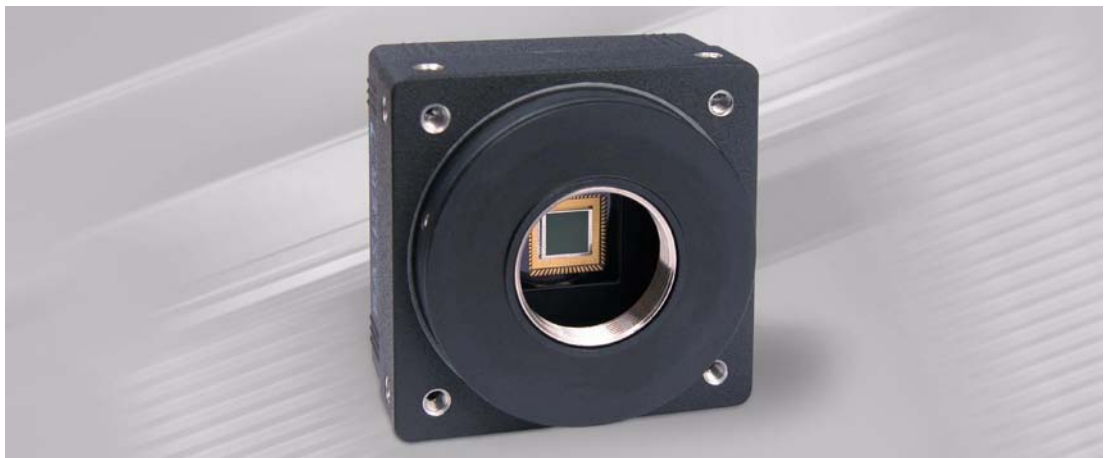


Basler A202k



USER'S MANUAL

Document Number: DA0440

Version: 08 Language: 000 (English)

Release Date: 29 June 2007

For customers in the U.S.A.

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

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

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

For customers in Canada

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

Pour utilisateurs au Canada

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

Life Support Applications

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

Warranty Note

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

All material in this publication is subject to change without notice and is copyright Basler Vision Technologies.

Contacting Basler Support Worldwide

Europe:

Basler AG
Ander Strusbek 60 - 62
22926 Ahrensburg
Germany

Tel.: +49-4102-463-500

Fax.: +49-4102-463-599

vc.support.europe@baslerweb.com

Americas:

Basler, Inc.
855 Springdale Drive, Suite 160
Exton, PA 19341
U.S.A.

Tel.: +1-877-934-8472

Fax.: +1-877-934-7608

vc.support.usa@baslerweb.com

Asia:

Basler Asia Pte Ltd
8 Boon Lay Way,
#03-03 Tradehub 21
Singapore 609964

Tel.: +65-6425-0472

Fax.: +65-6425-0473

vc.support.asia@baslerweb.com

www.basler-vc.com

Table of Contents

1 Introduction

1.1 Camera Models	1-1
1.2 Performance Specifications	1-2
1.3 Spectral Response	1-3
1.4 Environmental Requirements	1-5
1.4.1 Temperature and Humidity	1-5
1.4.2 Ventilation	1-5
1.5 Precautions	1-5

2 Camera Interface

2.1 Connections	2-1
2.1.1 General Description	2-1
2.1.2 Pin Assignments	2-2
2.1.3 Connector Types	2-3
2.2 Cable Information	2-4
2.2.1 Camera Link Cable	2-4
2.2.2 Power Cable	2-4
2.3 Camera Link Implementation in the A202k	2-4
2.4 Input Signals	2-6
2.4.1 ExSync: Controls Frame Readout and Exposure Time	2-6
2.5 Output Signals	2-7
2.5.1 Pixel Clock	2-7
2.5.2 Frame Valid Bit	2-7
2.5.3 Line Valid Bit	2-7
2.5.4 Video Data	2-8
2.5.4.1 Bit Assignments	2-8
2.5.4.2 Video Data Output Modes	2-9
2.5.5 Integrate Enabled Signal	2-13
2.6 RS-644 Serial Communication	2-14
2.6.1 Making the Serial Connection	2-14
2.7 Converting Camera Link Output to RS-644 with a k-BIC	2-15
2.8 DC Power	2-15
2.9 Status LED	2-16

3 Basic Operation and Features

3.1 Functional Description	3-1
3.2 Exposure Time Control	3-3
3.2.1 ExSync Controlled Operation	3-3
3.2.1.1 Basics of ExSync Controlled Operation	3-3
3.2.1.2 Recommendations for Controlling Exposure in ExSync Level-Controlled Mode	3-4
3.2.1.3 Recommendations for Controlling Exposure in ExSync Programmable Mode	3-7
3.2.2 Free-run Operation	3-10
3.2.2.1 Recommendations for Controlling Exposure in Free-run Programmable Mode	3-11
3.3 Video Data Output Modes	3-12
3.4 Integrate Enabled Signal	3-12
3.5 Gain and Offset	3-13
3.5.1 Setting the Gain.	3-14
3.5.2 Balancing the Left Side and Right Side Gain	3-15
3.5.2.1 Balancing Gain Settings When Using Binary Commands	3-16
3.5.3 Setting the Offset.	3-18
3.5.4 Balancing the Left Side and Right Side Offset	3-19
3.5.4.1 Balancing Offset Settings When Using Binary Commands	3-19
3.5.5 Balancing Gain and Offset	3-21
3.6 Digital Shift	3-22
3.6.1 Digital Shift in 10 bit Output Mode.	3-22
3.6.2 Digital Shift in 8 bit Output Modes.	3-23
3.6.3 Precautions When Using Digital Shift	3-25
3.7 Area of Interest (AOI)	3-26
3.7.1 AOI Setup Guidelines	3-27
3.7.2 Changes to the Maximum Frame Rate with Area of Interest.	3-27
3.7.3 Changes to the Pixel Timing and Output with AOI	3-28
3.8 Binning	3-30
3.8.1 Changes to the Maximum Frame Rate with Binning.	3-31
3.9 Mirror Image	3-31
3.10 Color Creation in the A202kc	3-32
3.11 Test Images	3-33
3.11.1 Test Image One.	3-33
3.11.2 Test Image Two.	3-34
3.11.3 Test Image Three	3-34
3.12 Configuration Sets	3-35
3.13 Camera Temperature	3-36
3.14 Camera Status	3-36

4 Configuring the Camera

4.1 Configuring the Camera with the Camera Configuration Tool Plus (CCT+)	4-2
4.1.1 Opening the Configuration Tool	4-2
4.1.2 Closing the Configuration Tool	4-2
4.1.3 Configuration Tool Basics	4-3
4.1.4 Configuration Tool Help	4-4
4.2 Configuring the Camera with Binary Programming Commands	4-5
4.2.1 Command Frame and Response Format	4-6
4.2.2 Error Checking	4-8
4.2.2.1 ACK/NAK	4-8
4.2.2.2 Time-outs	4-8
4.2.2.3 Read Command	4-8
4.2.2.4 Write Command	4-8
4.2.3 Example Commands	4-9
4.2.3.1 Read command	4-9
4.2.3.2 Write Command	4-9
4.2.3.3 Calculating the Block Check Character	4-10
4.2.4 Commands for Setting Camera Parameters	4-11
4.2.4.1 Video Data Output Mode	4-11
4.2.4.2 Exposure Time Control Mode	4-12
4.2.4.3 Timer 1	4-13
4.2.4.4 Timer 2	4-13
4.2.4.5 Digital Shift	4-14
4.2.4.6 Area of Interest Starting Column	4-15
4.2.4.7 Area of Interest Width in Columns	4-15
4.2.4.8 Area of Interest Starting Line	4-16
4.2.4.9 Area of Interest Height in Lines	4-16
4.2.4.10 Left Side Gain	4-17
4.2.4.11 Left Side Offset	4-17
4.2.4.12 Right Side Gain	4-18
4.2.4.13 Right Side Offset	4-18
4.2.4.14 Horizontal Binning	4-19
4.2.4.15 Vertical Binning	4-19
4.2.4.16 Mirror Image	4-20
4.2.4.17 Test Image Command	4-21
4.2.5 Query Commands	4-22
4.2.5.1 Read Vendor Information	4-22
4.2.5.2 Read Model Information	4-22
4.2.5.3 Read Product ID	4-22
4.2.5.4 Read Serial Number	4-23
4.2.5.5 Read Camera Version	4-23
4.2.5.6 Read EEPROM Firmware Version	4-23
4.2.5.7 Read Microcontroller Firmware Version	4-24

4.2.5.8 Read FPGA Firmware Version	4-24
4.2.5.9 Read Camera Temperature	4-25
4.2.5.10 Reference Values	4-26
4.2.6 Commands for Manipulating Configuration Sets	4-27
4.2.6.1 Copy the Factory Set or a User Set into the Work Set	4-27
4.2.6.2 Copy Work Set into a User Set	4-28
4.2.6.3 Select the Startup Pointer	4-29
4.2.7 Camera Status Command	4-30
4.2.8 Bitrate Command	4-31
4.2.9 Camera Reset Command	4-32

5 Mechanical Considerations

5.1 Camera Dimensions and Mounting Facilities	5-2
5.2 Sensor Positioning Accuracy	5-3
5.3 C-Mount Adapter Dimensions	5-4
5.4 F-Mount Adapter Dimensions	5-4
5.5 Maximum Lens Thread Length on C-mount Equipped Cameras	5-5

6 Troubleshooting

6.1 Fault Finding Using the Camera LED	6-1
6.2 Troubleshooting Charts	6-2
6.2.1 No Image	6-2
6.2.2 Image Quality Problems	6-4
6.2.3 Interfacing	6-5
6.2.4 RS-644 Serial Communication	6-6
6.3 Before Calling Basler Technical Support	6-7

Revision History	i
-------------------------------	----------

Feedback	iii
-----------------------	------------

Index	v
--------------------	----------

1 Introduction

The **BASLER A202k** 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 sensitivity
- 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
- 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 **A202k**) and a color model (the **A202kc**). Throughout the manual, the camera will be called the **A202k**. Passages that are only valid for a specific model will be so indicated.

1.2 Performance Specifications

Specification	A202k	A202kc
Sensor	Kodak KAI-1020 Interline Transfer Progressive Scan CCD Sensor	
Pixels	1004 (H) x 1004 (V)	
Pixel Size	7.4 μm x 7.4 μm	
Mono or Color	Mono	Color
Spectral Response	See Figure 1-1	See Figure 1-2
Photo Response Non-uniformity	$\pm 5\%$ (typical)	
Dark Signal Non-uniformity	± 1 gray value (typical)	
Pixel Clock Speed	40 MHz (20 MHz when horizontal or full binning is used)	
Max. Frame Rate	48 Frames/sec. at full resolution	
Video Output Type	Camera Link LVDS (RS-644 when used with the optional Basler Interface Controller)	
Video Output Formats	Dual 8 Bit or Dual 10 Bit	
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	
Connectors	One, 26-pin, female MDR connector One, 6-pin, Hirose micro-miniature receptacle	
Power Requirements	12 VDC ($\pm 10\%$), max. 5.5 W, < 1% ripple	
Lens Adapters	C-mount or F-mount	
Housing Size (L x W x H)	without lens adapter: 37.6 mm x 62 mm x 62 mm with C-mount adapter: 40.1 mm x 62 mm x 62 mm with F-mount adapter: 69.1 mm x 62 mm x 62 mm	
Weight	without lens adapter: ~ 180 g with C-mount adapter: ~ 220 g with F-mount adapter: ~ 290 g	
Conformity	CE, FCC	

Table 1-1: A202k Performance Specifications

1.3 Spectral Response

The spectral response for the A202k monochrome camera is shown in Figure 1-1.

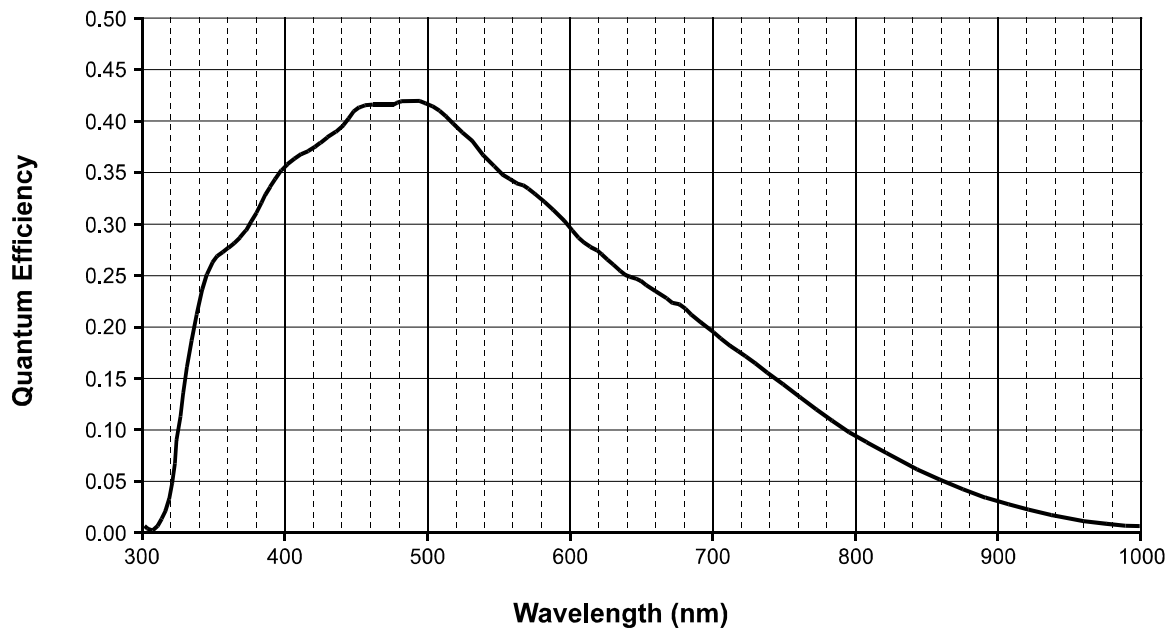


Figure 1-1: A202k Mono Spectral Response

The spectral response for the **A202kc** color camera is shown in Figure 1-2.

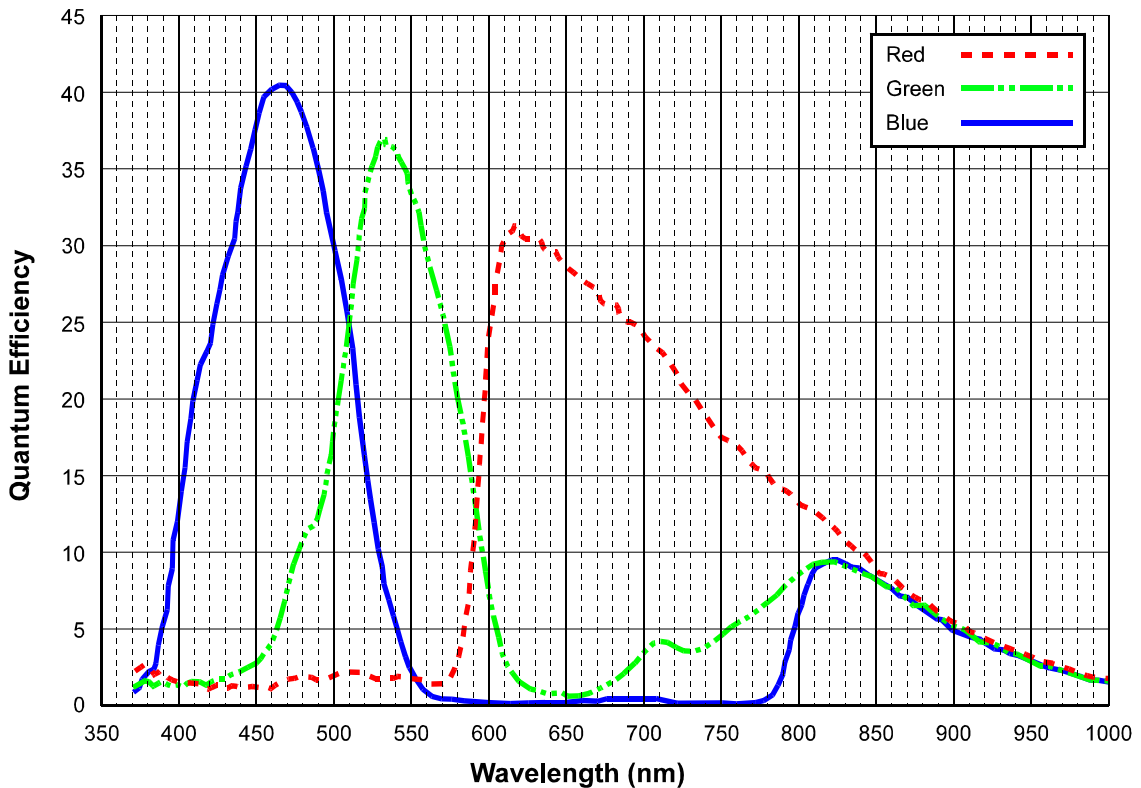


Figure 1-2: **A202kc** Color Spectral Response



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!

A202kc 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 Environmental Requirements

1.4.1 Temperature and Humidity

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

1.4.2 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.


	<p>Warning!</p> <p>Without sufficient cooling, the camera can get hot enough during operation to cause burning when touched.</p>
---	---


1.5 Precautions

To ensure that your warranty remains in force:

Power

	<p>Caution!</p> <p>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.</p>
---	---

	<p>Caution!</p> <p>The camera has no overvoltage protection. An input voltage higher than 14 VDC will damage the camera.</p>
---	---

	<p>Caution!</p> <p>Do not reverse the polarity of the input power to the camera. Reversing the polarity of the input power can severely damage the camera and leave it non-operational.</p>
---	--

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 high quality window cleaner. Do not use methylated alcohol.

Because electrostatic discharge can damage the CCD sensor, you must use a cloth that will not generate static during cleaning (cotton is a good choice).

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

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

2 Camera Interface

2.1 Connections

2.1.1 General Description

The A202k 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.

