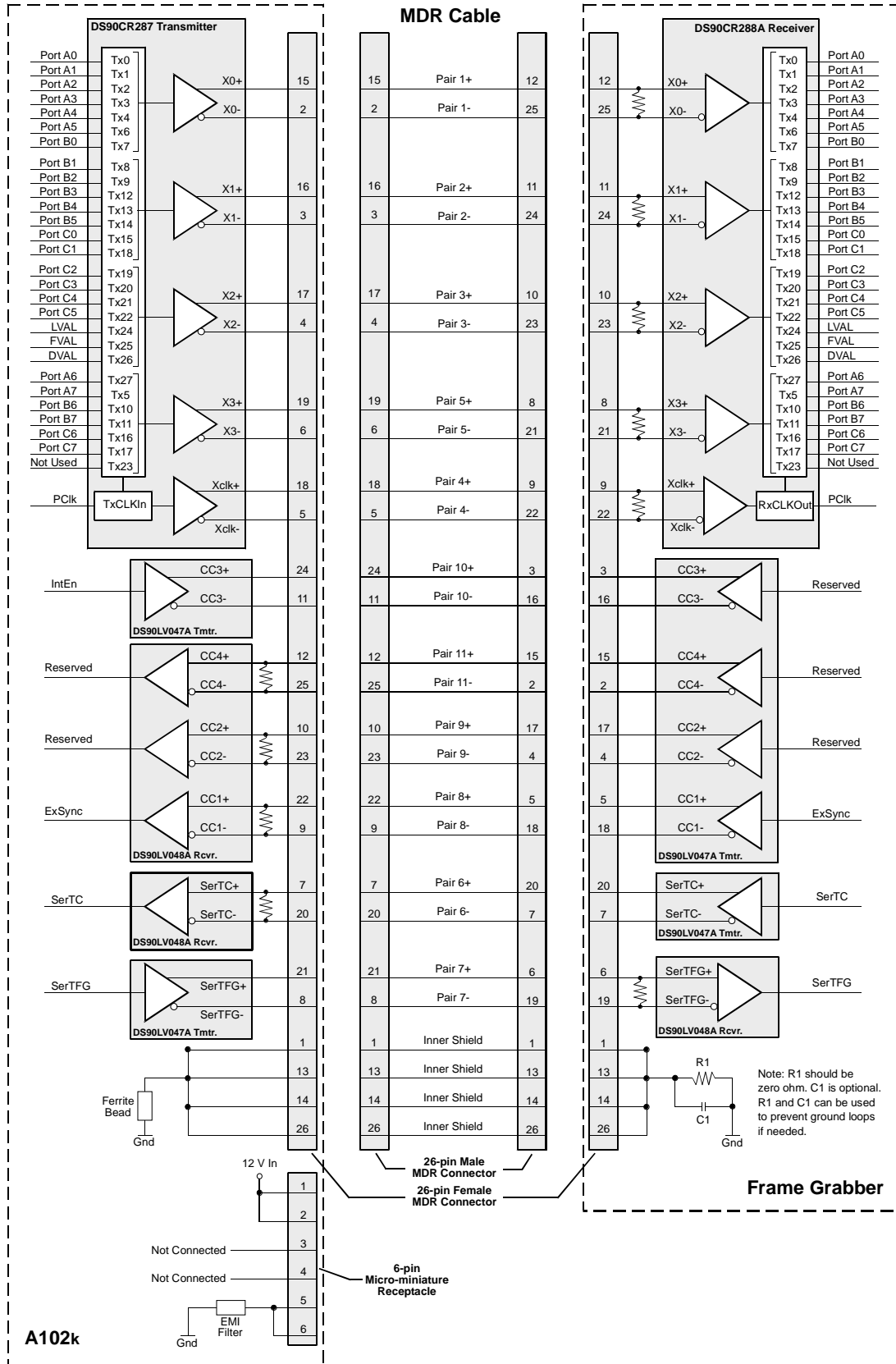
Figure 2-3: Camera / Frame Grabber Interface

2.4 Input Signals

The only control signal that can be input into the **A102k** is an external sync (ExSync) signal. ExSync is an RS-644 LVDS signal as specified in the Camera Link standard. Section 2.4.1 describes the function of the ExSync signal.

2.4.1 ExSync: Controls Frame Readout and Exposure Time

The ExSync input signal is used to control exposure time and frame read out. When the camera is operating with an ExSync signal, two exposure time control modes are available: level-controlled and programmable. (see Section 3.2)

ExSync can be a periodic or non-periodic function.

The frequency of the ExSync signal determines the camera's frame rate:

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

Note that ExSync is edge sensitive and therefore must toggle.

Minimum high time for the ExSync signal depends on whether ExSync Level-controlled or ExSync Programmable mode is used (see Sections 3.2.1.2 or 3.2.1.3, respectively)

The ExSync signal is typically supplied to the camera by a frame grabber board. You should refer to the manual supplied with your frame grabber to determine how to set up the ExSync signal that is being supplied to the camera.

2.5 Output Signals

The camera's output signals include a pixel clock, video data, and video data qualifiers such as frame valid and line valid. An integrate enabled output signal is also available. Sections 2.5.1 through 2.5.6 describe the output signals.

2.5.1 Pixel Clock

As shown in Figure 2-3 and in Table 2-3, the pixel clock is assigned to the TxClkIn (transmit clock) pin of the Camera Link transmitter. The pixel clock is used to time the sampling and transmission of pixel data as shown in Figure 2-4 and Figure 2-5. The transmitter used in **A102k** cameras requires pixel data to be sampled and transmitted on the rising edge of the clock.

The frequency of the pixel clock is 28 MHz.

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

2.5.2 Frame Valid Bit

As shown in Figure 2-4 and Figure 2-5, the frame valid bit indicates that a valid frame is being transmitted.

2.5.3 Line Valid Bit

As shown in Figure 2-4 and Figure 2-5, the line valid bit indicates that a valid line is being transmitted. Pixel data is only valid when the frame valid bit and the line valid bit are both high.

2.5.4 Data Valid Bit

The data valid bit is used for horizontal binning only (see Section 3.9.2). In normal operation, it is always high and should be ignored.

2.5.5 Video Data

2.5.5.1 Bit Assignments

Table 2-3 lists the assignment of pixel data bits to the input ports on the transmitter in the camera and the corresponding output pins on the receiver in the frame grabber. These bit assignments comply with the Camera Link standard. As shown in the table, the bit assignments for pixel data vary depending on the output mode setting of the camera. The available output modes are explained in more detail in Section 2.5.5.2.

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

Port	Camera	Frame Grabber	Single 12 Bit[1] Output Mode	Single 10 Bit Output Mode	Single 8 Bit Output Mode	3 x 8 Bit RGB[2] Output Mode
Port A0	TxIN0	RxOUT0	Bit 0	Bit 0	Bit 0	Red Bit 0
Port A1	TxIN1	RxOUT1	Bit 1	Bit 1	Bit 1	Red Bit 1
Port A2	TxIN2	RxOUT2	Bit 2	Bit 2	Bit 2	Red Bit 2
Port A3	TxIN3	RxOUT3	Bit 3	Bit 3	Bit 3	Red Bit 3
Port A4	TxIN4	RxOUT4	Bit 4	Bit 4	Bit 4	Red Bit 4
Port A5	TxIN6	RxOUT6	Bit 5	Bit 5	Bit 5	Red Bit 5
Port A6	TxIN27	RxOUT27	Bit 6	Bit 6	Bit 6	Red Bit 6
Port A7	TxIN5	RxOUT5	Bit 7	Bit 7	Bit 7 (MSB)	Red Bit 7
Port B0	TxIN7	RxOUT7	Bit 8	Bit 8	Not Used	Green Bit 0
Port B1	TxIN8	RxOUT8	Bit 9	Bit 9 (MSB)	Not Used	Green Bit 1
Port B2	TxIN9	RxOUT9	Bit10	Not Used	Not Used	Green Bit 2
Port B3	TxIN12	RxOUT12	Bit 11 (MSB)	Not Used	Not Used	Green Bit 3
Port B4	TxIN13	RxOUT13	Not Used	Not Used	Not Used	Green Bit 4
Port B5	TxIN14	RxOUT14	Not Used	Not Used	Not Used	Green Bit 5
Port B6	TxIN10	RxOUT10	Not Used	Not Used	Not Used	Green Bit 6
Port B7	TxIN11	RxOUT11	Not Used	Not Used	Not Used	Green Bit 7
Port C0	TxIN15	RxOUT15	Not Used	Not Used	Not Used	Blue Bit 0
Port C1	TxIN18	RxOUT18	Not Used	Not Used	Not Used	Blue Bit 1
Port C2	TxIN19	RxOUT19	Not Used	Not Used	Not Used	Blue Bit 2
Port C3	TxIN20	RxOUT20	Not Used	Not Used	Not Used	Blue Bit 3
Port C4	TxIN21	RxOUT21	Not Used	Not Used	Not Used	Blue Bit 4
Port C5	TxIN22	RxOUT22	Not Used	Not Used	Not Used	Blue Bit 5
Port C6	TxIN16	RxOUT16	Not Used	Not Used	Not Used	Blue Bit 6
Port C7	TxIN17	RxOUT17	Not Used	Not Used	Not Used	Blue Bit 7
LVAL	TxIN24	RxOUT24	Line Valid	Line Valid	Line Valid	Line Valid
FVAL	TxIN25	RxOUT25	Frame Valid	Frame Valid	Frame Valid	Frame Valid
DVAL	TxIN26	RxOUT26	Data Valid	Data Valid	Data Valid	Data Valid
Not Used	TxIN23	RxOUT23	Not Used	Not Used	Not Used	Not Used
PClk	TxCLKIn	RxCLKOut	Pixel Clock	Pixel Clock	Pixel Clock	Pixel Clock

Table 2-3: Bit Assignments

[1] The single 12 bit output mode was added in January 2004. This mode is not available on older **A102k** cameras.

[2] The 3 x 8 bit RGB output mode is available on **A102kc** cameras only.

2.5.5.2 Video Data Output Modes

The **A102k** and the **A102kc** can output pixel data in a single 12 bit, a single 10 bit, or a single 8 bit output mode. The **A102kc** can also output data in a 3 x 8 bit RGB mode.

> (i) The single 12 bit output mode was added in January 2004. It is not available on older **A102k** camera.

Operation in Single 12 Bit, Single 10 Bit, or Single 8 Bit Modes

In single 12 bit mode, on each clock cycle, the camera transmits data for one pixel at 12 bit depth, a frame valid bit, a line valid bit and a data valid bit. The assignment of the bits is shown in Table 2-3.

The pixel clock is used to time data sampling and transmission. As shown in Figure 2-4 and Figure 2-5, the camera samples and transmits data on each rising edge of the pixel clock.

The frame valid bit indicates that a valid frame is being transmitted. The line valid bit indicates that a valid line is being transmitted. Pixel data is only valid when the frame valid bit and the line valid bit are both high. The data valid bit is not used and should be ignored.

Operation in single 10 bit mode is similar to single 12 bit mode except that the 2 least significant bits output from the ADC are dropped and the 10 most significant bits of data per pixel are transmitted.

Operation in single 8 bit mode is similar to single 12 bit mode except that the 4 least significant bits output from the ADC are dropped and the 8 most significant bits of data per pixel are transmitted.

> (i) The data sequence outlined below, along with Figure 2-4 and Figure 2-5, describe what is happening at the inputs to the Camera Link transmitter in the camera.
>
> Note that the timing used for sampling the data at the Camera Link receiver in the frame grabber varies from device to device. On some receivers, data must be sampled on the rising edge of the pixel clock (receive clock), and on others, it must be sampled on the falling edge. Also, some devices are available which allow you to select either rising edge or falling edge sampling. Please consult the data sheet for the receiver that you are using for specific timing information.

Video Data Sequence[1]

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

• The frame valid bit will become high.

• On the pixel clock cycle where data transmission for line one begins, the line valid bit will become high. Twelve of the bits transmitted during this clock cycle will contain the data for pixel number one in line one.

• On the next cycle of the pixel clock, the line valid bit will be high. Twelve of the bits transmitted during this clock cycle will contain the data for pixel number three in line one.

• This pattern will continue until all of the pixel data for line one has been transmitted.

• After all of the pixels in line one have been transmitted, the line valid bit will become low indicating that valid data for line one is no longer being transmitted.

• On the pixel clock cycle where data transmission for line two begins, the line valid bit will become high. Twelve of the bits transmitted during this clock cycle will contain the data for pixel number one in line two.

• On the next cycle of the pixel clock, the line valid bit will be high. Twelve of the bits transmitted during this clock cycle will contain the data for pixel number two in line two.

• On the next cycle of the pixel clock, the line valid bit will be high. Twelve of the bits transmitted during this clock cycle will contain the data for pixel number three in line two.

• This pattern will continue until all of the pixel data for line two has been transmitted.

• After all of the data for the pixels in line two has been transmitted, the line valid bit will become low indicating that valid data for line two is no longer being transmitted.

• The camera will continue to transmit pixel data for each line as described above until all of the lines in the frame have been transmitted. After all of the lines have been transmitted, the frame valid bit will become low indicating that a valid frame is no longer being transmitted.

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

Figure 2-5 shows the data sequence when the camera is operating in programmable exposure mode.

_____

[1] The data sequence assumes that the camera is operating in 12 bit mode. If the camera is operating in 10 bit or 8 bit mode, only 10 bits or 8 bits of data per pixel will be transmitted.

Operation in 3 x 8 Bit RGB Mode

A 3 x 8 bit RGB mode is available on **A102kc** cameras. In 3 x 8 bit RGB mode, on each clock cycle, the camera transmits 8 bits of red data, 8 bits of green data, and 8 bits of blue data for a single pixel. A frame valid bit, a line valid bit and a data valid bit are also transmitted on each clock cycle. The assignment of the bits is shown in Table 2-3. For more information about how the camera determines the RGB values for each pixel, see Section 3.11.

The pixel clock is used to time data sampling and transmission. As shown in Figure 2-4 and Figure 2-5, the camera samples and transmits data on each rising edge of the pixel clock.

The frame valid bit indicates that a valid frame is being transmitted. The line valid bit indicates that a valid line is being transmitted. Pixel data is only valid when the frame valid bit and the line valid bits are both high. The data valid bit is not used and should be ignored.

(i) | The data sequence outlined below, along with Figure 2-4 and Figure 2-5, describe what is happening at the inputs to the Camera Link transmitter in the camera.

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

Video Data Sequence

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

- The frame valid bit will become high.
- On the pixel clock cycle where data transmission for line one begins, the line valid bit will become high. Eight of the bits transmitted during this clock cycle will contain the red data for pixel number one in line one, eight of the bits will contain the green data for pixel number one in line one, and eight of the bits will contain the blue data for pixel number one in line one.
- On the next cycle of the pixel clock, the line valid bit will be high. Eight of the bits transmitted during this clock cycle will contain the red data for pixel number two in line one, eight of the bits will contain the green data for pixel number two in line one, and eight of the bits will contain the blue data for pixel number two in line one.
- On the next cycle of the pixel clock, the line valid bit will be high. Eight of the bits transmitted during this clock cycle will contain the red data for pixel number three in line one, eight of the bits will contain the green data for pixel number three in line one, and eight of the bits will contain the blue data for pixel number three in line one.
- This pattern will continue until all of the pixel data for line one has been transmitted.
- After all of the pixels in line one have been transmitted, the line valid bit will become low indicating that valid data for line one is no longer being transmitted.
- On the pixel clock cycle where data transmission for line two begins, the line valid bit will become high. Eight of the bits transmitted during this clock cycle will contain the red data for pixel number one in line two, eight of the bits will contain the green data for pixel number one in line two, and eight of the bits will contain the blue data for pixel number one in line two.

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

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

- This pattern will continue until all of the pixel data for line two has been transmitted.

- After all of the data for the pixels in line two has been transmitted, the line valid bit will become low indicating that valid data for line two is no longer being transmitted.

- The camera will continue to transmit pixel data for each line as described above until all of the lines in the frame have been transmitted. After all of the lines have been transmitted, the frame valid bit will become low indicating that a valid frame is no longer being transmitted.

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

Figure 2-5 shows the data sequence when the camera is operating in programmable exposure mode.

The diagram assumes that the area of interest (AOI) feature is not being used. With the AOI feature enabled, the number of lines transferred and the number of pixels in each line could be smaller.

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-4: Pixel Data Output with Level Controlled Exposure
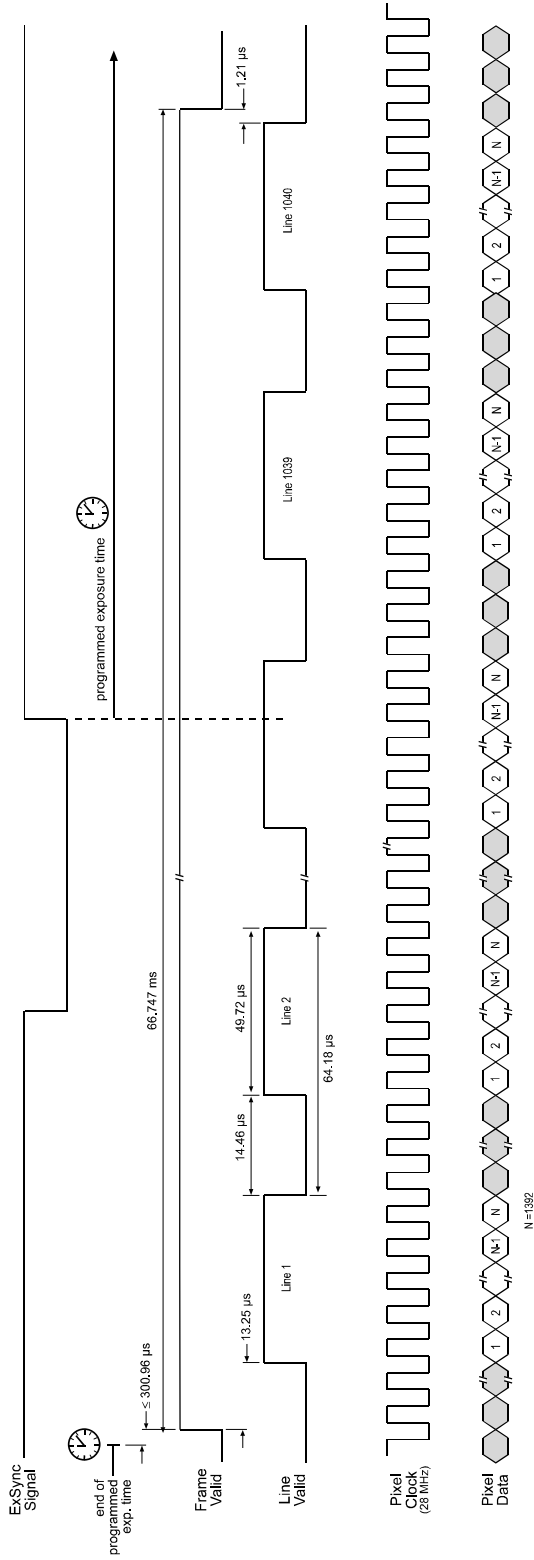
ExSync Signal

Frame Valid

Line Valid

Pixel Clock (28 MHz)

Pixel Data

exposure

≤ 300.68 µs

66.747 ms

1.21 µs

Line 1

Line 2

Line 1039

Line 1040

13.25 µs

14.46 µs

49.72 µs

64.18 µs

N = 1392

The diagram assumes that the area of interest (AOI) feature is not being used. With the AOI feature enabled, the number of lines transferred and the number of pixels in each line could be smaller.

