



Technical Manual

High-speed high-resolution CMOS camera

V2.3.0

2013-Sep-30

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Contacting Allied Vision Technologies

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Introduction

This **Bonito Technical Manual** describes in depth the technical specifications, dimensions, all pixel formats, bandwidth and frame rate related subjects.

Note Please read through this manual carefully.



Document history

Version	Date	Remarks
V2.0.0	03.11.11	New Bonito Technical Manual
V2.1.0	23.01.12	<ul style="list-style-type: none"> Corrected power supply values and mass values in chapter Bonito CL-400B/C, Bonito CL-400B/C 200fps on page 13 Added F-Mount in legend of Figure 5: Bonito CL-400B/C C-/EF-/F-Mount (back) on page 18 Corrected power supply values in: <ul style="list-style-type: none"> chapter Accessories on page 22 chapter Camera I/O connector pin assignment (15-pin D-sub connector) on page 25 chapter Power supply (pin 1-4) on page 25 Marked pin 5,6 and 14,15 as reserve in chapter Camera I/O connector pin assignment (15-pin D-sub connector) on page 25 and changed description in chapter Reserve I/O (pin 5, 9 and 14-15) on page 28 Some minor corrections in <ul style="list-style-type: none"> chapter Fixed pattern noise (FPN) correction (C) on page 39 chapter Number of lines (N) on page 58 chapter Camera Link output mode setting (S) on page 60
V2.2.0	03.05.12	Added description of new features in camera firmware V1.0.7 <ul style="list-style-type: none"> Changed max. current from 0.36 A to 0.4 A: <ul style="list-style-type: none"> Description to power supply: see chapter Bonito CL-400B/C, Bonito CL-400B/C 200fps on page 13 chapter Accessories on page 22
to be continued on next page		

Table 1: Document history

Version	Date	Remarks
continued from previous page		
V2.2.0 (continued)	03.05.12 (continued)	<ul style="list-style-type: none"> • chapter Power supply (pin 1-4) on page 25 • Pin 6 changed from Reserve to Sync: see chapter Camera I/O connector pin assignment (15-pin D-sub connector) on page 25 • chapter Synchronization output (pin 6) on page 26 • In chapter Exposure output (pin 12-13) on page 27: added Note This output is not recommended for new system designs. on page 28 • Added chapter Synchronization output (J) on page 44 • Updated the following chapter to new bit field order: chapter Exposure control mode (M) on page 45 • Range from N=0 (not N=1) in chapter Number of lines (N) on page 58 • Added values 5 and 7 in chapter Camera Link output mode setting (S) on page 60 • In chapter Reset to factory defaults (Z) on page 64: Corrected E=000006BE (not 000006C1), F=000006BF (not 000006C2) Inserted J=01 and S=00 • Added new command reference description in chapter Command reference on page 70 • Added hyperlink to AVT website for DeviceConfig in chapter Serial I/O on page 22 • Changed AOI to ROI in the whole manual
V2.2.1	11 May 2012	<ul style="list-style-type: none"> • Some minor corrections • Added 80 bit to Camera Link Full+ <ul style="list-style-type: none"> – chapter Bonito CL-400B/C, Bonito CL-400B/C 200fps on page 13 • Added 80 bit to clearly describe the 10-tap configuration of the Camera Link standard: <ul style="list-style-type: none"> – chapter Camera Link interface (01-04 or CL1, CL2) on page 29 – chapter Camera link connectors and 10-tap pin assignment on page 29
to be continued on next page		

Table 1: Document history

Version	Date	Remarks
continued from previous page		
V2.2.1 (continued)	11 May 2012 (continued)	<ul style="list-style-type: none"> Added example drawing: see Figure 10: Example conversion circuit from +/- 6 V RS232 output to 5 V TTL input on page 26 Added information <i>to use exact multiples of the current line duration</i>: see chapter Timer prescaler value (K) on page 45 Changed +/-2 t_L to t_L in Table 13: Exposure control modes: Exposure timing mode (bit group: e) on page 42 Added <i>rising edge</i> description (bit group e, value=2): see Image on demand mode (IOD) with exposure timer on page 43 Added more precise description of PIV mode: see PIV mode = On on page 45 Added new chapter Product variant code (b) on page 65 Added new chapter Command reference on page 70
V2.3.0	2013-Sep-30	<ul style="list-style-type: none"> Updated RoHS (2002/95/EC) to RoHS (2011/65/EU) Added „Surge“ warning as requested for the EMC lab test Corrections derived from terminology alignment Change of font, necessary due to changes in typeface Redesigned the complete PIV mode description, added flow diagram and table Redesigned the biggest part of the Exposure Mode Control description, incl. new tables and flow diagrams Redesigned the Baud Rate description Introduced overview of value ranges, default values and examples for each parameter described in the chapter Camera interfaces on page 21 Replaced the drawings with new drawings that show all four sides of the camera in chapter Camera dimensions on page 16

Table 1: Document history

Manual overview

This **manual overview** outlines the contents of each chapter of this manual.

- chapter [Contacting Allied Vision Technologies](#) on page 5 lists AVT contact data (phone number and URL) for both:
 - Technical information / ordering
 - Commercial information
- chapter [Introduction](#) on page 6 (this chapter) gives you the document history, a manual overview (short description of each chapter) and conventions used in this manual (styles and symbols).

- chapter [Conformity](#) on page 12 gives you information about conformity of AVT cameras (CE, FCC, RoHS).
- chapter [Specifications](#) on page 13 lists camera details and measured spectral sensitivity diagrams for each camera type.
- chapter [Camera dimensions](#) on page 16 provides CAD drawings of standard housing models (2D drawings and 3D isometric drawings), tripod adapter and cross sections of CS-Mount and C-Mount. Furthermore, you find information on adjustment of C-Mount and CS-Mount.
- chapter [Camera interfaces](#) on page 21 describes in general the inputs/ outputs of the cameras (incl. trigger features).
- chapter [Index](#) on page 79 gives you quick access to all relevant data in this manual.

Conventions used in this manual

To give this manual an easily understood layout and to emphasize important information, the following typographical styles and symbols are used:

Styles

Style	Function	Example
Bold	Programs, inputs or highlighting important things	bold
Courier	Code listings, camera output etc.	Output
Courier bold	Commands sent to the camera	Command
Upper case	Register	REGISTER
Italics	Modes, fields	<i>Mode</i>
Parentheses and/or blue	Internet links, cross references	(www.link)

Table 2: Styles

Symbols

Note _____ This symbol highlights important information.



Caution

This symbol highlights important instructions. You have to follow these instructions to avoid malfunctions.

**www**

This symbol highlights URLs for further information. The URL itself is shown in blue.



Example:

<http://www.alliedvisiontec.com>

Before operation

Target group This **Technical Manual** is the guide to detailed technical information of the camera and **is written for experts.**

Note

Please read through this manual carefully before operating the camera.

**Caution**

Before operating any AVT camera read the following **safety instructions** and **ESD warnings.**



Safety warnings

Caution**Electrostatic discharge**

The camera contains sensitive electronic components that can be destroyed by means of electrostatic discharge.

Use sufficient grounding to minimize the risk of damage.



Caution



Surge

To avoid damage caused by surge, connect the camera to an AC/DC power supply. Use a certified industrial power supply that complies with common industrial standards. Make sure the polarization of the power supply is correct.

For the DC (direct current) signal, use cable lengths less than 30 m. Consider that the voltage drop increases with the cable length.

AVT (or your local dealer) provides suitable power supplies:

<http://www.alliedvisiontec.com/emea/products/accessories.html>

Conformity

Allied Vision Technologies declares under its sole responsibility that all standard cameras of the **Bonito** to which this declaration relates, are in conformity with the following standard(s) or other normative document(s):

- CE, following the provisions of 2004/108/EG directive
- RoHS (2011/65/EU)

CE

We declare, under our sole responsibility, that the previously described **Bonito** cameras conform to the directives of the CE.

Specifications

Note



The correct polarity of the 12 V supply voltage must be assured. The warranty becomes void in case of unauthorized tampering or any modifications not approved by Allied Vision Technologies.

Bonito CL-400B/C, Bonito CL-400B/C 200fps

Feature	Specification
Sensor	Type 4/3, CMOS progressive with global shutter
Effective chip size	16.24 mm (H) x 12.08 mm (V)
Cell size	7 μm x 7 μm
Resolution (max.)	2320 (H) x 1726 (V)
Lens mount	C-Mount, Canon EF-Mount, Nikon F-Mount
Frame rate	Bonito CL-400B/C: up to 386 fps, higher rates with smaller ROI Bonito CL-400B/C 200fps: with one Camera Link channel: up to 193 fps
ADC	10 bit
Exposure time	1.5 μs to approx. 1 s
Operating temperature	0 °C to +45 °C
Storage temperature	-30 °C to +70 °C
Humidity (operating and storage)	max. 95% RH, non-condensing
Power supply	12 V DC, -10% to +5%, 0.35 A (4.2 W), max. 0.4 A
Digital output	Bonito CL-400B/C: 2 x 10-tap Camera Link Full+, 80 bits, 80 MHz, 8 bits per pixel Bonito CL-400B/C 200fps: 1 x 10-tap Camera Link Full+, 80 bits, 80 MHz, 8 bits per pixel
Camera control	CC1: trigger input, CC2: reserve
Serial control	Serial via Camera Link or RS232 via control connector
Optocoupler inputs	1 external trigger input
Optocoupler outputs	1 exposure active signal

Table 3: Specification **Bonito CL-400B/C, Bonito CL-400B/C 200fps**

Feature	Specification
Smart features	ROI (Region of Interest), fixed pattern noise (FPN) correction, digital gain (selects 8 of 10 bits for output), offset (brightness), continuous mode (image acquisition with maximum frame rate), image on demand mode (triggered image acquisition)
Dimensions	44.2 mm x 80 mm x 70 mm (C-Mount) 71 mm x 80 mm x 70 mm (EF-Mount) 73.5 mm x 80 mm x 70 mm (F-Mount)
Mass	Bonito CL-400B/C (C-Mount): ~360 g Bonito CL-400B/C (EF-Mount): ~410 g Bonito CL-400B/C (F-Mount): ~390 g Bonito CL-400B/C 200fps (C-Mount): ~350 g Bonito CL-400B/C 200fps (EF-Mount): ~400 g Bonito CL-400B/C 200fps (F-Mount): ~380 g
Regulations	CE, RoHS (2011/65/EU)

Table 3: Specification **Bonito CL-400B/C, Bonito CL-400B/C 200fps**

Note

The design and specifications for the products described above may change without notice.



Caution

The camera contains sensitive electronic components that may be destroyed by electrostatic discharge (ESD). When handling the camera ensure sufficient grounding to minimize the risk of damage.



Spectral sensitivity

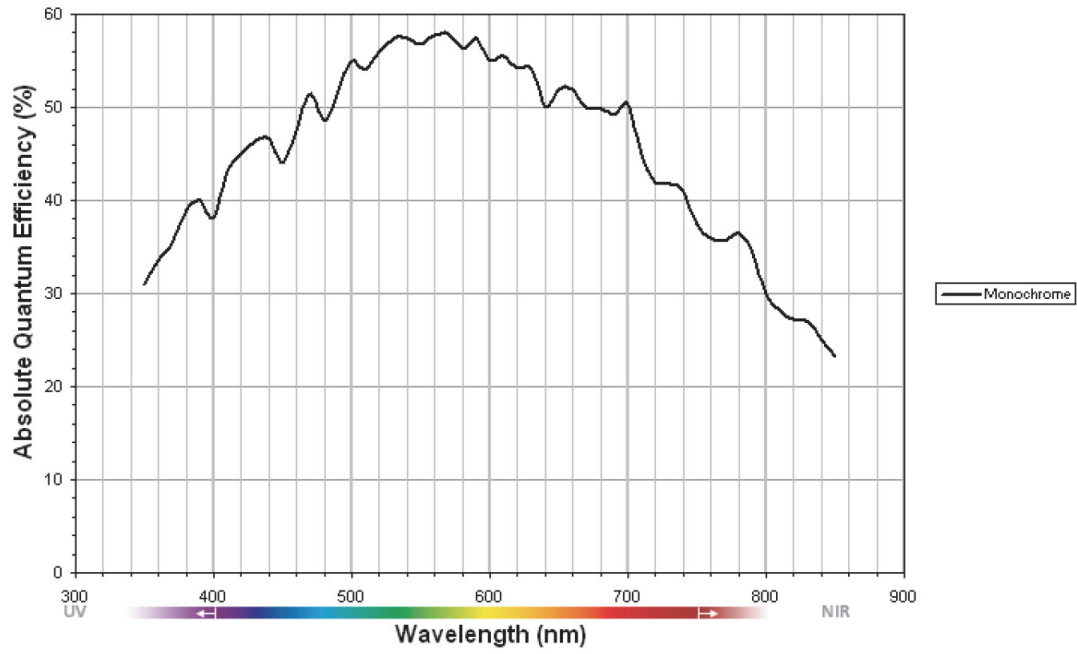


Figure 1: Spectral sensitivity of **Bonito CL-400B**

Note The spectral sensitivity curve for the color sensor is not available.