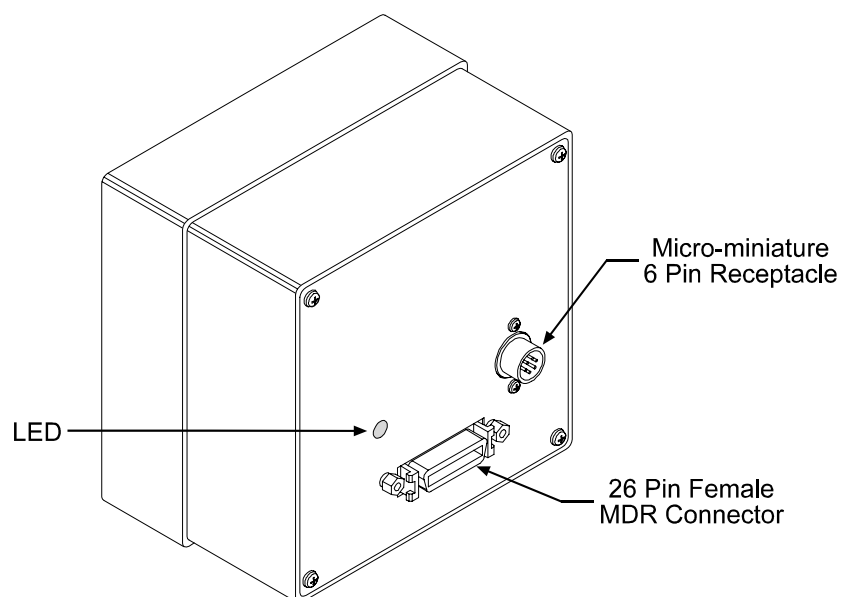


Figure 2-1: A202k Connectors and LED

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: A202k Pin Assignments for the 26-pin MDR Connector

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

6-Pin Micro-miniature Receptacle

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

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

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

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

Table 2-2: **A202k** Pin Assignments for the 6-pin Micro-miniature Receptacle

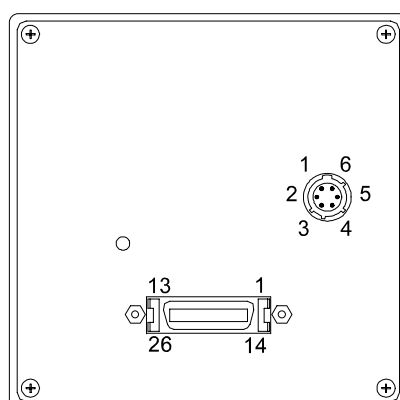


Figure 2-2: **A202k** Pin Numbering

2.1.3 Connector Types

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

The 6 pin connector on the camera is a Hirose micro-miniature locking receptacle (part # HR10A-7R-6PB) or the equivalent. The recommended mating connector is the Hirose micro-miniature locking plug (part # HR10A-7P-6S). A 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. 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.

2.2 Cable Information

2.2.1 Camera Link Cable

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

The maximum allowed length for the MDR cable used with an **A202k** is 10 meters.



In order to access the Integrate Enabled signal, you must use the Basler stock cable (see Sect. [2.5.5](#)).

2.2.2 Power Cable

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

Power requirements are given in Section [2.8](#).

2.3 Camera Link Implementation in the A202k

The **A202k** uses a National Semiconductor DS90CR287 as a Camera Link transmitter. For a Camera Link receiver, we recommend that you use the National Semiconductor DS90CR288, the National Semiconductor DS90CR288A or an equivalent. Detailed data sheets for these components are available at the National Semiconductor web site (www.national.com). The data sheets contain all of the information that you need to implement Camera Link, including application notes.



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

The **A202k** 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 **A202k** and a typical implementation for the frame grabber interface.

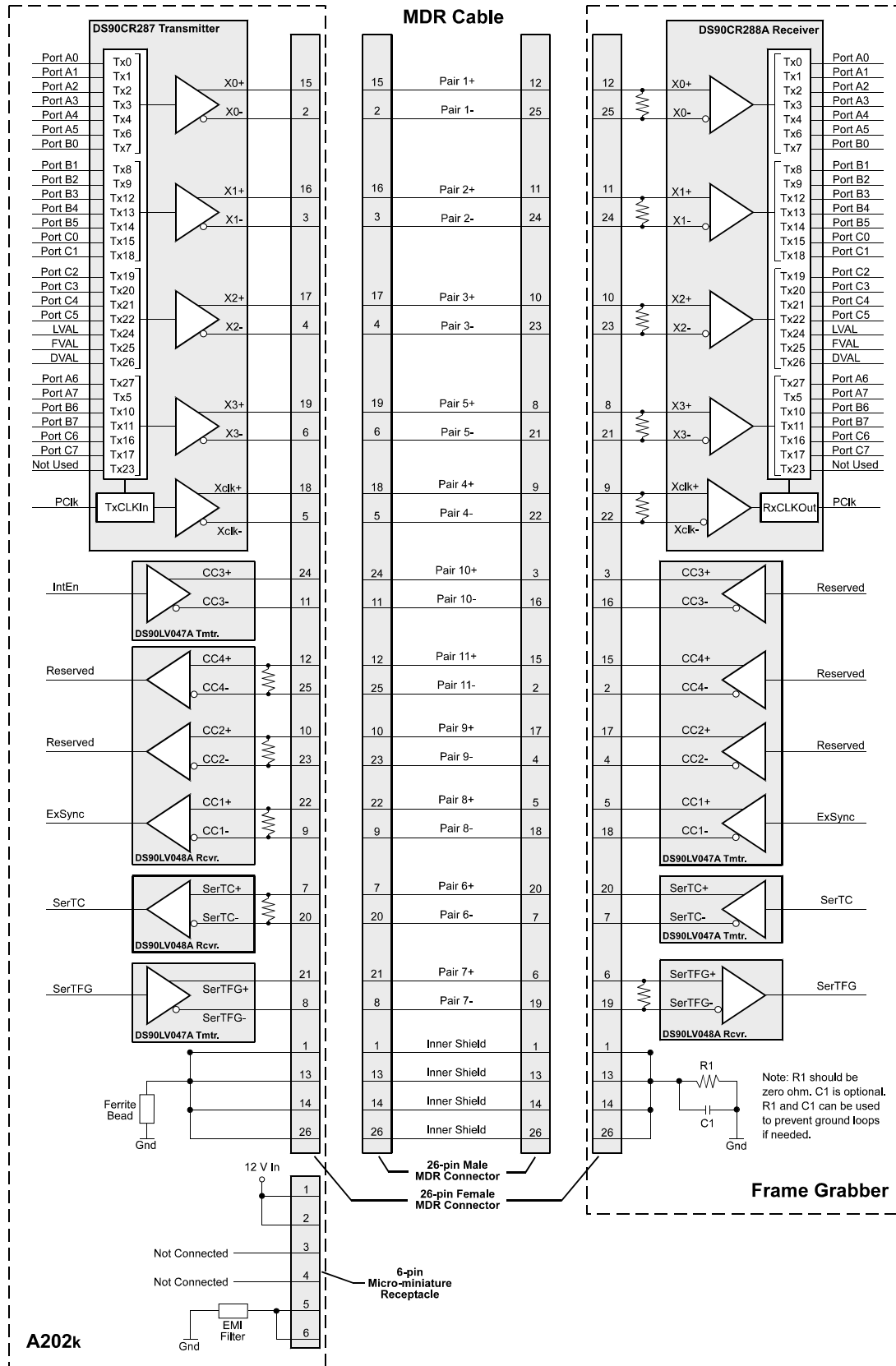


Figure 2-3: Camera / Frame Grabber Interface

2.4 Input Signals

The only control signal that can be input into the **A202k** 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. For more detailed information on the two modes, 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 is 4 μs .

The ExSync signal is typically supplied to the camera by a frame grabber board. You should refer to the manual supplied with your frame grabber to determine how to set up the ExSync signal 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 2.5.5 describe the output signals.

2.5.1 Pixel Clock

As shown in Figure 2-3 and in Table 2-3, the pixel clock is assigned to the TxClkIn (transmit clock) pin of the Camera Link transmitter. The pixel clock is used to time the sampling and transmission of pixel data as shown in Figures 2-4 and 2-5. The transmitter used in A202k cameras requires pixel data to be sampled and transmitted on the falling edge of the clock.

The frequency of the pixel clock is normally 40 MHz. However, when horizontal or full binning is enabled, the pixel clock is 20 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 Figures 2-4 and 2-5, the frame valid bit indicates that a valid frame is being transmitted.

2.5.3 Line Valid Bit

As shown in Figures 2-4 and 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 Video Data

2.5.4.1 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 2.5.4.2.

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

Table 2-3: Bit Assignments

2.5.4.2 Video Data Output Modes

The A202k can output pixel data in either a Dual 10 Bit, or a Dual 8 Bit output mode. These modes are described in detail below.

Operation in Dual 10 Bit or Dual 8 Bit Output Mode

In Dual 10 Bit mode, the pixel clock operates at 40 MHz. On each clock cycle, the camera transmits data for two pixels at 10 bit depth, a frame valid bit, and a line valid bit. The assignment of the bits is shown in Table 2-3.

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

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



The data sequence outlined below, along with Figures 2-4 and 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 Sequence¹

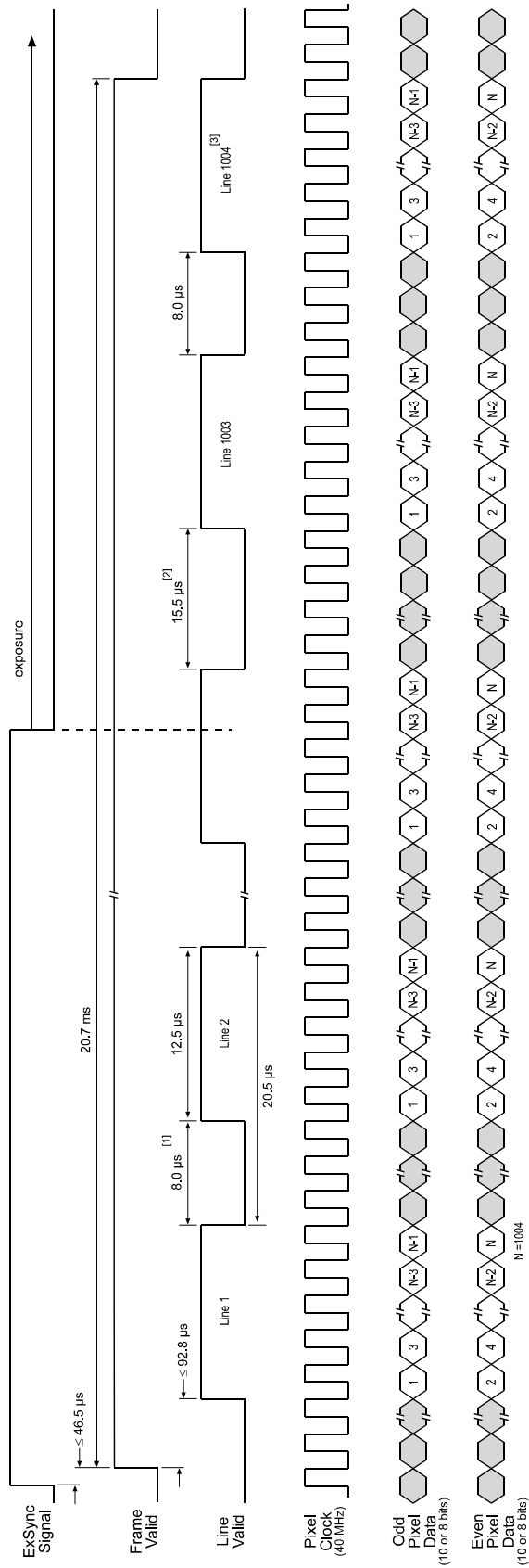
When the camera is not transmitting valid data, the frame valid and line valid bits sent on each cycle of the pixel clock will be low. Once the camera has completed frame acquisition, it will begin to send valid data:

- On the pixel clock cycle where frame data transmission begins, 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. Ten of the bits transmitted during this clock cycle will contain the data for pixel number one in line one and ten of the bits will contain data for pixel number two in line one.
- On the next cycle of the pixel clock, the line valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number three in line one and ten of the bits will contain data for pixel number four in line one.
- On the next cycle of the pixel clock, the line valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number five in line one and ten of the bits will contain data for pixel number six in line one.
- This pattern will continue until all of the pixel data for line one has been transmitted.

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

- 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. Ten of the bits transmitted during this clock cycle will contain the data for pixel number one in line two and ten of the bits will contain data for pixel number two in line two.
- On the next cycle of the pixel clock, the line valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number three in line two and ten of the bits will contain data for pixel number four in line two.
- On the next cycle of the pixel clock, the line valid bit will be high. Ten of the bits transmitted during this clock cycle will contain the data for pixel number five in line two and ten of the bits will contain data for pixel number six 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 line valid low time is 8.0 μs except as described in note 2 below.

[2] In the level controlled exposure mode, the fall of ExSync starts exposure. If ExSync falls while a frame is being transferred (while frame valid is high), one line valid low time immediately following the fall of ExSync will be 15.5 μs .

[3] 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: Dual 10 Bit or Dual 8 Bit Output Mode with Level Controlled Exposure

2.5.5 Integrate Enabled Signal

An RS-644 LVDS output signal called Integrate Enabled (IntEn) is available on **A202k** 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 2-5, the IntEn signal is available on pins 24 and 11 of the **A202k**.

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.

i If you use a standard Camera Link cable to connect the **A202k** 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 2-5. 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.

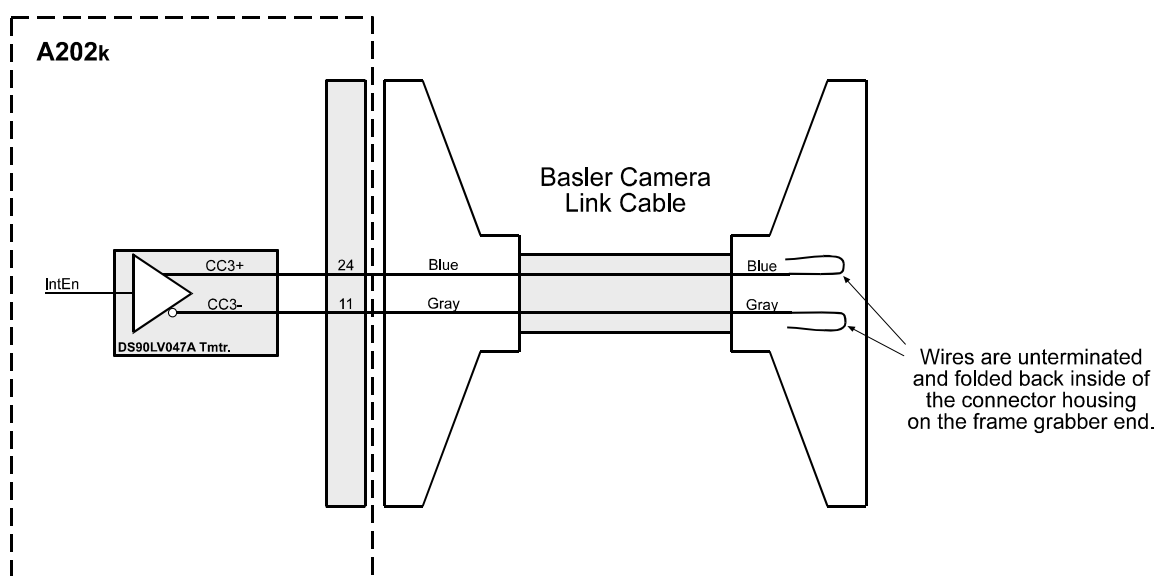


Figure 2-6: Basler Camera Link Cable

2.6 RS-644 Serial Communication

The A202k 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. Detailed instructions for using the tool are included in the on-line help file that is installed with the tool.

Basler has also developed a binary command protocol that can be used to change camera modes and parameters directly from your own application via the serial connection. 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 Camera Configuration Tool Plus to configure the camera, the tool will detect the characteristics of the serial port on the frame grabber and will determine the appropriate settings so that the tool can open and use the port.



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

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

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

On the **A202k**, 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 **A202k** 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 **A202k** with a Camera Link compatible cable. For complete information on the k-BIC, refer to the k-BIC User's Manual and the k-BIC installation guide.

2.8 DC Power

The **A202k** requires 12 VDC ($\pm 10\%$) power. A 12 V power supply is available from Basler as a stock item (part # 1000013046).



Caution!

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



Caution!

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

The camera's maximum power consumption is approximately 5.5 watts. Ripple must be less than 1%.



A Hirose, 6-pin locking plug will be shipped with each camera. This plug should be used to connect the power supply cable to 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 **A202k** 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 **A202k** 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 two horizontal shift registers as shown in Figure 3-1. Charges from the left side of the line (pixel 1 through pixel 502) are moved to the left side horizontal shift register. Charges from the right side of the line (pixel 503 through pixel 1004) are moved to the right side horizontal shift register. The left side horizontal register shifts out charges from left to right, that is, pixel 1, pixel 2, pixel 3, and so on. The right side horizontal register shifts out charges from right to left, that is, pixel 1004, pixel 1003, pixel 1002 and so on.

As charges move out of the two horizontal shift registers, they are converted to voltages proportional to the size of each charge. Shifting is clocked according to the camera's 40 MHz internal data rate.

The voltages moving out of each shift register are amplified by an internal Variable Gain Control (VGC) and then digitized by a 10 bit, Analog-to-Digital converter (ADC). Once the pixels are digitized, they are reordered so that they will be transmitted out of the camera in ascending numerical order from pixel 1 through pixel 1004.

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.