TIMING CHARTS ARE NOT DRAWN TO SCALE

Figure 2-5: Pixel Data Output with Programmable Exposure

2.5.6 Integrate Enabled Signal

An RS-644 LVDS output signal called Integrate Enabled (IntEn) is available on **A102k** cameras. The integrate enabled signal indicates that an exposure is taking place. The signal will go high when each exposure begins and go low when the exposure ends. As shown in the schematic on page 2-6, the IntEn signal is available on pins 24 and 11 of the **A102k**.

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

In the Basler cable, the wires which carry the integrate enabled signal from the camera are not attached to the pins in the frame grabber end of the cable. Instead, the wires are unterminated and are folded back inside of the connector housing on the frame grabber end (see Figure 2-6 below). If you open the connector housing, you can locate the wires and use them to access the integrate enabled signal. As shown below, a blue wire carries the positive signal and a gray wire carries the negative signal. The wires require a 100 Ohm termination resistor.

ⓘ	If you use a standard Camera Link cable to connect the **A102k** to a Camera Link frame grabber, the RS-644 LVDS transmitter for the integrate enabled signal will be connected to an RS-644 LVDS transmitter in the frame grabber as shown in the schematic on page 2-6. Because the transmitter in the camera is a low current source and because the opposing transmitter in the frame grabber is typically short circuit protected, this configuration will not cause damage to the camera or the frame grabber.
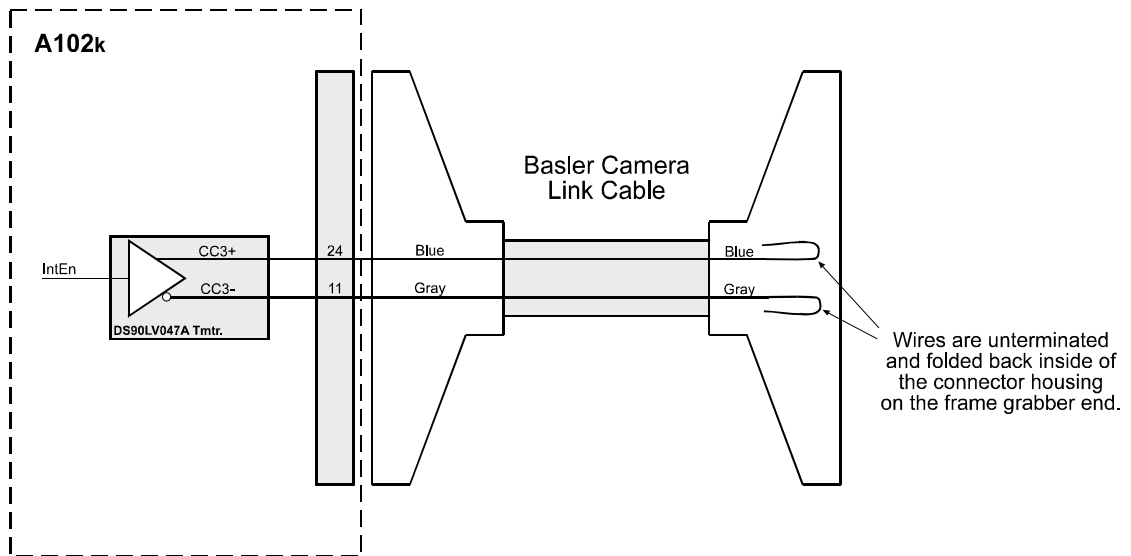
Figure 2-6: Basler Camera Link Cable

2.6 RS-644 Serial Communication

The **A102k** is equipped for RS-644 serial communication via the frame grabber as specified in the Camera Link standard. The RS-644 serial connection in the Camera Link interface is used to issue commands to the camera for changing modes and parameters. The serial link can also be used to query the camera about its current setup.

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

Basler has also developed a binary command protocol that can be used to change camera modes and parameters directly from your application via the serial connection. See Section 4.2 for details on the binary command format.

2.6.1 Making the Serial Connection

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

The port must have the following settings: 8 data bits, no parity, 1 stop bit, baud rate = 9600 bps

If you are using the Basler 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.

> (i) In order for the Basler CCT+ to detect and use the port, the characteristics of the port must comply with the Camera Link standard and the DLL called for in the standard must be present.

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

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

On the **A102k**, video data is output from the camera in Camera Link LVDS format and parameter change commands are issued to the camera using RS-644 serial communication via the frame grabber. On older cameras, video data was output using an RS-644 LVDS format and commands were issued using RS-232 serial communication via the host PC. The output from **A102k** cameras can be converted to the older style of output by using a Basler Interface Converter for k-series cameras (k-BIC). The k-BIC is a small device which attaches to the **A102k** with a Camera Link compatible cable. For complete information on the k-BIC, refer to the k-BIC Users Manual and the k-BIC installation guide.

2.8 DC Power

The **A102k** requires 12 VDC (± 10%) power. A 12 V power supply is available from Basler as a stock item (part # 1000013046).

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

The camera's maximum power consumption is below 3.5 watts. Ripple must be less than 1%.

> (i) A Hirose 6-pin locking plug will be shipped with each camera. This plug should be used to terminate the cable on the power supply for the camera.
>
> For proper EMI protection, the power supply cable attached to the Hirose plug must be a twin-cored, shielded cable. Also, the housing of the plug must be connected to the cable shield and the cable shield must be connected to earth ground at the power supply.

2.9 Status LED

The **A102k** has a status LED on the back of the camera. The LED is used to indicate that power is present and to indicate an error condition if one is detected. See Section 6.1 for details.

3 Basic Operation and Features

3.1 Functional Description

The **A102k** area scan camera employs a CCD-sensor chip which provides features such as electronic exposure time control and anti-blooming. Exposure time is normally controlled via an externally generated sync signal (ExSync). The ExSync signal facilitates periodic or non-periodic pixel readout.

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

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

At readout, accumulated charges are transported from the light-sensitive sensor elements (pixels) to the CCD vertical shift registers. The charges from the bottom line of pixels in the CCD array are then moved into a horizontal shift register as shown in Figure 3-1. The horizontal register shifts out charges from left to right, that is, pixel 1, pixel 2, pixel 3, and so on.

As charges move out of the horizontal shift register, they are converted to voltages proportional to the size of each charge. Shifting is clocked according to the camera's 28 MHz internal data rate.

The voltages moving out of the shift register are amplified by an internal Variable Gain Control (VGC) and then digitized by a 12 bit, Analog-to-Digital converter (ADC). Once the pixels are digitized, they will be transmitted out of the camera in ascending numerical order from pixel 1 through pixel 1392. All lines are read out in a single frame (progressive scan).

The digitized video data is transmitted from the camera to the frame grabber using a format compatible with the Camera Link standard. Lines are output sequentially in a progressive scan until one full frame is obtained.

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

CCD Sensor
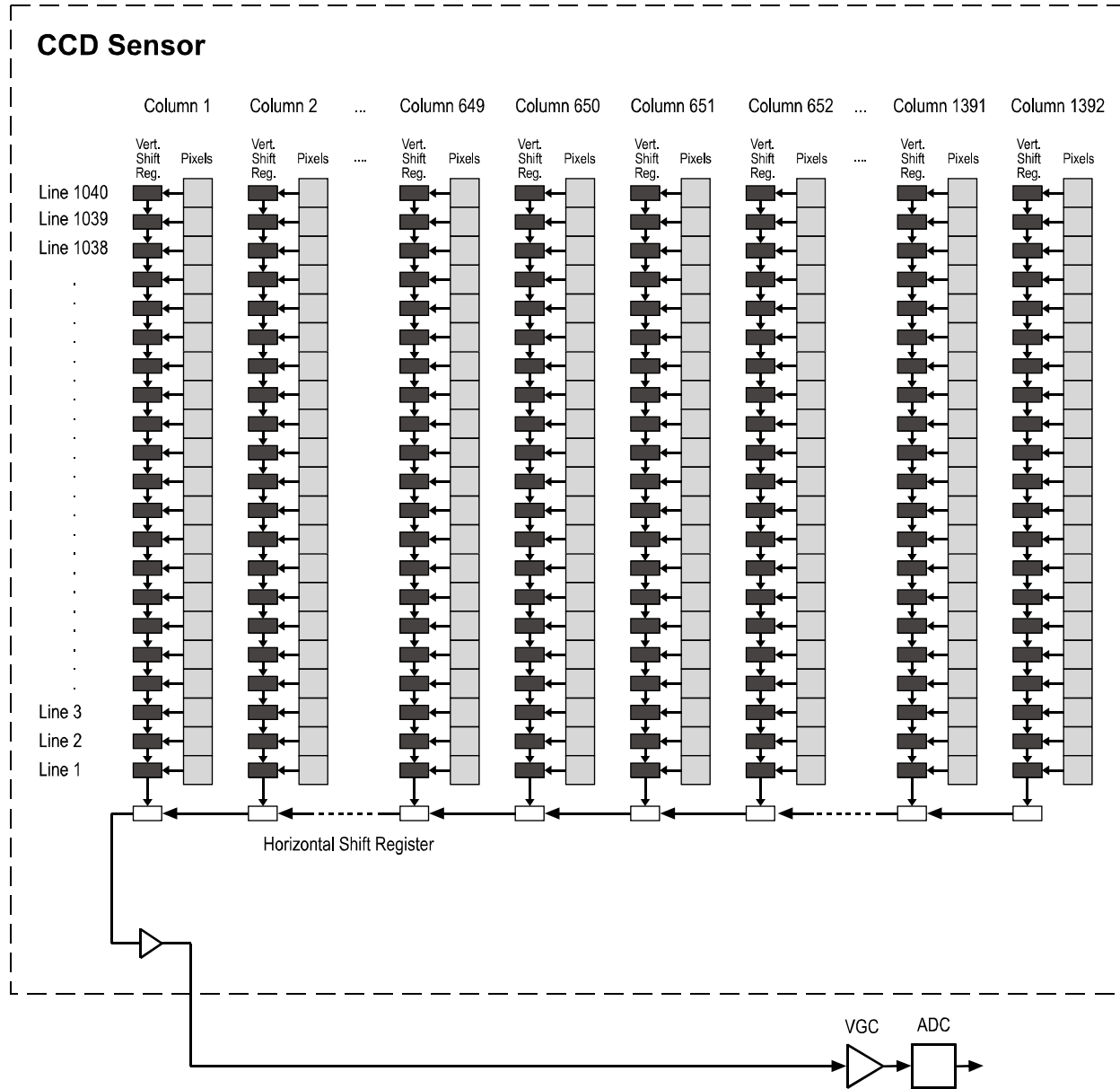
Figure 3-1: **A102k** Sensor Architecture

3.2 Exposure Time Control

The **A102k** can operate under the control of an external sync signal (ExSync) or can operate in "free-run". In free-run, the camera generates its own internal control signal and does not require an ExSync signal.

3.2.1 ExSync Controlled Operation

3.2.1.1 Basics of ExSync Controlled Operation

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

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

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

- In **ExSync, level-controlled** mode, the exposure time is determined by the time between the falling edge of ExSync and the next rising edge. The pixels are exposed and charge is accumulated only when ExSync is low. The frame is read out and transferred on the rising edge of the ExSync signal (see Figure 3-2).
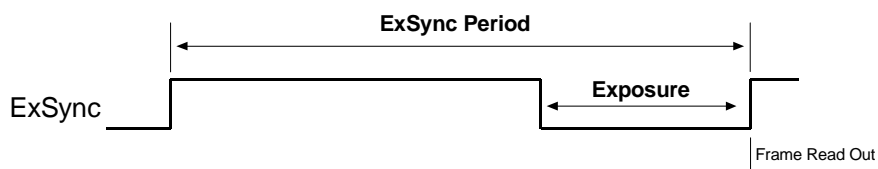
Figure 3-2: ExSync, Level-controlled Mode

- In **ExSync, programmable** mode, the rising edge of ExSync triggers exposure and charge accumulation for a pre-programmed period of time. The frame is read out and transferred at the end of the pre-programmed period.
The falling edge of ExSync is irrelevant (see Figure 3-3). A parameter called "Timer 1" is used to set the length of the pre-programmed exposure period.
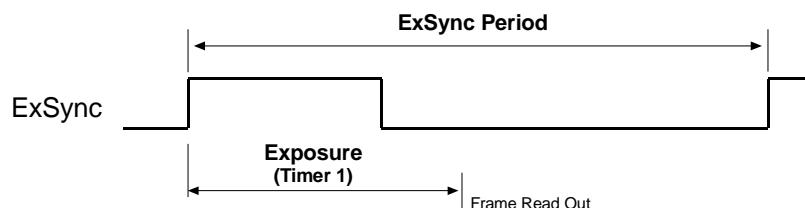
Figure 3-3: ExSync, Programmable Mode

You can set the camera to operate in one of the ExSync controlled exposure modes using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help) or binary commands (see Section 4.2).

With the configuration tool, you use the Exposure Time Control Mode setting in the Exposure group to set the camera for ExSync level-controlled or ExSync programmable exposure time control mode. If you select the programmable mode, you can also adjust the exposure time. When you enter an exposure time, the configuration tool will automatically set the "Timer 1" parameter to the correct value.

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

3.2.1.2 Recommendations for Controlling Exposure in ExSync Level-Controlled Mode

When using the ExSync level-controlled mode to control exposure, several general guidelines must be followed:

- The ExSync signal must toggle.
- The ExSync signal must remain high for at least 15 µs.
- The minimum exposure time is 15 µs.
  This means that the ExSync signal must remain low for at least 15 µs.
- If the AOI and Vertical Binning features are **not** being used, the minimum ExSync signal period is 67,500 µs.
- If the AOI feature is being used, the minimum ExSync signal period is equal to 1/Maximum Frame Rate where the maximum frame rate is determined by the formula in Section 3.8.2.1 on page 3-28.
- If the Vertical Binning feature is being used, the minimum ExSync signal period is equal to 1/Maximum Frame Rate where the maximum frame rate is determined by the formula in Section 3.8.2.2 on page 3-28.
- With very short exposures, use flash light to prevent smearing.

Assuming that these general guidelines are followed, the reaction of the camera to a falling ExSync signal will be one of two cases:

- In case one (see Figure 3-4), the falling edge of ExSync occurs while the camera is transmitting a previously captured frame, that is, when frame valid is high. This will occur when the frame rate is high.
- In case two (see Figure 3-5), the falling edge of ExSync occurs after the previously captured frame has been transmitted, that is, when frame valid is low. This will occur when the frame rate is medium or low.

Case 1 - Exposure Start With Frame Valid High

Figure 3-4: ExSync, Level-controlled Mode - Exposure Start with Frame Valid High

If the ExSync signal falls while frame valid is high as shown in Figure 3-4:

- The actual start of exposure can be up to 65 µs later than the fall of the ExSync signal. (This is commonly referred to as an exposure start jitter.)

- Due to the jitter, you may find that the actual length of the exposure time decreases even though you increase the length of the ExSync signal low time, or that the exposure time increases even though you reduce the length of the ExSync signal low time.

- The actual length of the exposure time will be equal to the ExSync signal low time plus / minus the jitter time.

> (i) As shown in Figure 3-4, FVAL **must** be low for at least 1 µs before the ExSync signal rises.

Case 2 - Exposure Start With Frame Valid Low

Figure 3-5: ExSync, Level-controlled Mode - Exposure Start with Frame Valid Low

If the ExSync signal falls while frame valid is low as shown in Figure 3-5:

- Exposure will start after a delay of 12.4 µs.
- The actual length of the exposure time will be equal to the ExSync signal low time plus 15 µs.

> **(i)** As shown in Figure 3-5, FVAL **must** be low for at least 1 µs before the ExSync signal falls.

3.2.1.3 Recommendations for Controlling Exposure
in ExSync Programmable Mode

When using the ExSync programmable mode to control exposure, several general guidelines must be followed:

- The ExSync signal must toggle.

- The ExSync signal must remain high for at least 1 µs.

- The minimum programmable exposure time is 15 µs.

- The programmed exposure time must be less than the ExSync signal period.

- If the AOI and Vertical Binning features are **not** being used, the minimum ExSync signal period is 67,500 µs.

- If the AOI feature is being used, the minimum ExSync signal period is equal to 1/Maximum Frame Rate where the maximum frame rate is determined by the formula in Section 3.8.2.1 on page 3-28.

- If the Vertical Binning feature is being used, the minimum ExSync signal period is equal to 1/Maximum Frame Rate where the maximum frame rate is determined by the formula in Section 3.8.2.2 on page 3-28.

- With very short exposures, use flash light to prevent smearing.

Assuming that these general guidelines are followed, the reaction of the camera to a rising ExSync signal will be one of two cases. In case one (see Figure 3-6), the rising edge of ExSync occurs while the camera is transmitting a previously captured frame, that is, when frame valid is high. In case two (see Figure 3-7), the rising edge of ExSync occurs after the previously captured frame has been transmitted, that is, when frame valid is low.

Case 1 - Exposure Start With Frame Valid High
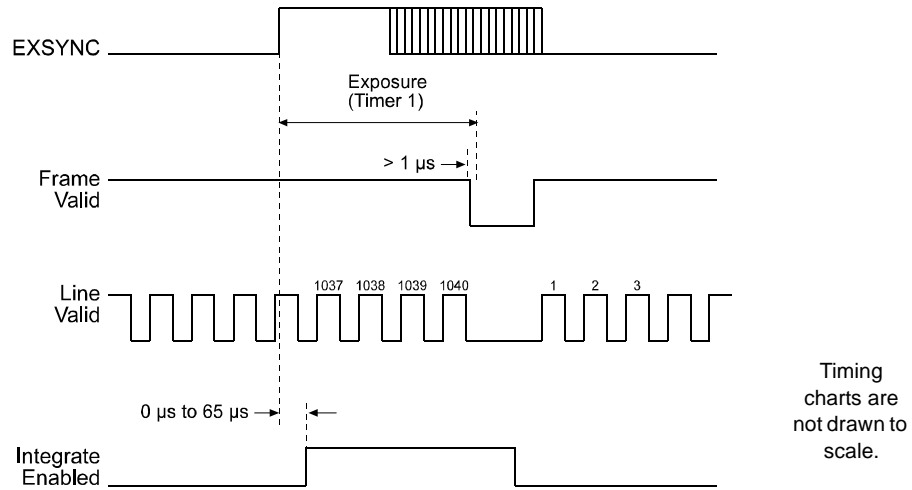
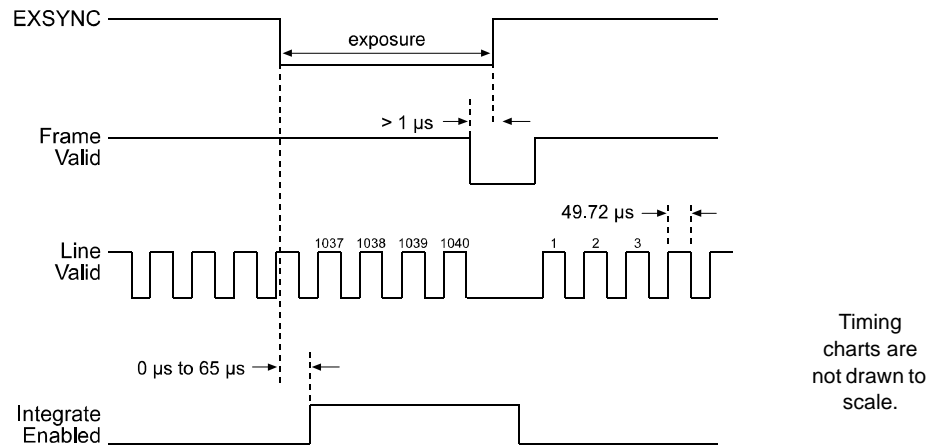
Figure 3-6: ExSync, Programmable Mode - Exposure Start with Frame Valid High

If the ExSync signal rises while frame valid is high as shown in Figure 3-6:

• The actual start of exposure can be up to 65 µs later than the rise of the ExSync signal. (This is commonly referred to as an exposure start jitter.)