Camera dimensions

Bonito CL-400B/C C-Mount

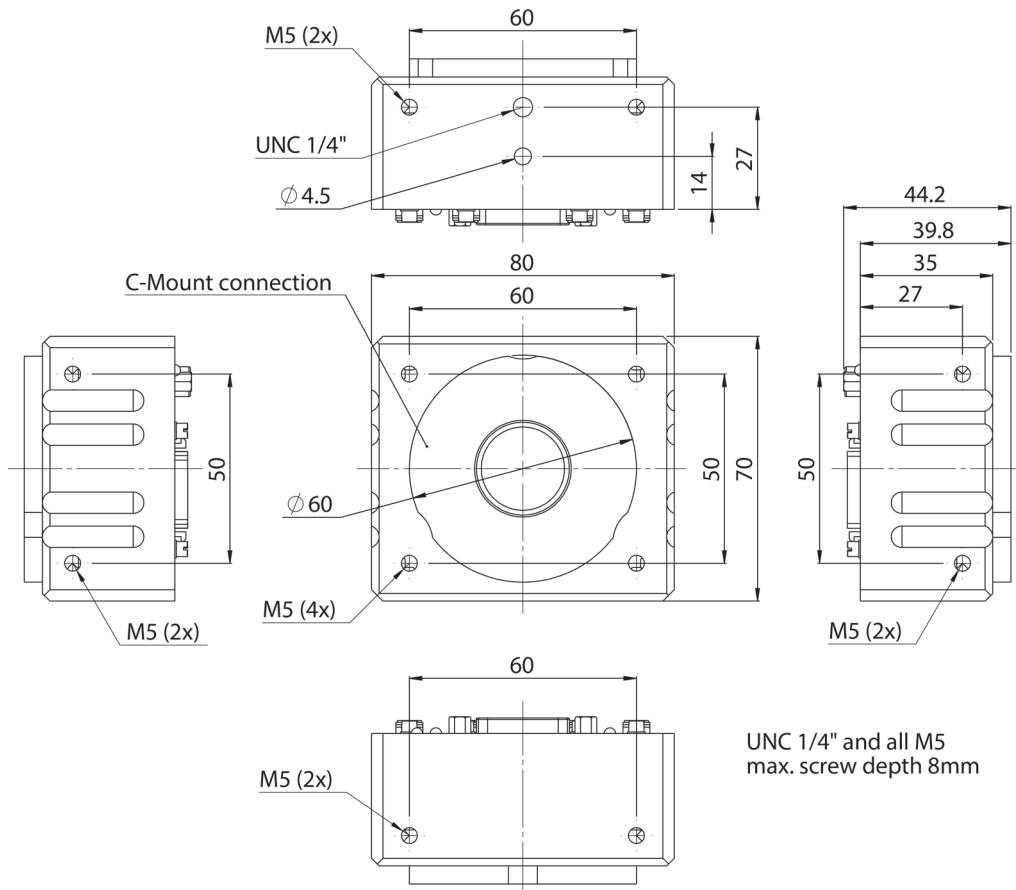


Figure 2: Camera dimensions: **Bonito CL-400B/C** C-Mount

Bonito CL-400B/C EF-Mount

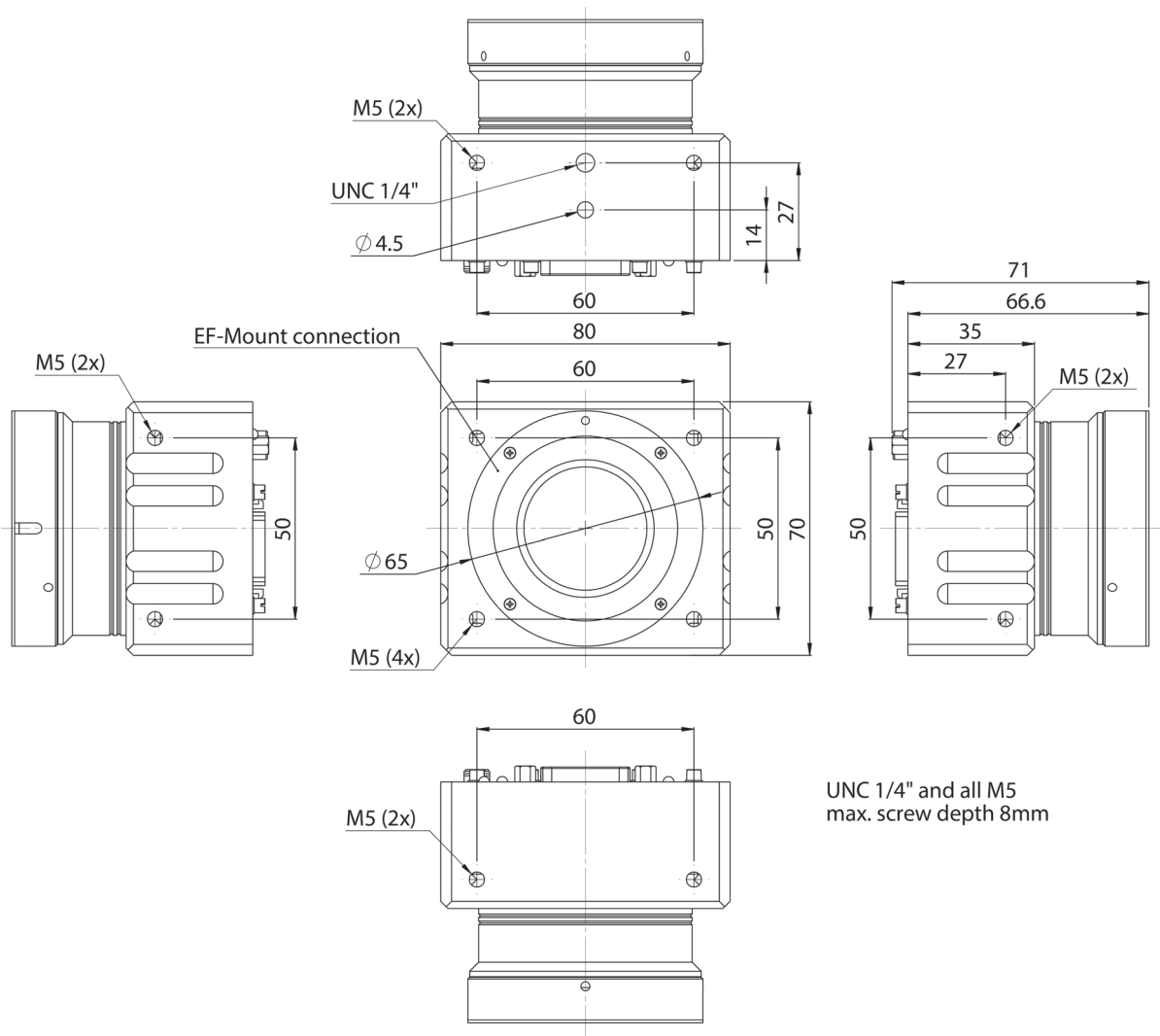


Figure 3: Camera dimensions: **Bonito CL-400B/C** EF-Mount

Bonito CL-400B/C F-Mount

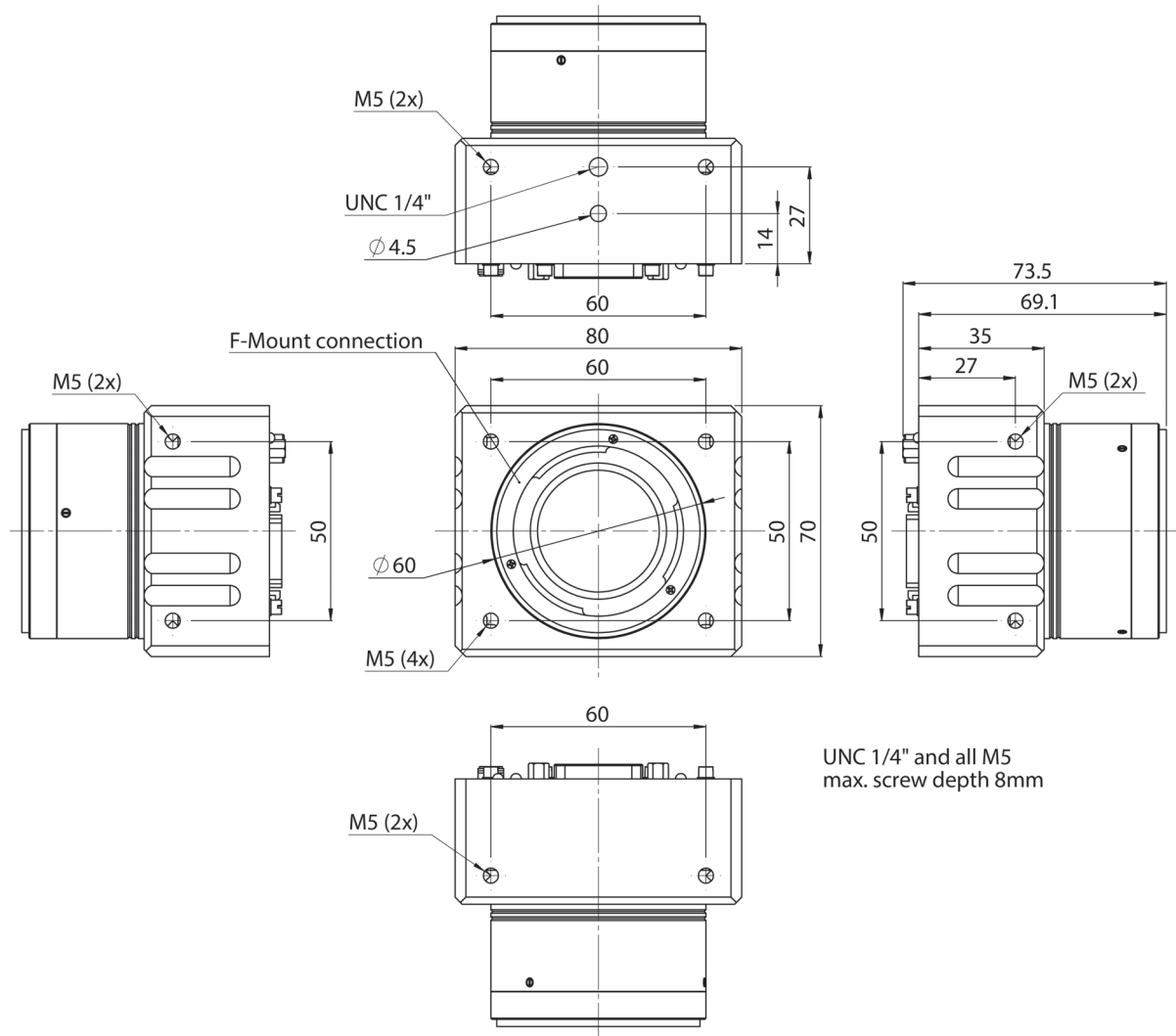


Figure 4: Camera dimensions: **Bonito CL-400B/C** F-Mount

Back view of Bonito CL-400B/C C-/EF-/F-Mount

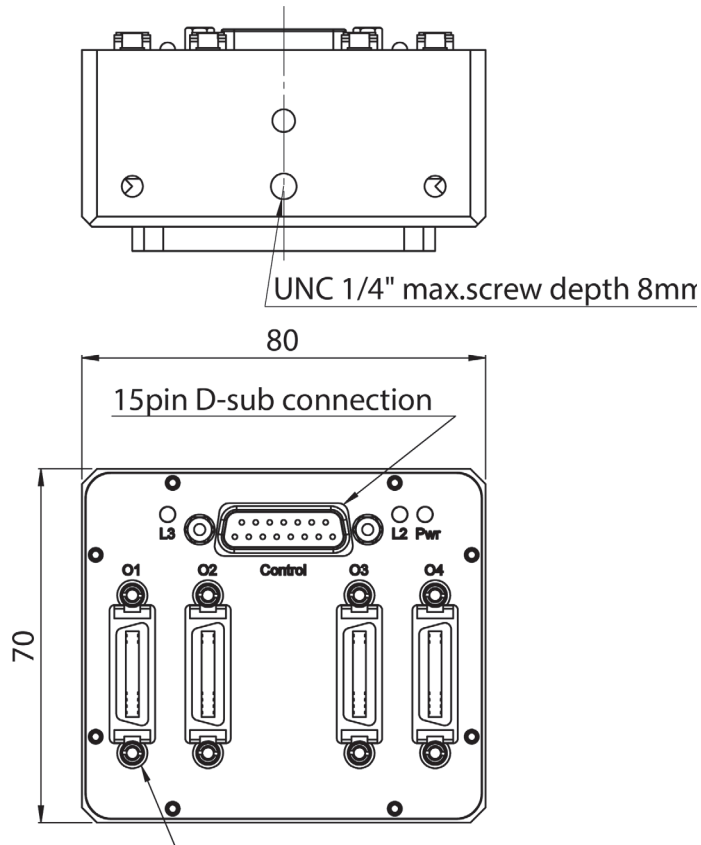


Figure 5: **Bonito CL-400B/C** back view (C-/EF-/F-Mount)

Connectors	Description
Control	12 V DC power supply, RS-232, optocoupler inputs and outputs
O1	Camera Link channel A (left) medium/full
O2	Camera Link channel A (left) base
O3	Camera Link channel B (right) medium/full
O4	Camera Link channel B (right) base

Figure 6: Connectors

Back view of Bonito CL-400B/C C-/EF-/F-Mount 200fps

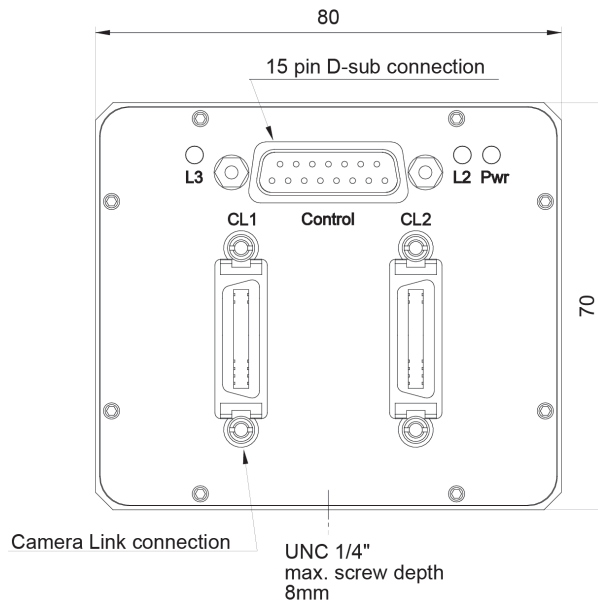


Figure 7: **Bonito CL-400B/C** back view (C-/EF-/F-Mount 200fps)

Connectors	Description
Control	12 V DC power supply, RS-232, optocoupler inputs and outputs
CL1	Camera Link Base
CL2	Camera Link Medium/Full

Figure 8: Connectors

Camera interfaces

This chapter gives you information on the control interface, inputs and outputs and trigger features.

www



For accessories like cables or power supply see:
<http://www.alliedvisiontec.com/emea/products/accessories/camera-link.html>

Requirements and serial I/O

Frame grabber requirements

Take special care in selecting the Camera Link frame grabbers. They should be able to process the 10 taps of each Bonito channel at 80 MHz clock frequency. This stands for a mean data rate of approx. 2 x 737 MiB/s (= 2 x 773 MB/s) net and a burst rate of up to 2 x 763 MiB/s (= 2 x 800 MB/s) net.