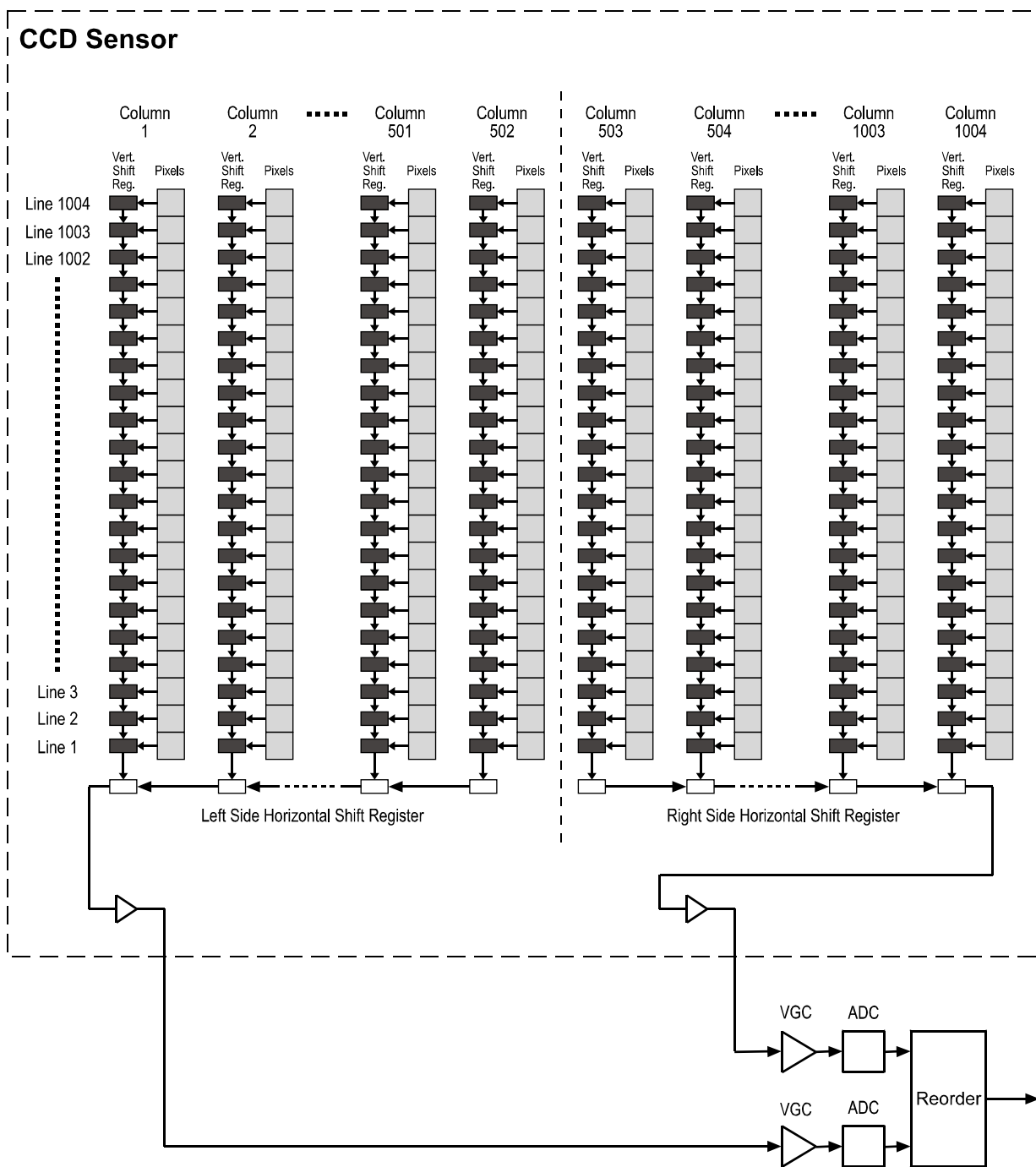


Figure 3-1: A202k Sensor Architecture

3.2 Exposure Time Control

The A202k 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 = $1/\text{ExSync Signal Period}$.) 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).

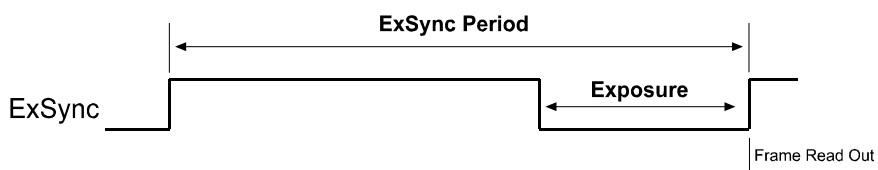


Figure 3-2: ExSync, Level-controlled Mode

- 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.

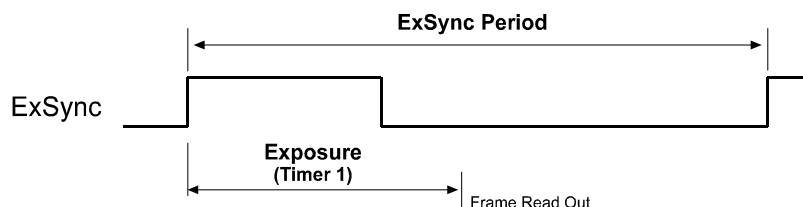


Figure 3-3: ExSync, Programmable Mode

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 operation and to select the level-controlled or programmable exposure time control mode. If you select the programmable mode, you must also enter an exposure time. When you enter an exposure time, the configuration tool will automatically set the "Timer 1" parameter to the correct value.

With binary commands, you must use the Exposure Time Control Mode command to select ExSync edge-controlled 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 4 μ s.
- The ExSync signal must remain low for at least 10 μ s.
- If the AOI and Binning features are **not** being used, the minimum ExSync signal period is 20.83 ms.
- If the AOI feature is being used, the minimum ExSync signal period is equal to $1/\text{Maximum Frame Rate}$ where the maximum frame rate is determined by the formula on page 3-27.
- If the binning feature is being used, the minimum ExSync signal period is equal to $1/\text{Maximum Frame Rate}$ where the maximum frame rate is determined by the formula on page 3-31.
- 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. 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.

Case 1 - Exposure Start With Frame Valid High

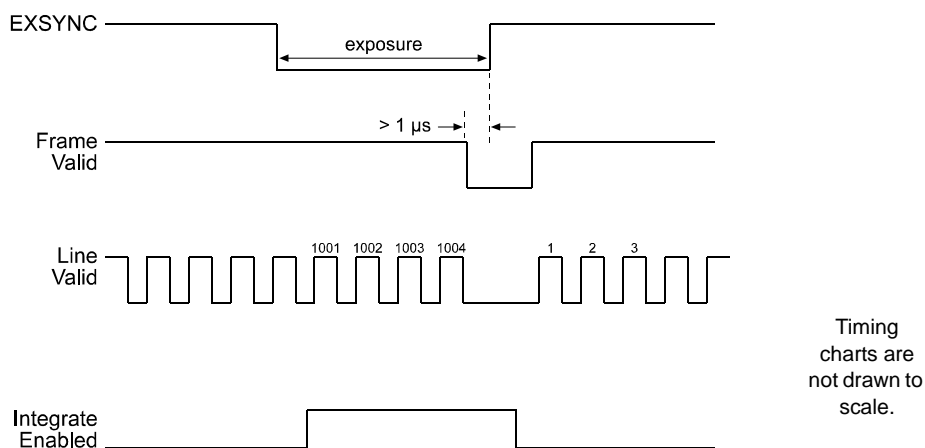


Figure 3-4: ExSync, Level-controlled Mode - Exposure Start with Frame Valid High

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 25 μs later than the fall 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 ExSync signal low time plus 77.7 μs minus the jitter time.



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

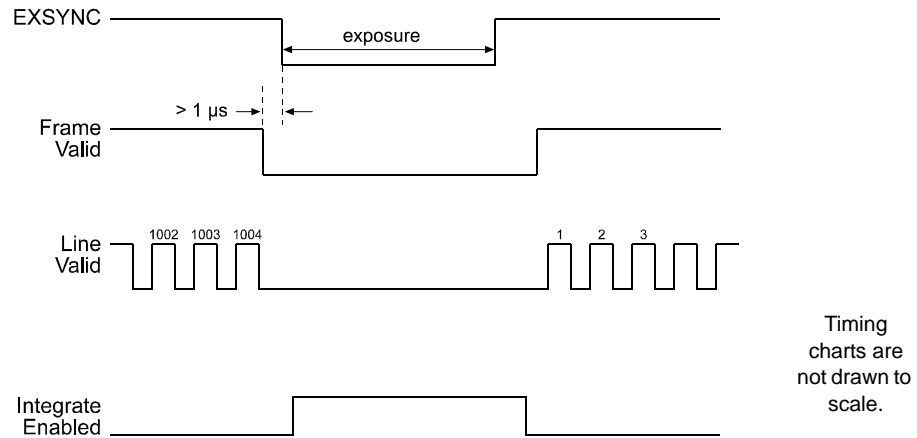



Figure 3-5: ExSync, Level-controlled Mode - Exposure Start with Frame Valid Low

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

- Exposure will start after a delay of 4.4 μs .
- The actual length of the exposure time will be equal to the ExSync signal low time plus 77.7 μs .

 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 4 μ s.
- The minimum setting for Timer 1 is 13 μ s.
- The programmed exposure time must be less than the ExSync signal period.
- If the AOI and Binning features are **not** being used, the minimum ExSync signal period is 20.83 ms.
- If the AOI feature is being used, the minimum ExSync signal period is equal to $1/\text{Maximum Frame Rate}$ where the maximum frame rate is determined by the formula on page 3-27.
- If the binning feature is being used, the minimum ExSync signal period is equal to $1/\text{Maximum Frame Rate}$ where the maximum frame rate is determined by the formula on page 3-31.
- 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

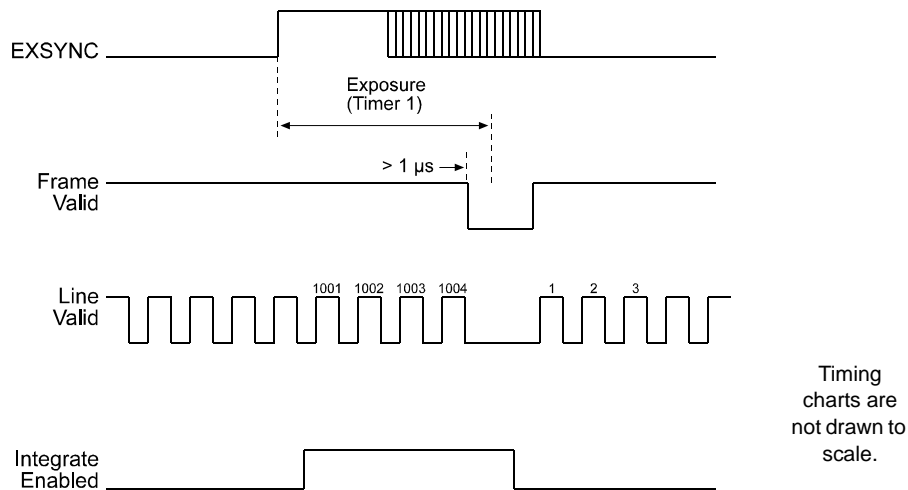



Figure 3-6: ExSync, Programmable Mode - Exposure Start with Frame Valid High

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 25 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 77.7 μs minus the jitter time.

	<p>As shown in Figure 3-6, FVAL must be low for at least 1 μs before the programmed exposure time ends.</p>
---	--

Case 2 - Exposure Start With Frame Valid Low

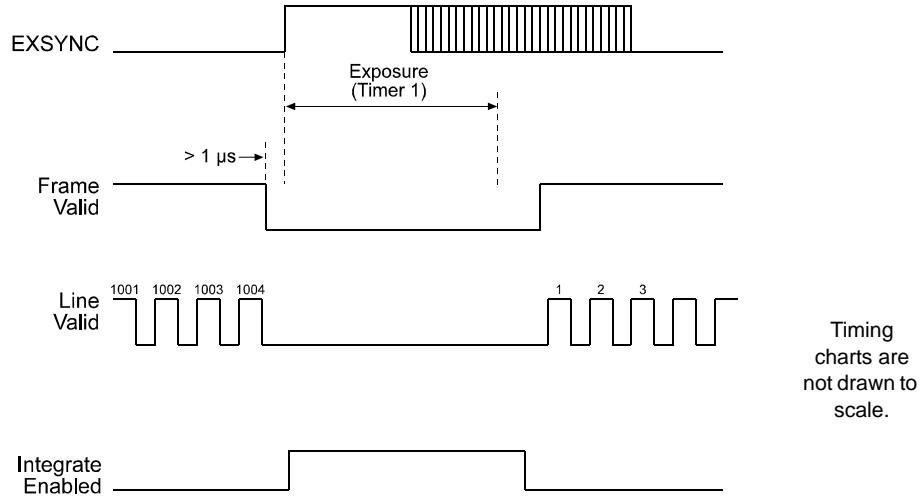


Figure 3-7: ExSync, Programmable Mode - Exposure Start with Frame Valid Low

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

- The actual start of exposure can be up to 11.5 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 77.7 μs minus the jitter time.



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. 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 exposure time can be programmed as desired by varying the setting of the "Timer 1" parameter.

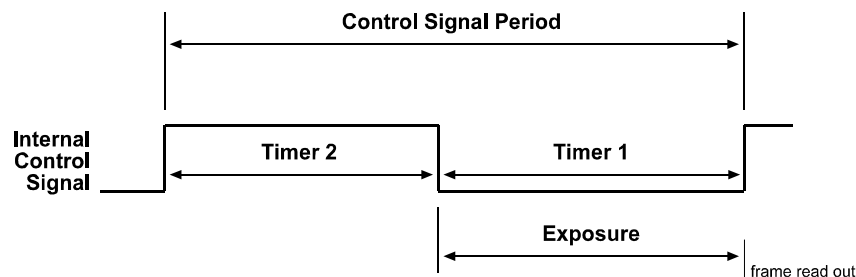


Figure 3-8: Free-run, Programmable Mode

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 and to select the programmable exposure time control mode. If you choose to operate the camera in free-run, the tool will require you to enter a frame rate and an exposure time in the Exposure group. 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 13 μ s.
- The minimum setting for Timer 2 is 35 μ s.
- The actual length of the exposure time will be equal to the programmed time plus 77.7 μ s.
- 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 plus 77.7 μ s. If the AOI and Binning features are **not** being used, the sum of the Timer 1 setting plus the Timer 2 must be greater than 20.83 ms.
- 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 on page 3-27.
- If the 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 on page 3-31.



If you are using the Camera Configuration Tool Plus to set up the free-run programmable mode, the tool will ask you to 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 **A202k** can output video data using two different modes: dual 10 bit mode, or dual 8 bit mode. In dual 10 bit mode, the camera outputs data for two pixels on each cycle of the pixel clock and the pixel data is at 10 bit depth. In dual 8 bit mode, the camera outputs data for two pixels on each cycle of the pixel clock and the pixel data is at 8 bit depth. These modes are described in detail in Section [2.5.4.2](#).

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 and 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 **A202k** 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 [2.5.5](#).

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 Gain and Offset

The major components in the **A202k** electronics include: a CCD sensor, two VGCs (Variable Gain Controls), and two ADCs (Analog to Digital Converters). When exposed to light, the pixels in the CCD sensor output voltage signals. These voltages are amplified by the VGCs and transferred to the ADCs which convert the voltages to digital output signals.

Two parameters, gain and offset are associated with each VGC. As shown in Figure 3-9 and Figure 3-10, 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 2 and white should have a gray value of 253 (in 8 bit output mode). Attempt to achieve this by varying exposure and illumination rather than changing the camera's gain. The default gain is the optimal operating point (minimum noise) and should be used if possible.

Internally, the **A202k** processes the left side and the right side of each image separately in two different data channels (see Figure 3-1). Consequently, gain and offset must be adjusted separately for the left side and the right side. Due to variations in the camera's electronics, the gain and offset needed on the left side channel to correctly map the output from the VGC to the input of the ADC may be different from the gain and offset needed on the right side channel. Gain balance

and offset balance between the left side and right side channels is important to maintain uniform output data with minimal gray value differences between the left and right side of the image.

See Section 3.5.2 for more information on balancing the gain. See Section 3.5.4 for more information on balancing the offset.

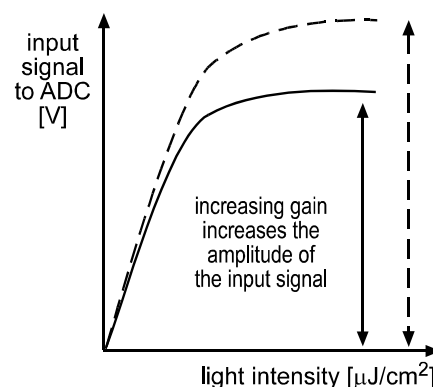


Figure 3-9: Gain

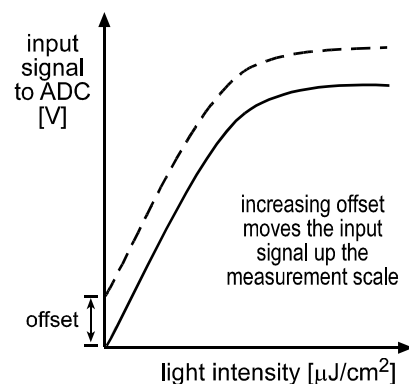




Figure 3-10: Offset

	Initially, it may not be obvious whether gray value differences between the left and right side of the image result from gain imbalance and/or offset imbalance. See the procedure in Section 3.5.5 for adjustments addressing both, gain imbalance and offset imbalance.
	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 settings in the Gain & Offset group to easily adjust gain and offset.

With binary commands, you must use the Left Side Gain and Right Side Gain binary commands to set the gain and the Left Side Offset and Right Side Offset binary commands to set the offset.

3.5.1 Setting the Gain

When the gain is set to default, the sensor’s linear output range directly matches the input voltage range of the ADCs. Thus, with the default gain of 0 dB, a gray value of 0 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 288. (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 288 maps a smaller portion of the sensor’s linear output range to the ADC’s input.

Increasing the gain is useful when at your brightest exposure, a gray value lower than 255 is reached. For example, if you found that at your brightest exposure your gray values were no higher than 127, you could increase the gain to 6 dB (amplification factor of 2) and thus reach gray values of 254 (see Figure 3-11).