• The actual length of the exposure time will be equal to the programmed exposure time plus / minus the jitter time.

> (i) As shown in Figure 3-6, FVAL **must** be low for at least 1 µs before the programmed exposure time ends.

Case 2 - Exposure Start With Frame Valid Low

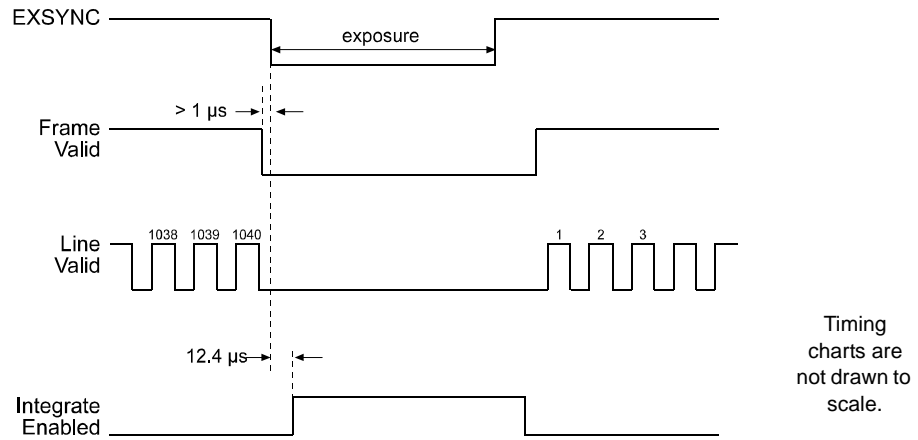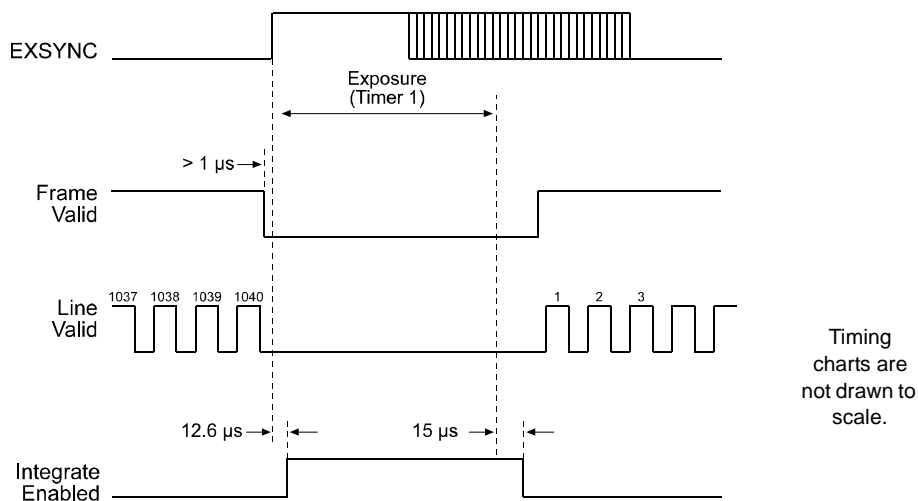Figure 3-7: ExSync, Programmable Mode - Exposure Start with Frame Valid Low

If the ExSync signal falls while frame valid is low as shown in Figure 3-7:

• Exposure will start after a delay of 12.6 µs.

• The actual length of the exposure time will be equal to the programmed time plus 15 µs.

> (i) As shown in Figure 3-7, FVAL must be low for at least 1 µs before the ExSync signal rises.

3.2.2 Free-run Operation

In free-run, no ExSync signal is required. The camera generates a continuous internal control signal based on two programmable parameters: "Timer 1" and "Timer 2." Timer 1 determines how long the internal signal will remain low and the Timer 2 determines how long the signal will remain high (see Figure 3-8). The control signal period is equal to Timer 1 plus Timer 2.

When the camera is operating in free-run, the length of the control signal period determines the camera's frame rate. (Frame Rate = 1/Control Signal Period.)

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

In free-run, only the programmable mode of exposure time control is available.

- In **free-run, programmable** mode, the pixels are exposed and charge is accumulated when the internal control signal is low. The frame is read out and transferred on the rising edge of internal control signal (see Figure 3-8).

  In this mode, the length of exposure can be programmed as desired by varying the setting of the "Timer 1" parameter:

Timer 1 = Exposure

Timer 2 = Rest of control signal period

Timer 1 + Timer 2 = Control signal period
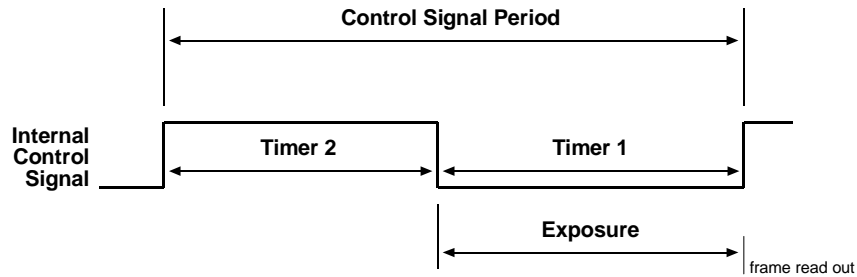
Figure 3-8: Free-run, Programmable Mode

You can set the camera to operate in free-run using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help) or binary commands (see Section 4.2).

With the Camera Configuration Tool Plus, you use the Exposure Time Control Mode setting in the Exposure group to set the camera for free-run programmable exposure time control mode. If you choose to operate the camera in free-run, you can also adjust the frame rate and exposure time. The configuration tool will then automatically set the Timer 1 and Timer 2 parameters so that the camera will operate with the frame rate and exposure time that you enter.

With binary commands, you must use the Exposure Time Control Mode command to select the free-run, programmable mode. You must also use the Timer 1 command to set Timer 1 and the Timer 2 command to set Timer 2.

3.2.2.1 Recommendations for Controlling Exposure in Free-run Programmable Mode

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

- The minimum setting for Timer 1 is 15 µs.

- The minimum setting for Timer 2 is 70 µs.

- In free-run mode, the period of the internal control signal is equal to the sum of the Timer 1 setting plus the Timer 2 setting.

- If the AOI and Vertical Binning features are **not** being used, the sum of the Timer 1 setting plus the Timer 2 must be greater than 67,500 µs.

- If the AOI feature is being used, the sum of the Timer 1 setting plus the Timer 2 setting must be greater than 1/Maximum Frame Rate where the maximum frame rate is determined by the formula in Section 3.8.2.1 on page 3-28.

- If the Vertical Binning feature is being used, the sum of the Timer 1 setting plus the Timer 2 setting must be greater than 1/Maximum Frame Rate where the maximum frame rate is determined by the formula in Section 3.8.2.2 on page 3-28.

ⓘ | If you are using the Camera Configuration Tool Plus to set up the free-run programmable mode, you will enter a frame rate and an exposure time. Once you have entered these numbers, the value for Timer 1 and Timer 2 will be automatically calculated and sent to the camera. If one of the guidelines listed above is violated, an error message will appear.

ⓘ | When the camera is operating in free-run, external control of exposure start is not possible. In free-run, the camera generates all control signals internally. The camera determines when each exposure will start and controls the length of the exposure time.

3.3 Video Data Output Modes

The **A102k** can output video data using two different modes: single 10 bit mode, or single 8 bit mode. In single 10 bit mode, the camera outputs data for one pixel on each cycle of the pixel clock and the pixel data is at 10 bit depth. In single 8 bit mode, the camera outputs data for one pixel on each cycle of the pixel clock and the pixel data is at 8 bit depth. These modes are described in detail in Section 2.5.5.2.

You can select the video data output mode using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help) or binary commands (see Section 4.2). With the configuration tool, you use the Video Data Output Mode setting in the Output group to select the data output mode. With binary commands, you use the Video Data Output Mode binary command.

3.4 Integrate Enabled Signal

An output signal called Integrate Enabled (IntEn) is available on **A102k** cameras. The integrate enabled signal indicates that an exposure is taking place. The signal will go high when each exposure begins and go low when the exposure ends. The characteristics of the signal are described in more detail in Section 2.5.6.

This signal is especially useful when you are operating a system where either the camera or the object being imaged is movable. For example, assume that the camera is mounted on an arm mechanism and that the mechanism can be used to move the camera to view different portions of a product assembly. Typically, you do not want the camera to move during exposure. In this case, you can monitor the IntEn signal to know when exposure is taking place and thus know when to avoid moving the camera.

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

3.5 Low Smear

In applications where a CCD sensor is under constant illumination, high-contrast images may show an unwanted effect that converts dark pixels into brighter ones. This effect is commonly called "smearing".

With the help of the Low Smear feature on the **A102k**, smearing is reduced in the upper part of the image. The effect of the Low Smear feature is illustrated in Figure 3-9.

The left image was captured without the low smear feature. There is smearing both in the upper and lower part of the image.

The right image was captured with low smear active. There is no smearing in the upper part of the image.
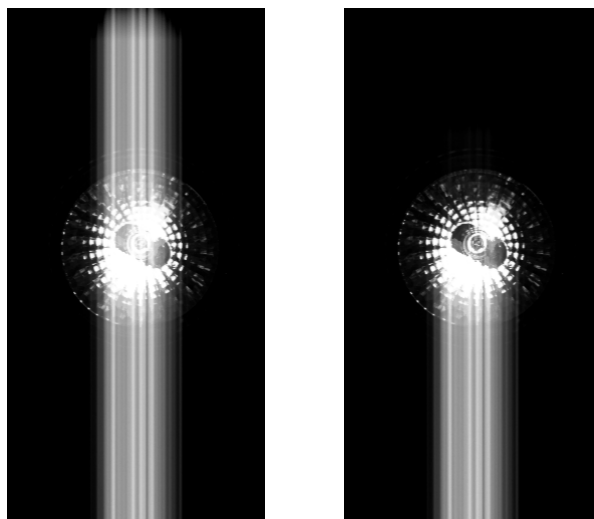
Figure 3-9: Full Smear (left), Low Smear (right)

Smearing is caused by two things:

- an unwanted post-exposure of the pixels when they are being moved out through the vertical shift registers. Only those pixels located above the area of exposure on the CCD array which must pass the light source during shift-out are subject to post-exposure. For this reason, post-exposure only produces smearing in the lower part of the image. (Remember that the lens causes the image on the sensor to be inverted, so the lower part of the image is at the top of the sensor.)

- an unwanted existing accumulation of charges in those shift registers which have passed points of constant illumination during the previous frame transfer and have thus been exposed before they receive the next pixels. These unwanted charges add to the next pixels when these pixels are shifted from the sensor cells into the vertical shift registers. This causes smearing in the upper part of the image.

The amount of unwanted charges accumulated in the shift registers grows with the amount of exposure. For that reason, smearing does not appear under short-term illumination such as flash light. It only appears under constant illumination.

The Low Smear feature cannot be activated or deactivated. It is active all of the time. To use this feature to its best advantage, the frame rate must not exceed a maximum setting. The setting can be calculated using the below equations.

First, you need to calculate the frame transfer time based on the height of the area of interest (AOI) using this formula:

$$T(f) = 390.71 \ \mu s + \left[(1040 - AOIH) \times 12.14 \ \mu s \right] + \left[(AOIH + 1) \times 64.29 \ \mu s \right]$$

where: $T(f)$ = frame transfer time
AOIH = number of lines in the AOI

Second, you need to calculate the maximum recommended frame rate for low smear using this formula:

$$\text{Frames/sec.} \leq \cfrac{1}{T(f) + \left[\left(AOIH - \cfrac{T(e)}{64.29\ \mu s}\right) \times 5.57\ \mu s\right] + T(e)}$$

where: $T(f)$ = frame transfer time
AOIH = number of lines in the AOI
$T(e)$ = exposure time

If you use an example with a 2000 µs exposure time and a 1392 (H) x 600 (V) area of interest, the calculations look like this:

$$T(f) = 390.71\ \mu s + \left[(1040 - 600) \times 12.14\ \mu s\right] + \left[(600 + 1) \times 64.29\ \mu s\right]$$

$$T(f) = 44371\ \mu s$$

and:

$$\text{Frames/sec.} \leq \cfrac{1}{44371\ \mu s + \left[\left(600 - \cfrac{2000}{64.29\ \mu s}\right) \times 5.57\ \mu s\right] + 2000\ \mu s}$$

$$\text{Frames/sec.} \leq 20.18$$

If the camera's actual frame rate is higher than the maximum recommended frame rate, the smearing will come back. When you exceed the maximum recommended frame rate by a small amount, the upper part of the image will show partial smearing (Figure 3-10). As the frame rate is increased, the smearing will become worse.
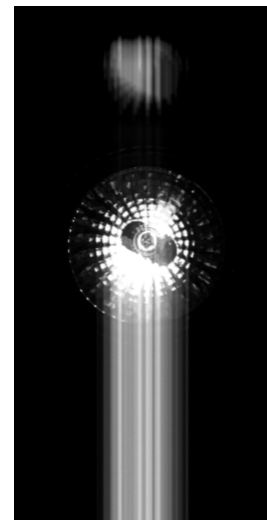
Figure 3-10: Partial Smear

3.6 Gain and Offset

The major components in the **A102k** electronics include: a CCD sensor, one VGC (Variable Gain Control), and one ADC (Analog to Digital Converter). The pixels in the CCD sensor output voltage signals when they are exposed to light. These voltages are amplified by the VGC and transferred to the ADC which converts the voltages to digital output signals.

Two parameters, gain and offset are associated with the VGC. As shown in Figures 3-11 and 3-12, increasing or decreasing the gain increases or decreases the amplitude of the signal that is input to the ADC. Increasing or decreasing the offset moves the signal up or down the measurement scale but does not change the signal amplitude.

For most applications, black should have a gray value of 1 and white should have a gray value of 255 (in 8 bit output mode) or 1023 (in 10 bit output mode). Attempt to achieve this by varying exposure and illumination rather than changing the camera's gain. The default gain is the optimal operating point (minimum noise) and should be used if possible.
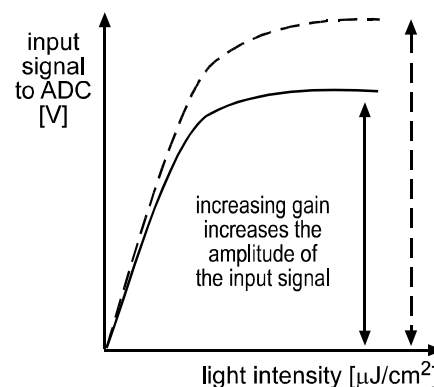
Figure 3-11: Gain
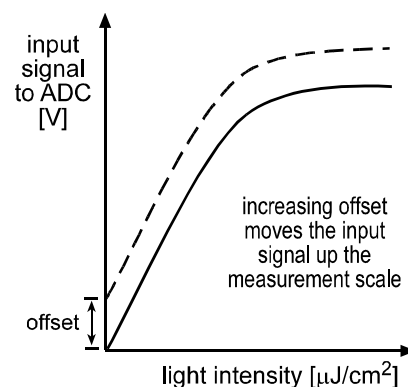
Figure 3-12: Offset

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

You can set the gain and offset using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help) or binary commands (see Section 4.2).

With the configuration tool, you use the Gain setting in the Gain & Offset group to adjust the gain, and the Offset setting in the Gain & Offset group to adjust the offset.

With binary commands, you must use the Gain binary command to set the gain and the Offset binary command to set the offset (see Sections 4.2.4.10 and 4.2.4.11).

3.6.1 Setting the Gain

When the gain is set to default, the sensor's linear output range directly matches the input voltage range of the ADC. Thus, with the default gain of 0 dB, a gray value of 1 is produced when the pixels are exposed to no light and a gray value of 255 (8-bit mode) or 1023 (10-bit mode) is produced when the pixels are exposed to bright light.

The 0 dB default gain is achieved when gain is programmed to a decimal value of 240. (Due to tolerances in the electronic components in your camera, you may find that the 0 dB default gain is achieved with a slightly different setting.) Increasing the gain setting to more than 240 maps a smaller portion of the sensor's linear output range to the ADC's input.
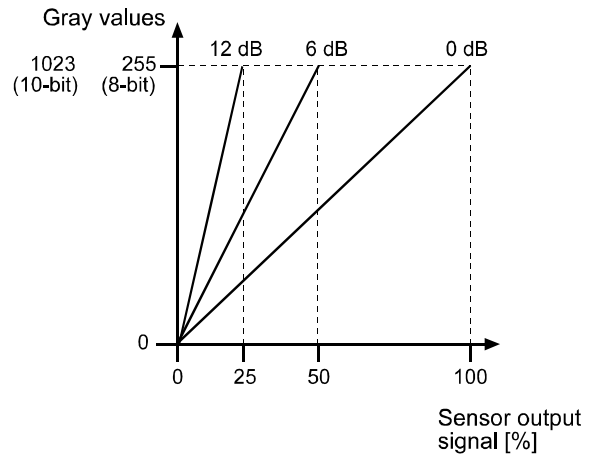
Figure 3-13: Gain Settings in dB

Increasing the gain is useful when at your brightest exposure, a gray value lower than 255 (8-bit mode) or 1023 (10-bit mode) is reached. For example, if you found that at your brightest exposure your gray values were no higher than 127 (8-bit mode), you could increase the gain to 6 dB (amplification factor of 2) and thus reach gray values of 254 (see Figure 3-13).

Gain is adjustable and can be programmed on a decimal scale that ranges from 240 to 1023 (hex 0x00F0 to 0x03FF).

ⓘ The degree of amplification that can be achieved with a gain setting depends on whether vertical binning is active.

If Vertical Binning is disabled on your camera, refer to Section 3.6.1.1.

If Vertical Binning is enabled on your camera, refer to Section 3.6.1.2.

ⓘ Due to the sensor characteristics, if the gain is set to 768 decimal (hex 0x0300) or higher, the first 16 pixels in each line may vary in their sensitivity. To avoid variation, you can use the Area of Interest feature and set column 17 as the Area of Interest Starting Column (see page 3-27).

3.6.1.1 Setting the Gain with Vertical Binning Disabled

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

When the gain setting is between 240 DN and 511 DN, the gain curve follows a (1+x)/(1-x) shape, which is similar to a linear-in-dB shape.

When DN setting = 240 to 511
$$dB = 20 \times \log_{10} \left(\frac{658 + DN}{658 - DN} \right) - 6.642$$

From gain setting 512 DN to gain setting 1023 DN, the curve follows a linear-in-dB shape:

When DN setting = 512 to 1023
$$dB = 0.0354 \times DN - 6.642$$

If the Vertical Binning feature is disabled, the gain settings result in the following amplifications:

Decimal Number (DN)	Hexadecimal	dB	Factor
240	0x00F0	0	X1
409	0x0199	6	X2
527	0x020F	12	X4
696	0x02B8	18	X8
866	0x0362	24	X16
1023	0x03FF	29.572	X30.1

Table 3-1: Gain Settings in dB (with Vertical Binning Disabled)

> (i) In normal operation, a gain setting lower than 240 (0x00F0) should not be used. When the gain setting is lower than 240, the sensor output signal that is mapped to the input of the ADC will not be linear.