Camera configuration files for several frame grabbers are available from Allied Vision Technologies on request.

Note

For more information on frame grabbers see manuals from frame grabber manufacturer.



PC hardware requirements

A PC with high performance PCI Express (PCIe) system architecture is needed to cope with the high data rates. At least one free PCIe x4/x8/x16 slot is needed per frame grabber, depending on the specific frame grabber requirements.

Generally, a short PCIe card may be plugged into a longer PCIe slot (e.g. a PCIe x4 frame grabber into a PCIe x16 slot). Often main board manufacturers do not connect all lanes of a physical slot to the chipset. Therefore, ensure that at least the number of lanes needed by the frame grabber are electrically connected in the slot. Refer to the reference manual of the main board for details.

Currently, we recommend main boards with Intel X58 chipset or better specification regarding the PCIe architecture.

Camera link cable length

The tested maximum Camera Link cable length for the Bonito is 7 m, depending on the cable quality and the frame grabber.

Accessories

The Bonito needs a DC power supply with 12 V at an average current of 0.35 A (max. 0.4 A). The camera is delivered with suitable power supply without power cord.

The Bonito is available with C-Mount, F-Mount or EF-Mount lens adapter. Consider the CMOS sensor size for lens selection. The lens should fully illuminate an area of $\geq 16 \text{ mm} \times 12 \text{ mm}$ ($\varnothing 20 \text{ mm}$, type 4/3).

The software depends on the frame grabber. A software development kit (SDK) and a demo software for first live preview is usually provided by the frame grabber manufacturer.

Serial I/O

To configure the Bonito camera, an asynchronous serial command interface is provided. By default this command interface is internally routed via the Camera Link connector O2 (SerTC, SerTFG) or CL1 (**Bonito CL-400B/C 200fps**), but the RS232 signals at the 15-pin D-sub connector may also be used.

AVT provides the **DeviceConfig** software to control the camera via standard PC RS232 COM ports. Beginning with version 1.2.1 camera control is also possible via the serial interface of the frame grabber. The frame grabber needs a DLL provided by the frame grabber's manufacturer (clser*.dll).

www



For more information on **DeviceConfig** see:

<http://www.alliedvisiontec.com/emea/products/software/windows/deviceconfig.html>

Note



For more information about serial communication via Camera Link refer to the documentation of the particular frame grabber.

By default the serial interface uses the following parameters:

- 115200 baud
- 8 data bits
- 1 stop bit
- No parity
- No handshake

The baud rate is factory-set to 115200 but can also be configured to other values: see chapter [Serial control interface configuration \(s\)](#) on page 66.

All command examples are formatted in the following styles:

- **Bold Courier font:** characters sent to the camera
- `Courier font:` the camera's answer

At power-up the camera loads the stored parameter configuration from its non-volatile memory and sends a start message after successful initialization to all activated serial interfaces.

The following is an example of the start message

```
Bonito CL / CMC-4000 CMOS High-Speed Camera
Version: CMC.040.xx.yy
>
```

The command prompt character `>` indicates that the camera is ready to receive and process the next command. Each command consists of a command letter, followed by an equality sign and a parameter value in hexadecimal number representation. The command letter is case sensitive. Hexadecimal values are always upper case and are 1 to 8 hex digits long. The command is activated by a carriage return (`[CR]`, ASCII character number `0D`). Serial communication operates in echo mode by default. This means that each character received by the camera is echoed back to the sender.

For that reason, all serial commands (exceptions: `v`, `y`, `a`, `?`) have the following general syntax:

>A=wxyz [CR]

Sign	Description
A	Command or parameter letter (observe upper and lower case printing!)
=	Equality sign (3D)
wxyz	1-8 digits long value in hexadecimal number representation (capital letters)
[CR]	Carriage Return (0D)
[LF]	Line Feed (0A)

Table 4: Syntax of serial commands

The following example sets the exposure time to 1000 = 3E8 time units:

1. User sends the six characters
E=3E8 [CR]
2. Camera answers with nine characters (echo followed by new prompt)
E=3E8 [CR] [CR] [LF]>

3. A terminal program without local echo displays

```
E=3E8  
>
```

After the execution of the command has finished the command prompt character **>** is displayed again. If any error occurred, a question mark character **?** is sent previous to the prompt character.

To query a parameter value, send the corresponding command letter followed by the equality sign and a question mark character:

```
>s=? [CR]
```

If the intended action does not need any parameter it is also sufficient in most cases – as a shortcut – to send the command letter only, directly followed by **[CR]**.

At the beginning of a command sequence it is good practice to check the serial communication by sending a **[CR]** only to the camera and verify that the command prompt **>** is returned.

Note



There is an input buffer holding a few characters but no hardware handshake. For that reason, a sequence of commands should not be sent to the camera without awaiting the intermediate input prompts. This is especially important for serial command processing through user-developed software routines. Otherwise, the camera's serial input buffer may overflow.

Camera I/O connector pin assignment (15-pin D-sub connector)

This connector is intended for supplying power as well as external input/output signals.

Pin	Signal	Direction	Level	Description	RS232 9-pin D-sub
1	External Power		+12 V DC (+5%, to 10%), 0.35 A (4.2 W), max. 0.36 A	Power supply	
2					
3	External GND				5 (GND)
4					
5	Reserve				
6	Sync	Out	RS232	Synchronization signal	
7	RXD	In	RS232		3 (TXD)
8	TXD	Out	RS232	Serial control	2 (RXD)
9	Reserve				
10	Trigger input	-	Optocoupler input, 5 V to 12 V, max. 15 mA	External trigger signal	
11		+			
12	Exposure output	-	Optocoupler output, open collector, 30 V, max. 150 mW	Active exposure signal	
13		+			
14	Reserve				
15	Reserve				

Figure 9: Camera I/O connector pin assignment

Power supply (pin 1-4)

The camera requires 12 V DC (+5%, -10%) at a continuous maximum of 0.4 A. We recommend to use all pins for power supply, 1 and 2 as well as 3 and 4).

Synchronization output (pin 6)

Note Only cameras with firmware CMC.040.01.07 or newer support this feature.



If you use a camera with an older firmware version: don't connect pin 6.

Use this signal for the following:

- Synchronize external devices to the effective exposure of Bonito. Examples of external devices are flash lights, flash strobes or timer circuits.
- Reduce the timing jitter of start and end point of exposure. Several modes are available: for more information see chapter [Synchronization output \(J\)](#) on page 44

The output is a RS232 compatible driver, signaling at +/- 6 V levels typically. The output delivers a reliable, low-jitter transmission, even over relatively long cable runs. The driver adds a delay of 0.75 μ s typically at rising or falling edge.

Caution Do not directly connect this output to a TTL or CMOS logic input.



Input may be destroyed, because output delivers several 10 mA at voltage levels - 6 V to +6 V. These voltages may exceed the absolute limits of the input.

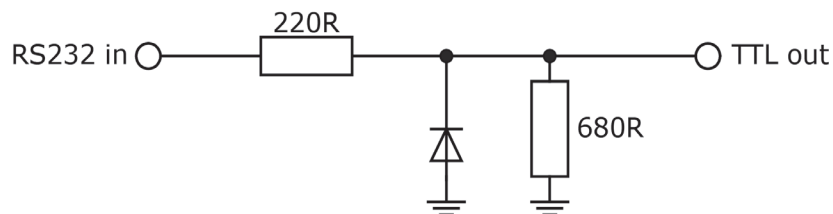


Figure 10: Example conversion circuit from +/- 6 V RS232 output to 5 V TTL input

Serial interface (pin 7-8)

The camera can be controlled externally via an RS232 COM Porty by using serial interface at pin 7 and 8. A simple terminal program (e.g. HyperTerminal) is sufficient for manually controlling the camera. Note that operating this serial interface and the available port(s) via Camera Link concurrently may lead to unexpected results. Both interfaces share the same receive buffer, so the characters of simultaneously sent commands may be randomly mixed up. For more information on general command syntax: see chapter [Serial I/O](#) on page 22.

Trigger input (pin 10-11)

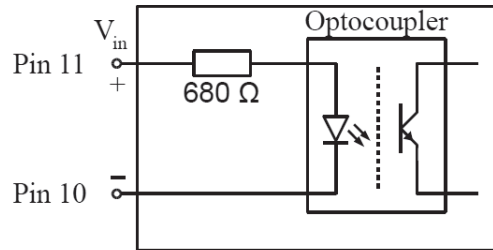


Figure 11: Trigger input diagram

The current through the optocoupler’s LED should be in the range from 5 mA to 15 mA. This is the case if $5.0\text{ V} \leq V_{in} \leq 12\text{ V}$.

Note If you use higher voltages, you have to connect externally an additional current limiting resistor.



A rising edge at this optocoupler input starts the exposure. It depends on the trigger input selection T and the current trigger mode M whether this input is enabled and how it controls the exposure time.

The optocoupler adds a typical delay of about 0.1 μs to the externally applied signal.

For more information on the various trigger and exposure modes: see chapter [Exposure control mode \(M\)](#) on page 45.

Exposure output (pin 12-13)

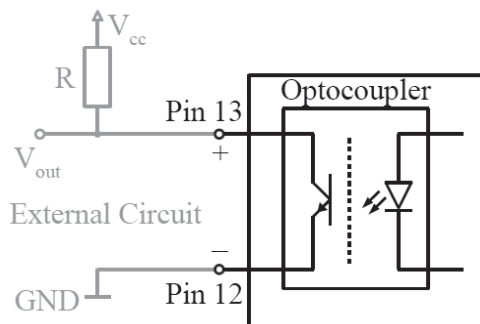


Figure 12: Exposure output

This is an open collector optocoupler output. The transistor is conductive during the active exposure time of the image sensor. The optocoupler adds an intrinsic delay to the signal.

The power dissipation through the optocoupler's transistor must not exceed 150 mW.

A typical value for the external pull-up resistor is $R = 4700 \Omega$. This ensures risk-free operation to the upper V_{cc} limit.

Note This output is not recommended for new system designs.



Use the synchronization output feature instead: see chapter [Synchronization output \(pin 6\)](#) on page 26.

The start-of-exposure edge (falling edge at V_{out}) is delayed for about 3 μs typically, the end-of-exposure edge for about 20 – 50 μs . The latter is mainly caused by the storage time of the photo transistor and is strongly dependent on the external pull-up resistor value R . To safely toggle the output between high and low state use exposure times above 10 μs and also observe a gap of 50 μs or more between two exposures. Faster rates may also work, but should be tested individually. Consequently, in the default continuous mode (**M=0**) the output does not toggle because the inter-exposure gap is too short.

Active exposure is also displayed by the **L3** indicator at the camera's back side.

Reserve I/O (pin 5, 9 and 14-15)

Note The pins 5, 9, 14 and 15 are reserved for future use. Do not connect. Currently they have no function, but this may change.



Camera Link interface (01-04 or CL1, CL2)

Camera Link is an interface for the transmission of digital video data. The standard defines data transfer on a physical base and determines connectors, cables and components for transmission and reception. Three different configurations (base, medium and full) are available, distinguished by the number of transmitter–receiver pairs (one, two or three respectively). While the base configuration is able to operate with one cable, for the medium and the full configuration two cables between camera and grabber are necessary.

Each transmitter–receiver channel implements the so called *Channel Link* technology. One Channel Link transmitter serializes 28 parallel data bits in a ratio of 7:1 and transfers them via five differential signal pairs (four data pairs plus one for the clock). By using the LVDS (Low Voltage Differential Signaling) standard, net parallel clock rates up to 85 MHz (up to 595 Mbit/s on the wire pairs) can be achieved.