Gain is adjustable and can be programmed on a decimal scale that ranges from 288 to 569 (0x0120 to 0x0239). The settings result in the following amplifications:

Decimal Number (DN)	Hexadecimal	dB	Factor
288	0x0120	0	x1
569	0x0239	12	x4

Table 3-1: Gain Settings

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

When DN setting = 288 ... 511 Gain in dB = $20 \log_{10} \left(\frac{658 + DN}{658 - DN} \right) - 8.15$

When DN setting = 512 ... 569 Gain in dB = $.0354 (DN) - 8.15$

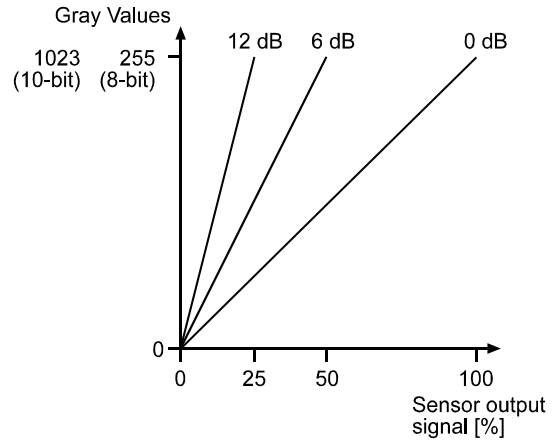


Figure 3-11: Gain Settings in dB



In normal operation, gain settings lower than 288 (0x0120) should not be used. With gain settings lower than 288, the sensor output signal mapped to the input of the ADCs will not be linear.

3.5.2 Balancing the Left Side and Right Side Gain

As described on page 3-13, gain alignment between the channels, combined with offset alignment, is important to maintain uniform output data with minimal gray value differences between the left side and the right side of the image.

In some applications, multiple cameras are used, for example, when two area scan cameras are used next to each other to form one large image. In some cases, a camera in an existing application must be replaced. In these situations, it is also necessary to balance the gains between cameras.

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

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

If you use the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's on-line help) to set the gain on your camera, the camera will automatically use the stored reference values to keep the channels in balance. In addition, you can use the Gain Balance setting in the CCT+ to manually adjust the gain balance.

If you use binary commands (see Section 4.2) to set the gain, you can use the reference values to calculate gain settings that will keep the channels in balance. Section 3.5.2.1 describes the method for using the reference values when changing the gain with binary commands.

3.5.2.1 Balancing Gain Settings When Using Binary Commands

The left side gain is set using the Left Side Gain binary command (see Section 4.2.4.10) and the right side gain is set using the Right Side Gain binary command (see Section 4.2.4.12). Each gain setting can be programmed on a decimal scale that ranges from 0 to 569 (0x0000 to 0x0239), however, values lower than 288 (0x0120) should not be used.

The reference gain values can be read using the Read Reference Values binary command (see Section 4.2.5.10). The sample calculation below shows how to use the reference gain values.

Sample Calculation Using the Reference Gain Values

Assume that you are working with an **A202k**, that you want to set the gain to 6 dB, and that you want to keep the left side and the right side of the image in balance.

1. Read the reference values that were stored during the camera's calibration procedure using the "Read Reference Values" binary command (see Section 4.2.5.10). For our example, we will assume that the camera returned the following reference gain values:

<i>Byte 1 - Low byte left side reference gain after decimal point</i>	<i>0x00</i>
<i>Byte 2 - High byte left side reference gain after decimal point</i>	<i>0x65</i>
<i>Byte 3 - Low byte left side reference gain before decimal point</i>	<i>0x20</i>
<i>Byte 4 - High byte left side reference gain before decimal point</i>	<i>0x01</i>
<i>Byte 5 - Low byte right side reference gain after decimal point</i>	<i>0x00</i>
<i>Byte 6 - High byte right side reference gain after decimal point</i>	<i>0xD1</i>
<i>Byte 7 - Low byte right side reference gain before decimal point</i>	<i>0x25</i>
<i>Byte 8 - High byte right side reference gain before decimal point</i>	<i>0x01</i>

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

<i>Byte 1 = 0</i>	<i>Byte 2 = 101</i>	<i>Byte 3 = 32</i>	<i>Byte 4 = 1</i>
<i>Byte 5 = 0</i>	<i>Byte 6 = 209</i>	<i>Byte 7 = 37</i>	<i>Byte 8 = 1</i>

3. Use the decimal values of Byte 4 through Byte 1 to determine the reference gain for the left side (RG_{LS}):

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

$$RG_{LS} = (1 \times 256) + 32 + \frac{101}{256} + \frac{0}{65536}$$

$$RG_{LS} = 288.39$$

4. Enter the decimal value for the left side reference gain (RG_{LS}) and the decimal value for the desired gain (G) into the formula below:

$$X_{LS} = 20 \log_{10} \left[\frac{658 + RG_{LS}}{658 - RG_{LS}} \right] - 8.15 + G$$

Where:

G = Desired gain in dB

G is set so that $X_{LS} \leq 28.06$

For our example, the calculation would be:

$$X_{LS} = 20 \log_{10} \left[\frac{658 + 288.39}{658 - 288.39} \right] - 8.15 + 6$$

$$X_{LS} = 6.02$$

5. Calculate the gain setting for the left side by using formula A or formula B below:

Formula A

$$\text{Left Side Gain Setting} = \frac{\left(658 \times 10^{\frac{X_{LS} + 8.15}{20}} \right) - 658}{1 + 10^{\frac{X_{LS} + 8.15}{20}}} \quad \text{When } X_{LS} < 10.0$$

Formula B

$$\text{Left Side Gain Setting} = \frac{X_{LS} + 8.15}{0.0354} \quad \text{When } X_{LS} \geq 10.0$$

Since our calculated X_{LS} is less than 10.0, we would use formula A:

$$\text{Left Side Gain Setting} = \frac{\left(658 \times 10^{\frac{6.02 + 8.15}{20}} \right) - 658}{1 + 10^{\frac{6.02 + 8.15}{20}}}$$

$$\text{Left Side Gain Setting} = 442.65$$

Round up to 443

6. Use the same method as shown in steps 3, 4, and 5 to calculate the right side gain setting. For our example, the result would be 446.

7. Convert the results to hexadecimal:

Left Side Gain Setting of 443 decimal = 0x01BB

Right Side Gain Setting of 446 decimal = 0x01BE

8. Use the left side gain and the right side gain binary commands to set the left side gain and the right side gain to the calculated values.

After you use the commands to enter the calculated values, the camera will be operating at 6 dB with respect to the reference camera and the left side and right side pixels will be balanced.



You may get a better left side/right side match by increasing either the left side gain or the right side gain by one.

3.5.3 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 Left Side Offset binary command to set the left side offset and the Right Side Offset binary command to set the right side offset (see Section [4.2.4.11](#) and [4.2.4.13](#)). The left side and right side offset settings can be programmed on a decimal scale that ranges from 0 to 255 (0x0000 to 0x00FF).

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

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

3.5.4 Balancing the Left Side and Right Side Offset

As described on page 3-13, offset alignment between the channels, combined with gain alignment, is important to maintain uniform output data with minimal gray value differences between the left side and the right side of the image.

In some applications, multiple cameras are used, for example, when two area scan cameras are used next to each other to form one large image. In some cases, a camera in an existing application must be replaced. In these situations, it is also necessary to balance the offsets between cameras.

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

- The factory offset settings for the left side and the right side channels are adjusted to result in an offset of 2 (decimal) at 8 bit output and to provide a uniform output on both channels. In addition, they are set to a low offset value to obtain an optimal operating point.
- The reference offset values are stored in the camera. These stored values can be used to calculate higher or lower offset settings that will keep the left side and right side channels in balance and comparable to other cameras of the same type.

If you use the Camera Configuration Tool Plus (see Section 4.1 and the configuration tool's online help) to set the offset on your camera, the camera will automatically use the stored reference values to keep the channels in balance. In addition, you can use the Offset Balance setting in the CCT+ to manually adjust the offset balance.

If you use binary commands (see Section 4.2) to set the offset, you can use the reference values to calculate offset settings that will keep the channels in balance. Section 3.5.4.1 describes the method for using the reference values when changing the offset with binary commands.

3.5.4.1 Balancing Offset Settings When Using Binary Commands

The left side offset is set using the Left Side Offset binary command (see Section 4.2.4.11) and the right side offset is set using the Right Side Offset binary command (see Section 4.2.4.13). Each offset setting can be programmed on a decimal scale that ranges from 0 to 255 (0x0000 to 0x00FF).

The reference offset values can be read using the Read Reference Values binary command (see Section 4.2.5.10). The sample calculation below shows how to use the reference offset values.

Sample Calculation Using the Reference Offset Values

Assume that you are working with an **A202k**, that you have selected an 8 bit output mode, that you want an offset of 5, and that you want to keep the left side and the right side of the image in balance.

1. Read the reference values that were stored during the camera's calibration procedure using the "Read Reference Values" binary command (see Section 4.2.5.10). For our example, we will assume that the camera returned the following reference offset values:

Byte 9 - Low byte left side reference offset after decimal point 0x00

Byte 10 - High byte left side reference offset after decimal point 0x00

Byte 11 - Low byte left side reference offset before decimal point 0x19

Byte 12 - High byte left side reference offset before decimal point 0x00

Byte 13 - Low byte right side reference offset after decimal point 0x00

Byte 14 - High byte right side reference offset after decimal point 0x00

Byte 15 - Low byte right side reference offset before decimal point 0x18

Byte 16 - High byte right side reference offset before decimal point 0x00

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

Byte 9 = 0 *Byte 10 = 0* *Byte 11 = 25* *Byte 12 = 0*

Byte 13 = 0 *Byte 14 = 0* *Byte 15 = 24* *Byte 16 = 0*

3. Use the decimal values of Byte 9 through Byte 12 to determine the reference offset setting for the left side (RO_{LS}):

$$RO_{LS} = (\text{Byte 12} \times 256) + \text{Byte 11} + \frac{\text{Byte 10}}{256} + \frac{\text{Byte 9}}{65536}$$

$$RO_{LS} = (0 \times 256) + 25 + \frac{0}{256} + \frac{0}{65536}$$

$$RO_{LS} = 25$$

4. Calculate the offset setting for the left side, where O = desired offset. Take into account here, that in 8 bit output mode an increase of 16 (decimal) in the offset setting will result in a positive offset of 1.

$$\text{Left Side Offset Setting} = RO_{LS} + (16 \times (O - 2))$$

$$\text{Left Side Offset Setting} = 25 + (16 \times 3)$$

$$\text{Left Side Offset Setting} = 73$$

5. Use the same method as shown in steps 3 and 4 to calculate the right side offset setting. For our example, the result would be 72.

6. Convert the results to hexadecimal:

Left Side Offset Setting of 73 decimal = 0x0049

Right Side Offset Setting of 72 decimal = 0x0048

7. Use the left side offset and the right side offset binary commands to set the left side offset and the right side offset to the calculated values.

After you use the commands to enter the calculated values, the camera will be operating at an offset of 5 with respect to the reference camera and the left side and right side pixels will be balanced.

3.5.5 Balancing Gain and Offset

Initially, it may not be obvious whether gray value differences between the left and right side of the image result from gain imbalance and/or offset imbalance.

To balance gray value differences between the left and right side of the image addressing both, gain imbalance and/or offset imbalance:

1. Prevent light from striking the camera's sensor, e.g. by putting the cap that is shipped with the camera on the lens mount.
2. Capture an image.
If there are gray value differences between the left and right side of the image adjust the offset balance (see Section [3.5.4](#)).
3. If a lens is not already in place, mount a lens on the camera and expose the camera's sensor to light.
4. Capture an image.
If there are gray value differences between the left and right side of the image adjust the gain balance (see Section [3.5.2](#)).

Offset and gain between the left and right side of the image are balanced.

3.6 Digital Shift

The “digital shift” feature allows you to change the group of bits that is output from each ADC. Using the digital shift feature will effectively multiply the output of the camera by 2 times or 4 times. Section 3.6.1 describes how digital shift works when the camera is operating in 10 bit output mode and Section 3.6.2 describes how digital shift works when the camera is operating in 8 bit output mode.

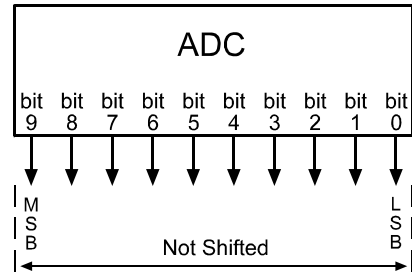
Also note the precautions that you must observe to effectively use this feature (see Section 3.6.3).

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.

3.6.1 Digital Shift in 10 bit Output Mode

No Shift

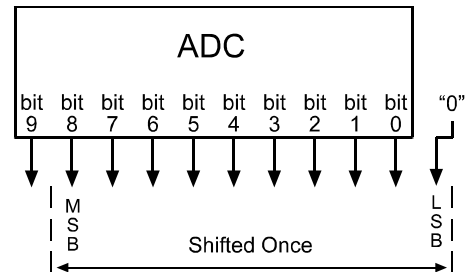
As mentioned in Section 3.1, the A202k uses 10 bit ADCs to digitize the output from the CCD sensor. When the camera is operating in 10 bit output mode, by default, the camera transmits the 10 bits that are output from each ADC.



Shift Once

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

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



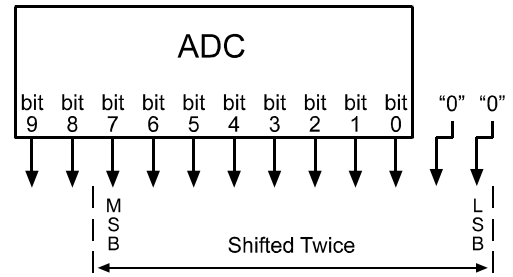
Note that if bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 10 bit mode with no digital shift are all below 512.


Since the shift once setting requires that the least significant bit always be "0", no odd gray values can be output. In this case, 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 7 through bit 0 from each ADC along with two zeros as LSBs.

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

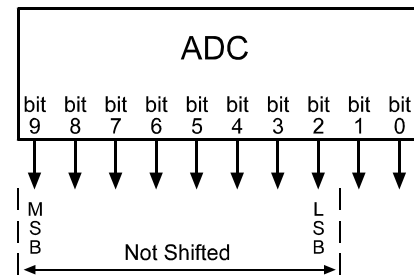


	<p>Note that if bit 9 or bit 8 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift twice setting when your pixel readings in 10 bit mode with no digital shift are all below 256.</p> <p>Since the shift twice setting requires that the two least significant bits always be "0", the gray value scale will only include every 4th gray value. For example, 4, 8, 16 and so forth.</p>
---	--

3.6.2 Digital Shift in 8 bit Output Modes

No Shift

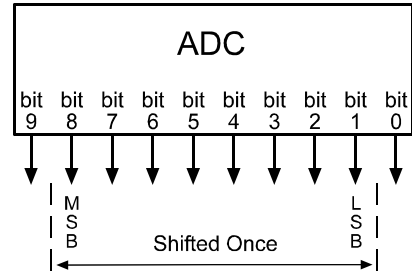
As mentioned in Section 3.1, the A202k uses 10 bit ADCs to digitize the output from the CCD sensor. When the camera is operating in 8 bit output mode, by default, it drops the least two significant bits from each ADC and transmits the 8 most significant bits (bit 9 through bit 2).




Shift Once

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

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

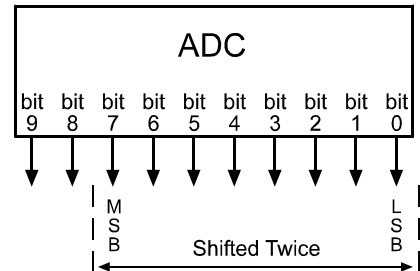



	<p>Note that if bit 9 is set to 1, all of the other bits will automatically be set to 1. This means that you should only use the shift once setting when your pixel readings in 8 bit mode with no digital shift are all below 128.</p>
---	---

Shift Twice

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

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



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

3.6.3 Precautions When Using Digital Shift

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

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

1. Use binary commands or the Video Data Output Mode setting in the Output group on the configuration tool to put the camera in 10 bit output mode.
2. Use binary commands or the Digital Shift setting in the Output group on the configuration tool 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 you will be using the camera in 8 bit output mode, make this check:

1. Use binary commands or the Video Data Output Mode setting in the Output group on the configuration tool to put the camera in 8 bit output mode.
2. Use the binary commands or the Digital Shift setting in the Output group on the configuration tool 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.

3.7 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. 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 3-12.

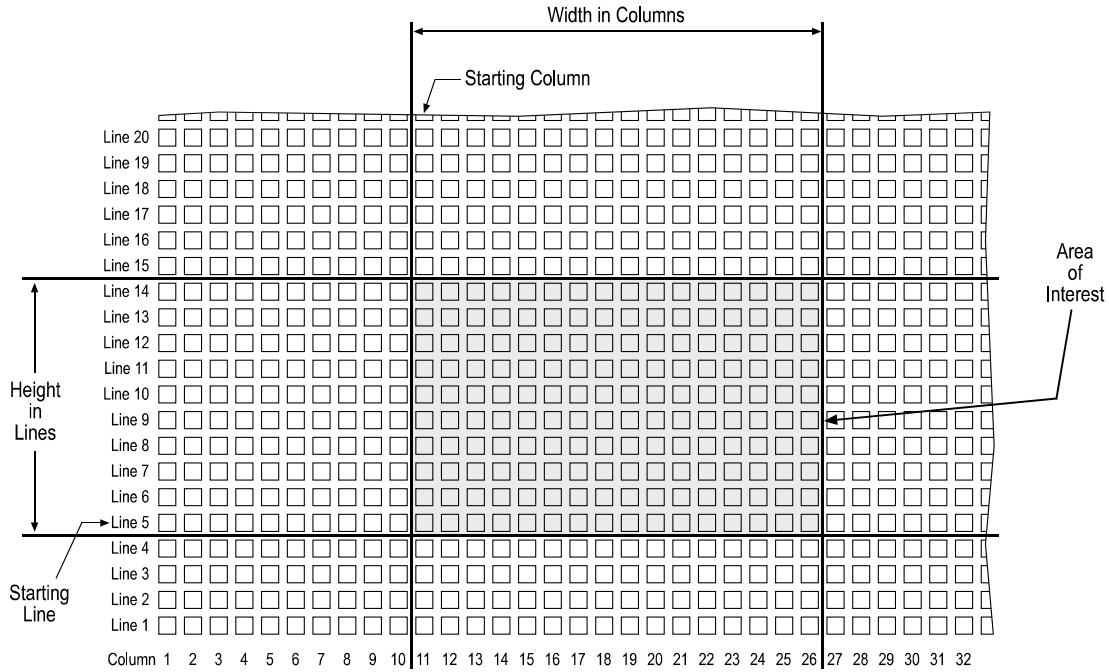


Figure 3-12: Area of Interest

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.