3.6.1.2 Setting the Gain with Vertical Binning Enabled

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

When the gain setting is between 192 DN and 511 DN, the gain curve follows a (1+x)/(1-x) shape, which is similar to a linear-in-dB shape.

When DN setting = 192 to 511
$$dB = 20 \times \log_{10}\left(\frac{658 + DN}{658 - DN}\right) - 5.221$$

From gain setting 512 DN to gain setting 1023 DN, the curve follows a linear-in-dB shape:

When DN setting = 512 to 1023
$$dB = 0.0354 \times DN - 5.221$$

If the Vertical Binning feature is enabled, the gain settings result in the following amplifications:

Decimal Number (DN)	Hexadecimal	dB	Factor
192	0x00C0	0	X1
374	0x0176	6	X2
499	0x01F3	12	X4
656	0x0290	18	X8
825	0x0339	24	X16
1023	0x03FF	31	X35.5

Table 3-2: Examples of Gain Settings in dB (with Vertical Binning Enabled)

> (i) In normal operation, a gain setting lower than 192 (0x00C0) should not be used. When the gain setting is lower than 192, the sensor output signal that is mapped to the input of the ADC will not be linear.

3.6.2 Setting the Offset

You can use the Camera Configuration Tool Plus to set the offset on your camera. For more information on using the configuration tool to adjust offset, refer to the on-line help that is included with the tool.

You can also use the Offset binary command to set the offset (see Section 4.2.4.11). The offset setting can be programmed on a decimal scale that ranges from 0 to 255, which translates to a hexadecimal scale of 0x0000 to 0x00FF.

If the camera is operating in 8 bit output mode, an offset setting of around 8 (decimal) will result in an offset of 0 in the digital values output for the pixels. (Due to tolerances in the electronic components in your camera, you may find that the default offset of 0 digital values is achieved with a slightly different setting.) An increase of 16 (decimal) in the offset setting will result in a positive offset of 1 in the digital values output for the pixels. For example, an offset setting of around 24 (8 + 16, decimal) would be required to reach a positive offset of 1. An offset setting of around 40 (8 + 16 + 16, decimal) would be required to reach a positive offset of 2, and so on.

If the camera is operating in 10 bit output mode, an offset setting of around 2 (decimal) will result in an offset of 0 in the digital values output for the pixels. (Due to tolerances in the electronic components in your camera, you may find that the default offset of 0 digital values is achieved with a slightly different setting.) An increase of 4 (decimal) in the offset setting will result in a positive offset of 1 in the digital values output for the pixels. For example, an offset setting of around 6 (2 + 4, decimal) would be required to reach a positive offset of 1. An offset setting of around 10 (2 + 4 + 4, decimal) would be required to reach a positive offset of 2, and so on.

If the camera is operating in 12 bit output mode, an offset setting of around 0 (decimal) will result in an offset of 0 in the digital values output for the pixels. (Due to tolerances in the electronic components in your camera, you may find that the default offset of 0 digital values is achieved with a slightly different setting.) An increase of 1 (decimal) in the offset setting will result in a positive offset of 1 in the digital values output for the pixels. For example, an offset setting of around 1 (0 + 1, decimal) would be required to reach a positive offset of 1. An offset setting of around 2 (0 + 2, decimal) would be required to reach a positive offset of 2, and so on.

3.7 Digital Shift

The "digital shift" feature allows you to change the group of bits that is output from the ADC. Using the digital shift feature will effectively multiply the output of the camera by 2 times, 4 times or 8 times. Section 3.7.1 describes how digital shift works when the camera is operating in 12 bit output mode, Section 3.7.2 describes how digital shift works when the camera is operating in 10 bit output mode, and Section 3.7.3 describes how digital shift works when the camera is operating in 8 bit output mode.

Also note the precautions that you must observe to effectively use this feature (see Section 3.7.4).

You can set digital shift using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help) or binary commands (see Section 4.2). With the configuration tool, you use the Digital Shift setting in the Output group to set digital shift. With binary commands, you use the Digital Shift command.

3.7.1 Digital Shift in 12 bit Output Mode

No Shift

As mentioned in Section 3.1, the **A102k** uses a 12 bit ADC to digitize the output from the CCD sensor. When the camera is operating in 12 bit output mode, by default, the camera transmits all 12 bits from the ADC.

Shift Once

When the camera is set to shift once, the output from the camera will include bit 10 through bit 0 from the ADC along with a zero as an LSB.

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

(i) Note that if bit 11 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 12 bit mode with no digital shift are all below 2048.

Since the shift once setting requires that the least significant bit (LSB) always be "0", no odd gray values can be output. The gray value scale will only include gray values of 2, 4, 6 and so forth. The absence of some gray values is commonly called "Missing Codes".

Shift Twice

When the camera is set to shift twice, the output from the camera will include bit 9 through bit 0 from the ADC along with two zeros as LSBs.

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

ADC

| bit 11 | bit 10 | bit 9 | bit 8 | bit 7 | bit 6 | bit 5 | bit 4 | bit 3 | bit 2 | bit 1 | bit 0 | "0" | "0" |

MSB — Shifted Twice — LSB

> ⓘ Note that if bit 11 or bit 10 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 12 bit mode with no digital shift are all below 1024.
>
> Since the shift once setting requires that the two least significant bits (LSBs) always be "0", only gray values divisible by 4 can be represented. The gray value scale will only include gray values of 4, 8, 12 and so forth. The absence of some gray values is commonly called "Missing Codes".

Shift Three Times

When the camera is set to shift three times, the output from the camera will include bit 8 through bit 0 from the ADC along with three zeros as LSBs.

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

ADC

| bit 11 | bit 10 | bit 9 | bit 8 | bit 7 | bit 6 | bit 5 | bit 4 | bit 3 | bit 2 | bit 1 | bit 0 | "0" | "0" | "0" |

MSB — Shifted 3 Times — LSB

> ⓘ Note that if bit 11, bit 10 or bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift three times setting when your pixel readings in 12 bit mode with no digital shift are all below 512.
>
> Since the shift once setting requires that the three least significant bits (LSBs) always be "0", only gray values divisible by 8 can be represented. The gray value scale will only include gray values of 8, 16, 24 and so forth. The absence of some gray values is commonly called "Missing Codes".

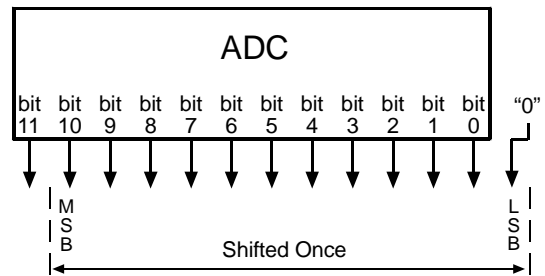## 3.7.2 Digital Shift in 10 bit Output Mode

No Shift

As mentioned in Section 3.1, the **A102k** uses a 12 bit ADC to digitize the output from the CCD sensor. When the camera is operating in 10 bit output mode, by default, the camera transmits bit 11 through bit 2 from the ADC.

Shift Once

When the camera is set to shift once, the output from the camera will include bit 10 through bit 1 from the ADC.

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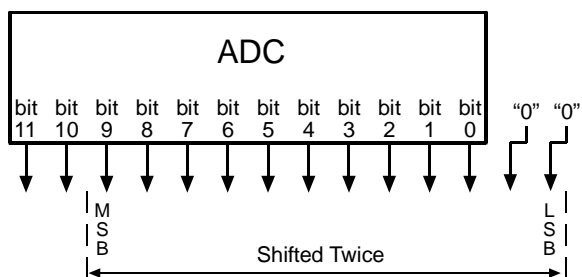

> (i) Note that if bit 11 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 10 bit mode with no digital shift are all below 512.

Shift Twice

When the camera is set to shift twice, the output from the camera will include bit 9 through bit 0 from the ADC.

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

ADC

bit 11 bit 10 bit 9 bit 8 bit 7 bit 6 bit 5 bit 4 bit 3 bit 2 bit 1 bit 0

M S B   Shifted Twice   L S B
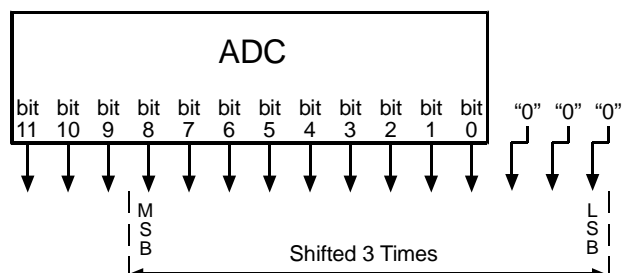
ⓘ Note that if bit 11 or bit 10 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 10 bit mode with no digital shift are all below 256.

Shift Three Times

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

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

ADC

bit 11 bit 10 bit 9 bit 8 bit 7 bit 6 bit 5 bit 4 bit 3 bit 2 bit 1 bit 0 "0"

M S B   Shifted 3 Times   L S B

ⓘ Note that if bit 11, bit 10 or bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift three times setting when your pixel readings in 10 bit mode with no digital shift are all below 128.

Since the shift three times setting requires that the least significant bit (LSB) always be "0", no odd gray values can be output. The gray value scale will only include gray values of 2, 4, 6 and so forth. The absence of some gray values is commonly called "Missing Codes".

3.7.3 Digital Shift in 8 bit Output Mode

No Shift

As mentioned in Section 3.1, the **A102k** uses a 12 bit ADC to digitize the output from the CCD sensor. When the camera is operating in 8 bit output mode, by default, it drops the four least significant bits from the ADC and transmits the 8 most significant bits (bit 11 through bit 4).

Shift Once

When the camera is set to shift once, the output from the camera will include bit 10 through bit 3 from the ADC.

The result of shifting once is that the output of the camera is effectively doubled. For example, assume that the camera is set for no shift, that it is viewing a uniform white target and that under these conditions the reading for the brightest pixel is 20. If you changed the digital shift setting to shift once, the reading would increase to 40.
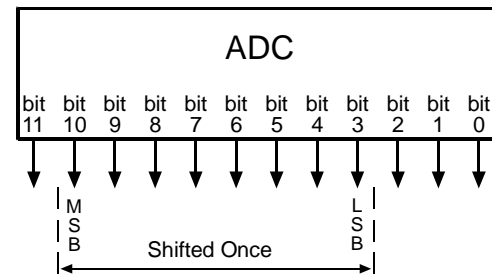
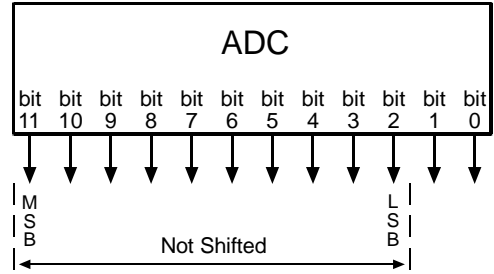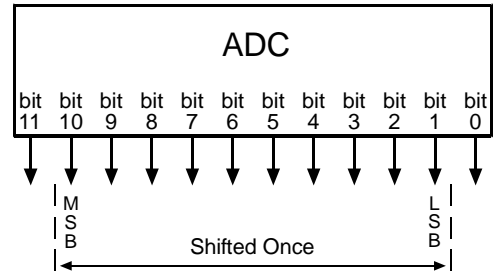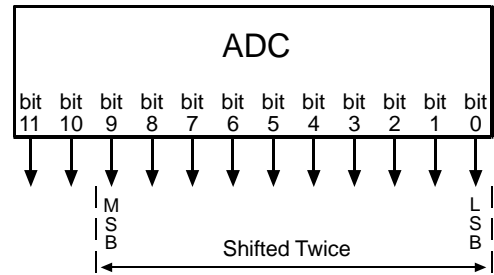> ⓘ   Note that if bit 11 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 8 bit mode with no digital shift are all below 128.

Shift Twice

When the camera is set to shift twice, the output from the camera will include bit 9 through bit 2 from the ADC.

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

ADC

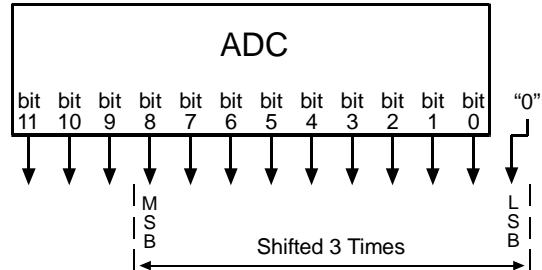| bit 11 | bit 10 | bit 9 | bit 8 | bit 7 | bit 6 | bit 5 | bit 4 | bit 3 | bit 2 | bit 1 | bit 0 |

M S B — Shifted Twice — L S B

(i) Note that if bit 11 or bit 10 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 8 bit mode with no digital shift are all below 64.

Shift Three Times

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

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

ADC

| bit 11 | bit 10 | bit 9 | bit 8 | bit 7 | bit 6 | bit 5 | bit 4 | bit 3 | bit 2 | bit 1 | bit 0 |

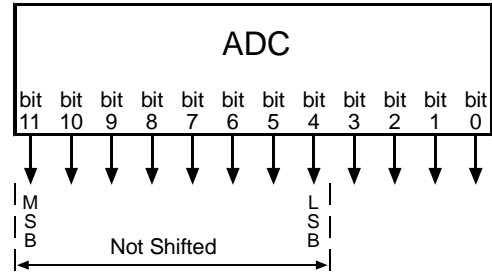M S B — Shifted 3 Times — L S B

(i) Note that if bit 11, bit 10 or bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 8 bit mode with no digital shift are all below 32.

3.7.4 Precautions When Using Digital Shift

There are several checks and precautions that you must follow before using the digital shift feature. The checks and precautions differ depending on whether you will be using the camera in 12 bit output mode, in 10 bit output mode or in an 8 bit output mode.

If you will be using the camera in 12 bit output mode, make this check:

1. Use binary commands or the Video Data Output Mode setting in the Output group of the CCT+ to put the camera in 12 bit output mode.
2. Use binary commands or the Digital Shift setting in the Output group of the CCT+ to set the camera for no digital shift.
3. Check the output of the camera under your normal lighting conditions with no digital shift and note the readings for the brightest pixels.
   - If any of the readings are above 2048, do not use digital shift.
   - If all of the readings are below 2048, you can safely use the 2X digital shift setting.
   - If all of the readings are below 1024, you can safely use the 2X or 4X digital shift setting.
   - If all of the readings are below 512, you can safely use the 2X, 4X, or 8X digital shift setting.

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

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

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

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

3.8   Area of Interest (AOI)

The area of interest (AOI) feature allows you to specify a portion of the CCD array and during operation, only the pixel information from the lines included in the AOI is transferred out of the camera.

The size of the area of interest is defined by declaring a starting column, a width in columns, a starting line and a height in lines. Reference position is the top left corner of the image. For example, if you specify the starting column as 11, the width in columns as 16, the starting line as 5 and the height in lines as 10, the AOI will be as shown in Figure 3-14.
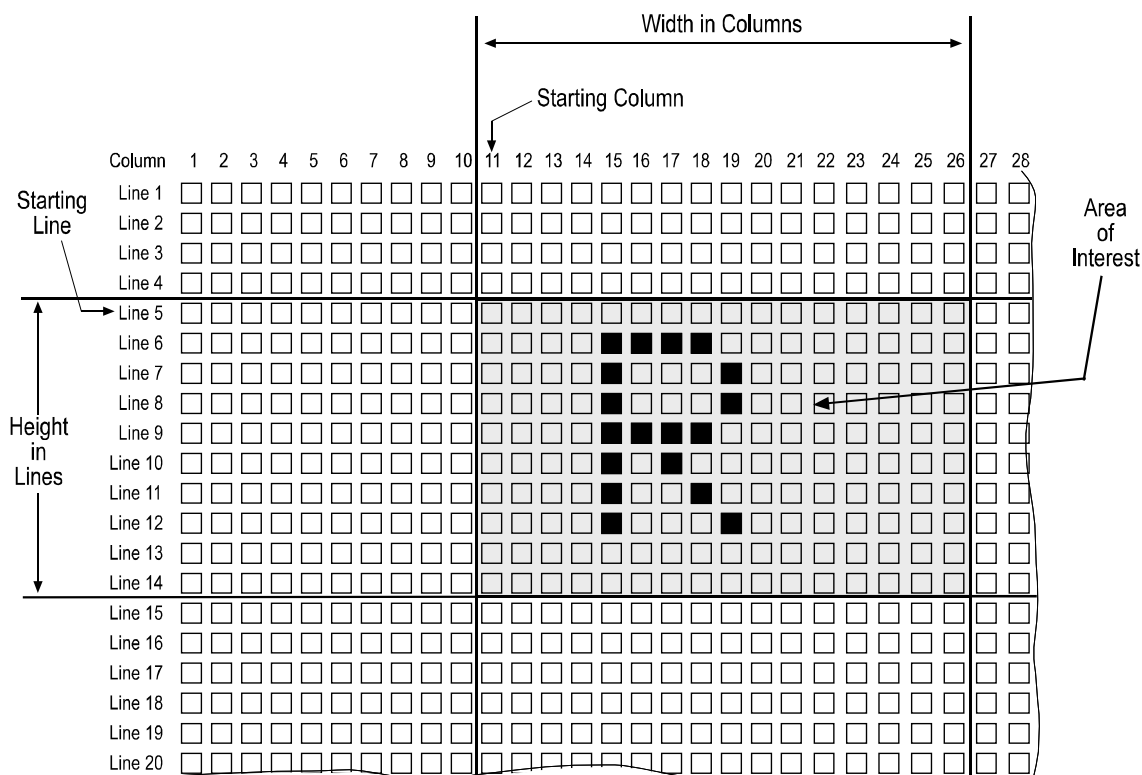
Figure 3-14: Area of Interest

You can set the area of interest using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help file) or binary commands (see Section 4.2).

With the configuration tool, you use the AOI Starting Column, AOI Width, AOI Starting Line, and AOI Height settings in the AOI & Binning group to set the area of interest.

With binary commands, you use the Area of Interest Starting Column, Area of Interest Width in Columns, Area of Interest Starting Line, and Area of Interest Height in Lines commands.

3.8.1 AOI Setup Guidelines

When setting up the area of interest, a few guidelines must be followed:

- The sum of the setting for the *Starting Column* plus the setting for the *Width in Columns* can not exceed 1393.
- The sum of the setting for the *Starting Line* plus the setting for the *Height in Lines* can not exceed 1041.

In normal operation, the camera is set to use all of the pixels in the array. To use all of the pixels, the starting column should be set to 1, the width in columns should be set to 1392, the starting line should be set to 1, and the height in lines should be set to 1040.

> (i) If you use the AOI feature on an **A102kc** color camera and you change the position of the AOI, you may change the order of the pixel colors output from the camera. See Section 3.11 for more details.

3.8.2 Changes to the Maximum Frame Rate with Area of Interest

When the area of interest feature is used, the camera's maximum allowed frame rate increases. The amount that the maximum frame rate increases depends on the number of lines included in the area of interest. The smaller the number of lines in the area of interest, the higher the maximum frame rate.

If Vertical Binning is disabled on your camera, refer to the formula in Section 3.6.1.1.

If Vertical Binning is enabled on your camera, refer to the formula in Section 3.6.1.2.