The Camera Link standard also defines non-serialized signals. There are four direct camera control lines (CC1 – CC4) from frame grabber to the camera, as well as a bi-directional asynchronous serial communication channel, all of them are transmitted using the LVDS standard.

Due to the high bandwidth requirements the Bonito makes use of an extension to the Camera Link Full standard.

Camera Link Full defines 8 ports with 8 bits each. It has a payload of 64 bits, that – including synchronization signals – only occupy 76 of the $3 \times 28 = 84$ available transmitter bits. By incorporating the unused bits and some redundant synchronization signals, it is possible to transmit $10 \times 8 = 80$ bits net. This is also known as Camera Link 10-tap standard with 80 bits.

One Camera Link 80-bit channel provides enough bandwidth to achieve nearly 200 frames per second at four megapixels per frame. To reach the 400 frames per second the Bonito uses two Camera Link 80-bit channels in parallel.

Camera link connectors and 10-tap pin assignment

The Bonito implements two Camera Link 80-bit channels in 10-tap configuration grouped at the connector pairs 02/01 and 04/03 respectively. The **Bonito CL-400B/C 200fps** cameras implement only one Camera Link 80-bit channel at the connector pair CL1/CL2.

Each channel delivers ten Camera Link ports labelled A to J. Every port has eight bits and is assigned to a corresponding sensor tap that outputs specific pixel columns of the image. Consequently, up to $2 \times 10 = 20$ simultaneous pixels are transferred to the frame grabber(s) in parallel per Camera Link clock cycle.

The following illustrations depict the bit and wire assignments at the Camera Link connectors:

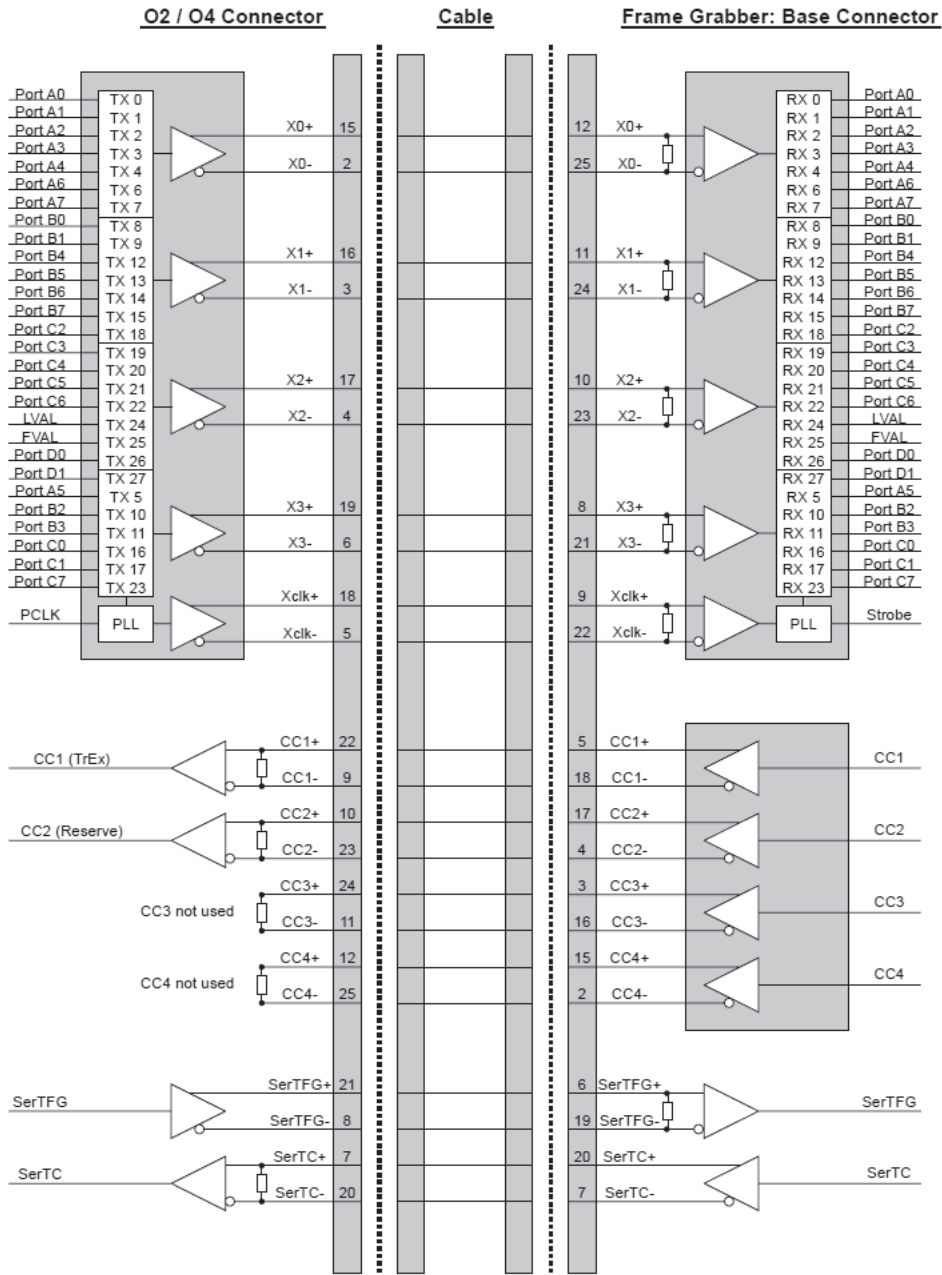


Figure 13: Camera link connector: 10-tap pin assignment (O2/O4 or CL1 connector)

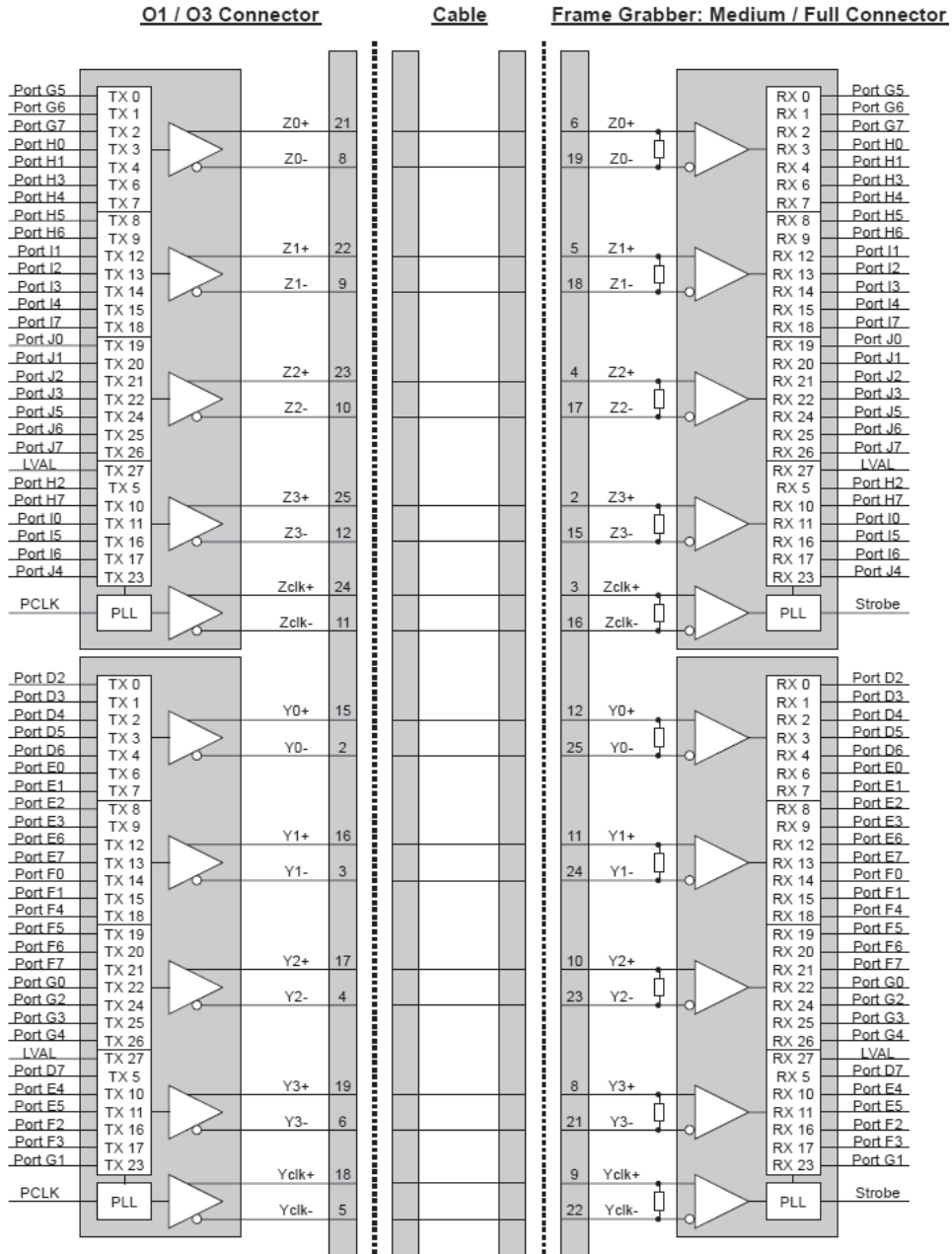


Figure 14: Camera link connector: 10-tap pin assignment (01/03 or CL2 connector)

Serial interface (SerTC, SerTFG)

The Camera Link connectors **02** and **04** (Bonito CL-400B/C 200fps: connector **CL1** only) each provide the asynchronous serial control lines SerTC and SerTFG. This is the preferred communication channel to control the various camera

functions. Both Camera Link serial interfaces (and also the third RS-232 interface at the 15-pin D-sub connector) are virtually equal. They all use one global baud rate setting. They also share the same receive buffer. Output characters (including echo) are always sent to all activated serial ports. The ports are not intended for concurrent activity, although it might be possible under particular circumstances.

However, the serial ports at **02** and **04** (or at **CL1**) may be deactivated.

Note

The **Bonito CL-400B/C 200fps** cameras provide only one Camera Link channel. The serial interface via Camera Link is only available at the CL1 connector.

Note

- For more information on serial interface configuration: see chapter [Serial control interface configuration \(s\)](#) on page 66.
- Consult the documentation of the frame grabber for more information on how to operate its integrated serial ports.

Trigger inputs (CC1)

The two Camera Link connectors **02** and **04** (or connector **CL1**) each provide a camera control signal **CC1**. A rising edge at either input may start an exposure. It depends on the trigger input selection τ and the current trigger mode m , which of the two **CC1** inputs is enabled and how it controls the exposure time.

Note

The **Bonito CL-400B/C 200fps** cameras provide only one Camera Link channel. The serial interface via Camera Link is only available at the **CL1** connector.

Note

For more information on the various trigger and exposure modes: see chapter [Exposure control mode \(M\)](#) on page 45.

Reserve control input (CC2)

The camera control signals **CC2** at the Camera Link connectors 02 and 04 (or connector **CL1**) are reserved for future use.

Pixel order

Each frame in single channel mode ($s=0$, max. 193 full frames per second) is transmitted from top left to bottom right, line per line. The diagram below shows how the image is reconstructed from the ten Camera Link taps **A – J**.

Because every tap directly corresponds to a Camera Link port, the port labels are reused as tap labels here. Each Camera Link clock cycle transmits one block of ten pixels. Note that the number of lines may vary depending on the value of parameter N .

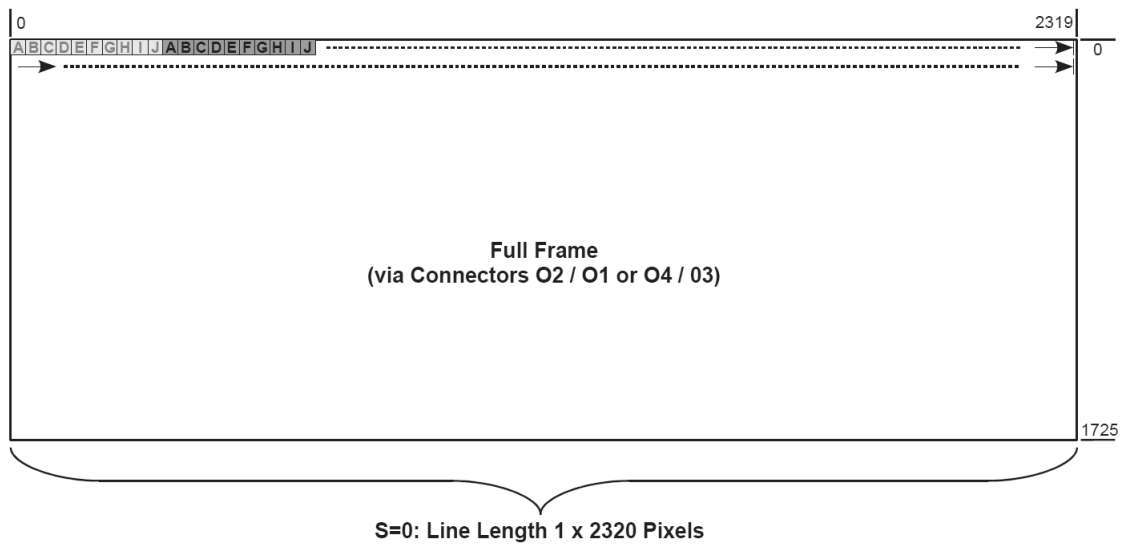


Figure 15: Pixel order: full frame

In the high-speed dual channel modes ($s=1$ or $s=3$, max. 386 full frames per second) the image is split up vertically into two equal sized halves. Each half uses its own Camera Link channel and the pixel data travels over the corresponding connector pair.