3.7.1 AOI Setup Guidelines

When setting up the area of interest, several guidelines must be followed. The setup rules are listed below.

- The starting line must be an odd numbered line and the starting column must be an odd numbered column.
- The number of columns included in the AOI must be divisible by 2 the number of lines included in the AOI must be divisible by 2.
- The sum of the setting for the *Starting Column* plus the setting for the *Width in Columns* can not exceed 1005.
- The sum of the setting for the *Starting Line* plus the setting for the *Height in Lines* can not exceed 1005.

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 1004, the starting line should be set to 1, and the height in lines should be set to 1004.

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

$$\text{Maximum Frames per Second} = \frac{1,000,000 \mu\text{s}}{(\text{LI} \times 20.55 \mu\text{s}) + [(1004 - \text{LI}) \times 7.3 \mu\text{s}] + 204.8 \mu\text{s}}$$

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

3.7.3 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 below the AOI. The length of the delay depends on the number of lines below 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).

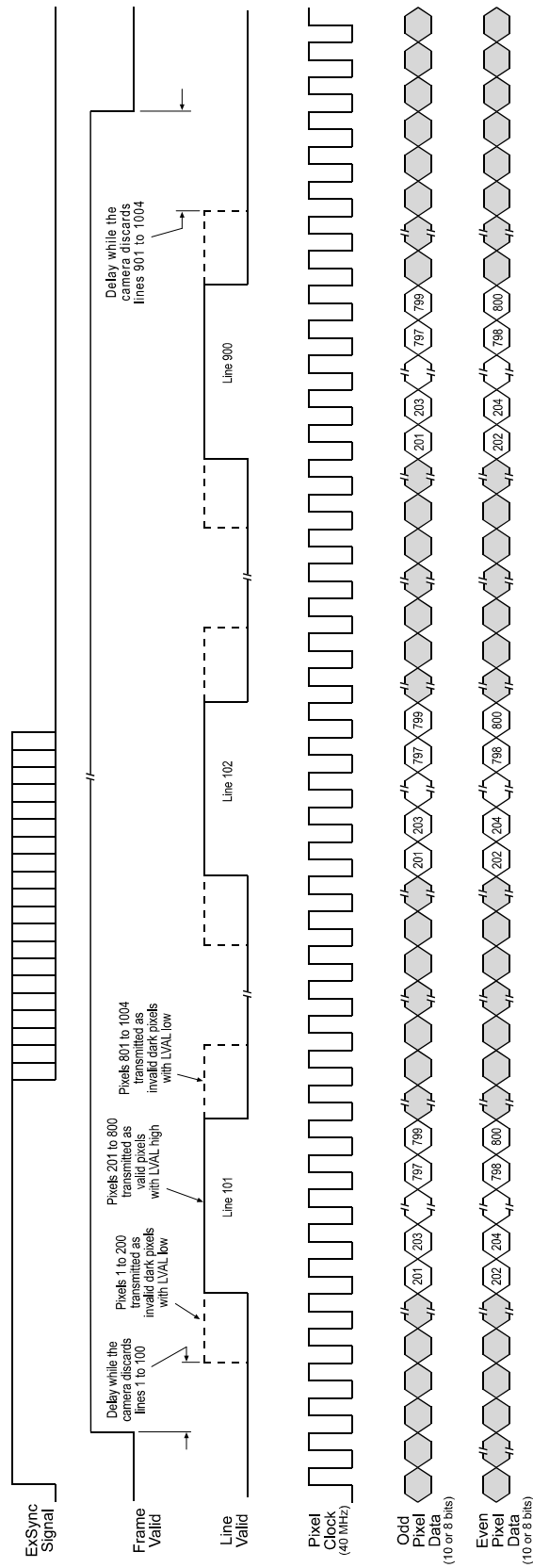
After all of the lines in the AOI have been transmitted, the line valid bit will remain low. The fall of the frame valid bit will be delayed as the lines located above the AOI are discarded. The length of the delay depends on the number of lines above the AOI. Once the lines are discarded, the frame 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 3-13. 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 while 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 801 through 1004, 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 1004 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.



TIMING CHART IS NOT TO SCALE

Figure 3-13: Timing and Output Changes with AOI

3.8 Binning

Binning is available on **A202k** monochrome cameras. Binning increases the camera's sensitivity to light by summing the charges from adjacent pixels into one pixel. There are three types of binning available: horizontal binning, vertical binning, and full binning.

With horizontal binning, pairs of adjacent pixels in each line are summed (see Figure 3-14). With vertical binning, pairs of adjacent pixels from two lines are summed. Full binning is a combination of horizontal and vertical binning in which four adjacent pixels are summed.

When horizontal binning is active, image resolution decreases to 502 pixels (H) by 1004 pixels (V). When vertical binning is active, resolution decreases to 1004 (H) by 502 (V). With full binning, resolution decreases to 502 (H) by 502 (V).

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. For full binning, you must enable both Horizontal Binning and Vertical Binning. With binary commands, you use the Horizontal Binning and Vertical Binning commands.

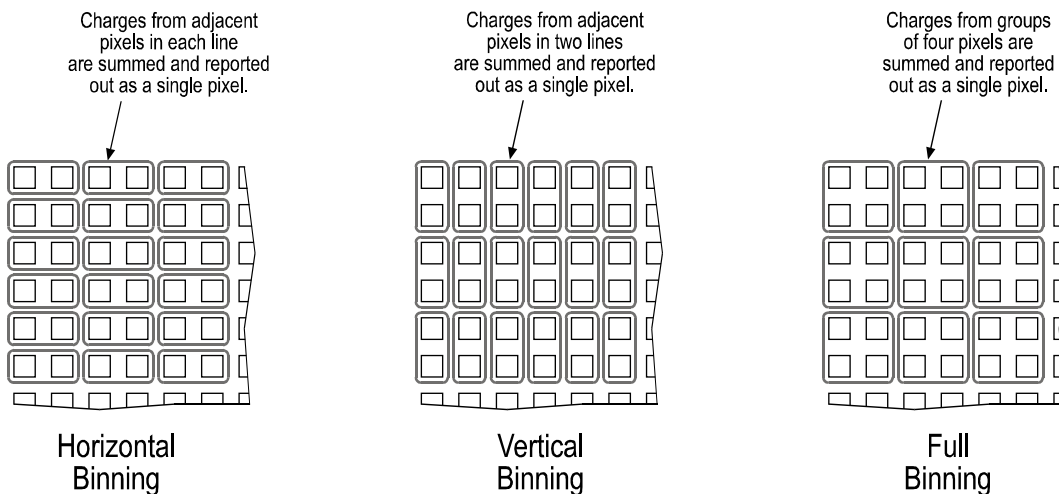


Figure 3-14: Binning



Binning is not available on **A202kc** color cameras.

Using horizontal or vertical binning generally increases the camera's sensitivity by up to two times normal. Full binning increases sensitivity up to four times normal. After switching on binning, the image might look overexposed. Reduce the lens aperture, light intensity, or exposure in this case.

With horizontal binning active, frame grabbers often require the information that the horizontal resolution is 502. With vertical binning active, they often require the information that the vertical resolution is 502. With full binning active, they often require the information that the horizontal resolution is 502 and the vertical resolution is 502.

The camera's pixel clock normally operates at 40 MHz. However, when horizontal or full binning is used, the pixel clock is 20 MHz.

3.8.1 Changes to the Maximum Frame Rate with Binning

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 following formula:

$$\text{Maximum Frames per Second} = \frac{1000000 \mu\text{s}}{(\text{LI} \times 27.85 \mu\text{s}) + [(502 - \text{LI}) \times 14.6 \mu\text{s}] + 204.8 \mu\text{s}}$$

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

(Remember that when you are working with vertical or full binning, the resolution of the sensor is effectively reduced to 502 lines.)



Horizontal binning has no effect on the frame rate.

3.9 Mirror Image

The mirror image feature will cause a horizontal switch around the center-line of the sensor. In other words, the left side of the image will become the right side and the right side will become the left.

You can enable the mirror image feature 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 Mirror Image setting in the Output group to enable mirror image. With binary commands, you use the Mirror Image command.

3.10 Color Creation in the A202kc

The CCD sensor used in the **A202kc** 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 **A202kc** is shown in Figure 3-15. 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.)

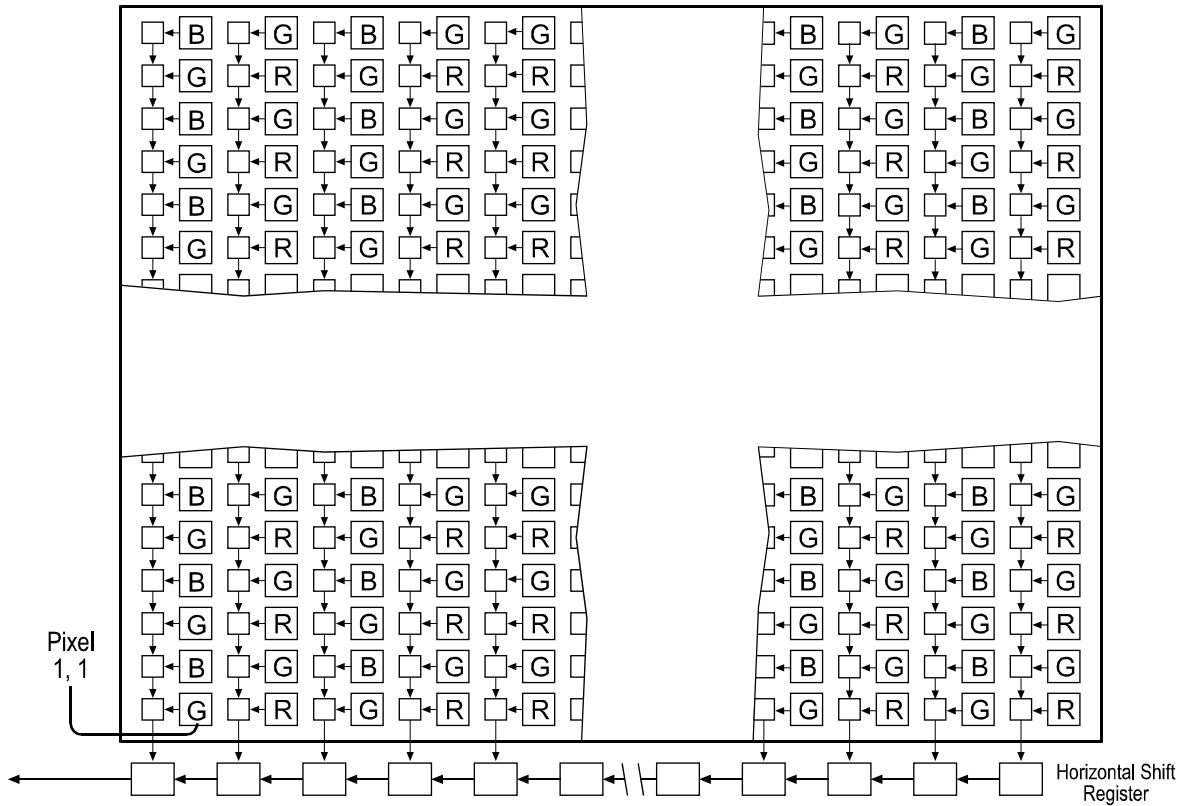


Figure 3-15: Bayer Filter Pattern on the **A202kc**

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 image, 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.

3.11 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, VGCs or ADCs. 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.



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.

3.11.1 Test Image One

The left half of test image one consists of lines with repeated gray scale gradients ranging from 255 to 0 as you move from the center of the image to the left. The top line of the left half starts with a gray value of 255 on pixel 502. The second line starts with a gray value of 254 on the pixel 502. The third line starts with a gray value of 253 on the pixel 502, and so on.

The right half of test image one consists of lines with repeated gray scale gradients ranging from 255 to 0 as you move from the center of the image to the right. The top line of the right half starts with a gray value of 255 on the pixel 503. The second line starts with a gray value of 254 on the pixel 503. The third line starts with a gray value of 253 on the pixel 503, and so on.

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.

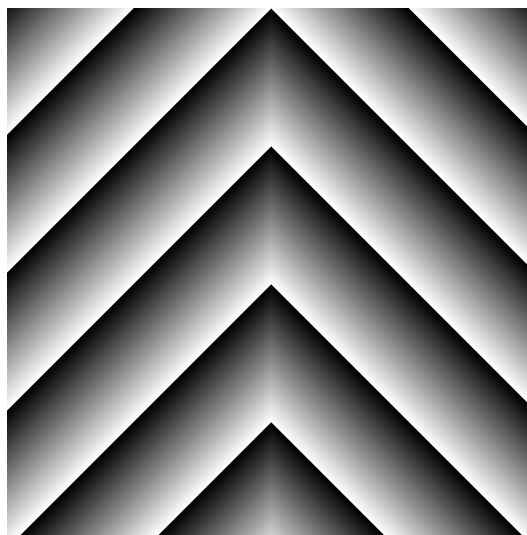


Figure 3-16: Test Image One

3.11.2 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.

3.11.3 Test Image Three

Test image three contains two vertical gradients on the left side of the image and four horizontal gradients on the right side. Test image three is useful for determining if your frame grabber has dropped any columns or lines from your image.

Vertical Gradients

The two vertical gradients on the left side of the image are a total of 502 columns wide.

The left vertical gradient begins on column 1. The pixels in column 1 have a value of 10, the pixels in column 2 have a value of 11, the pixels in column 3 have a value of 12, and so on. This pattern continues until column 246, where the pixels have a value of 255.

The second vertical gradient begins in column 247. The pixels in column 247 have a value of 0, the pixels in column 248 have a value of 1, the pixels in column 249 have a value of 2, and so on. This pattern continues until column 502 where the pixels have a value of 255.

Horizontal Gradients

All of the horizontal gradients on the right side of the image are 502 columns wide.

The pixels in the bottom line of the bottom gradient (image line 1) have a gray value of 235, the pixels in line 2 have a gray value of 234, the pixels in line 3 have a gray value of 233, and so on. This pattern continues until line 236 where the pixels have a gray value of 0.

The second gradient begins on line 237. The pixels in line 237 have a gray value of 255, the pixels in line 238 have a gray value of 254, the pixels in line 239 have a gray value of 253, and so on. This pattern continues until line 492 where the pixels have a gray value of 0.

The third gradient begins on line 493. The pixels in line 493 have a gray value of 255, the pixels in line 494 have a gray value of 254, the pixels in line 495 have a gray value of 253, and so on. This pattern continues until line 748 where the pixels have a gray value of 0.

The top gradient begins on line 749. The pixels in line 749 have a gray value of 255, the pixels in line 750 have a gray value of 254, the pixels in line 751 have a gray value of 253, and so on. This pattern continues until line 1004 where the pixels have a gray value of 0.

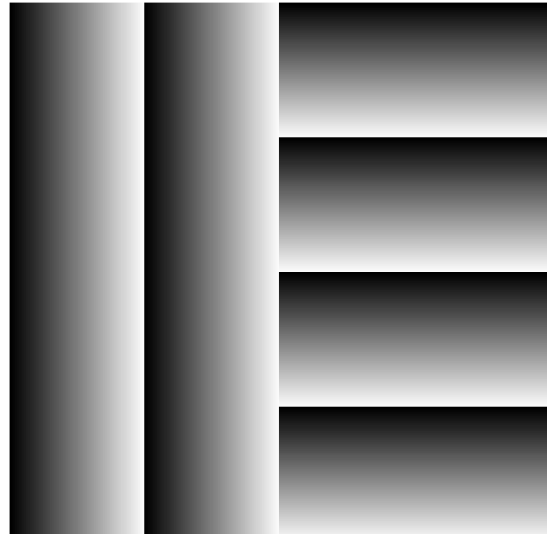


Figure 3-17: Test Pattern Three

3.12 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.

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

User Sets

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

Startup Pointer

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

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

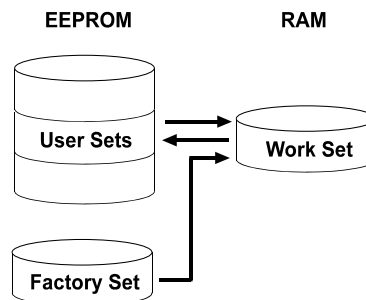



Figure 3-18: Configuration Sets

3.13 Camera Temperature

A202k series cameras include a sensor that measures the temperature on one of the electronic boards inside of the camera. The readings of this sensor allow you to monitor that ventilation works correctly.

You can use the Read Camera Temperature binary command to read out the current temperature (see Section [4.2.5.9](#)).

	<p>Warning!</p> <p>The reading for the internal camera temperature must not exceed 90 °C. If the internal camera temperature rises higher than 90 °C, electronic components may get damaged.</p> <p>To prevent internal heat build-up, observe the ventilation requirements described in Section 1.4.2.</p>
---	--

3.14 Camera Status

The A202k monitors its status by performing a regular series of self checks. The current status of the camera can be viewed in several ways:

- with the Camera Configuration Tool Plus. You can use the Camera Status information in the Camera Information group (see Section [4.1](#) and the configuration tool's on-line help) to check a list of several possible errors and an indication of whether those errors are present.
- 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 flash (see Section [6.1](#)).

4 Configuring the Camera

The **A202k** 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:

- 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
- Mirror Image

The **A202k** 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. On the desktop of your computer, click **Start**, click **Programs**, click **Basler Vision Technologies**, click **CCT+**, and then click **CCT+** to start the CCT+ (default installation).

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

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

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

4.1.2 Closing the Configuration Tool

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

4.1.3 Configuration Tool Basics

The RAM memory in the camera contains the set of parameters that controls the current operation of the camera. This set of parameters is known as the Work Set (see Section 3.12). The CCT+ is used to view the present settings for the parameters in the Work Set or to change the settings.

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

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

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

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

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

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

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.