3.8.2.1 With Vertical Binning Disabled

The maximum allowed frame rate can be calculated using the following formula:

$$\text{Frames / sec.} = \frac{1}{390.71 \ \mu s + [\ (1040 - AOIH) \times 12.14 \ \mu s\ ] + [(AOIH + 1) \times 64.29 \ \mu s]}$$

Where: AOIH = the number of lines included in the area of interest

3.8.2.2 With Vertical Binning Enabled

The maximum allowed frame rate can be calculated using the following formula:

$$\text{Frames / sec.} = \frac{1}{390.71 \ \mu s + [\ (1040 - AOIH) \times 12.14 \ \mu s\ ] + \left[\left(\dfrac{AOIH}{2} + 1 \right) \times 76.43 \ \mu s \right]}$$

Where: AOIH = the number of lines included in the area of interest

3.8.3 Changes to the Pixel Timing and Output with AOI

When the AOI feature is being used, frame valid will rise at the normal time, however, there will be a delay between the rise of frame valid and the rise of the first line valid while the camera discards data from the lines above the AOI. The length of the delay depends on the number of lines above the AOI.

When the camera reaches the first line in the AOI the camera will begin to output pixel data, but the line valid bit will remain low indicating that the pixels are not valid. On the pixel clock cycle where the starting column in the AOI is reached, the line valid bit will become high. The line valid bit will remain high as the pixels within the AOI are transmitted indicating that these are valid pixels. Once the pixels within the AOI have been transmitted, the line valid bit will become low. The camera will continue to transmit the remaining pixels in the line, but as indicated by the low line valid bit, these pixels are not valid. Any invalid pixels at the beginning and the end of each line are transmitted as dark pixels (gray value = 0).

After all of the lines in the AOI have been transmitted, the line valid bit will remain low. There will be a delay as the lines located below the AOI are discarded. The length of the delay depends on the number of lines below the AOI. Once the lines are discarded, the frame valid bit will become low indicating that frame transmission is complete.

To better understand the timing and output changes that occur when using AOI, refer to Figure 3-15. This timing chart shows what would happen if the AOI was set up with a starting column of 201, a width in columns of 600, a starting line of 101 and a height in lines of 800. As you can see, there is a delay after the rise of frame valid as the camera discards the data for lines 1 through 100. When the camera reaches line 101, pixels 1 through 200 are output as dark pixels and the LVAL bit stays low indicating that these pixels are not valid. On pixels 201 through 800, LVAL is high indicating that the data for these pixels is valid. For pixels 800 through 1392, the camera outputs dark pixels and LVAL is low indicating that these pixels are not valid. This pattern repeats as the camera outputs pixel data for lines 102 through 900. After line 900 has been transmitted, there is a delay while the camera discards lines 901 through 1040 and during this time the FVAL bit remains high. Once these lines are discarded, the FVAL bit becomes low indicating that frame transfer is complete.

ⓘ	If you use a frame grabber that does not take the fall of the line valid bit into account, you must set the frame grabber for the number of horizontal pixels in the area of interest. For example, if your area of interest is 600 columns wide, you must set the grabber for a 600 pixel image width.
	If you use a frame grabber that does not take the fall of the frame valid bit into account, you must set the frame grabber for the number of vertical pixels in the area of interest. For example, if your area of interest is 800 lines high, you must set the grabber for an 800 pixel image height.
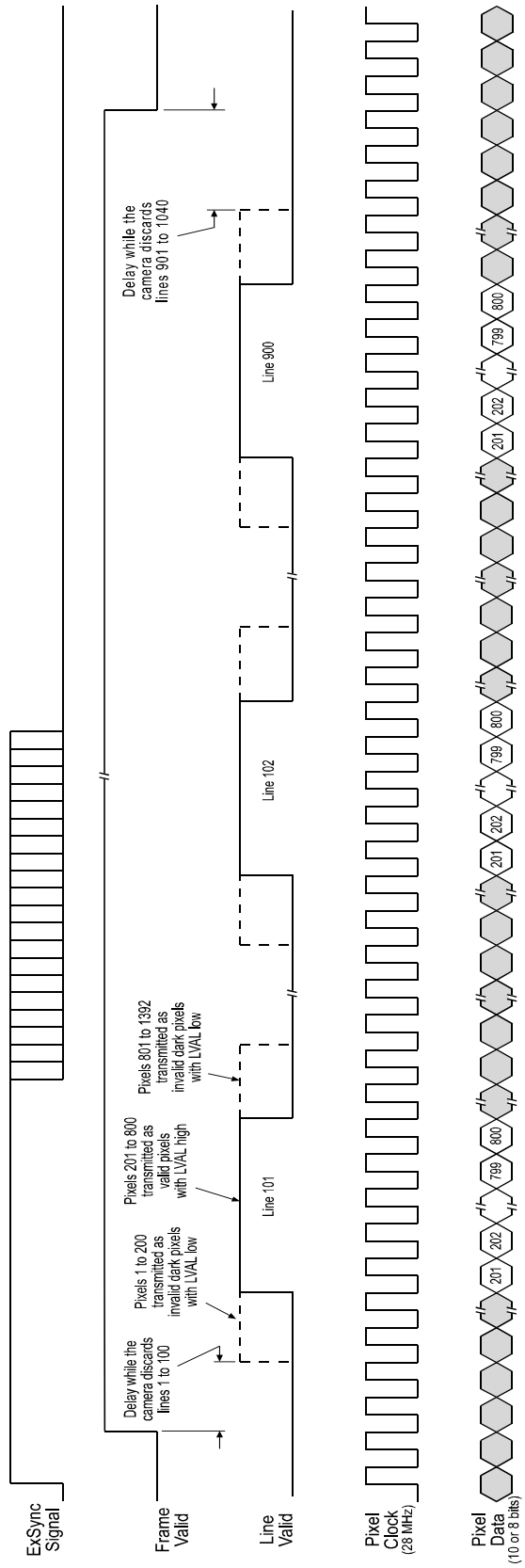
Figure 3-15: Timing and Output Changes with AOI

3.9 Binning

There are three types of binning available: vertical binning, horizontal binning, and full binning.

You can set binning using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help file) or binary commands (see Section 4.2). With the configuration tool, you use the Horizontal Binning and Vertical Binning settings in the AOI & Binning group to enable binning. To enable full binning, you must enable both Horizontal Binning and Vertical Binning. With binary commands, you use the Horizontal Binning and Vertical Binning commands.

(i) Binning should only be used on **A102k** monochrome cameras. Using binning on **A102kc** color cameras is not recommended.

3.9.1 Vertical Binning

Vertical binning increases the camera's responsivity to light by summing the charges from adjacent pixels into one pixel. With vertical binning, pairs of adjacent pixels from two lines are summed and reported out as a single pixel.

Vertical binning reduces the noise portion in the pixel output. With vertical binning, the signal-to-noise ratio will increase by typically 1 to 2 dB.

When vertical binning is active, resolution decreases to 1392 (H) by 520 (V).
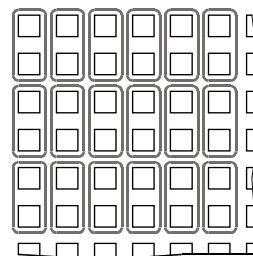
Figure 3-16: Vertical Binning

(i) Using vertical or full binning generally increases the camera's responsivity by up to two times normal. After switching on binning, the image might look overexposed. Reduce the lens aperture, light intensity, or exposure in this case.

With vertical binning active, frame grabbers often require the information that the vertical resolution is 520.

When vertical binning or full binning is used, the camera's maximum allowed frame rate increases. The maximum allowed frame rate can be calculated using the formula given in Section 3.8.2.2 on page 3-28.

3.9.2 Horizontal Binning

With horizontal binning, the digitized data of pairs of adjacent pixels in each line are averaged and reported out as a single pixel (see Figure 3-17). Horizontal binning does not change the camera's responsivity to light but it reduces the noise portion in the pixel output.

Horizontal binning improves the signal-to-noise ratio in the camera output by typically 3 dB.

When horizontal binning is active, image resolution decreases to 696 pixels (H) by 1040 pixels (V).

Figure 3-17: Horizontal Binning

> (i) With horizontal binning or full binning active, frame grabbers must take the state of the data valid bit into account. And they often require the information that the horizontal resolution is 696.

Changes to the Pixel Output with Horizontal Binning

Whenever horizontal binning or full binning is used, frame valid and line valid will rise at the normal time. On the first pixel clock cycle, the averaged data for pixel number one is transmitted. On the third pixel clock cycle, the averaged data for pixel number two is transmitted. On the fifth pixel clock cycle, the averaged data for pixel number three is transmitted, and so forth. The data valid bit is used to signal the even numbered pixel clock cycles as invalid.

As illustrated in Figure 3-18, the data for pixel number one is transmitted on the first pixel clock cycle and data valid is high. On the second pixel clock cycle, valid data is not transmitted and the data valid bit is low. On the third pixel clock cycle, data for pixel number two is transmitted and data valid is high. On the fourth pixel clock cycle, valid data is not transmitted and the data valid bit is low, and so forth.
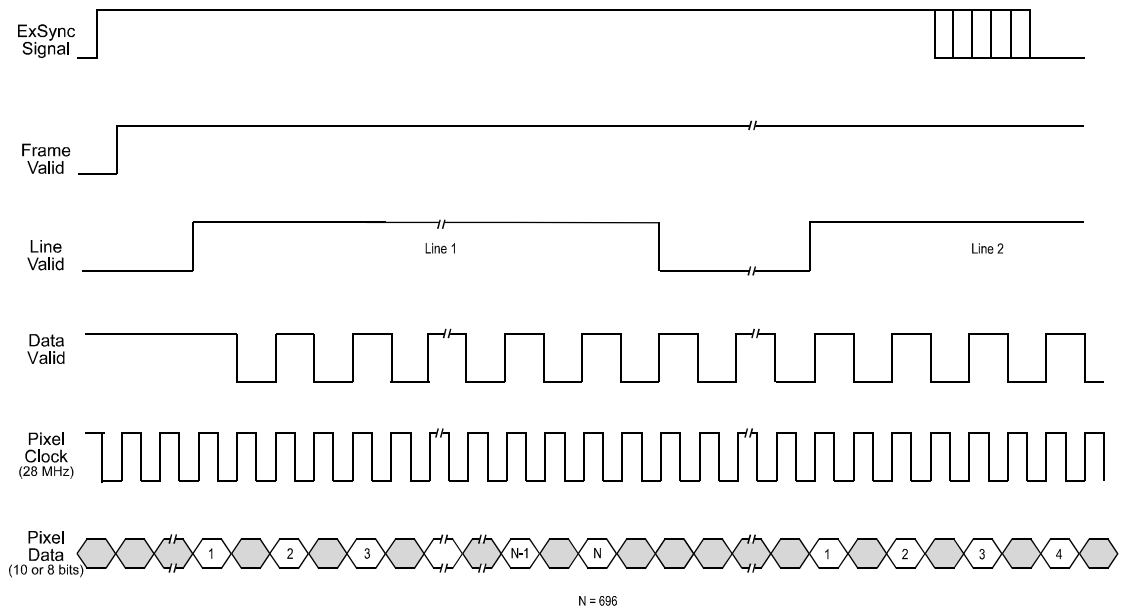
Figure 3-18: Output Changes with Horizontal Binning

3.9.3 Full Binning

Full binning is a combination of horizontal and vertical binning in which four adjacent pixels are reported as a single pixel (see Figure 3-19).

Using full binning generally increases the camera's responsivity by up to two times normal. In addition, it increases the signal-to-noise ratio in the camera output by typically 4 to 5 dB.

With full binning, resolution decreases to 696 (H) by 520 (V).
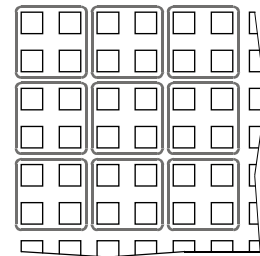
Figure 3-19: Full Binning

> (i) With full binning active, frame grabbers often require the information that the horizontal resolution is 696 and the vertical resolution is 520.

3.10 Gamma Correction

A gamma correction feature is available on **A102k** cameras. When gamma correction is enabled, a correction factor will be applied to each pixel value before the value is transmitted from the camera.

The formula for the correction is:

$$\text{Corrected Pixel Value} = \text{Original Pixel Value}^{\left[\frac{1}{\gamma}\right]}$$

(round to the nearest lower integer)

The value of gamma (γ) in the formula can be set to 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, or 2.8. (When the value is set to 1, there is no correction and the feature is disabled.)

You can use the Camera Configuration Tool Plus to set the gamma correction value on your camera. For more information on using the configuration tool to adjust gamma, refer to the on-line help included with the tool.

You can also use the Gamma binary command to set the gamma correction value (see Section 4.2.4.14).

Example

Assume that the cameras has captured an image and that the value for pixel one in line one is 110. Also assume that gamma correction is enabled and set for a value of 1.4.

$$\text{Corrected Pixel Value} = 110^{\left[\frac{1}{1.4}\right]}$$

Corrected Pixel Value = 21.7

(round to 21)

ⓘ If you are using an **A102kc** color camera and the camera is set for 3 x 8 bit RGB output, the gamma correction will be applied to the red value, to the green value, and to the blue value for each pixel.

The gamma correction feature uses a piecewise linear approximation. There may be small deviations from the ideal gamma curve that would be generated by using a full set of lookup tables to perform the correction.

The gamma correction feature was added in January 2004. It is not available on older **A102k** camera.

3.11 Color Creation in the A102kc

The CCD sensor used in the **A102kc** is equipped with an additive color separation filter known as a Bayer filter. With the Bayer filter, each individual pixel is covered by a micro-lens which allows light of only one color to strike the pixel. The pattern of the Bayer filter used in the **A102kc** is shown in Figure 3-20. As the figure illustrates, within each block 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.)
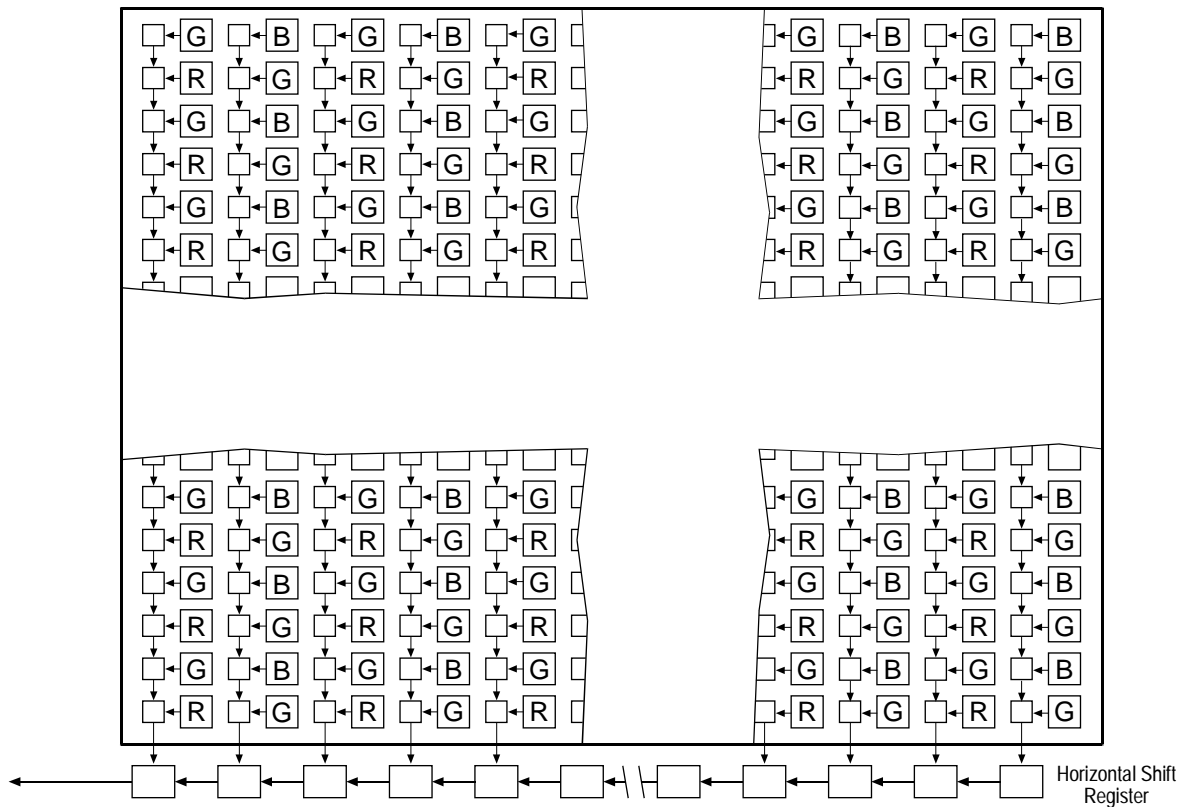
Figure 3-20: Bayer Filter Pattern on the **A102fc**

When an **A102kc** is operating in single 8 bit, 10 bit, or 12 bit output mode, a single value is transmitted out of the camera for each pixel in a captured image. If you want to get full RGB color information for a given pixel in the iamge, you must perform a color interpolation using the information from the surrounding pixels. Some frame grabbers are capable of performing the color interpolation and many algorithms are available for performing the interpolation in your host PC.

> (i) When you are using an **A102kc** color camera and the camera is set for a single pixel output mode, the order of the pixel colors output from the camera is determined by the alignment of the Bayer filter to the sensor as shown in Figure 3-20. If you use the AOI feature (see Section 3.8) and you change the position of the AOI, be aware that you may change the order of the pixel colors output from the camera.

When an **A102kc** is operating in 3 x 8 bit RGB mode, the camera automatically performs a color interpolation and outputs 8 bits of red data, 8 bits of green data, and 8 bits of blue data for each pixel in the captured image.

The interpolation algorithm used by the camera to create full RGB data for each pixel is known as "nearest neighbor". For example, if the camera is working with a pixel that is covered with a red microlens, it will transmit the actual value of the pixel as the red value, it will transmit the value of a neighboring blue pixel as the blue value, and it transmit the average of two neighboring green pixels as the green value.

> (i) When an **A102kc** is operating in 3 x 8 bit RGB mode, the color interpolation algorithm causes the first column and the first line of any transmitted image to be black. You will see this effect regardless of the size of the AOI.

3.11.1 White Balance

White balance capability has been implemented on the **A102kc**. With white balancing, an individual adjustment can be made to:

- the gain applied to the red pixels.
- the gain applied to the green pixels in the lines that include green and red pixels.
- the gain applied to the green pixels in the lines that include green and blue pixels.
- the gain applied to the blue pixels.

There is a white balance setting available for each of these items. You can use the settings to reduce the gain by as much as 6 dB or to increase the gain by as much as 6 db.

For example, assume that your images look too red and you want to reduce the "redness." There are two ways you could accomplish this using the white balance settings. One way would be to reduce the gain on the red pixels. A second way would be to increase the gain on the blue and the green pixels.

You can use the Camera Configuration Tool Plus to adjust the white balance settings on your camera. For more information on using the configuration tool to adjust white balance, refer to the on-line help included with the tool.

You can also use the White Balance binary commands to set the white balance (see Section 4.2.4.15).

> (i) We strongly recommend that you set the camera's global gain (see Section 3.6.1) to at least 6 dB before you use the white balance feature. If the camera's global gain is set to less than 6 dB and you use the white balance feature to lower the gain on one of the colors, you could end up with a negative gain for that color. The camera would then have a non-linear response and captured images may exhibit incorrect color characteristics.

3.12 Test Images

The test image mode is used to check the camera's basic functionality and its ability to transmit an image via the video data cable. The test image can be used for service purposes and for failure diagnostics. In test mode, the image is generated with a software program and the camera's digital devices and does not use the optics, CCD sensor, VGC or ADC. Three test images are available.