Note This mode is not available for the **Bonito CL-400B/C 200fps** cameras.



From the host's point of view the Bonito behaves like two cameras with half of the possible image width. The host computer receives two images at the same time that are reconstructed in the order shown below. It is the duty of the system designer to allow for assembly of the two halves if the application demands it.

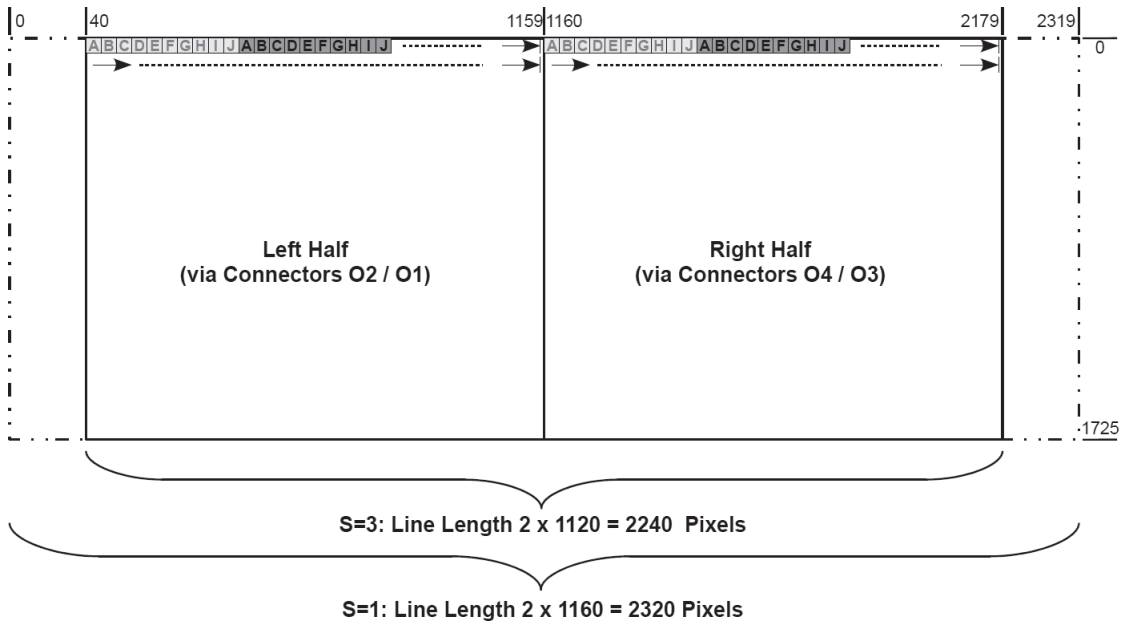


Figure 16: Pixel order: half frame

Timing (FVAL, LVAL, PCLK)

The Camera Link pixel clock frequency of the Bonito is 80 MHz.

The 10-tap configuration transfers 10 pixels per clock cycle at once, or 20 pixels per clock cycle in the dual-channel mode). The synchronization signals LVAL (line valid) and FVAL (frame valid) are used to designate valid data output.

Single channel mode

The charts below illustrate the Camera Link timing for single channel mode ($S=0$), in continuous mode ($M=0$). The frame gap may vary in other trigger modes. Additionally, the number of active lines per frame can be configured by the user (parameter N).

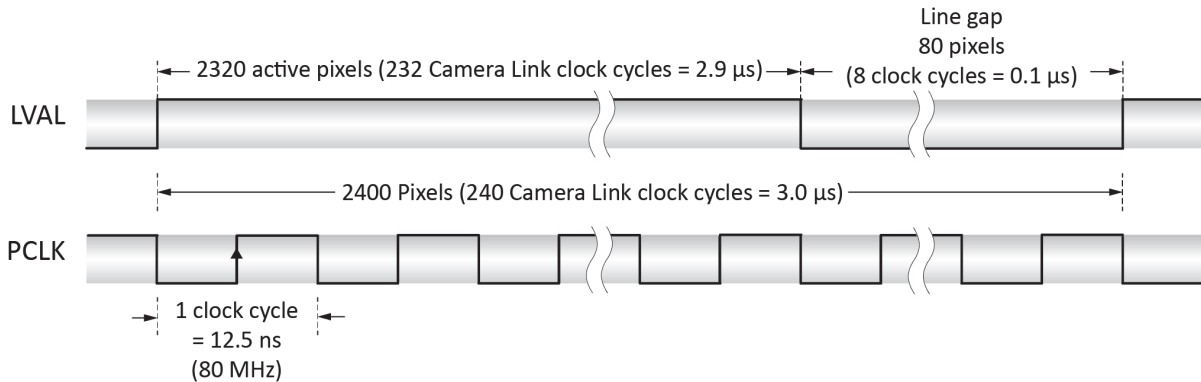


Figure 17: Line timing for single channel mode ($S=0$)

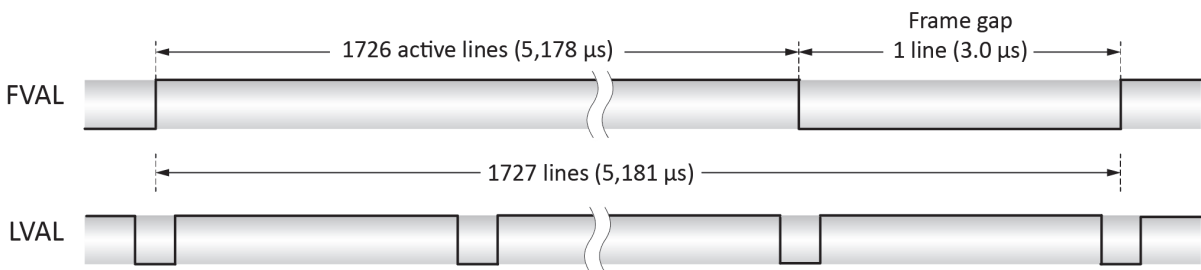


Figure 18: Frame timing for single channel mode ($S=0$)

Dual channel, full line length

The charts below illustrate the Camera Link timing for dual channel mode (full line length, $S=1$), in continuous mode ($M=0$). The frame gap may vary in other trigger modes. Additionally, the number of active lines per frame can be configured by the user (parameter N).

Note The diagrams displayed are not applicable for the **Bonito CL-400B/C 200fps** cameras.

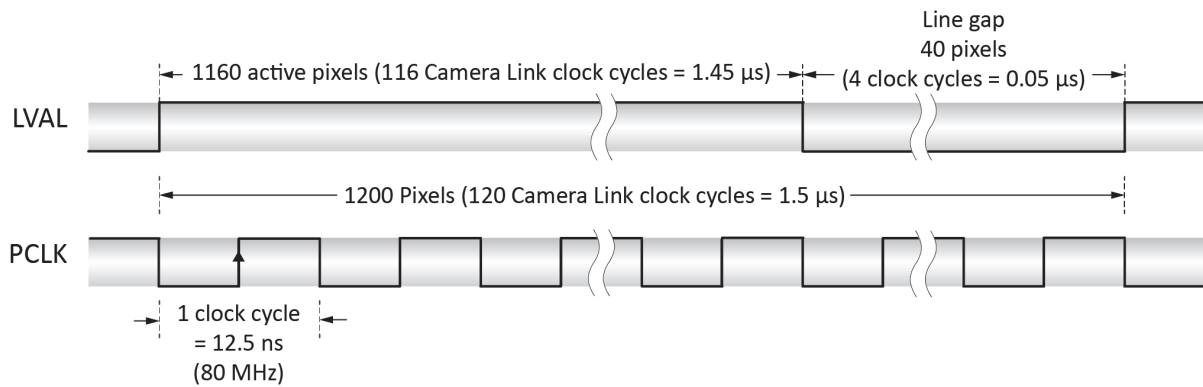


Figure 19: Line timing for dual channel mode (full line length, $S=1$)

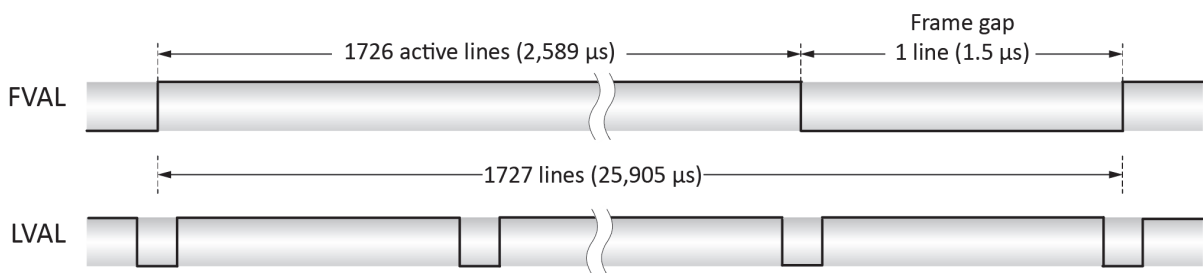


Figure 20: Frame timing for dual channel mode (full line length, $S=1$)

Dual channel, reduced line length

The charts below illustrate the Camera Link timing for dual channel mode (compatibility mode with reduced line length, $S=3$), in continuous mode ($M=0$). The frame gap may vary in other trigger modes. Additionally, the number of active lines per frame can be configured by the user (parameter N).

Note The diagrams displayed are not applicable for the **Bonito CL-400B/C 200fps** cameras.

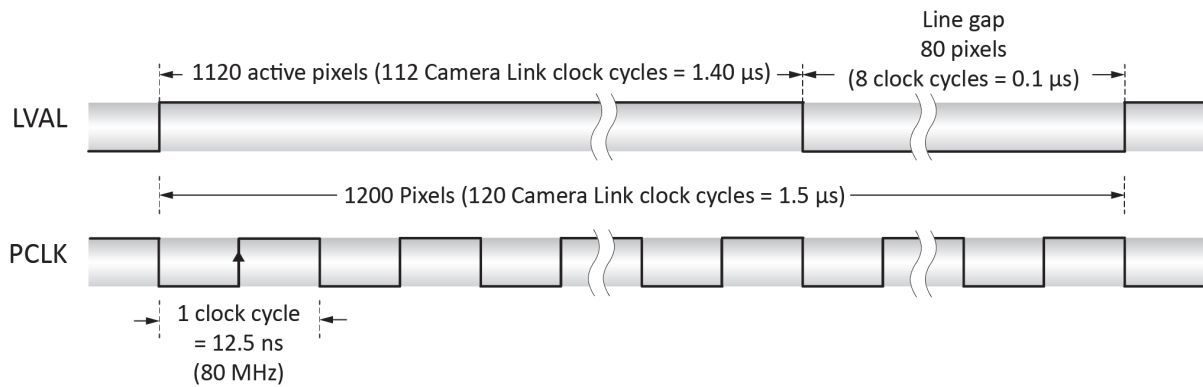


Figure 21: Line timing for dual channel mode (compatibility mode with reduced line length, $S=3$)

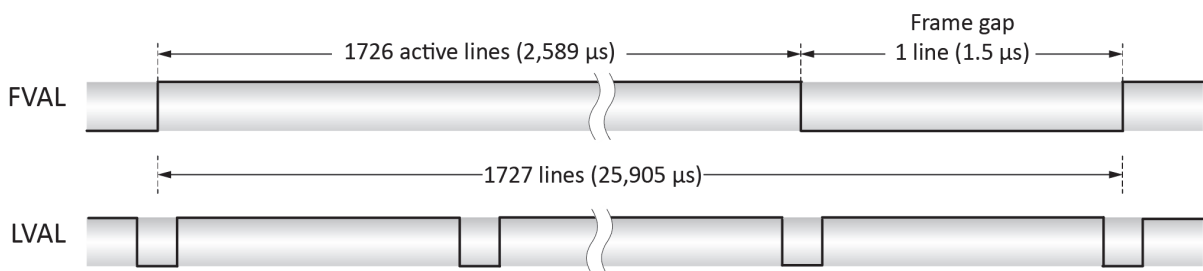


Figure 22: Frame timing for dual channel mode (compatibility mode with reduced line length, $S=3$)

Parameters and commands

This section explains the basic Bonito configuration parameters and general commands available to the user. Parameters and commands are communicated using the camera's serial interface. For more information see chapter [Serial I/O](#) on page 22.

Note



In this section, all values and examples noted in **mono-spaced font** are denoted in the hexadecimal numbering system, if not otherwise noted.

In all cases, explicit base notation (e.g. 0x4711 or 045H) is omitted to be directly compatible to the camera's command interface syntax.

Example: to set **M** to the value of $M=0x21$, use the command **M=21**.

Primary starting address (A)

The parameter **A** defines the line address of the image sensor that is the first line of the output image. The value of **A** in conjunction with **N** and **I** is used to create a region of interest (ROI1).

Range	From 0 (topmost line) to 6BD (lowermost line)
Default	0
Related	Parameters B , D , N and I
Example	<p>A=35E (0x35E = 862), first line at address 862, that is the 863rd line of the sensor</p> <p>N=F read 16 lines</p> <p>I=2 read every second line</p>

Note



For more information on double ROI mode and a diagram displaying the ROI parameters, see chapter [Double region of interest mode \(D\)](#) on page 40.