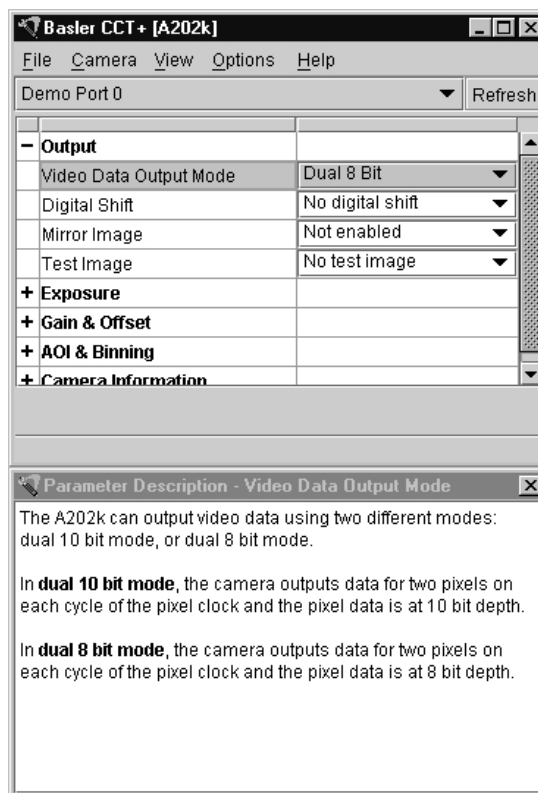


Figure 4-1: CCT+



Keep in mind that the Work Set is stored in a volatile memory. Any changes you make to the Work Set using the configuration tool will be lost when the camera is switched off. To save changes you make to the Work Set, open the Camera menu of the configuration tool and save the modified Work Set into one of the camera's 15 User Sets. The User Sets are stored in non-volatile memory and will not be lost when the camera is switched off (see Section [3.12](#)).

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 configuration tool 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 **A202k** via the RS-644 serial connection in the Camera Link interface between the frame grabber and the camera. Commands are issued using a binary protocol. With this protocol, data is placed into a frame and sent to the camera. Once the data is received it is checked for validity. If valid, the data is extracted and the command is executed.

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

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

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

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

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

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



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

A202k cameras will only work with the CCT+ version of the configuration tool. If you want to use the configuration tool with an **A202k** 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

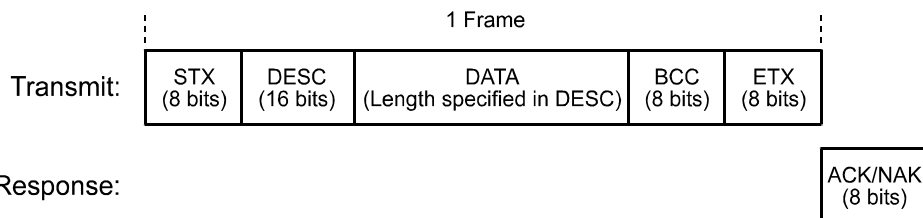


Figure 4-2: Representation of a Command Frame and Response

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 sent to the host. If any check is incorrect, a NAK is sent.

4.2.2.2 Time-outs

Byte Time-out

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

4.2.2.3 Read Command

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

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

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

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

4.2.2.4 Write Command

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

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

After a write command has been issued by the host, the host can verify the write by issuing a corresponding read command and checking that the returned data is as expected. The host can also issue a camera status read command (see Section [4.2.7](#)) 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 [4-32](#), 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 4-32. If you check the table on page 4-30, you will find that the ID for the camera status read command is 0x43.

0x82 - is the second byte of the descriptor. The MSB in this byte represents the read/write flag and since this is a read command, the bit should be set to a 1. The other seven bits of this byte represent the data size (in bytes) that will be transferred using this command. If you check the table on page 4-30, the data size for the camera status command is 2 bytes. So the arrangement of the bits in the second byte of the descriptor should be 1000 0010 which translates to 0x82.

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

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

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

4.2.3.2 Write Command

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

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

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

0x46 - is the first byte of the descriptor. If you check the table on page 4-28, you will find that the ID for the command to copy the Work Set to a User Set is 0x46.

0x01 - is the second byte of the descriptor. The MSB in this byte represents the read/write flag and since this is a write command, the bit should be set to a 0. The other seven bits of this byte represent the data size (in bytes) that will be transferred using this command. If you check the table on page 4-28, the data size for the Copy Work Set to User Set command is 1 byte. So the arrangement of the bits in the second byte of the descriptor should be 0000 0001 which translates to 0x01.

0x02 - is the data byte. If you check the table on page 4-28, you will find that to copy the Work Set to User Set 2, the data byte must be set to 0x02.

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

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

4.2.3.3 Calculating the Block Check Character

The block check character in any **A202k** 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 2.5.4.2 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		
	0x01	Dual 8 Bit mode		
	0x03	Dual 10 Bit mode		

4.2.4.2 Exposure Time Control Mode

Purpose:	To set the exposure time control mode or to read the current exposure time control mode setting. See Section 3.2 for an explanation of exposure time control modes.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xA0	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xA0	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xA0	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the exposure mode (see the table below).		
	ID	Exposure Time Control Mode		
	0x00	Free-run, Programmable		
	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 1 settings can range from 13 μ s to 16777215 μ s (0x00000D to 0xFFFFFFFF).			

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 2 settings can range from 35 μ s to 16777215 μ s (0x000023 to 0xFFFFFFFF).			

4.2.4.5 Digital Shift

Purpose: To enable or disable digital shift. See Section 3.6 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)		



See Section 3.6.3 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 3.7 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 0x0000 to 0x03EB. 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 3.7 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 0x0001 to 0x03EC.			




See Section [3.7.1](#) 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 3.7 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 0x0000 to 0x03EB. 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 3.7 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 0x0001 to 0x03EC			

	See Section 3.7.1 or a list of guidelines which must be followed when entering the settings for the area of interest.
---	---

4.2.4.10 Left Side Gain

Purpose:	To set the gain for the left side of the CCD array or to read the current left side gain setting. See Section 3.5 for more information on gain.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x80	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x80	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x80	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of left side gain setting		
	Byte 2	High byte of left side gain setting		
Data Range:	Left side gain settings can range from 288 to 569 (0x0120 to 0x0239).			

4.2.4.11 Left Side Offset

Purpose:	To set the offset for the left side of the CCD array or to read the current left side offset setting. See Section 3.5 for more information on offset.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x81	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x81	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x81	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of left side offset setting		
	Byte 2	High byte of left side offset setting		
Data Range:	Left side offset settings can range from 0 to 255 (0x0000 to 0x00FF).			

4.2.4.12 Right Side Gain

Purpose:	To set the gain for the right side of the CCD array or to read the current right side gain setting. See Section 3.5 for more information on gain.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x82	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x82	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x82	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of right side gain setting		
	Byte 2	High byte of right side gain setting		
Data Range:	Right side gain settings can range from 288 to 569 (0x0120 to 0x0239).			

4.2.4.13 Right Side Offset

Purpose:	To set the offset for the right side of the CCD array or to read the current right side offset setting. See Section 3.5 for more information on offset.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0x83	R/W-Flag 1	Data Length 2	Data -
Response:	Cmd-ID 0x83	R/W-Flag 0	Data Length 2	Data 2 Bytes
Write Command:	Cmd-ID 0x83	R/W-Flag 0	Data Length 2	Data 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte of right side offset setting		
	Byte 2	High byte of right side offset setting		
Data Range:	Right side offset settings can range from 0 to 255 (0x0000 to 0x00FF).			

4.2.4.14 Horizontal Binning

Purpose:	To enable or disable horizontal binning. See Section 3.8 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		

4.2.4.15 Vertical Binning

Purpose:	To enable or disable vertical binning. See Section 3.8 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		



For full binning, enable both horizontal and vertical binning.

4.2.4.16 Mirror Image

Purpose:	To enable or disable the mirror image feature. See Section 3.9 for an explanation of mirror image.			
Type:	This is a read or write command.			
Read Command:	Cmd-ID 0xC1	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0xC1	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0xC1	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the mirror image status (see the table below).		
	ID	Mirror Image		
	0x00	Mirror image not enabled		
	0x01	Mirror image enabled		

4.2.4.17 Test Image Command

Purpose:	To enable or disable a test image. See Section 3.11 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's 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's version	BCD coded	
	Byte 2	High Byte of camera's 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 Camera Temperature

Purpose: To read the camera's internal temperature. See Section 3.13 for the allowed maximum temperature.																				
Type: This is a read only command.																				
Read Command:	Cmd-ID 0x70	R/W-Flag 1	Data Length 1	Data -																
Response:	Cmd-ID 0x70	R/W-Flag 0	Data Length 1	Data 1 Byte																
Data Format:	<p>The temperature is given in °C as an 8 bit signed number. If the MSB is 1, a temperature below 0° C is present. If the MSB is 0, the temperature is 0° C or higher. For temperatures below 0° C, a two's complement representation is used, that is, to obtain the actual temperature, the digital output must be inverted and 1 must be added. For example:</p> <p>A digital output of 11110110 would indicate a negative value because the MSB is 1</p> <p>11110110 would be inverted to 00001001</p> <p>00001001 translates to 9</p> <p>9 + 1 = 10</p> <p>The indicated temperature is therefore - 10° C</p> <p>See more examples in the table below.</p> <table border="1"> <thead> <tr> <th>Temp.</th> <th>Digital Output</th> </tr> </thead> <tbody> <tr> <td>- 20° C</td> <td>11101100</td> </tr> <tr> <td>- 10° C</td> <td>1111 0110</td> </tr> <tr> <td>0° C</td> <td>0000 0000</td> </tr> <tr> <td>+ 10° C</td> <td>0000 1010</td> </tr> <tr> <td>+ 25° C</td> <td>0001 1001</td> </tr> <tr> <td>+ 50° C</td> <td>0011 0010</td> </tr> <tr> <td>+ 100° C</td> <td>0110 0100</td> </tr> </tbody> </table>				Temp.	Digital Output	- 20° C	11101100	- 10° C	1111 0110	0° C	0000 0000	+ 10° C	0000 1010	+ 25° C	0001 1001	+ 50° C	0011 0010	+ 100° C	0110 0100
Temp.	Digital Output																			
- 20° C	11101100																			
- 10° C	1111 0110																			
0° C	0000 0000																			
+ 10° C	0000 1010																			
+ 25° C	0001 1001																			
+ 50° C	0011 0010																			
+ 100° C	0110 0100																			

4.2.5.10 Reference Values

Purpose: To read the reference values that are determined during the camera's factory calibration procedure (see Sections 3.5.2 and 3.5.4 for information on how to use these values). Bytes 1 through 8 refer to reference gain values, bytes 9 through 16 to reference offset values.				
Type: This is a read only command.				
Read Command:	Cmd-ID 0x08	R/W-Flag 1	Data Length 16	Data -
Response:	Cmd-ID 0x08	R/W-Flag 0	Data Length 16	Data 16 Bytes
Data Format: Each reference value is stored as 16 bits followed by a decimal point followed by 16 more bits.				
	Byte 1	Low byte after the decimal point for the left side reference gain value		
	Byte 2	High byte after the decimal point for the left side reference gain value		
	Byte 3	Low byte before the decimal point for the left side reference gain value		
	Byte 4	High byte before the decimal point for the left side reference gain value		
	Byte 5	Low byte after the decimal point for the right side reference gain value		
	Byte 6	High byte after the decimal point for the right side reference gain value		
	Byte 7	Low byte before the decimal point for the right side reference gain value		
	Byte 8	High byte before the decimal point for the right side reference gain value		
	Byte 9	Low byte after the decimal point for the left side reference offset value		
	Byte 10	High byte after the decimal point for the left side reference offset value		
	Byte 11	Low byte before the decimal point for the left side reference offset value		
	Byte 12	High byte before the decimal point for the left side reference offset value		
	Byte 13	Low byte after the decimal point for the right side reference offset value		
	Byte 14	High byte after the decimal point for the right side reference offset value		
	Byte 15	Low byte before the decimal point for the right side reference offset value		
	Byte 16	High byte before the decimal point for the right side reference offset value		

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 3.12 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 0x45	R/W-Flag 1	Data Length 1	Data -
Response:	Cmd-ID 0x45	R/W-Flag 0	Data Length 1	Data 1 Byte
Write Command:	Cmd-ID 0x45	R/W-Flag 0	Data Length 1	Data 1 Byte
Response:	None			
Data Format:	Byte 1	An ID that specifies the set. (see the table below).		
	Set ID	Set		
	0x00	Factory Set		
	0x01	User Set 1		
	0x02	User Set 2		
	0x03	User Set 3		
	0x04	User Set 4		
	0x05	User Set 5		
	0x06	User Set 6		
	0x07	User Set 7		
	0x08	User Set 8		
	0x09	User Set 9		
	0x0A	User Set 10		
	0x0B	User Set 11		
	0x0C	User Set 12		
	0x0D	User Set 13		
	0x0E	User Set 14		
	0x0F	User Set 15		
	0xFF	No active set		

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 3.12 for an explanation of configuration sets.																																			
Type:	This is a write only command.																																			
Write Command:	Cmd-ID 0x46	R/W-Flag 0	Data Length 1	Data 1 Byte																																
Response:	None																																			
Data Format:	Byte 1	An ID that specifies the user set. (see the table below).																																		
	<table border="1"> <thead> <tr> <th>Set ID</th> <th>Set</th> </tr> </thead> <tbody> <tr><td>0x01</td><td>User Set 1</td></tr> <tr><td>0x02</td><td>User Set 2</td></tr> <tr><td>0x03</td><td>User Set 3</td></tr> <tr><td>0x04</td><td>User Set 4</td></tr> <tr><td>0x05</td><td>User Set 5</td></tr> <tr><td>0x06</td><td>User Set 6</td></tr> <tr><td>0x07</td><td>User Set 7</td></tr> <tr><td>0x08</td><td>User Set 8</td></tr> <tr><td>0x09</td><td>User Set 9</td></tr> <tr><td>0x0A</td><td>User Set 10</td></tr> <tr><td>0x0B</td><td>User Set 11</td></tr> <tr><td>0x0C</td><td>User Set 12</td></tr> <tr><td>0x0D</td><td>User Set 13</td></tr> <tr><td>0x0E</td><td>User Set 14</td></tr> <tr><td>0x0F</td><td>User Set 15</td></tr> </tbody> </table>				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
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 3.12). 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 bit rate on the frame grabber's RS-644 serial port.
 - b) If you are using the camera with a k-BIC, change the bit rate on your PC's RS-232 serial port.
4. Resume communication.

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

The RS-644 serial port on some Camera Link frame grabbers will only support a bitrate of 9600. 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 2 Bytes
Response:	None			
Data Format:	Byte 1	Low byte	0xCF is always used	
	Byte 2	High byte	0x07 is always used	

5 Mechanical Considerations

The **A202k** camera housing is manufactured with high precision. Planar, parallel, and angular sides guarantee precise mounting with high repeatability.

**Caution!**

The camera is shipped with a cap on the lens mount. To avoid collecting dust on the sensor, make sure that at all times either the cap is in place or a lens is mounted on the camera.

5.1 Camera Dimensions and Mounting Facilities

The dimensions for A202k cameras are as shown in Figure 5-1.

A202k cameras are equipped with four M4 mounting holes on the front and two M4 mounting holes on each side as indicated in the drawings.

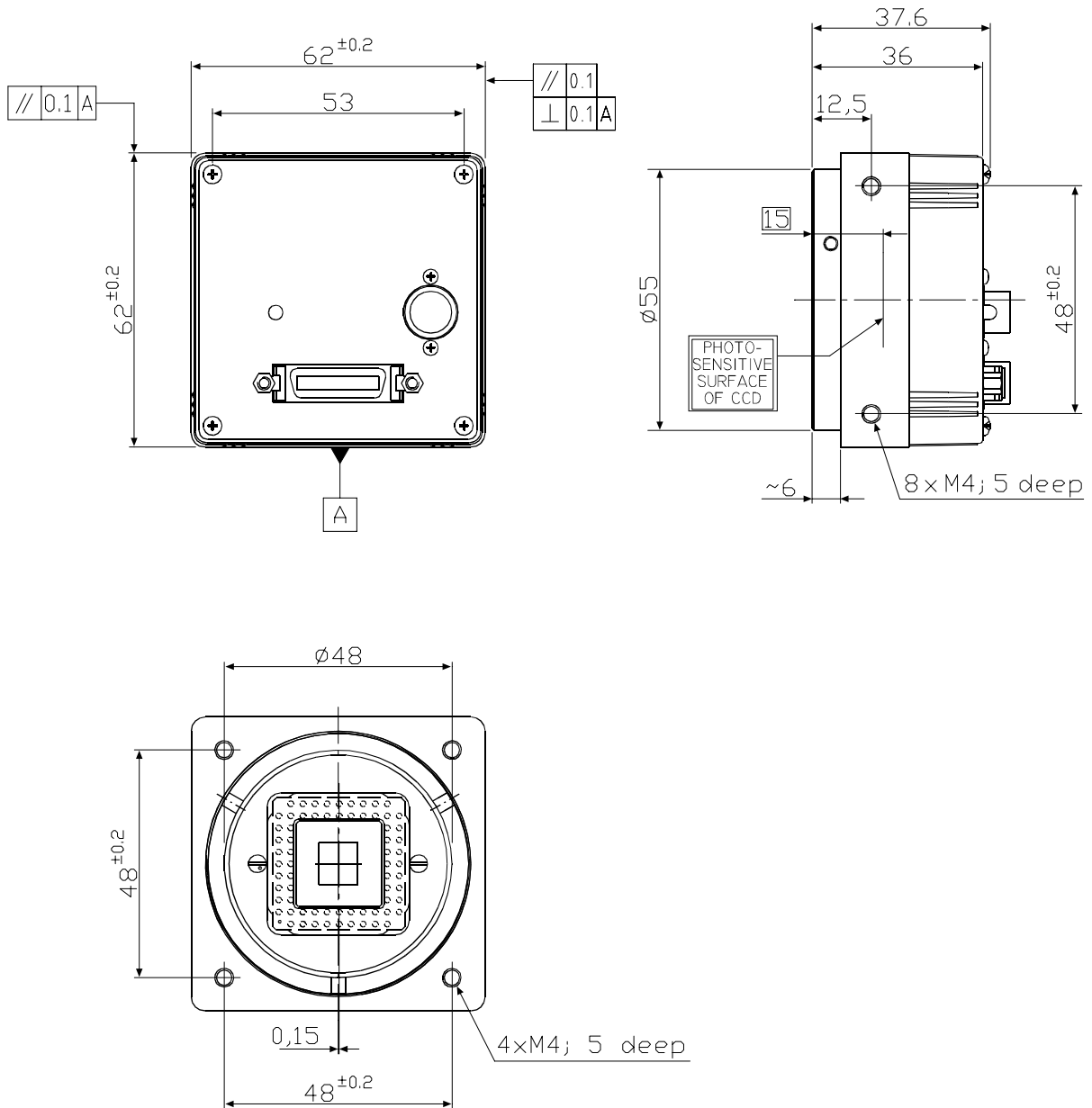


Figure 5-1: A202k Mechanical Dimensions (in mm)

5.2 Sensor Positioning Accuracy

The sensor positioning accuracy is as shown in Figure 5-2.