You can put the camera in test image mode using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help file) or binary commands (see Section 4.2). With the configuration tool, you use the Test Image setting in the Output group to select the test image. With binary commands, you use the Test Image command.

> (i) When a test image is active, the gain, offset, and exposure time have no effect on the image.
>
> Digital shift makes test images appear very light, therefore, digital shift should be disabled when a test image is active.
>
> Binning and Area of Interest will effect the appearance of test images.
>
> 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 for the camera to output test images.

3.12.1 Test Image One

Test image one consists of lines with repeated gray scale gradients.

If the camera is set for an 8 bit output mode, the gradients range from 0 to 255. The top line starts with a gray value of 0 on pixel 1. The second line starts with a gray value of 1 on the pixel 1. The third line starts with a gray value of 2 on the pixel 1, and so on. Line 256 starts with a gray value of 255 on pixel 1. Line 257 restarts a gradient with a gray value of 0 on the pixel 1, and so on.
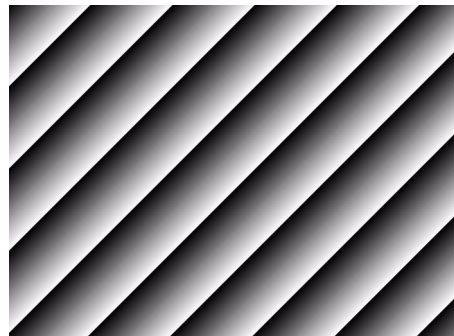
Figure 3-21: Test Image One (8 bit mode)

If the camera is set for a 10 bit output mode, the gradients range from 0 to 1023. The top line starts with a gray value of 0 on pixel 1. The second line starts with a gray value of 1 on the pixel 1. The third line starts with a gray value of 2 on the pixel 1, and so on. Line 1024 starts with a gray value of 1023 on the pixel 1. Line 1025 restarts a gradient with a gray value of 0 on the pixel 1, and so on.
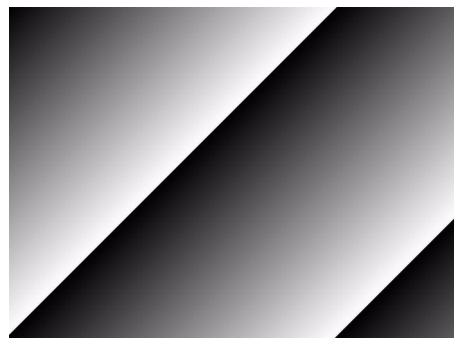
Figure 3-22: Test Image One (10 bit mode)

If the camera is set for an 12 bit output mode, the gradients range from 0 to 4095. The top line starts with a gray value of 0 on pixel 1. The second line starts with a gray value of 1 on the pixel 1. The third line starts with a gray value of 2 on the pixel 1, and so on. (Because the test pattern is only 1392 x 1040 pixels, it will not include even one complete gradient.)
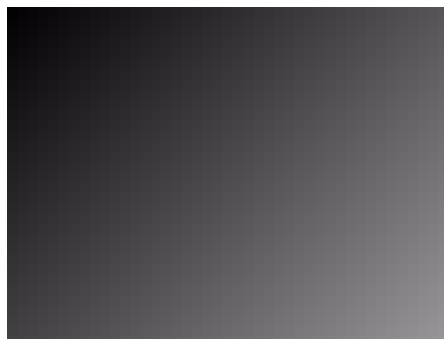
Figure 3-23: Test Image One (12 bit mode)

Depending on the output mode selected on the camera, either the 8 bit test image, the 10 bit test image, or the 12 bit test image will be active.

If the camera is set for an exposure mode that uses an ExSync signal, an ExSync signal is required to output the test image. A test image will be generated and transmitted on each cycle of the ExSync signal.

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

3.12.2 Test Image Two

The basic pattern of test image two is similar to test image one. However, with test image two, the pattern of the image moves up by one pixel each time the ExSync signal cycles. 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 you camera is receiving and reacting to an ExSync signal.

If the camera is set for free-run, each cycle of the camera's internal control signal will cause the pattern of the test image to move up by one pixel.

3.12.3 Test Image Three

Test image three contains vertical gradients on the left side of the image (columns 1 to 696) and horizontal gradients on the right side (columns 697 to 1392). Test image three is useful for determining if your frame grabber has dropped any columns or lines from your image.

Vertical Gradients

The vertical gradient(s) on the left side of the image are a total of 696 columns wide. A full vertical gradient is 256 columns wide if the camera is set for an 8 bit output mode, 1024 columns wide if the camera is set for a 10 bit output mode, and 4096 columns wide if the camera is set for a 12 bit output mode. (This means that if the camera is set for a 10 or a 12 bit output mode, only part of a gradient will be displayed.)

The left vertical gradient begins on column 1. The pixels in column 1 have a value of 0, the pixels in column 2 have a value of 1, the pixels in column 3 have a value of 2, and so on. This pattern continues until column 256 (8 bit mode), where the pixels have a value of 255, or column 696 (10 or 12 bit mode), where the pixels have a value of 695.

In 8 bit mode, a second vertical gradient begins in column 257. The pixels in column 257 have a value of 0, the pixels in column 258 have a value of 1, the pixels in column 259 have a value of 2, and so on. This pattern continues until column 512 where the pixels have a value of 255.

In 8 bit mode, a third vertical gradient begins in column 513. The pixels in column 513 have a value of 0, the pixels in column 514 have a value of 1, the pixels in column 515 have a value of 2, and so on. This pattern continues until column 696 where the pixels have a value of 183.

Horizontal Gradients

All of the horizontal gradients on the right side of the image are 696 columns wide.

In 8 bit mode:

- The pixels in the top line of the top gradient (image line 1040) have a gray value of 0, the pixels in line 1039 have a gray value of 1, the pixels in line 1038 have a gray value of 2, and so on. This pattern continues until line 785, where the pixels have a gray value of 255.
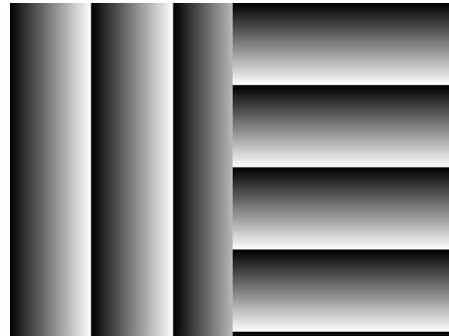
Figure 3-24: Test Image 3 (8 bit mode)
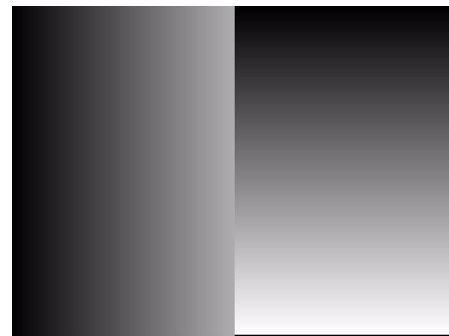
Figure 3-25: Test Image 3 (10 bit mode)

Figure 3-26: Test Image 3 (12 bit mode)

- A second gradient begins on line 784. The pixels in line 784 have a gray value of 0, the pixels in line 783 have a gray value of 1, the pixels in line 782 have a gray value of 2, and so on. This pattern continues until line 529 where the pixels have a gray value of 255.

- A third gradient begins on line 528. The pixels in line 528 have a gray value of 0, the pixels in line 527 have a gray value of 1, the pixels in line 526 have a gray value of 2, and so on. This pattern continues until line 273 where the pixels have a gray value of 255.

- A fourth gradient begins on line 272. The pixels in line 272 have a gray value of 0, the pixels in line 271 have a gray value of 1, the pixels in line 270 have a gray value of 2, and so on. This pattern continues until line 17 where the pixels have a gray value of 255.

- The bottom gradient begins on line 16. The pixels in line 16 have a gray value of 0, the pixels in line 15 have a gray value of 1, the pixels in line 14 have a gray value of 2, and so on. This pattern continues until line 1 where the pixels have a gray value of 15.

In 10 bit mode:

- The pixels in the top line of the top gradient (image line 1040) have a gray value of 0, the pixels in line 1039 have a gray value of 1, the pixels in line 1038 have a gray value of 2, and so on. This pattern continues until line 17, where the pixels have a gray value of 1023.

- A second gradient begins on line 16. The pixels in line 16 have a gray value of 0, the pixels in line 15 have a gray value of 1, the pixels in line 14 have a gray value of 2, and so on. This pattern continues until line 1 where the pixels have a gray value of 15.

In 12 bit mode:

- The pixels in the top line of the top gradient (image line 1040) have a gray value of 0, the pixels in line 1039 have a gray value of 1, the pixels in line 1038 have a gray value of 2, and so on. This pattern continues until line 1, where the pixels have a gray value of 1039.

3.13 Configuration Sets

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

Figure 3-27: Configuration Sets

Work Set

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

Factory Set

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

User Sets

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

Startup Pointer

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

You can work with configuration sets and the startup pointer using either the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help file) or binary commands (see Section 4.2).

With the configuration tool, you can use the Camera menu to copy the Work Set to a User Set, to Copy a User Set or the Factory Set to the Work Set, or to set the Startup Pointer.

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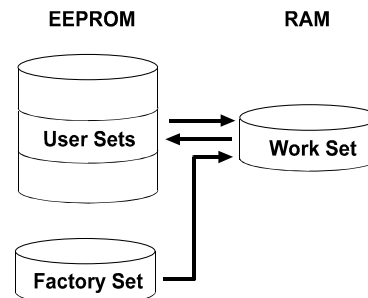
3.14 Camera Status

The **A102k** monitors its status by performing a regular series of self checks. The current status of the camera can be viewed in two several ways:

- with the Camera Configuration Tool Plus. You can use the Camera Status information in the Camera Information group (see Section 4.1 and the configuration tool's on-line help).

- with binary commands. You can use the Camera Status command (see Section 4.2.7) to check if the camera has detected any errors.

- by checking the LED on the back of the camera. If certain error conditions are present, the LED will blink (see Section 6.1).

4 Configuring the Camera

The **A102k** comes factory-set so that it will work properly for most applications with only minor changes to the camera's settings. For normal operation, the following settings are usually configured by the user:

- Video data output mode (single 8 bit or single 10 bit)
- Exposure time control mode
- Exposure time (for ExSync programmable mode or free-run programmable mode)

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

- Gain
- Offset
- Digital Shift
- Area of Interest
- Binning

The **A102k** is programmable via the Camera Link serial port on the frame grabber. Two methods can be used to change the camera's settings. The first and easier approach is to change the settings using the Camera Configuration Tool Plus. See Section 4.1 and the configuration tool's on-line help file for instructions on using the configuration tool. You can also change the settings directly from your application using binary commands. Section 4.2 lists the binary commands and provides instructions for their use.

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

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

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

4.1.1 Opening the Configuration Tool

1. Make sure that the properties for the RS-644 serial port on your frame grabber are properly configured and that the camera has power.

2. To start the CCT+, click **Start**, click **Programs**, click **Basler Vision Technologies**, click **CCT+**, and then click **CCT+** (default installation).

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

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

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

4.1.2 Closing the Configuration Tool

Close the CCT+ by clicking on the ⊠ button in the upper right corner of the window.

4.1.3 Configuration Tool Basics

The RAM memory in the camera contains the set of parameters that controls the current operation of the camera. This set of parameters is known as the Work Set (see Section 3.13). The CCT+ is used to view the present settings for the parameters in the Work Set or to change the settings.

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

To simplify navigation, parameters are organized in related groups. For example, all parameters related to the camera output can be found in the Output group.

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

To get an overview of all parameters available on the connected camera, maximize the CCT+ window and click the + sign beside each group.
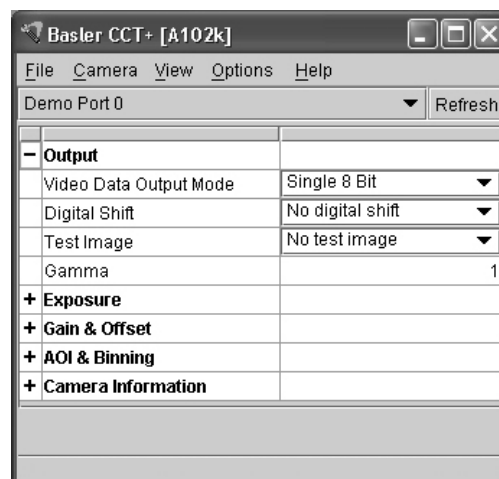
Figure 4-1: Output Group

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

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

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

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

> (i) Keep in mind that the Work Set is stored in a volatile memory. Any changes you make to the Work Set using the configuration tool will be lost when the camera is switched off. To save changes you make to the Work Set, go to the Sets Tab and save the modified Work Set into one of the camera's 15 User Sets. The User Sets are stored in non-volatile memory and will not be lost when the camera is switched off (see Section 3.13).
>
> Alternatively, you can also save the Work Set to the hard disk of your computer and load it from hard disk.
>
> If you want your changes to be loaded into the Work Set at the next power on, go to the Sets Tab and set the Startup Pointer to the User Set where you saved your changes.

4.1.4 Configuration Tool Help

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

4.2 Configuring the Camera with Binary Programming Commands

Configuration commands can be issued to the **A102k** via the RS-644 serial connection in the Camera Link interface between the frame grabber and the camera. Commands are issued using a binary protocol. With this protocol, data is placed into a frame and sent to the camera. Once the data is received it is checked for validity. If valid, the data is extracted and the command is executed.

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

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

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

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

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

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

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

A102k cameras will only work with the CCT+ version of the configuration tool. If you want to use the configuration tool with an **A102k** camera, you must download and install the CCT+ version and you must use the CCT+ to access the camera.

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

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

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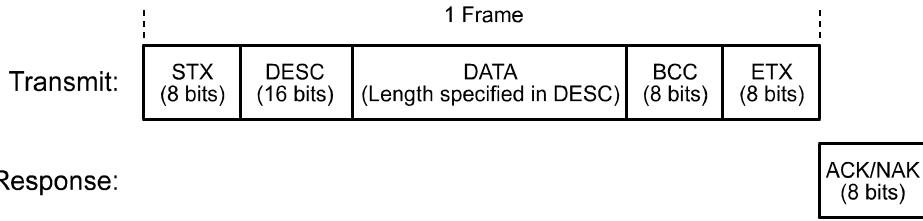
Figure 4-2: Representation of a Command Frame and Response

STX Identifies the start of the frame text

Size = 1 Byte

(The value of the STX byte is always 0x02)

DESC Descriptor

Size = 2 Bytes

The bits in the descriptor are assigned as follows:

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

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

DATA Data field

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

BCC Block check character

Size = 1 Byte

The block check character is the exclusive-or sum (XOR sum) of the bytes in the descriptor field and the data field.

ETX Identifies the end of the frame text

Size = 1 Byte

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

ACK/NAK Response   Positive frame acknowledge/negative frame acknowledge

Size = 1 byte

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

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

4.2.2 Error Checking

4.2.2.1 ACK/NAK

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

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

4.2.2.2 Time-outs

Byte Time-out

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

4.2.2.3 Read Command

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

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

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

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

4.2.2.4 Write Command

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

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

After a write command has been issued by the host, the host can verify the write by issuing a corresponding read command and checking that the returned data is as expected. The host can also issue a camera status read command (see Section 4.2.7) and check the returned data to see if an error condition has been detected.

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

4.2.3 Example Commands

4.2.3.1 Read Command

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

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

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

`0x43` - is the first byte of the descriptor. The first byte of the descriptor is the command ID. Command IDs can be found in the tables on pages 4-11 through 4-33. If you check the table on page 4-31, you will find that the ID for the camera status read command is 0x43.

`0x82` - is the second byte of the descriptor. The MSB in this byte represents the read/write flag and since this is a read command, the bit should be set to a 1. The other seven bits of this byte represent the data size (in bytes) that will be transferred using this command. If you check the table on page 4-31, the data size for the camera status command is 2 bytes. So the arrangement of the bits in the second byte of the descriptor should be 1000 0010 which translates to 0x82.

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

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

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

4.2.3.2 Write Command

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

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

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

`0x46` - is the first byte of the descriptor. If you check the table on page 4-29, you will find that the ID for the command to copy the Work Set to a User Set is 0x46.

`0x01` - is the second byte of the descriptor. The MSB in this byte represents the read/write flag and since this is a write command, the bit should be set to a 0. The other seven bits of this byte represent the data size (in bytes) that will be transferred using this command. If you check the table on page 4-29, the data size for the Copy Work Set to User Set command is 1 byte. So the arrangement of the bits in the second byte of the descriptor should be 0000 0001 which translates to 0x01.

`0x02` - is the data byte. If you check the table on page 4-29, you will find that to copy the Work Set to User Set 2, the data byte must be set to 0x02.

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

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

4.2.3.3 Calculating the Block Check Character

The block check character in any **A102k** command is the exclusive-or sum (XOR sum) of the bytes in the descriptor and the data fields. For the write command example shown in Section 4.2.3, the block check character is 0x45. Let's consider how this block check character was calculated.

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

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

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

    If both digits are 0, the result is 0.

    If both digits are 1, the result is 0.

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

With all of this in mind, here is how the BCC for the write command shown in Section 4.2.3 would be calculated:

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


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


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

4.2.4 Commands for Setting Camera Parameters

4.2.4.1 Video Data Output Mode

Purpose:	To set the video data output mode or to read the current video data output mode setting. See Sections 2.5.5.2 for an explanation of the available video data output modes.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xC0	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xC0	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xC0	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the data output mode (see the table below).		

ID	Output Mode
0x00	Single 8 bit mode
0x02	Single 10 bit mode
0x04	Single 12 bit mode
0x08	3 x 8 bit RGB mode

4.2.4.2 Exposure Time Control Mode

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

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

4.2.4.3 Timer 1

Purpose:	To set Timer 1 or to read the current Timer 1 setting. Timer 1 is used when the camera is operating in ExSync programmable mode or in free-run mode. See Section 3.2 for details.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA6	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0xA6	R/W-Flag 0	Data Length 3	Data 3 Bytes
Write Command:	Cmd-ID 0xA6	R/W-Flag 0	Data Length 3	Data 3 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the Timer 1 setting		
	Byte 2	Mid byte of the Timer 1 setting		
	Byte 3	High byte of the Timer 1 setting		
Data Range:	Timer settings can range from 15 μs (0x00000F) to 16,777,215 μs (0xFFFFFF).			

4.2.4.4 Timer 2

Purpose:	To set Timer 2 or read the current Timer 2 setting. Timer 2 is used when the camera is operating in free-run mode. See Section 3.2 for details.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA7	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0xA7	R/W-Flag 0	Data Length 3	Data 3 Bytes
Write Command:	Cmd-ID 0xA7	R/W-Flag 0	Data Length 3	Data 3 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the Timer 2 setting		
	Byte 2	Mid byte of the Timer 2 setting		
	Byte 3	High byte of the Timer 2 setting		
Data Range:	Timer settings can range from 70 μs (0x000046) to 16,777,215 μs (0xFFFFFF).			

4.2.4.5 Digital Shift

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

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

(i) See Section 3.7.4 for precautions that you must consider when using digital shift.

4.2.4.6 Area of Interest Starting Column

Purpose:	To set the starting column for the area of interest or to read the current setting. See Section 3.8 for details on the area of interest.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA9	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0xA9	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0xA9	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the starting column setting		
	Byte 2	High byte of the starting column setting		
Data Range:	The starting column setting can range from 0 (0x0000) to 1391 (0x056F).			
	When you set column *n* using this command, the actual starting column will be *n* + 1. For example, if you set the starting column to 0 with this command, the actual starting column = 0 + 1 = 1.			