Each image sensor line can only be read once per exposure. Two ROIs are only possible as long as they do not share the same line addresses.

Secondary starting address (B)

The value of parameter **B** is used to create the secondary region of interest (ROI2).

If the double ROI mode is active, **B** defines the line of the image sensor that is the first line of the second half of the output image.

Range	From 0 (topmost line) to 6BD (lowermost line)
Default	0
Related	Parameters A , B , D , N and I
Example	<p>A=F start first AOI at the 16th line</p> <p>B=1F (0x1F = 31), starts second AOI at the 32nd line</p> <p>D=1 enable double ROI mode</p> <p>N=F read 16 lines from each ROI, 32 lines in the output image</p> <p>I=1 read every line</p>

Note For more information on double ROI mode and a diagram displaying the ROI parameters, see chapter [Double region of interest mode \(D\)](#) on page 40.



Each image sensor line can only be read once per exposure. Two ROIs are only possible as long as they do not share the same line addresses.

Fixed pattern noise (FPN) correction (C)

The **Bonito** camera provides an FPN correction to improve image quality. Correction data has to be recorded under low-light conditions. For best correction quality new correction data should be acquired from time to time.

Range	0, 1, or 3 (value 3 is write-only, will be read as 1)
Default	0
Related	Parameter M
Example	<p>To acquire new FPN correction data follow this sequence:</p> <ul style="list-style-type: none"> Try to eliminate bright light sources, e.g. switch them off if possible. For best correction quality, close the iris or use a lens cover. Ensure that the camera continuously outputs images at a constant frame rate, e.g. using the continuous mode: <pre>>M=0 [CR] ></pre>

- Send the following serial command to record and apply new correction data. The camera answers with a new prompt sign if the command has successfully completed. The execution lasts for the duration of some images.

```
>C=1 [CR]
```

```
>
```

Use the command **C=3** to re-enable the FPN correction without acquiring new correction data. Instead, the correction data acquired by the last **C=1** call will be used. However, correction data is not stored beyond power loss.

Note

The correction data is volatile. So this command should be executed at least once after switching-on for best performance.



Double region of interest mode (D)

In double ROI mode (**D=1**) the camera outputs two equally sized regions of interest. Both ROIs share the parameters **N** and **I** and are output as two halves of one image. The top half contains the lines of the primary ROI (ROI1), the bottom half the lines of the secondary ROI (ROI2) accordingly.

The starting line address for ROI1 is configured using the parameter **A**.

Parameter **B** controls the starting line address of ROI2. Each ROI has the height of $(N + 1)$ lines, the resulting image has $(N + 1) * 2$ lines.

Parameter **D** also has an influence on the number of frames per second possible. Use the following formula to calculate the exact number:

- $\text{Max fps} = 1 / ((D + 1) * (N + 1) + 1 + \text{IOD}) * t_L$;

the parameters are explained in the table below

Parameter	Value
D	Parameter D
N	Parameter N
IOD	IOD=0 if Continuous mode (e.g. M=0), IOD=1 if not in Continuous mode
t_L	$t_L = 3 \mu\text{s}$ in single CL channel mode (e.g. S=0), $t_L = 1.5 \mu\text{s}$ in dual CL channel mode (e.g. S=1)

Table 6: Parameters for fps calculation

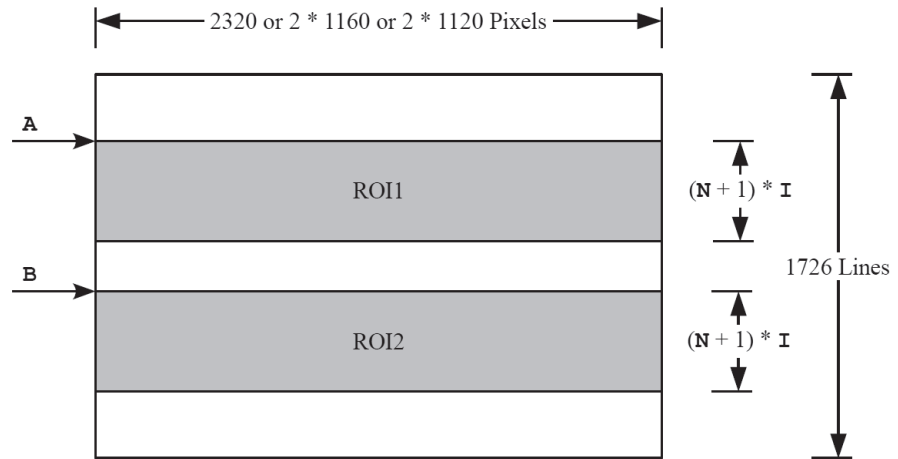


Figure 23: Parameters relevant in double ROI mode

The diagram illustrates the use of ROI parameters **A**, **B**, **I**, and **N**, from the sensor's point of view. The sensor's first (topmost) line has the address **0**, the last (lowermost) line has the address **6BD**.

Range	0 (=off) or 1 (=on)
Default	0
Related	Parameters A , B , D , N and I
Example	<p>A=0 start first AOI at the first line</p> <p>B=5BD ($0x5BD = 1469$), starts second AOI at the 1470th line</p> <p>D=1 enable double ROI mode</p> <p>N=FF ($0xFF = 255$), reads 256 lines from each ROI, 512 lines in the output image</p> <p>I=1 read every line</p>

Result: lines no 0 to 255 and no 1469 to 1724 of each image are read.

Exposure time (E)

The exposure time is a 32-bit value. Its time resolution depends on the prescaler value **K**. For detailed information see chapter [Timer prescaler value \(K\)](#) on page 45.

Technically, the value range is 32 bit, whereas the useful exposure times should be up to approx. 1 second.

Range	Useful from 1 to approx. 50000 at K=A7 , but not limited to that maximum.
Default	6BE (=1726)

Related Parameters **D**, **F**, **K**, **M**, **N** and **S**.

Frame duration must always be greater than exposure time.

Example 1 **K=53** (0x53 = 84), sets prescaler tick length to 84 clock cycles, which corresponds to 1.5 μ s

E=6BE (0x6BE = 1726), sets exposure time to 1726 prescaler ticks

F=FA0 (0xFA0 = 4000), sets frame duration to 4000 prescaler ticks

M=3 activate free-running exposure mode using **E** and **F**

Result:

exposure time = 1726 * 1.5 μ s = 2589 μ s

frame duration = 4000 * 1.5 μ s = 6000 μ s

Example 2 **K=A7** (0xA7 = 167), sets prescaler tick length to 167 clock cycles, which corresponds to 3 μ s

E=50000 (0x50000 = 327680), sets exposure time to 327680 prescaler ticks

F=50001 (0x50001 = 327681), sets frame duration to 327681 prescaler ticks (greater than exposure time)

M=3 activate free-running exposure mode using **E** and **F**

Result:

exposure time = 327680 * 3 μ s = 983040 μ s = approx. 1 s

frame duration = 327681 * 3 μ s = 983043 μ s

Note The exposure time control using this value is only active if the trigger mode **M** is set to the values of **2** or **3**.



This parameter will be ignored if the Permanent Exposure mode, or PIV mode, or Enhanced Full Well mode, is activated. However, even if one of the above mentioned modes are set, it may be necessary to set this parameter to get a correct internal timing sequence.

For more information see chapter [Exposure control mode \(M\)](#) on page 45.

Frame duration (F)

The frame duration is a 32-bit value. Its time resolution depends on the prescaler value **K**. For detailed information see chapter [Timer prescaler value \(K\)](#) on page 45.


Range From **2** to **FFFFFFFF**, depending on **K**, **M** and **N**. Observe meeting the respective minimum

Default **6BF**

Related Parameters **D**, **E**, **K**, **M**, **N** and **S**

Example **S=3** enable dual channel Camera Link with grabber compatibility

M=7	activate PIV and free-running exposure mode using E and F
N=6BD	(0x6BD = 1725), readout 1726 lines
K=53	(0x53 = 83), sets prescaler tick length to 84 clock cycles, which corresponds to 1.5 μ s
E=1	set small exposure time, although PIV has no exposure control, the exposure time is needed to create valid internal timing sequence
F=D7F	(0xD7F = 3455), sets frame duration to 3455 prescaler ticks, Result: frame duration = 3455 * 1.5 μ s = 5182.5 μ s, the minimum that is valid for the above-mentioned example settings

Note  The frame duration control using this value is only active if the trigger mode **M** is set accordingly. For more information see chapter [Exposure control mode \(M\)](#) on page 45.
For further information see explanation and examples in chapter [Timer prescaler value \(K\)](#) on page 45.

Digital gain (G)

The digital gain setting controls shifting of the pixel bits. It selects the eight of the ten digitizer bits that are output to Camera Link. Overflow is represented by saturation to maximum.

Range	0, 1, or 2						
Default	0						
Related	(none)						
Example	<table> <tr> <td>G=0</td> <td>1x digital gain</td> </tr> <tr> <td>G=1</td> <td>2x digital gain</td> </tr> <tr> <td>G=2</td> <td>4x digital gain</td> </tr> </table>	G=0	1x digital gain	G=1	2x digital gain	G=2	4x digital gain
G=0	1x digital gain						
G=1	2x digital gain						
G=2	4x digital gain						

Line address increment (I)

The line address increment value I is added to the current address at the end of each line read out from the sensor. Setting values > 1 will skip lines accordingly. In conjunction with a reduced N this is useful to gain higher frame rates without diminishing the field of view (also known as sub-sampling).

If the maximum line address has been reached before end of image readout, the address will wrap around and restart from the beginning.

Range	From 1 to FF
Default	1

- Related** Parameters **A**, **B**, **D**, and **N**
- Example** **I=4** output every 4th line
- N=1AF** (0x1AF = 431), sets number of lines to 431, which equals a quarter of the full image

Synchronization output (**J**)

Parameter **J** sends an output synchronization signal to pin 6 of the camera control connector.

- Valid values:** Either one of the values **0**, **1**, **2**, **3**, **8**, **9**, **A**, **B**
- Default** **1**
- Related** Parameters **D**, **E**, **F**, **M**, **N** and **S**

Setting	Output signal
J=0	Effective sensor exposure
J=1	Charge transfer pulse Active for one line duration at the end of exposure. End of this pulse marks the end of exposure and at the same time start of sensor readout. In PIV mode: this pulse occurs at the exposure end of only the first image of each PIV pair. For more information see chapter PIV mode (bit group p) on page 51
J=2	Effective sensor readout
J=3	Exposure phase Contrary to J=0 , this setting shows the exposure phase of the internal state machine and not the effective exposure of the sensor. This allows to synchronize external devices even if the sensor is in permanent exposure mode. For more details see chapter Exposure control mode (M) on page 45.
J=8	Same as J=0 , but with inverted logic on sync output
J=9	Same as J=1 , but with inverted logic on sync output
J=A	Same as J=2 , but with inverted logic on sync output
J=B	Same as J=3 , but with inverted logic on sync output

Table 7: Synchronization output

Timer prescaler value (K)

The prescaler value is used to divide the basic timer clock frequency of 56 MHz by a value of $(K + 1)$ down to a smaller clock frequency. The resulting frequency is utilized as the time base for exposure time **E** and frame duration **F**. This parameter is 16 bit wide.

The implementation of this value provides flexibility between the maximum interval length, the smallest possible resolution, and the size of the numbers involved.

If the value **K** is increased while the values **E** and **F** stay the same, the real exposure time and frame duration will decrease.

Range From 1 to **FFFF** ($0xFFFF = 65535$)

Default **A7**, leading to 3 μ s

Related Parameters **E**, **F**

Example 1 **K=A7** ($0xA7 = 167$, timer resolution of $((167 + 1) / 56 \text{ MHz}) = 3 \mu\text{s}$)
E=64 ($0x64 = 100$, sets exposure time to 100 prescaler ticks)
F=FA0 ($0xFA0 = 4,000$, set frame duration to 4,000 prescaler ticks)

Result:

exposure time: $100 * 3 \mu\text{s} = 300 \mu\text{s}$

frame duration = $4,000 * 3 \mu\text{s} = 12,000 \mu\text{s}$

Example 2 **K=53** ($0x53 = 83$, timer resolution of $((83 + 1) / 56 \text{ MHz}) = 1.5 \mu\text{s}$)
E=64 ($0x64 = 100$, sets exposure time to 100 prescaler ticks)
F=FA0 ($0xFA0 = 4,000$, set frame duration to 4,000 prescaler ticks)

Result:

exposure time: $100 * 1.5 \mu\text{s} = 150 \mu\text{s}$

frame duration = $4,000 * 1.5 \mu\text{s} = 6,000 \mu\text{s}$

Note Use **exact multiples** of the current line duration to minimize exposure and frame-to-frame jitter. (**K=A7** for 3 μ s, **K=53** for 1.5 μ s)



Exposure control mode (M)

Use parameter **M** to setup the exposure control mode. The exposure control depends on a number of general timing parameters that are specified in the table below.