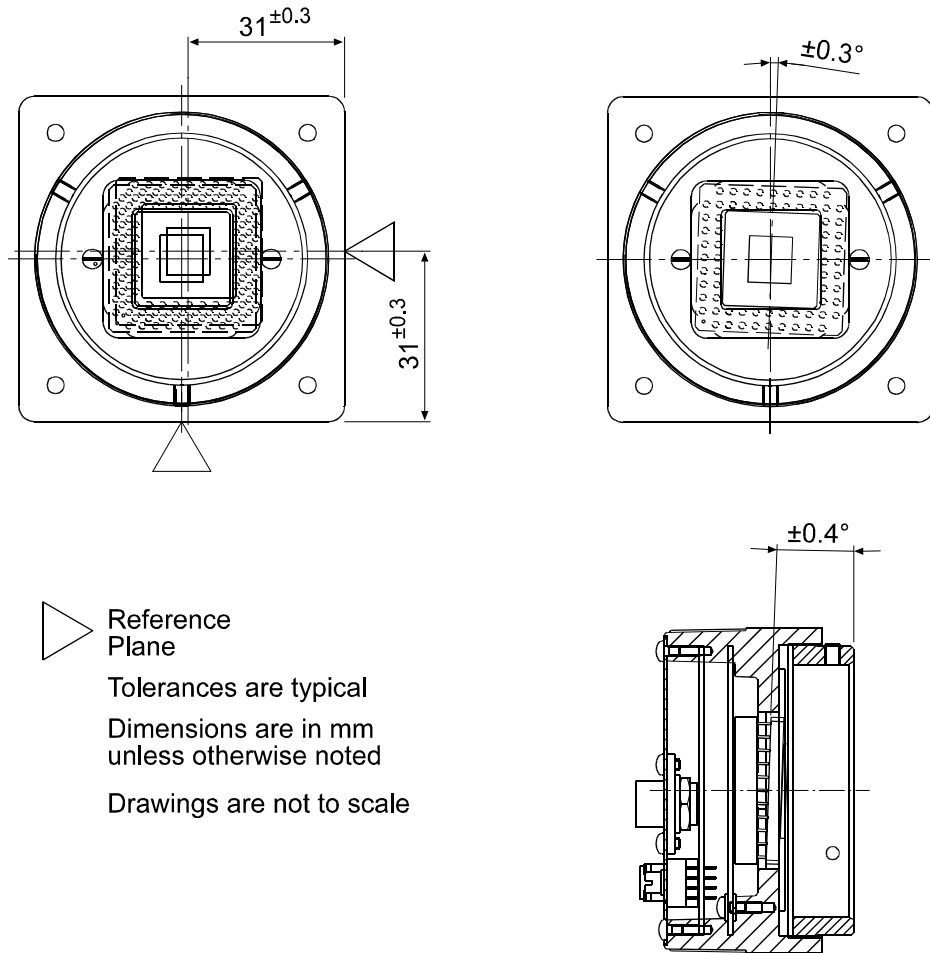


Figure 5-2: Sensor Positioning Accuracy (in mm or degrees)

5.3 C-Mount Adapter Dimensions

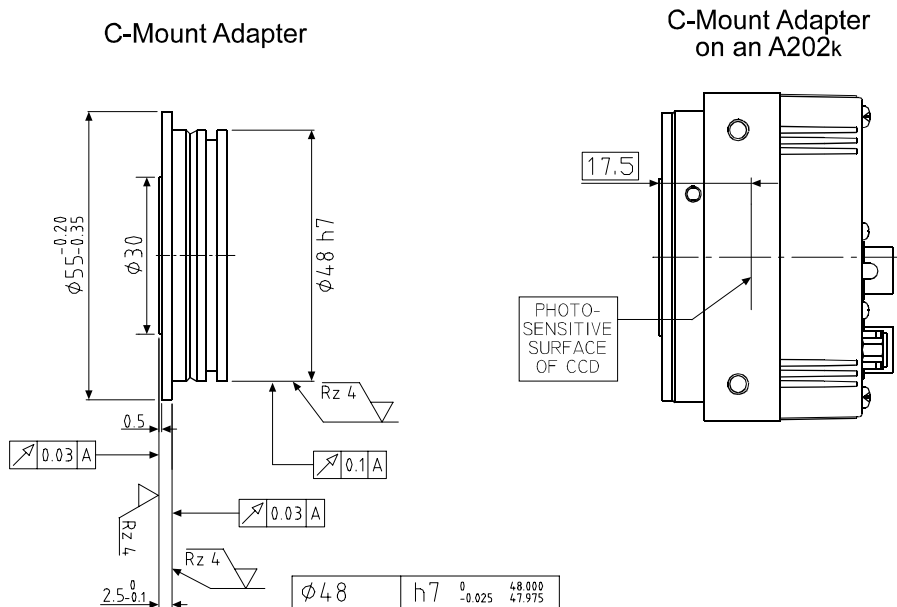


Figure 5-3: C-Mount Adapter Dimensions (in mm)

5.4 F-Mount Adapter Dimensions

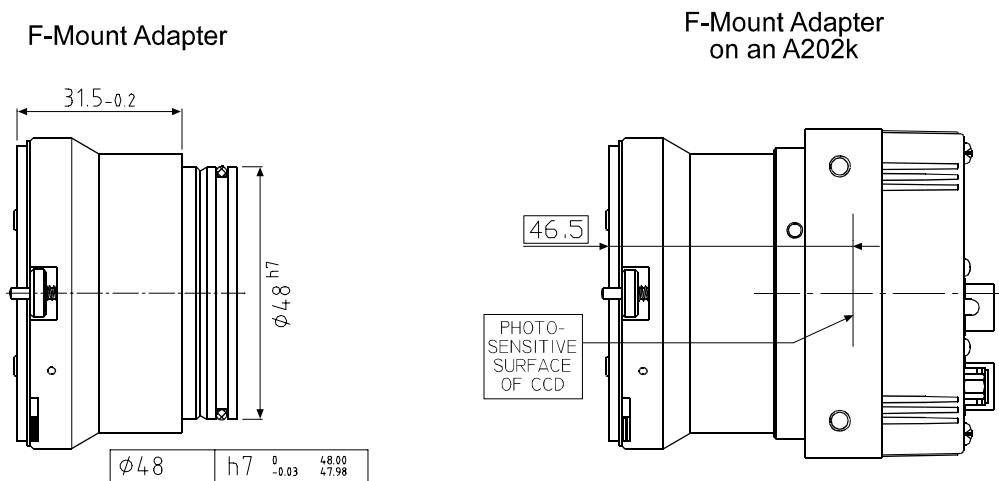
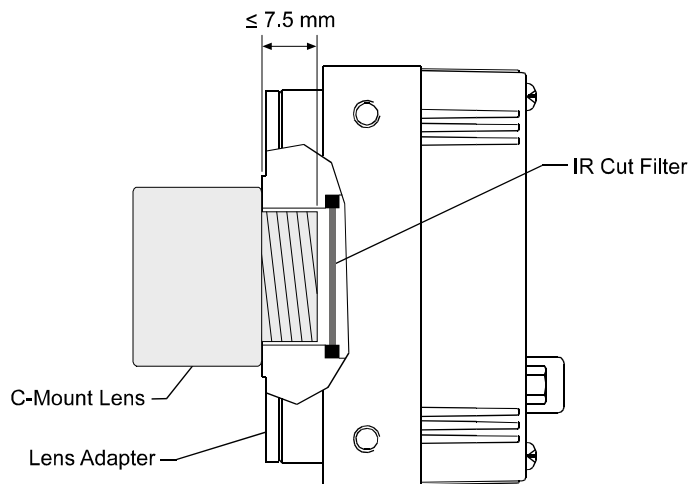


Figure 5-4: F-Mount Adapter Dimensions (in mm)


5.5 Maximum Lens Thread Length on C-mount Equipped Cameras

A202k_c 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

	<p>Caution!</p> <p>A202k_c 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.</p> <p>Cameras without an IR cut filter in the C-mount lens adapter are available on request.</p>
---	---

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 the LED then remains orange continuously, bootup has been successful.

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

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

Table 6-1: Camera Status Indications

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

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

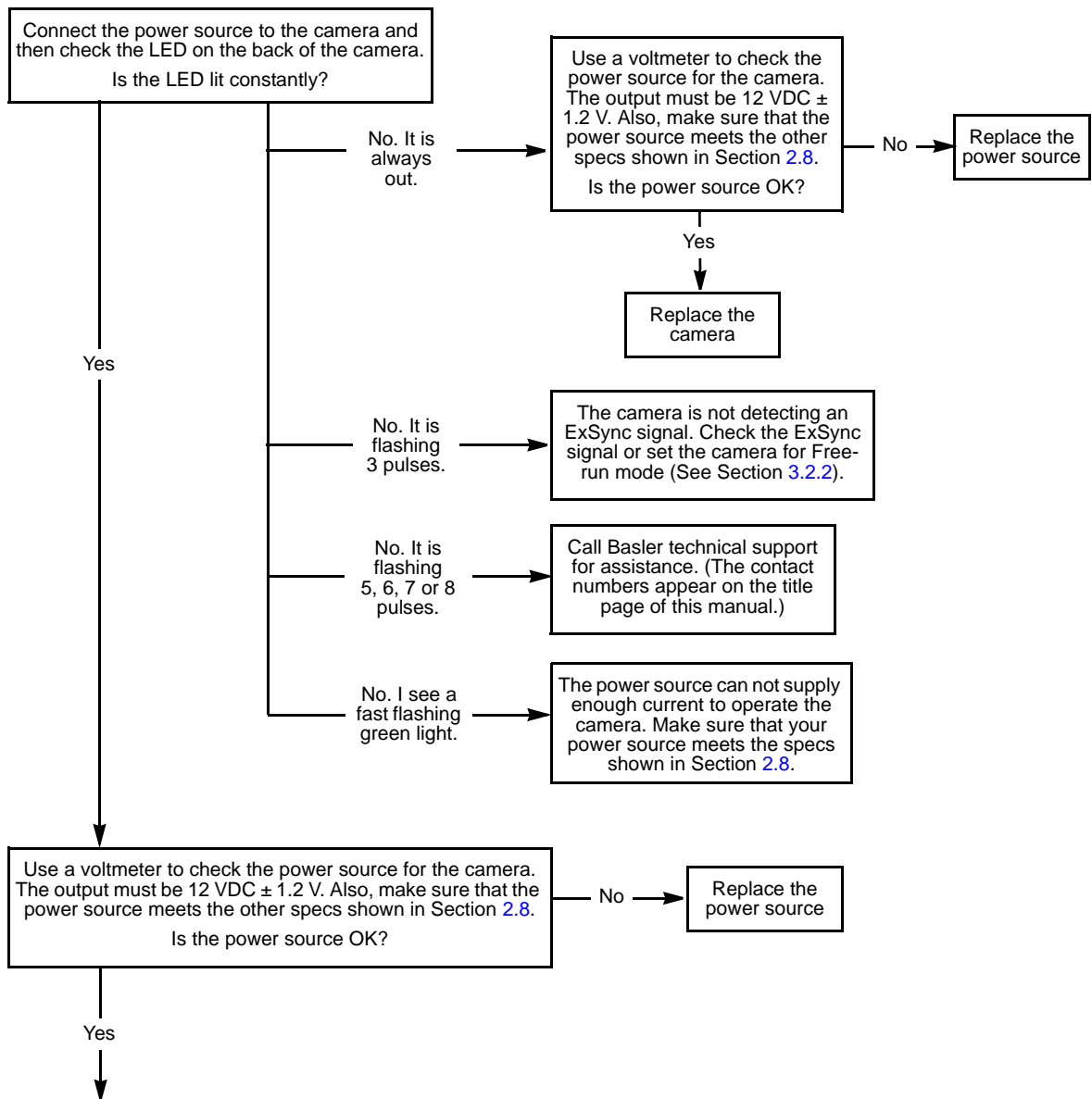
6.2 Troubleshooting Charts

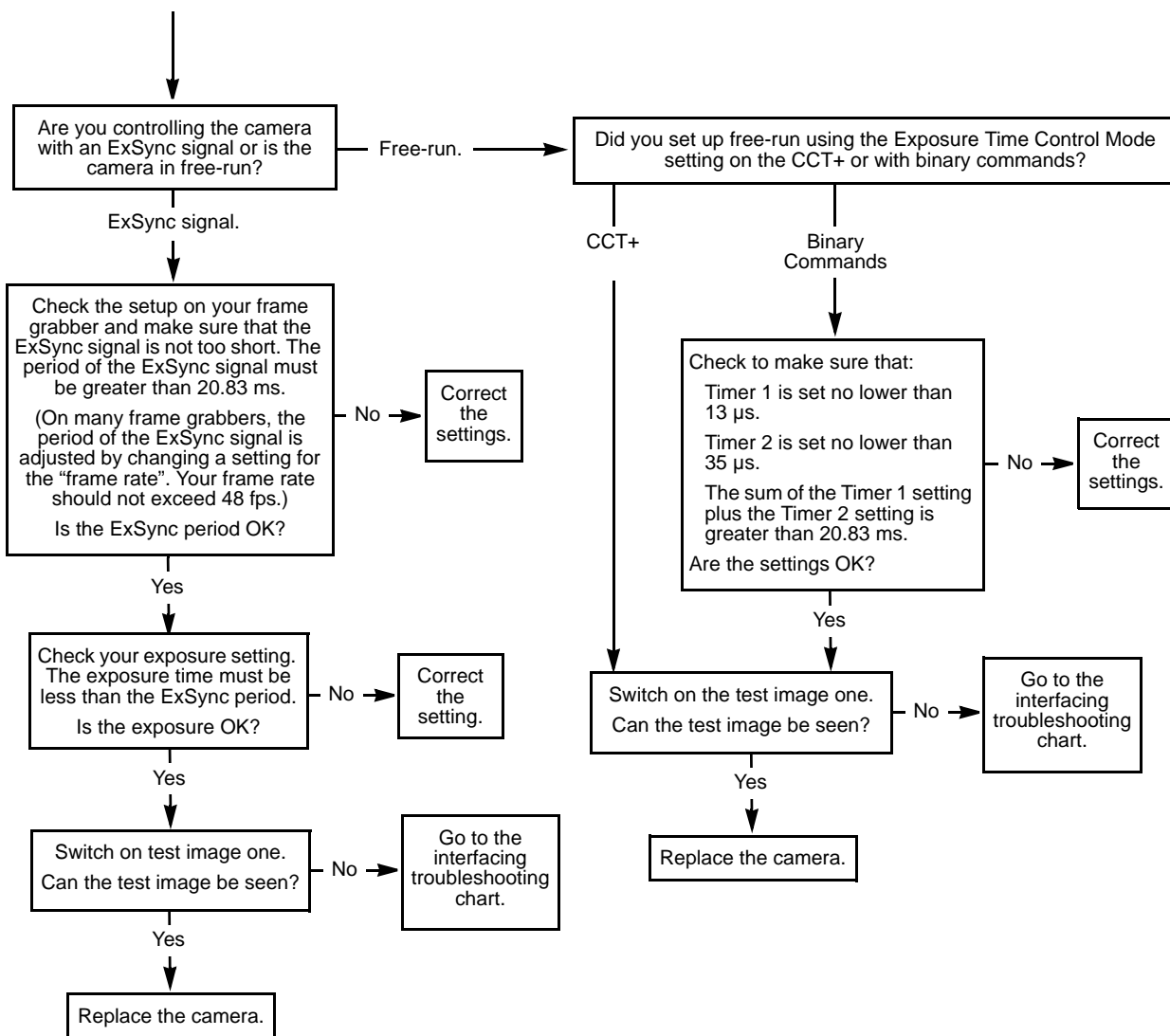
The following pages contain several troubleshooting charts which can help you find the cause of problems that users sometimes encounter. The charts assume that you are familiar with the camera's features and settings and with the settings for your frame grabber. If you are not, we suggest that you review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

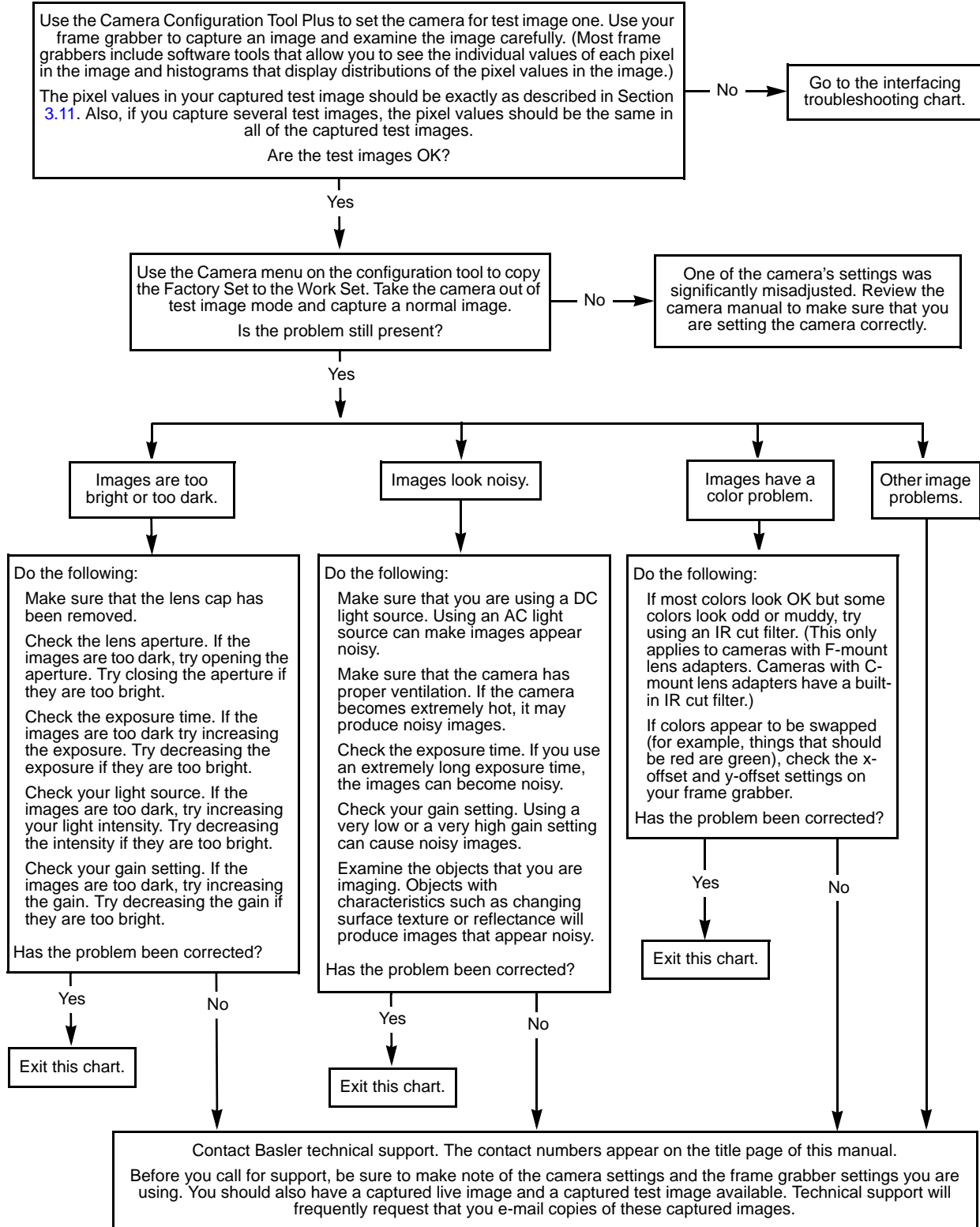
Always switch off power to the system before making or breaking any connection.