4.2.4.7 Area of Interest Width in Columns

Purpose:	To set the width in columns for the area of interest or to read the current setting. See Section 3.8 for details on the area of interest.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xAB	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0xAB	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0xAB	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the width in columns setting		
	Byte 2	High byte of the width in columns setting		
Data Range:	The width in columns setting can range from 1 (0x0001) to 1392 (0x0570).			

> See Section 3.8.1 for a list of guidelines which must be followed when entering the settings for the area of interest.

4.2.4.8 Area of Interest Starting Line

Purpose:	To set the starting line for the area of interest or to read the current setting. See Section 3.8 for details on the area of interest.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA8	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0xA8	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0xA8	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the starting line setting		
	Byte 2	High byte of the starting line setting		
Data Range:	The starting line setting can range from 0 (0x0000) to 1039 (0x040F).			
	When you set line n using this command, the actual starting line will be $n + 1$. For example, if you set the starting line to 0 with this command, the actual starting line $= 0 + 1 = 1$.			

4.2.4.9 Area of Interest Height in Lines

Purpose:	To set the height in lines for the area of interest or to read the current setting. See Section 3.8 for details on the area of interest.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xAA	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0xAA	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0xAA	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of the height in lines setting		
	Byte 2	High byte of the height in lines setting		
Data Range:	The height in lines setting can range from 1 (0x0001) to 1040 (0x0410).			

See Section 3.8.1 or a list of guidelines which must be followed when entering the settings for the area of interest.

4.2.4.10 Gain

Purpose:	To set the gain or to read the current gain setting. See Section 3.6 for more information on gain.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x80	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x80	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x80	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of gain setting		
	Byte 2	High byte of gain setting		
Data Range:	Gain settings can range from 0 (0x0000) to 1023 (0x03FF). The minimum recommended setting is 240 (0x00F0) with vertical binning disabled or 192 (0x00C0) with vertical binning enabled. See Section 3.6.1.			

4.2.4.11 Offset

Purpose:	To set the offset or to read the current offset setting. See Section 3.6 for more information on offset.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x84	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x84	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x84	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of offset setting		
	Byte 2	High byte of offset setting		
Data Range:	Offset settings can range from 0 (0x0000) to 255 (0x00FF).			

4.2.4.12 Horizontal Binning

Purpose:	To enable or disable horizontal binning. See Section 3.9 for an explanation of binning.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA3	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xA3	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xA3	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the binning status (see the table below).		

ID	Binning
0x00	Horizontal binning not enabled
0x01	Horizontal binning enabled

4.2.4.13 Vertical Binning

Purpose:	To enable or disable vertical binning. See Section 3.9 for an explanation of binning.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA4	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xA4	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xA4	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the binning status (see the table below).		

ID	Binning
0x00	Vertical binning not enabled
0x01	Vertical binning enabled

> (i) For full binning, enable both horizontal and vertical binning.

4.2.4.14 Gamma Correction

Purpose:	To enable or disable gamma correction. See Section 3.10 for an explanation of gamma correction.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xC5	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xC5	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xC5	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1		An ID that specifies the gamma correction status (see the table below).	

ID	Digital Shift
0x00	Gamma = 1.0 (no correction - feature disabled)
0x01	Gamma = 1.2
0x02	Gamma = 1.4
0x03	Gamma = 1.5
0x04	Gamma = 1.8
0x05	Gamma = 2.0
0x06	Gamma = 2.2
0x07	Gamma = 2.4
0x08	Gamma = 2.6
0x09	Gamma = 2.8

4.2.4.15 White Balance

The white balance commands allow you to change the color balance in captured images by individually adjusting the gain for different colors (see Section 3.11). Four commands are available: red gain, green gain 1, green gain 2, and blue gain.

Red Gain

Purpose:	To adjust the gain for the red pixels in the image.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x8D	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x8D	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x8D	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	The setting for red gain.		
Data Range:	Red gain settings can range from 0 (0x00) to 63 (0x3F).			
	A setting of 0 (0x00) will reduce the gain on the red pixels by approximately 6 dB. A setting of 32 (0x20) will result in no change in the gain on the red pixels. A setting of 63 (0x3F) will increase the gain on the red pixels by approximately 6 dB.			

Green Gain 1

Purpose:	To adjust the gain for the green pixels in the lines that have green pixels and red pixels (the odd lines).			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x8E	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x8E	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x8E	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	The setting for green gain 1.		
Data Range:	Green gain 1 settings can range from 0 (0x00) to 63 (0x3F).			
	A setting of 0 (0x00) will reduce the gain on the green pixels in the lines that have green and red pixels by approximately 6 dB. A setting of 32 (0x20) will result in no change in the gain on these green pixels. A setting of 63 (0x3F) will increase the gain on these green pixels by approximately 6 dB.			

Green Gain 2

Purpose:	To adjust the gain for the green pixels in the lines that have green pixels and blue pixels (the even lines).			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x8F	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x8F	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x8F	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	The setting for green gain 2.		
Data Range:	Green gain 2 settings can range from 0 (0x00) to 63 (0x3F).			
	A setting of 0 (0x00) will reduce the gain on the green pixels in the lines that have green and blue pixels by approximately 6 dB. A setting of 32 (0x20) will result in no change in the gain on these green pixels. A setting of 63 (0x3F) will increase the gain on these green pixels by approximately 6 dB.			

Blue Gain

Purpose:	To adjust the gain for the blue pixels in the image.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x90	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x90	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x90	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	The setting for blue gain.		
Data Range:	Blue gain settings can range from 0 (0x00) to 63 (0x3F).			
	A setting of 0 (0x00) will reduce the gain on the blue pixels by approximately 6 dB. A setting of 32 (0x20) will result in no change in the gain on the blue pixels. A setting of 63 (0x3F) will increase the gain on the blue pixels by approximately 6 dB.			

4.2.4.16 Test Image

Purpose:	To enable or disable a test image. See Section 3.12 for an explanation of the available test images.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA1	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xA1	R/W-Flag 0	Data Length 1	Data 1 Bytes
Write Command:	Cmd-ID 0xA1	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the test image (see the table below).		

ID	Test Image
0x00	No test image
0x01	Test Image 1 (diagonal gradient pattern)
0x02	Test Image 2 (moving gradient pattern)
0x03	Test Image 3 (vert./horiz. gradient pattern)

4.2.5 Query Commands

4.2.5.1 Read Vendor Information

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

4.2.5.2 Read Model Information

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

4.2.5.3 Read Product ID

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

4.2.5.4 Read Serial Number

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

4.2.5.5 Read Camera Version

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

4.2.5.6 Read EEPROM Firmware Version

Purpose:	To read the EEPROM firmware version information.			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x06	R/W-Flag 1	Data Length 3	Data -
Response:	Cmd-ID 0x06	R/W-Flag 0	Data Length 3	Data 3 Bytes
Data Format:	Byte 1	Low byte of firmware version	BCD coded	
	Byte 2	High byte of firmware version	BCD coded	
	Byte 3	Register Layout ID		

4.2.5.7 Read Microcontroller Firmware Version

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

4.2.5.8 Read FPGA Firmware Version

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

4.2.5.9 Read Minimum Gain Setting

Purpose:	To read the minimum gain setting for standard operation (vertical binning disabled) (see Section 3.6.1).			
Type:	This is a read only command.			
Read Command:	Cmd-ID 0x08	R/W-Flag 1	Data Length 16	Data -
Response:	Cmd-ID 0x08	R/W-Flag 0	Data Length 16	Data 16 Bytes
Data Format:	Bytes 1 and 2	Reserved.		
	Byte 3	Low byte of minimum gain setting.		
	Byte 4	High byte of minimum gain setting.		
	Bytes 5 to 16	Reserved.		

4.2.6 Commands for Manipulating Configuration Sets

4.2.6.1 Copy the Factory Set or a User Set into the Work Set

Purpose:	To copy the Factory Set or one of the 15 User Sets into the Work Set. See Section 3.13 for an explanation of configuration sets.
	The write command will cause the selected set to be copied into the Work Set and the set will become active immediately.
	The read command returns the ID of the set that was last copied into the Work Set. (If nothing has been copied to the Work Set since the last power up or reset, the read command will return the ID for "no active set." This condition indicates that no valid Factory Set or User Sets were found. It will also cause the orange LED on the back of the camera to show six pulses.)

Type:	This is a read or write command.

Read Command:	Cmd-ID	R/W-Flag	Data Length	Data
	0x45	1	1	-
Response:	Cmd-ID	R/W-Flag	Data Length	Data
	0x45	0	1	1 Byte

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

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

Set ID	Set
0x00	Factory Set
0x01	User Set 1
0x02	User Set 2
0x03	User Set 3
0x04	User Set 4
0x05	User Set 5
0x06	User Set 6
0x07	User Set 7
0x08	User Set 8
0x09	User Set 9
0x0A	User Set 10
0x0B	User Set 11
0x0C	User Set 12
0x0D	User Set 13
0x0E	User Set 14
0x0F	User Set 15
0xFF	No active set

4.2.6.2 Copy Work Set into a User Set

Purpose:	To copy the Work Set into one of the 15 User Sets. See Section 3.13 for an explanation of configuration sets.

Type:	This is a write only command.

Write Command:	Cmd-ID	R/W-Flag	Data Length	Data
	0x46	0	1	1 Byte
Response:	None			

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

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

4.2.6.3 Select the Startup Pointer

Purpose:	The Startup Pointer is used to tag the configuration set that will be copied into the Work Set at power on (see Section 3.13).
	The write command is used to set the Startup Pointer to the Factory Set or to one of the User Sets.
	The read command returns the Set ID for the current setting.

Type:	This is a read or write command.

Read Command:	Cmd-ID 0x47	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x47	R/W-Flag 0	Data Length 1	Data 1 Byte

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

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

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

4.2.7 Camera Status Command

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

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

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

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

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

4.2.8 Bitrate Command

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

Type:	This is a write only command.

Write Command:	Cmd-ID 0x44	R/W-Flag 0	Data Length 4	Data 4 Bytes
Response:	None			

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

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

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

1. Issue the write command with the new bitrate.
2. Wait one second.
3. Change the bitrate on the serial port that the camera is using:
   a) If you are using a Camera Link frame grabber, change the bitrate on the frame grabber's RS-644 serial port.
   b) If you are using the camera with a k-BIC, change the bitrate on your PC's RS-232 serial port.
4. Restart the PC and the camera.
5. Resume communication.

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

4.2.9 Camera Reset Command

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

5 Mechanical Considerations

5.1 Camera Dimensions and Mounting Facilities

The **A102k** camera housing is manufactured with high precision. Planar, parallel, and angular sides guarantee precise mounting with high repeatability.

The **A102k** camera is equipped with four M4 mounting holes on the front and two M4 mounting holes on each side as indicated in Figure 5-1.

⚠	**Caution!** To avoid collecting dust on the sensor, mount a lens on the camera immediately after unpacking it.
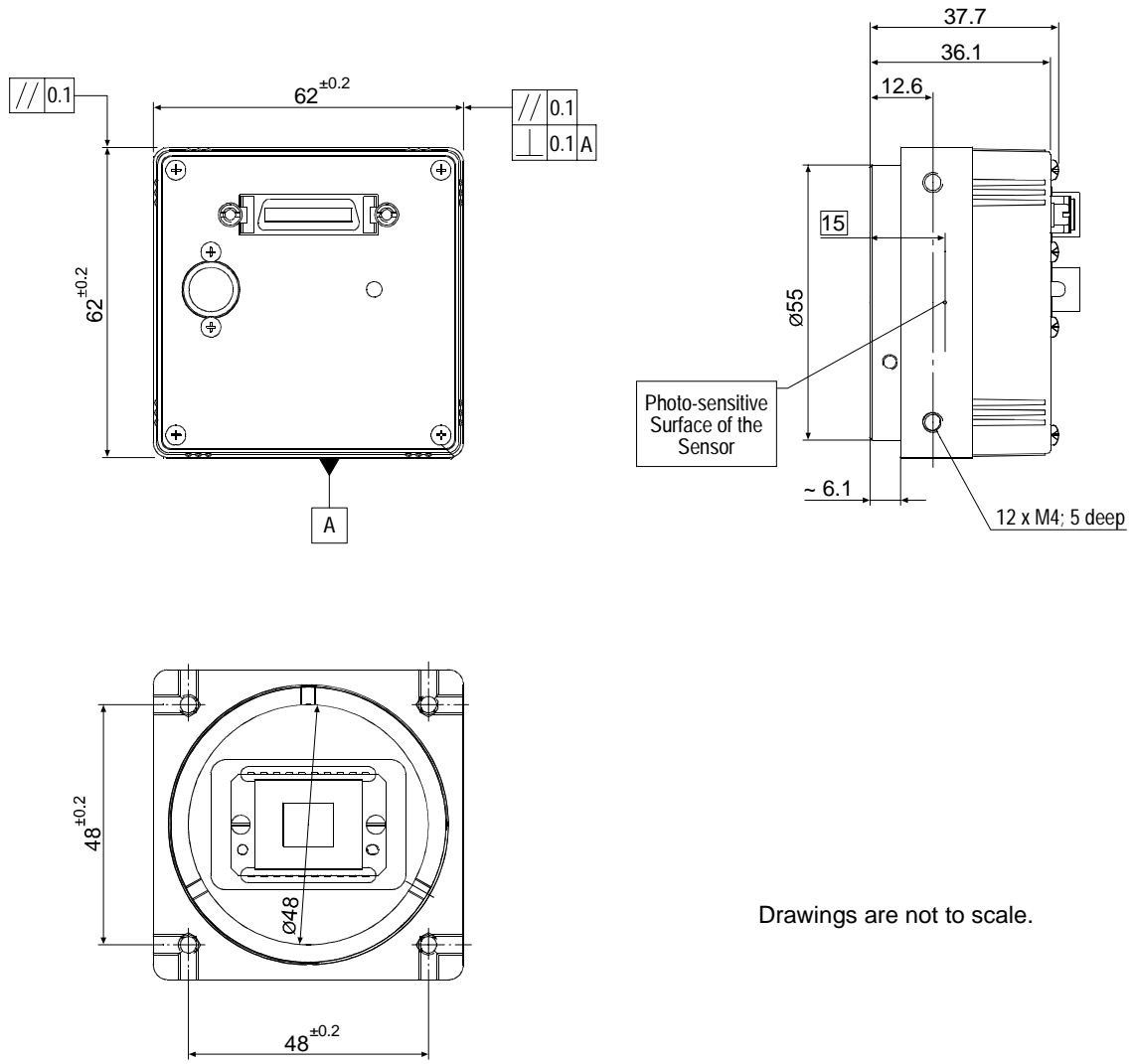
Figure 5-1: **A102k** Mechanical Dimensions (in mm)

5.2   C-Mount Adapter Dimensions

C-Mount Adapter with IR Cut-off Filter
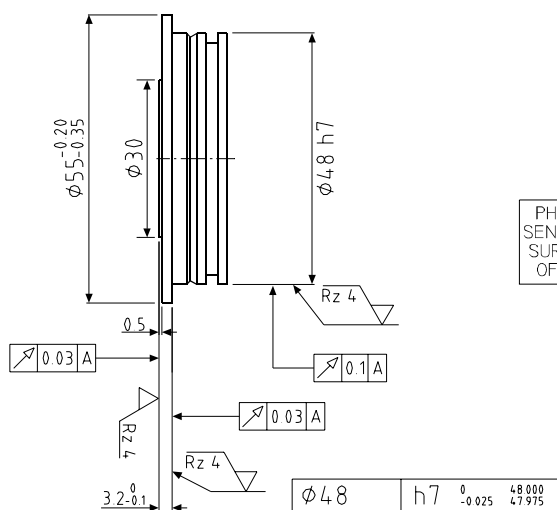
C-Mount Adapter
on an A102k
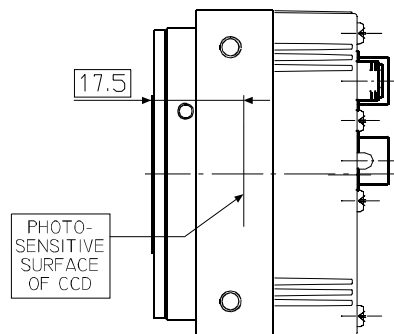
Drawings are not to scale.

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

5.3   F-Mount Adapter Dimensions

F-Mount Adapter
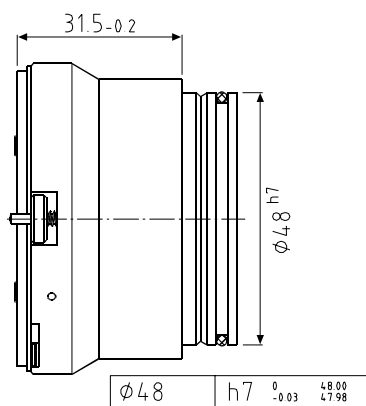
F-Mount Adapter
on an A102k
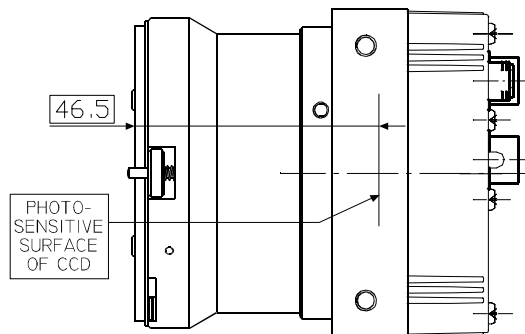
Drawings are not to scale.

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

5.4 Positioning Accuracy of the Sensor Chip

Positioning accuracy of the sensor chip in the horizontal and vertical direction is ± 0.15 mm. Rotational positioning accuracy is as shown in Figure 5-4. Reference position is the center of the camera housing.

Since the translatory and rotational positioning tolerance depend on each other, the worse case of maximum rotational and horizontal/vertical mis-positioning can not occur at the same time.
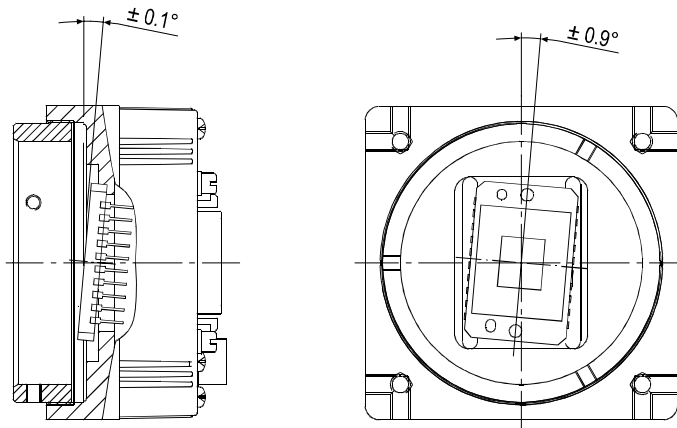
Drawings are not to scale.