Parameter	Value
Line Duration (S=0)	$t_L = 3 \mu s$
Line Duration (S=1)	$t_L = 1.5 \mu s$
Line Duration (S=3)	$t_L = 1.5 \mu s$
Frame Output Time (D=0)	$t_F = (N + 1) * t_L$
Frame Output Time (D=1)	$t_F = 2 * (N + 1) * t_L$
Minimum Frame Duration	$t_{FDmin} = t_F + t_L$
Timer Resolution	$t_{TR} = (K + 1) / 56 \text{ MHz}$

Table 8: Exposure control parameters

Range	From 0 to 7, from 10 to 17, from 20 to 27, from 30 to 37
Default	0
Related	Parameters D , E , F , J , N , and S

Three sub-fields are available to control the exposure time and frame duration of the **Bonito CL-400B/C**:

- Exposure timing mode
- PIV mode
- Exposure feature mode

All of these sub-fields are controlled by the parameter **M**, each of them working independently from the other sub-fields. The sub-fields within the parameter **M** are represented by differently sized bit groups.

Bit group	Sub-field description
e	Exposure timing mode
p	PIV mode
f	Exposure feature mode

Table 9: Exposure control mode: attribution of bit groups and sub-fields

7	6	5	4	3	2	1	0
-	-	f	f	-	p	e	e
		rw	rw		rw	rw	rw

Table 10: Exposure control mode: order of bit groups within parameter **M**

To set a sub-field to a certain value, modify the associated bit group by allocating **M** to the appropriate hexadecimal number.

Since all of the sub-fields are set using the parameter **M**, it is only possible to set all of them at the same time. The value of **M** is calculated as the aggregate sum of the hexadecimal values that are set to each of the three sub-fields.

The table below shows the hexadecimal weights that can be set for each sub-field. To work out the final value for **M**, select a setting for each sub-field, then add up the corresponding hexadecimal values.

Bit values	Setting	Weight (hexadecimal)
Exposure timing mode		
-- xx - x00	Continuous mode	0
-- xx - x01	Image on demand mode (IOD)	1
-- xx - x10	Image on demand mode (IOD) with exposure timer	2
-- xx - x11	Image on demand mode (IOD) with exposure timer and frame duration timer	3
PIV mode		
-- xx - 0xx	PIV mode off	0
-- xx - 1xx	PIV mode on	4
Exposure feature mode		
-- 00 - xxx	Standard mode	0
-- 01 - xxx	Enhanced full well (3T) mode	10
-- 10 - xxx	Permanent exposure mode	20
-- 11 - xxx	Reserved value	30

Table 11: Exposure control mode: values for each setting

See the following pages for detailed explanation of each sub-field.

Examples M=0 (Default)

Sets the bit field to „- - 0 0 - 0 0 0“

- Activates Continuous mode (weight = 0)
- Deactivates PIV mode (weight = 0)
- Activates Standard exposure feature mode (weight = 0)

M=21

(**0x21 = 0b100001**), sets the bit field to „- - 1 0 - 0 0 1“

- Activates Image on demand mode (IOD) (weight = 1)
- Deactivates PIV mode (weight = 0)
- Activates Permanent exposure mode (weight = 20)

M=22

(**0x22 = 0b100010**), sets the bit field to „- - 1 0 - 0 1 0“

- Activates Image on demand mode (IOD) with exposure timer (weight = 2)
- Deactivates PIV mode (weight = 0)
- Activates Permanent exposure mode (weight = 20)

M=2A

(0x2A = 0b101010. This value is not recommended since bit #3 is set to 1 here, even though it is not used by the parameter.)

Sets the bit field to „- - 1 0 - 0 1 0“

- Activates Image on demand mode (IOD) with exposure timer (weight = 2)
- Deactivates PIV mode (weight = 0)
- Activates Permanent exposure mode (weight = 20)

Exposure timing mode (bit group e)

The exposure timing mode allows to switch between the continuous mode and three different IOD modes.

Weight (hexadecimal)	Setting
0	Continuous mode
1	Image on demand mode (IOD)
2	Image on demand mode (IOD) with exposure timer
3	Image on demand mode (IOD) with exposure timer and frame duration timer

Table 12: Exposure timing mode - possible values

Continuous mode

Bit group: e

Value: 0

The camera outputs images as fast as possible in free-running mode.

The gap between two images is only one line, the total frame duration takes t_{FDmin} . The exposure time is nearly equal to this inherent minimal frame duration.

Image on demand mode (IOD)

Bit group: e

Value: 1

The exposure is triggered by an external signal.

Use parameter **T** to select the signal source. A rising edge starts exposure synchronizing to the line after the next line.

The next falling edge stops the exposure and starts the output of the image synchronized to the next line.

Due to the line jitter the next rising edge of the trigger should not appear earlier than $t_{FDmin} + t_L$ after the previous rising edge.

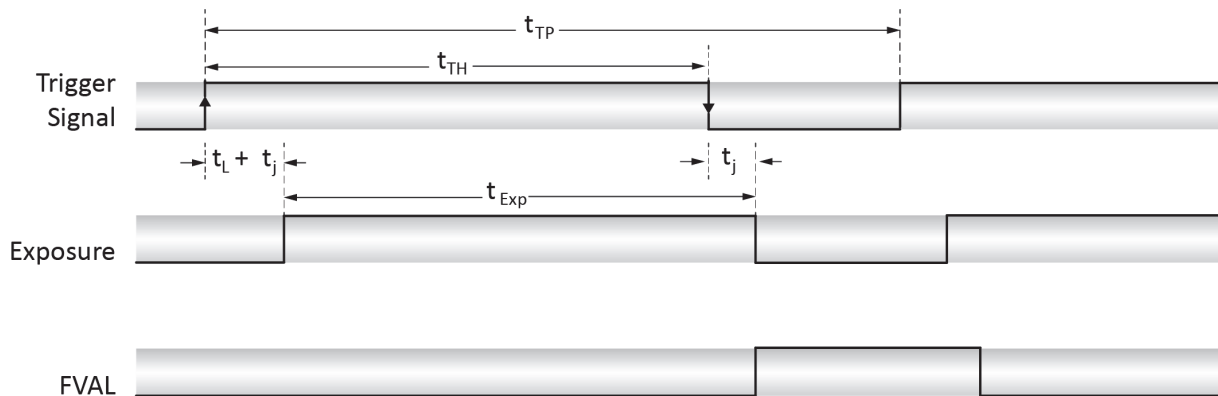


Figure 24: Exposure timing mode, M=1, flow diagram

Parameter	Value
Trigger Period	$t_{TP} > t_{FDmin} + t_L$
Trigger High Duration	$t_L < t_{TH} < t_{TP} - t_L$
Exposure Jitter	$0 < t_j < t_L$
Exposure Time	$t_{Exp} = t_{TH} - t_L \pm t_j$

Table 13: Exposure timing mode, M=1, timing parameters

Image on demand mode (IOD) with exposure timer

Bit group: e

Value: 2

The exposure time is controlled by the parameter **E**.

Each rising edge of an externally applied signal starts one exposure. Use parameter **T** to select the signal source.

A rising edge at the corresponding input starts exposure synchronized to the line after the next.

The next rising edge must not arrive earlier than

$$t_{FDmin} + t_L$$

or

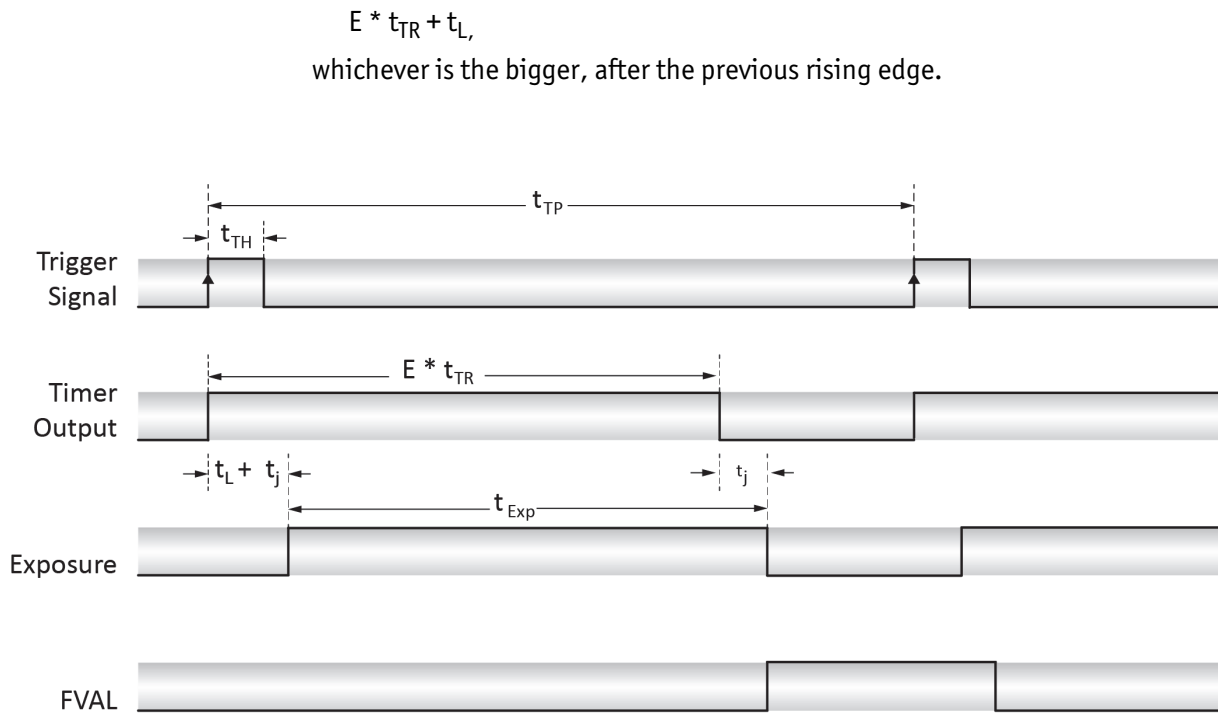


Figure 25: Exposure timing mode, M=2, flow diagram

Parameter	Value
Trigger Period	$t_{TP} > \max(t_{FDmin}, E * t_{TR}) + t_L$
Trigger High Duration	$t_L < t_{TH} < t_{TP} - t_L$
Exposure Jitter	$0 < t_j < t_L$
Exposure Time	$t_{Exp} = E * t_{TR} - t_L \pm t_j$

Table 14: Exposure timing mode, M=2, timing parameters

Image on demand mode (IOD) with exposure timer and frame duration timer

Bit group: e

Value: 3

This mode is also free-running (like **M=0**), but exposure time and frame duration is set accordingly, using the parameters **E** and **F**. Furthermore, the start of the exposure may optionally be synchronized to the rising edge of an externally applied synchronization pulse. Use parameter **T** to select the synchronization signal source. If any synchronization event takes place during exposure, the current frame may be exposed abnormally.

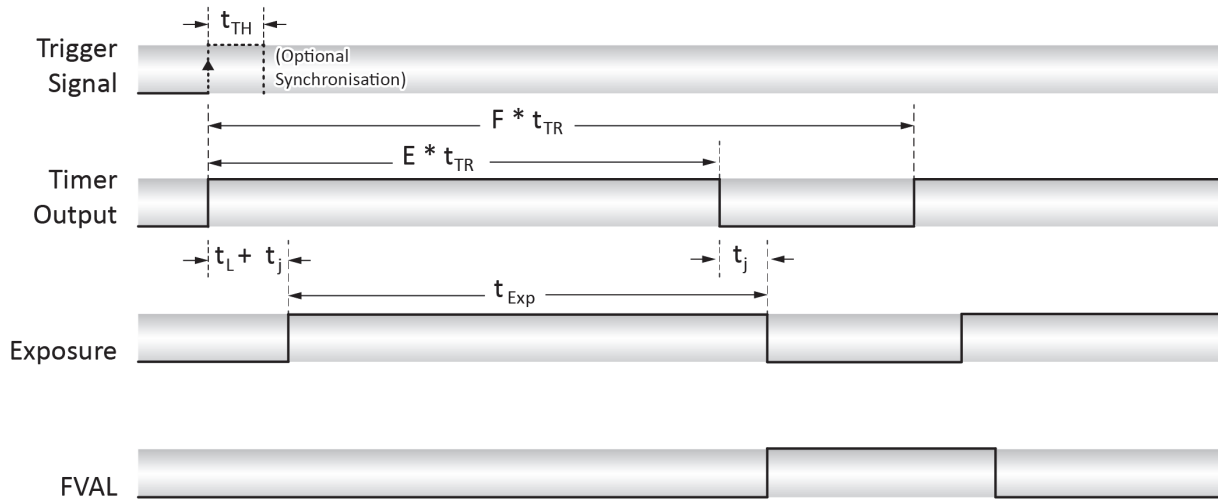


Figure 26: Exposure timing mode, M=3, flow diagram

Parameter	Value
Trigger High Duration (Sync Pulse)	$t_L < t_{TH} < F * t_{TR} - t_L$
Exposure Jitter	$0 < t_j < t_L$
Exposure Time	$t_{Exp} = E * t_{TR} - t_L \pm t_j$
Frame Duration	$F * t_{TR} \geq \max(t_{FDmin} + t_L, E * t_{TR} + t_L)$

Table 15: Exposure timing mode, M=3, timing parameters

PIV mode (bit group p)

Particle Image Velocimetry (PIV) is a contact-free method for tracking and visualizing the movement of particles in liquids or gases that travel at high velocity. At first, the position of identical particles in two subsequent images is determined. This allows to calculate speed and direction of the particles, in every part of the acquired images.