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.

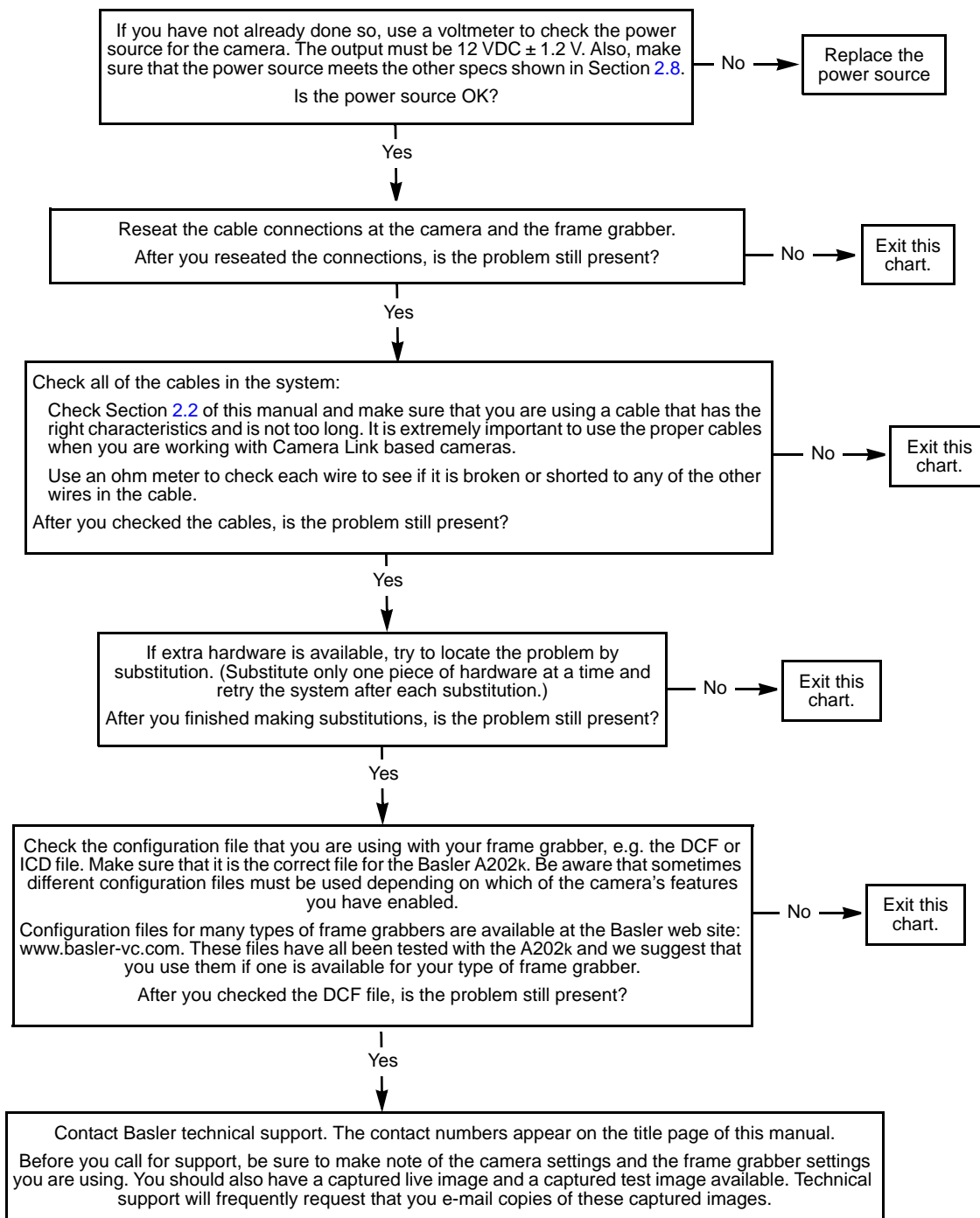


6.2.3 Interfacing

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.

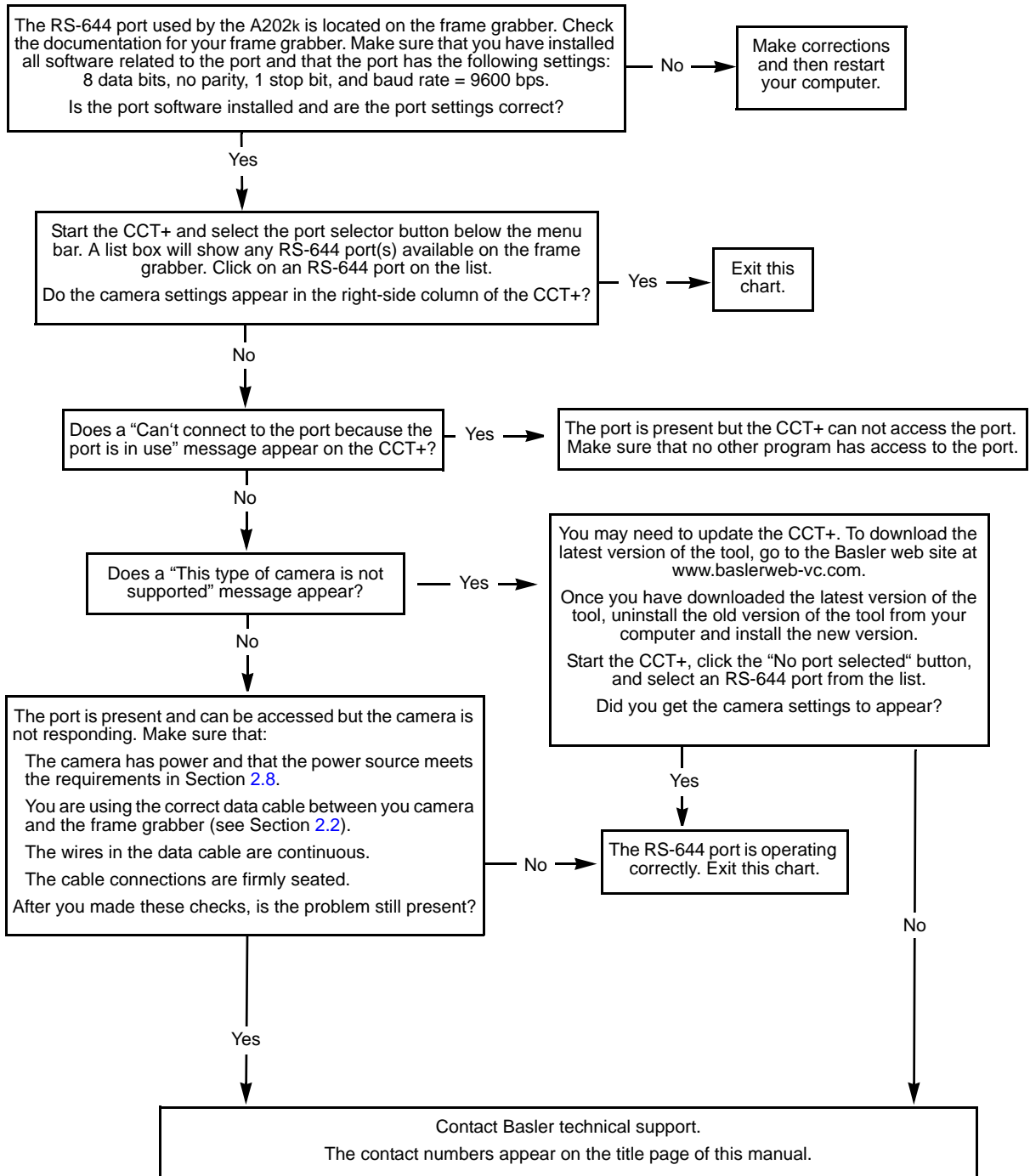


6.2.4 RS-644 Serial Communication

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.



6.3 Before Calling Basler Technical Support

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

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

- 1 The camera's product ID: _____
- 2 The camera's serial number: _____
- 3 The operating system: _____
- 4 Frame grabber that you use with the camera: _____

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

- 6 Describe the problem in as much detail as possible:
(If you need more space, use an extra sheet of paper.)

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

- 8 When did the problem occur? After start. While running.
 After a certain action (e.g., a change of parameters):

- 9 How often did/does the problem occur?
- Once. Every time.
- Regularly when:

- Occasionally when:

- 10 How severe is the problem?
- Camera can still be used.
- Camera can be used after I take this action:

- Camera can no longer be used.

- 11 Did your application ever run without problems? Yes No

12 Parameter set

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

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

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

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

13 Live image/test image

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

Revision History

Doc. ID Number	Date	Changes
DA 044001	3 July 2001	Initial release covering prototype cameras only.
DA 044002	26 October 2001	Initial release covering series production cameras.
DA044003	04 March 2002	<p>Update to camera version 1.01:</p> <ul style="list-style-type: none"> Changed the minimum high time for the ExSync signal from 1 μs to 4 μs. (Sect. 2.4.1, for example) Changed the exposure time offset to 94.5 μs. (Sect. 3.2) Changed the minimum setting for Timer 1 from 10 μs to 6 μs. (Sections 3.2.1.3, 3.2.2.1, 4.2.4.3, 6.2.1) Changed the decimal setting for 0 dB from 237 to 288. (Sections 3.5.1, 3.5.2.1, 4.2.4.10, 4.2.4.12) Changed the corresponding equations. (Sections 3.5.1 and 3.5.2) <p>Simplified the No Image troubleshooting chart (Section 6.2.1). Added more frame grabber configuration file formats to Sect. 6.2.3.</p>
DA044004	08-November-2002	<p>Update to camera version 1.02:</p> <ul style="list-style-type: none"> Changed the low time between the last two lines from 25 ns to 7.9 μs in the timing diagrams on pages 2-11 and 2-12. Described the Camera Temperature feature (page 3-36). Updated from the Classic Camera Configuration Tool to the Camera Configuration Tool Plus (page 4-2). Corrected the possible range of Timer 2 settings on page 4-13. Added the Mirror Image binary command on page 4-20. Revised the troubleshooting diagram on page 6-2.
DA044005	12 May 2003	<p>Update to FPGA firmware version 1.05:</p> <ul style="list-style-type: none"> Updated Figures 2-4 and 2-5. Updated the timing numbers on pages 3-5 through 3-9 and on page 3-11. Updated the frame rate formulas on page 3-27 and 3-31. Updated the Timer 1 range on page 4-13. Updated the timing numbers shown in the “No Image” troubleshooting guide in Section 6.
DA044006	22 July 2004	<p>Update to include A102kc color cameras:</p> <ul style="list-style-type: none"> Updated Table 1-1 and added Figure 1-2. Added Section 3.10 to describe color creation. Added Section 5.5 to describe maximum thread length. Updated troubleshooting table in Section 6.2.2 to include color cameras.
DA044007	9 March 2005	<ul style="list-style-type: none"> Updated the gain range stated in Sections 3.5.1, 3.5.2.1, 4.2.4.10 and 4.2.4.12. Updated the digital shift descriptions in Section 3.6. Updated the available digital shift settings stated in Section 4.2.4.5.

Revision History

Doc. ID Number	Date	Changes
DA044008	29 June 2007	<p>Updated Basler addresses in Singapore and the U.S.A .</p> <p>Added environmental requirements for storage in Section 1.4.1.</p> <p>Added warning against overvoltage in Section 1.5.</p> <p>Added warnings not to reverse polarity of input power in Sections 1.5 and 2.8.</p> <p>Modified Section 3.5 to include offset balance.</p> <p>Added Sections 3.5.4 and 3.5.5.</p> <p>Renamed the register and modified Section 4.2.5.10 to include offset balance.</p> <p>Removed step 4 and added to note box in Section 4.2.8.</p> <p>Corrected "Data", "Byte 1", and "Byte 2" in Section 4.2.9.</p> <p>Added Section 6.3.</p>

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>

Index

A

- area of interest
 - explained 3-26
 - setting with binary commands 4-15, 4-16

B

- balancing gain and offset 3-21
- bayer filter 3-32
- binary command frame 4-6
- binary commands
 - examples 4-9
 - explained 4-5
 - read command 4-8
 - timeouts 4-8
 - write command 4-8
- binning
 - explained 3-30
 - setting with binary commands 4-19
- bitrate
 - setting with binary commands 4-31
- block check character
 - calculating 4-10
 - defined 4-6

C

- cable length 2-4
- cable specifications 2-4
- cable type 2-4
- camera configuration tool
 - auto refresh 4-3
 - closing the tool 4-2
 - opening the tool 4-2
 - parameter description window 4-3
 - refresh button 4-3
 - selecting a port 4-3
- camera link implementation information 2-4
- camera status
 - see status*
- cleaning the camera and sensor 1-6
- C-mount adapter 5-4
- color creation 3-32
- configuration sets
 - explained 3-35
 - manipulating with binary commands . . 4-27, 4-28
- configuration tool
 - see camera configuration tool*
- configuring the camera
 - with binary commands 4-5
 - with the config tool 4-2
- connector types 2-3

D

- data output mode
 - see video data output mode(s)*
- digital shift
 - explained 3-22
 - setting with binary commands 4-14
- dimensions
 - camera 5-2
 - C-mount adapter 5-4
 - F-mount adapter 5-4

E

- environmental requirements 1-5
- exposure time 3-3–3-10
- exposure time control mode(s)
 - explained 3-3
 - setting with binary commands 4-12
- ExSync signal 2-6, 3-3

F

- factory set
 - copying to the work set 4-27
 - explained 3-35
- firmware versions
 - reading with binary commands 4-23, 4-24
- F-mount adapter 5-4
- frame rate
 - basic specification 1-2
 - changes with area of interest 3-27
- free-run
 - explained 3-10
 - setting with binary commands 4-12
- functional description 3-1

G

- gain
 - balance 3-15
 - explained 3-13
 - setting with binary commands 4-17, 4-18

H

- humidity requirements 1-5

I

- input signals 2-6
- interfacing the camera 2-1
- IR cut filter 5-5

L

- LED 2-16, 6-1
- lens thread length 5-5
- level-controlled exposure mode
 - explained 3-3, 3-10
 - setting with binary commands 4-12

M

- mirror image
 - explained 3-31
 - manipulating with binary commands 4-20
- model number
 - viewing with commands 4-22
- model tab 4-4
- mounting facilities 5-2

O

- offset
 - balance 3-19
 - explained 3-13
 - setting with binary commands 4-17, 4-18
- output mode
 - see video data output mode(s)*
- output signals 2-7

P

- photo response non-uniformity 1-2
- pin assignments 2-2
- pin numbering 2-3
- pixel clock 2-7
- pixel size 1-2
- power requirements 1-2
- precautions 1-5
- programmable exposure mode
 - explained 3-3
 - setting with binary commands 4-12

R

- read command
 - error checking 4-8
 - example 4-9
- reference values
 - reading with binary commands 4-26
- resetting the camera with binary commands 4-32
- RS-644 serial connection 2-14

S

- sensor
 - pixel size 1-2
 - positioning accuracy 5-3
 - size 1-2
 - type 1-2
- serial connection
 - see RS-644 serial connection*

- serial number
 - viewing with binary commands 4-23
- specifications 1-2
- startup pointer
 - explained 3-35
 - setting with binary commands 4-29
- status
 - checking with binary commands 4-30

T

- temperature
 - checking with binary commands 4-25
 - explained 3-36
- temperature requirements 1-5
- test image
 - explained 3-33
 - setting with binary commands 4-21
- timer 1
 - explained 3-3, 3-10
 - setting with binary commands 4-13
- timer 2
 - explained 3-10
 - setting with binary commands 4-13
- troubleshooting 6-1
- troubleshooting chart
 - image quality problems 6-4
 - interfacing 6-5
 - no image 6-2
 - RS-232 serial communication 6-6

U

- user sets
 - copying to the work set 4-27
 - explained 3-35

V

- ventilation 1-5
- video data output mode(s)
 - explained 2-9
 - setting with binary commands 4-11

W

- weight 1-2
- work set
 - copying to a user set 4-28
 - explained 3-35
 - relationship to the config tool 4-3
- write command
 - error checking 4-8
 - example 4-9