Figure 5-4: Rotational Positioning Accuracy

5.5 Maximum Lens Thread Length on C-mount Equipped Cameras

A102k and **A102kc** cameras shipped with a C-mount lens adapter are equipped with an IR cut filter as standard equipment. The filter is mounted in the lens adapter. As shown in Figure 5-5, the location of the filter limits the thread length of the lens used on the camera. The thread length of the C-mount lens must be less than 7.5 mm. If a lens with a longer thread length is used, the IR cut filter will be damaged or destroyed and the camera will no longer operate.
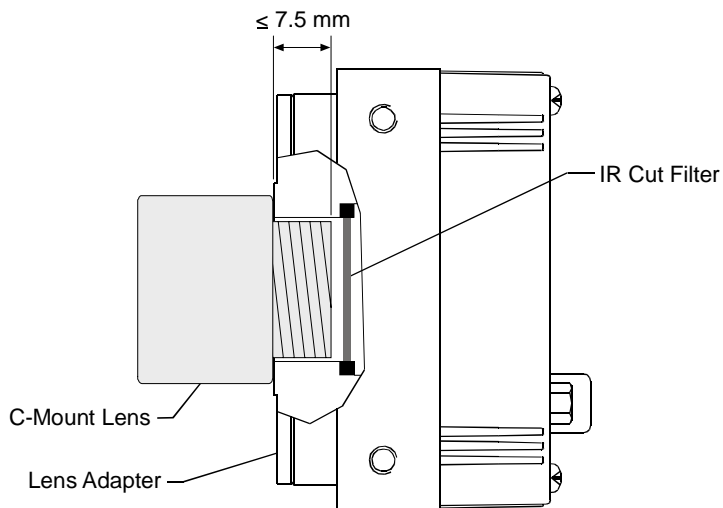
Drawing is not to Scale

Figure 5-5: Maximum Lens Thread Length on A102k Cameras

| ⚠ | **Caution!**
A102k and A102kc cameras shipped with a C-mount lens adapter are equipped with an IR cut filter mounted in of the adapter. The location of the filter limits the thread length of the lens that can be used on the camera. The thread length on your lens must be less than 7.5 mm. If a lens with a longer thread length is used, the camera will be damaged and will no longer operate.
Cameras without an IR cut filter in the C-mount lens adapter are available on request. |

6 Troubleshooting

6.1 Fault Finding Using the Camera LED

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

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

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

Table 6-1: Camera Status Indicators

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

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

6.2 Troubleshooting Charts

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

6.2.1 No Image

Use this chart if you see no image at all when you attempt to capture an image with your frame grabber (in this situation, you will usually get a message from the frame grabber such as "time-out"). If you see a completely white image, a completely black image, or if you have other image quality problems, use the chart in Section 6.2.2.

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

Use a voltmeter to check the power source for the camera. The output must be 12 VDC ± 1.2 V. Also, make sure that the power source meets the other specs shown in Section 2.8.

Is the power source OK?

No → Replace the power source

Yes ↓

Connect the power source to the camera and then check the LED on the back of the camera.

Is the LED lit constantly?

No. It is always out. → Replace the camera

No. It is blinking 3 pulses. → The camera is not detecting an ExSync signal. Check the ExSync signal or set the camera for Free-run mode (See Section 3.2.2).

No. It is blinking 5, 6, 7 or 8 pulses. → Call Basler Technical Support for assistance. (The contact numbers appear on the title page of this manual.)

No. I see a fast blinking green light. → The power source can not supply enough current to operate the camera. Make sure that your power source meets the specs shown in Section 2.8.

Yes ↓

Check to make sure that the RS-644 serial connection is working OK. You can do this by starting the CCT+. When you start the tool, the camera settings should appear in the right-hand column.

(If this is the first time that you are starting the tool, no RS-644 port will be selected when starting the tool. Click the "No Port Selected" button below the menu bar and select the RS-644 port you wish to use. The settings should appear.)

Did the camera settings appear?

No. The column is blank. → Go to the RS-644 serial communications troubleshooting chart.

Yes ↓

Are you controlling the camera with an ExSync signal or is the camera in free-run? → Free-run. → Did you set up free-run using the Exposure Time Control Mode setting on the CCT+ or with binary commands?

ExSync signal. ↓

CCT+ ↓

Binary Commands ↓

Check the setup on your frame grabber and make sure that the ExSync signal is not too short. The period of the ExSync signal must be greater than 67.5 ms.

(On many frame grabbers, the period of the ExSync signal is adjusted by changing a setting for the "frame rate". Your frame rate should not exceed 14.8 fps.)

Is the ExSync period OK?

No → Correct the settings.

Check to make sure that:

Timer 1 is set no lower than 15 µs.

Timer 2 is set no lower than 70 µs.

The sum of the Timer 1 setting plus the Timer 2 setting is greater than 67.5 ms.

Are the settings OK?

No → Correct the settings.

Yes ↓

Yes ↓

Check your exposure setting. The exposure time must be less than the ExSync period.

Is the exposure OK?

No → Correct the setting.

Switch on the test image one.

Can the test image be seen?

No → Go to the interfacing troubleshooting chart.

Yes ↓

Yes ↓

Switch on test image one.

Can the test image be seen?

No → Go to the interfacing troubleshooting chart.

Replace the camera.

Yes ↓

Replace the camera.

6.2.2 Image Quality Problems

Use this chart if the image is completely white, if the image is completely black, or if you have other image quality problems. If you get no image at all when you attempt to capture an image with the frame grabber, use the chart that appears in Section 6.2.1.

Use the CCT+ to set the camera for test image one. Use your frame grabber to capture an image and examine the image carefully. (Most frame grabbers include software tools that allow you to see the individual values of each pixel in the image and histograms that display distributions of the pixel values in the image.)

The pixel values in your captured test image should be exactly as described in Section 3.12. Also, if you capture several test images, the pixel values should be the same in all of the captured test images.

Are the test images OK?

No → Go to the interfacing troubleshooting chart.

Yes

Use the CCT+ to copy the Factory Set to the Work Set. Take the camera out of test image mode and capture a normal image.

Is the problem still present?

No → One of the camera's settings was significantly misadjusted. Review the camera manual to make sure that you are setting the camera correctly.

Yes

Images are too bright or too dark.

Images look noisy.

Images have a color problem.

Other image problems.

Do the following:

Make sure that the lens cap has been removed.

Check the lens aperture. If the images are too dark, try opening the aperture. Try closing the aperture if they are too bright.

Check the exposure time. If the images are too dark try increasing the exposure. Try decreasing the exposure if they are too bright.

Check your light source. If the images are too dark, try increasing your light intensity. Try decreasing the intensity if they are too bright.

Check your gain setting. If the images are too dark, try increasing the gain. Try decreasing the gain if they are too bright.

Has the problem been corrected?

Do the following:

Make sure that you are using a DC light source. Using an AC light source can make images appear noisy.

Make sure that the camera has proper ventilation. If the camera becomes extremely hot, it may produce noisy images.

Check the exposure time. If you use an extremely long exposure time, the images can become noisy.

Check your gain setting. Using a very low or a very high gain setting can cause noisy images.

Examine the objects that you are imaging. Objects with characteristics such as changing surface texture or reflectance will produce images that appear noisy.

Has the problem been corrected?

Do the following:

If most colors look OK but some colors look odd or muddy, try using an IR cut filter. (This only applies to cameras with F-mount lens adapters. Cameras with C-mount lens adapters have a built-in IR cut filter.)

If colors appear to be swapped (for example, things that should be red are green), check the x-offset and y-offset settings on your frame grabber.

If the captured images appear to be tinted, adjust the white balance (see Section 3.11.1).

Has the problem been corrected?

Yes / No

Yes → Exit this chart.

Yes → Exit this chart.

No

Yes → Exit this chart.

No

Yes → Exit this chart.

No

Contact Basler Technical Support. The contact numbers appear on the title page of this manual.

Before you call for support, be sure to make note of the camera settings and the frame grabber settings you are using. You should also have a captured live image and a captured test image available. Technical support will frequently request that you e-mail copies of these captured images.

6.2.3 Interfacing

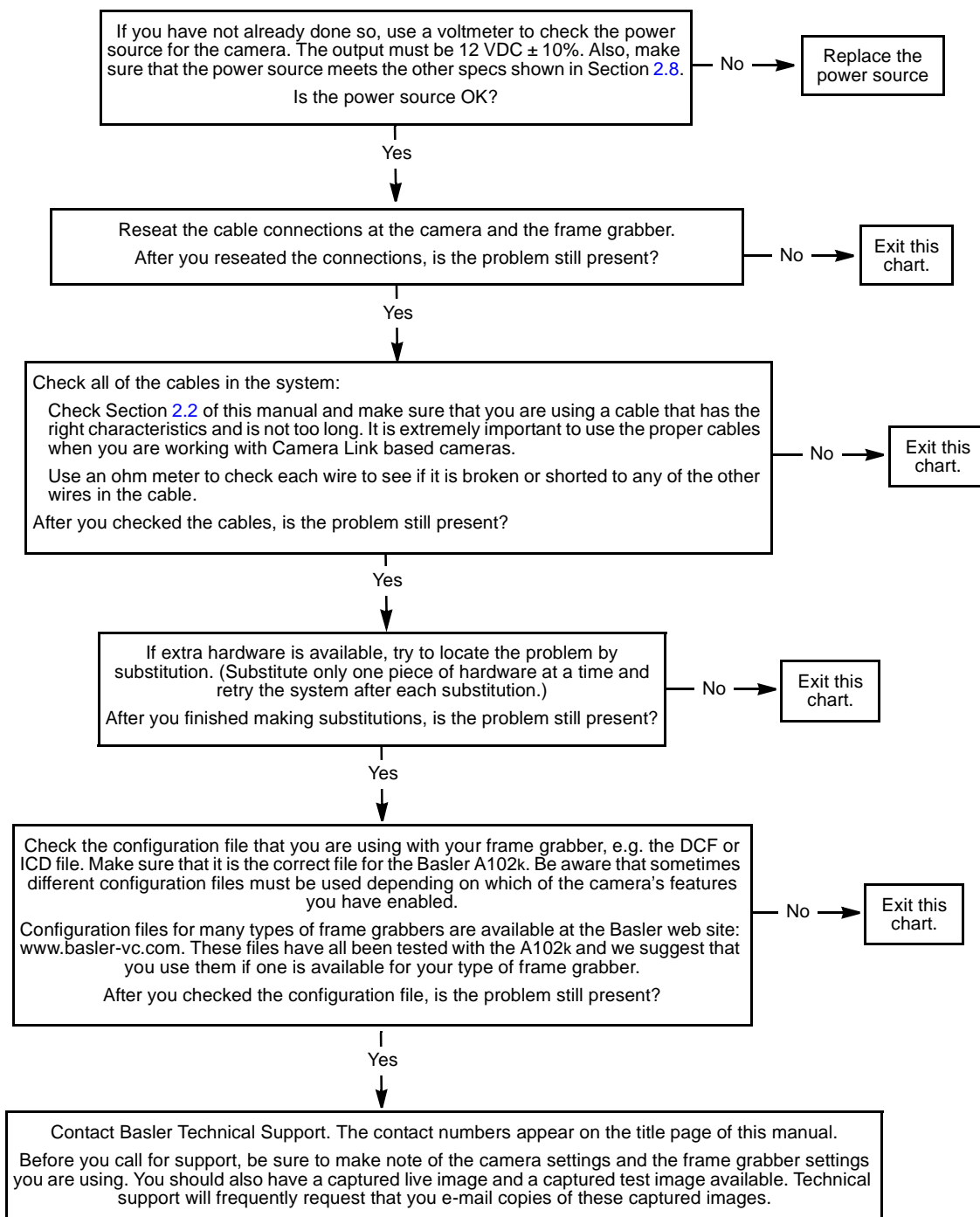Use the interfacing troubleshooting charts if you think that there is a problem with the cables between your devices or if you have been directed here from another chart.

Interfacing Chart

Always switch off power to the system before making or breaking any connection.
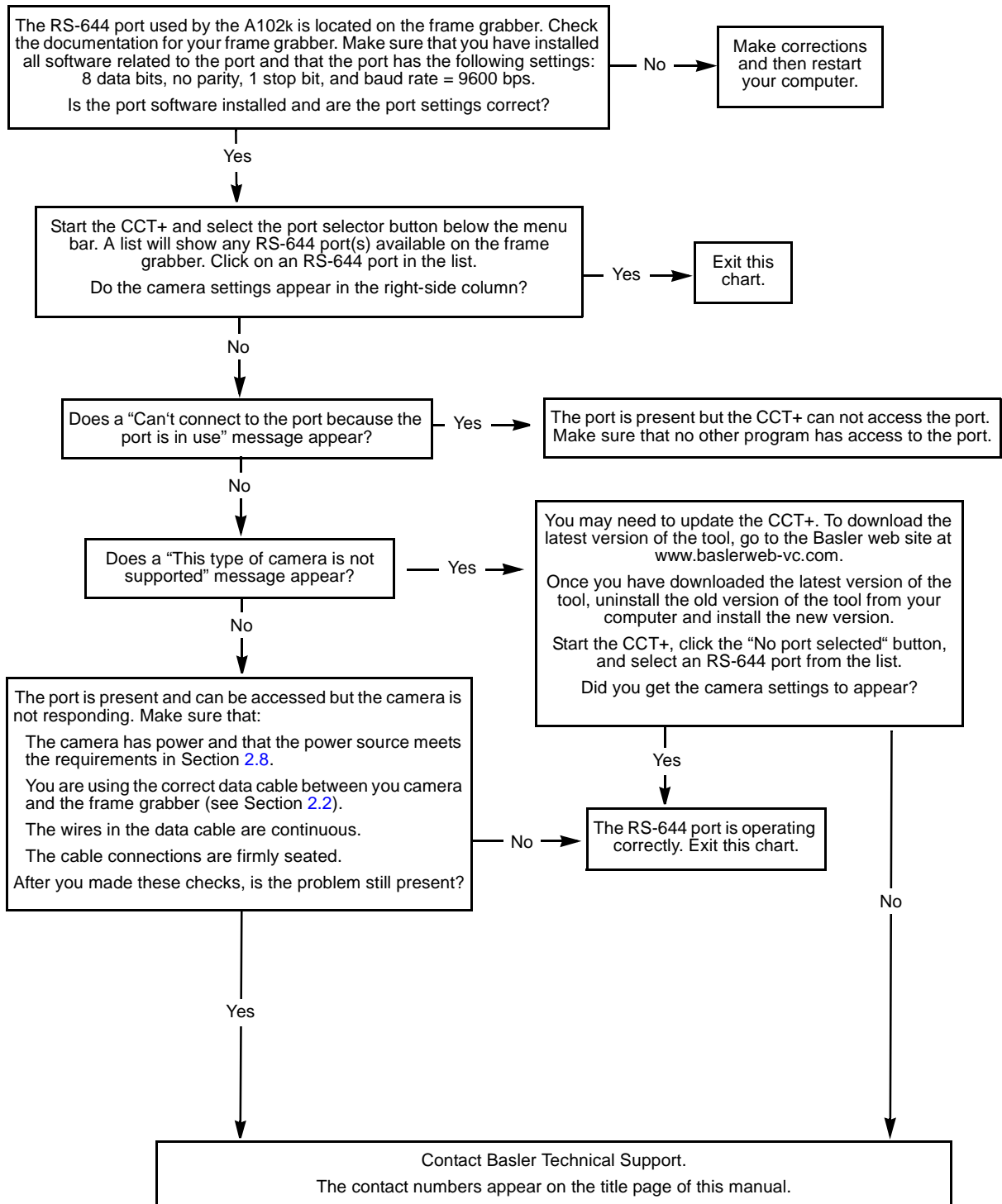
If you have not already done so, use a voltmeter to check the power source for the camera. The output must be 12 VDC ± 10%. Also, make sure that the power source meets the other specs shown in Section 2.8.

Is the power source OK?

No → Replace the power source

Yes

Reseat the cable connections at the camera and the frame grabber.

After you reseated the connections, is the problem still present?

No → Exit this chart.

Yes

Check all of the cables in the system:

Check Section 2.2 of this manual and make sure that you are using a cable that has the right characteristics and is not too long. It is extremely important to use the proper cables when you are working with Camera Link based cameras.

Use an ohm meter to check each wire to see if it is broken or shorted to any of the other wires in the cable.

After you checked the cables, is the problem still present?

No → Exit this chart.

Yes

If extra hardware is available, try to locate the problem by substitution. (Substitute only one piece of hardware at a time and retry the system after each substitution.)

After you finished making substitutions, is the problem still present?

No → Exit this chart.

Yes

Check the configuration file that you are using with your frame grabber, e.g. the DCF or ICD file. Make sure that it is the correct file for the Basler A102k. Be aware that sometimes different configuration files must be used depending on which of the camera's features you have enabled.

Configuration files for many types of frame grabbers are available at the Basler web site: www.basler-vc.com. These files have all been tested with the A102k and we suggest that you use them if one is available for your type of frame grabber.

After you checked the configuration file, is the problem still present?

No → Exit this chart.

Yes

Contact Basler Technical Support. The contact numbers appear on the title page of this manual.

Before you call for support, be sure to make note of the camera settings and the frame grabber settings you are using. You should also have a captured live image and a captured test image available. Technical support will frequently request that you e-mail copies of these captured images.

6.2.4 RS-644 Serial Communication

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

Serial Communication Chart A (without a k-BIC)

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

The RS-644 port used by the A102k is located on the frame grabber. Check the documentation for your frame grabber. Make sure that you have installed all software related to the port and that the port has the following settings: 8 data bits, no parity, 1 stop bit, and baud rate = 9600 bps.

Is the port software installed and are the port settings correct?

No → Make corrections and then restart your computer.

Yes

Start the CCT+ and select the port selector button below the menu bar. A list will show any RS-644 port(s) available on the frame grabber. Click on an RS-644 port in the list.

Do the camera settings appear in the right-side column?

Yes → Exit this chart.

No

Does a "Can't connect to the port because the port is in use" message appear?

Yes → The port is present but the CCT+ can not access the port. Make sure that no other program has access to the port.

No

Does a "This type of camera is not supported" message appear?

Yes → You may need to update the CCT+. To download the latest version of the tool, go to the Basler web site at www.baslerweb-vc.com.

Once you have downloaded the latest version of the tool, uninstall the old version of the tool from your computer and install the new version.

Start the CCT+, click the "No port selected" button, and select an RS-644 port from the list.

Did you get the camera settings to appear?

No

The port is present and can be accessed but the camera is not responding. Make sure that:

The camera has power and that the power source meets the requirements in Section 2.8.

You are using the correct data cable between you camera and the frame grabber (see Section 2.2).

The wires in the data cable are continuous.

The cable connections are firmly seated.

After you made these checks, is the problem still present?

No → The RS-644 port is operating correctly. Exit this chart.

Yes (from update box) → The RS-644 port is operating correctly. Exit this chart.

No (from update box) →

Yes →

Contact Basler Technical Support.
The contact numbers appear on the title page of this manual.

Revision History

Doc. ID Number	Date	Changes
DA00052201	11 December 2001	Initial release covering prototype production cameras.
DA00052202	30 May 2002	Initial release covering series production cameras.
DA00052203	31 May 2002	Revised Section 3.9.
DA00052204	20 September 2002	Added line/column information to Figure 3-1. Corrected the data format information in Section 4.2.5.9. Updated the passages describing the Camera Configuration Tool Plus.

DA00052205	23 January 2004	Revised the manual to include information for the color version of the A102k:
		  Updated the model information on page 1-1.
		  Updated the specification table on page 1-2.
		  Added the spectral response information on page 1-4.
		  Added information on color output modes in Sections 2.5.5.1 and 2.5.5.2.
		  Added information on color creation and white balance in Section 3.11.
		  Added information on maximum lens thread length in Section 5.5.
		Added information on other new features:
		  Added information on 12 bit output mode in Sections 2.5.5.1, 2.5.5.2 and 3.7.
		  Added information on gamma correction in Section 3.10.

Feedback

Your feedback will help us improve our documentation. Please click the link below to access an online feedback form. Your input is greatly appreciated.

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

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