If PIV mode is enabled, the camera outputs two images for each trigger event. That way, it is possible to minimize the time between the exposure of the two images to the possible minimum. This improves the measuring precision at high velocities.

The evaluation always and only takes place between images of the same pair.

Basic working principle of the CMOS sensor

A basic understanding of the CMOS sensor's working principle is required to understand how the PIV mode of the Bonito operates. For that reason, a simplified short explanation is included below.

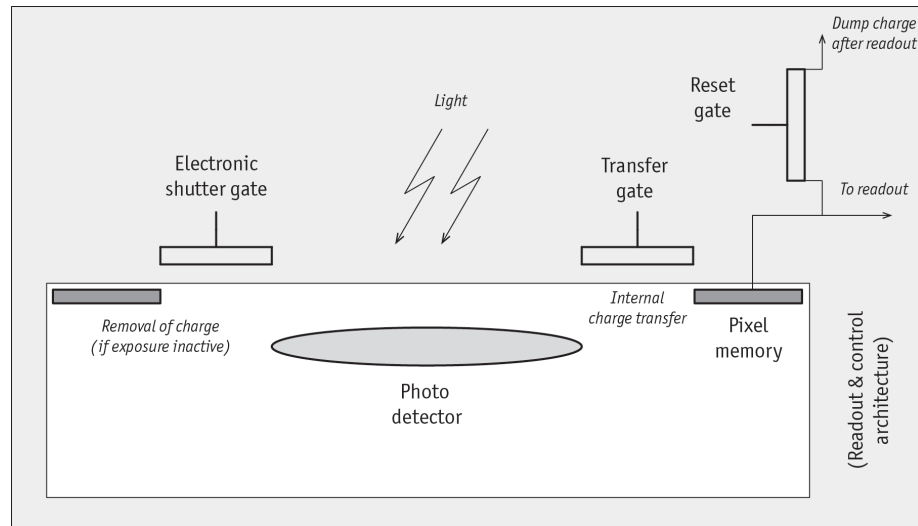


Figure 27: Simplified diagram of the CMOS pixel architecture

Each pixel of the sensor is a shutter pixel that includes a photo detector, a pixel memory, and a number of gates.

The photo detector accumulates the charge produced by light (exposure).

When the electronic shutter gate is open, the charge accumulated in the photo detector is removed, and the photo detector is reset. During exposure, the electronic shutter gate is closed.

When the transfer gate opens, the charge is transferred internally from the photo detector to the pixel memory. The photo detector keeps charging while the transfer takes place.

At readout, the charge from the pixel memory is converted into a digital signal that is output via the readout and control architecture to the Camera Link connection.

PIV sequence

Range	Either 0 (PIV mode off) or 4 (PIV mode on)
Default	0
Related	Parameter \mathcal{J}
Example	$\mathbf{M=4}$

($\mathbf{0x4 = bx100}$), sets the bit field to „- 0 0 - 1 0 0“.

- Activates Image on Demand mode (IOD) (weight = 0)
- Activates PIV mode (weight = 4)

- Sets Exposure feature mode to Standard (weight = 0)

For technical reasons, exposure control is not available in PIV mode, the exposure is permanently active (the reset gate in every pixel is always closed). This has two practical implications:

- A synchronized pulsed light source is necessary in order to generate relevant images that can be evaluated. To generate contrast-rich images, ambient light has to be minimized.
- To change the exposure time, change the frame rate. Exposure time of each image is directly determined by the frame rate. End of exposure is defined by the end of the internal charge transfer.

Note You cannot use the Exposure feature mode if the PIV mode is active.



There are two ways to control the frame rate:

- use parameter **F** to control the frame duration
- use an external trigger signal and apply parameter **T** to select the trigger source

However, the camera outputs two images per trigger event, therefore the highest trigger rate is limited to approx. half the usual (non PIV mode) rate.

www For practical applications of particle image velocimetry, refer to the AVT application notes online:



http://www.alliedvisiontec.com/fileadmin/content/PDF/Support/Application_Notes/PIV_Particle_Image_Velocimetry_en.pdf

Start of the PIV sequence

Since the exposure is always active, the sensor's photo-sensitive pixels are always integrating charge. No shutter control is available; exposure time is only determined by the frame rate.

The PIV sequence is triggered by the usual trigger input and timing settings of the camera. Each rising edge of the selected input signal starts the PIV sequence.

The trigger high duration t_{TH} should be shorter than the duration of $N+1$ lines, but at least 500 ns.

If not in Continuous mode, the time between two rising trigger edges must exceed $2 * ((N+1)+1)$ line durations t_L (see [Table 17: PIV mode timing parameters not depending on the setting of other parameters](#). on page 57).

If in Continuous mode, the camera is free-running and needs the time of $2 * ((N+1)+1)$ line durations t_L per PIV pair.

For that reason, the trigger signals' rising edge can be placed at least one line duration after the second readout of the previous PIV sequence is complete.

Internal charge transfer and readout

The internal charge transfer of the first image is started with some fixed delay and it takes the time of one line duration (t_L). The end of the charge transfer effectively terminates the exposure of the first PIV frame and internally starts exposure of the second PIV frame.

During any charge transfer, the sensor's photo detectors keep integrating charge. Even the charge that is newly integrated during the transfer process, is transferred to the sensor's pixel memory. I.e. a strobe or flash pulse that is fired during the charge transfer will contribute to the image.

Once the charge transfer for the first frame is completed, the new charge that integrates within the sensor's photo detectors, will contribute to the next frame.

The internal readout of the first PIV frame, from the sensor's pixel memory to the Camera Link output ports, starts directly after the end of charge transfer. It takes the time of $(N+1)$ line durations.

At the same time, the sensor's photo detectors continue to integrate charge, even during the readout process. The charge accumulated during this phase contributes to the exposure of the second PIV frame.

The internal charge transfer of the second PIV frame automatically starts directly after the internal readout of the first PIV frame is complete. It takes the time of one line duration (t_L), during which the sensor's photo detectors keep integrating charge for the second PIV frame.

When the charge transfer of the second PIV frame is complete, its internal readout starts automatically, which also takes the time of $(N+1)$ line durations.

During this phase, the exposure of the next first PIV image has already started. However, this image already belongs to the succeeding PIV image pair, which is not yet triggered at this stage.

After readout of the second PIV frame from the pixel memory is completed, the trigger may start the whole sequence anew. However, the camera needs at least one line duration of dead time before it is ready for the next trigger event, provided the camera is not configured to continuous mode (e.g. $M=4$).

Synchronization output

The synchronization output signal determines how the images are paired by externally communicating the start and end of each PIV sequences' first charge transfer. It allows to synchronize external devices, such as flashes, with the PIV sequence.

The falling edge at synchronization output signals that the charge transfer of the first PIV frame has begun (See [Figure 28: PIV mode flow diagram](#) on page 56). This requires the setting $J=1$, it may be used to trigger the first flash pulse, but the recommended guard interval t_{G1} of the flash pulse should not be undercut.

The rising edge at synchronization output signalizes externally that the exposure of the first PIV frame has ended. This requires setting $J=1$, and may be used to trigger the second flash pulse. The recommended guard interval t_{G2} will be kept automatically.

To move the second flash pulse closer to the first end of charge transfer, use an external timing device that is triggered by an external camera trigger or the previous falling edge of the synchronization output.

Depending on the synchronization output setting (parameter J), the corresponding pin at the camera's control connector may directly output the first charge transfer pulse for each PIV pair. By default, the falling edge of the synchronization signal always coincides with the beginning of the charge transfer of the first image, plus some delay (t_{S1}).

When the first charge transfer ends, the synchronization signal rises back to high level, again with a delay (t_{S2}).

The synchronization signal is accessible through pin 6 of the 15-pin D-sub connector. For more information about the synchronization signal, see section [Synchronization output \(pin 6\)](#) on page 26, and the chapter [Synchronization output \(J\)](#) on page 44.

Timing of the flash pulses

To ensure high quality image results, the flash pulses should contribute predominantly to the exposure of the images, also the ambient light should be minimized as much as possible.

The first strobe pulse should be placed shortly before the end of internal charge transfer of the first PIV frame.

The second strobe pulse should be placed after the end of internal charge transfer of the first PIV image.

To minimize the crosstalk between the first and the second image, do not shift the first strobe pulse position too close to the end of charge transfer. The guard interval time t_{G1} (see [Table 17: PIV mode timing parameters not depending on the setting of other parameters.](#) on page 57) is a recommended minimum. Depending on the application it may be adjusted individually.

For the same reason, the recommended minimum guard interval time t_{G2} (see [Table 17: PIV mode timing parameters not depending on the setting of other parameters.](#) on page 57) for the second strobe pulse should be kept, but depending on the application it may be adjusted individually.

Synchronization of the flash pulses can be realized e.g. by an external timing generator that generates a pair of strobe pulses. Alternatively, the synchronization can be implemented by using the corresponding output signal of the camera. For information on synchronization output see J in chapter [Synchronization output \(J\)](#) on page 44.

Examples $M=5$

($0x5 = 0b101$), sets the bit field to „- - 0 0 - 1 0 1“.

- Activates Image on Demand mode (IOD) (weight = 1)
- Activates PIV mode (weight = 4)

- Sets the Exposure feature mode to Standard. (weight = 0)
Even though the Exposure feature mode is set to Standard, not to Permanent Exposure mode, the exposure is always active, due to activation of the PIV mode.

M=7

(0x7 = 0b111), sets the bit field to „- - 0 0 - 1 1 1“.

- Activates Image on Demand mode (IOD) with exposure timer and frame duration timer mode (weight = 3)
- Activates PIV mode (weight = 4)
- Sets the Exposure feature mode to Standard. (weight = 0)

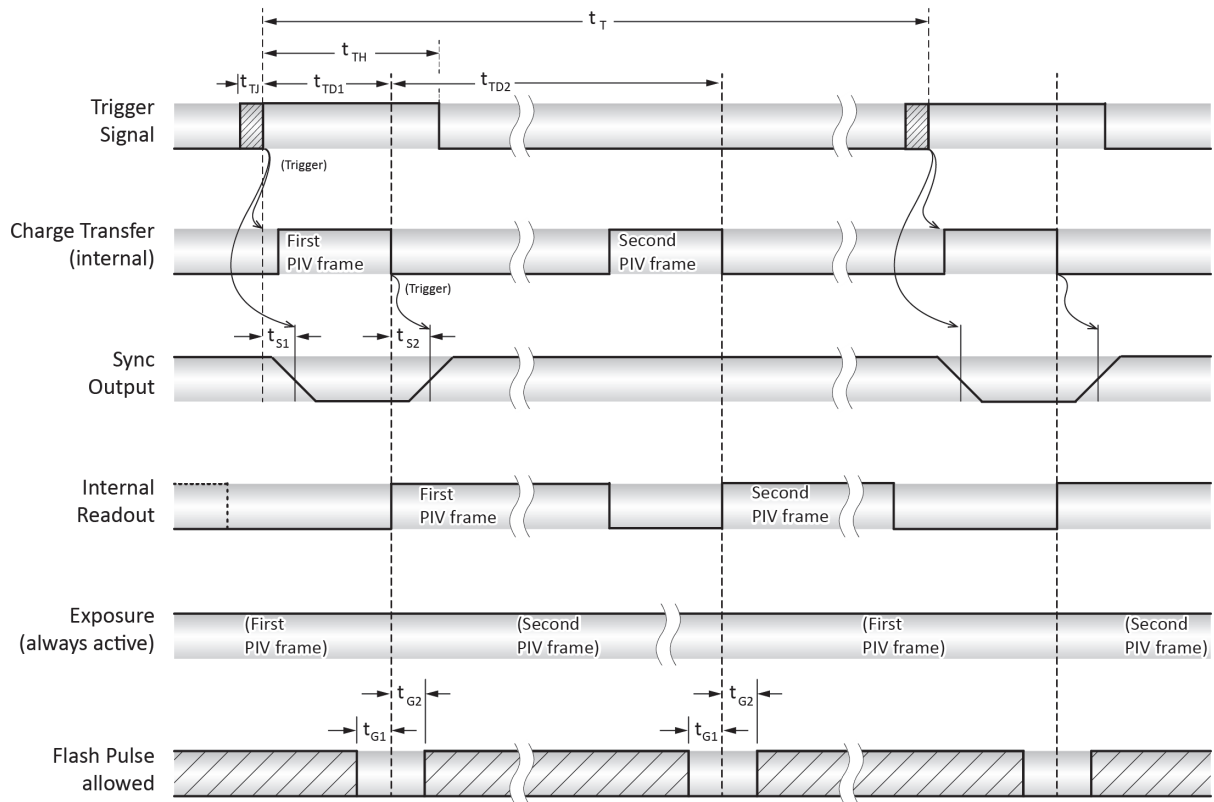


Figure 28: PIV mode flow diagram

Parameter	Value
Trigger rate requirement (or equivalent frame duration setting F)	$t_T > (2 * ((N + 1) + 1) + 1) * t_L$
Trigger high duration requirement (or equivalent exposure time setting E)	$t_{TH} < (N + 1) * t_L$ $t_{TH} > 500 \text{ ns}$

Table 16: PIV mode timing parameters - settings E and F depend on exposure timing mode setting of parameter M

Parameter	Value
First trigger to end-of-charge-transfer <i>delay</i>	$t_{TD1} = t_L + 250 \text{ ns}$ (@ T=2, typical) $t_{TD1} = t_L + 150 \text{ ns}$ (@ T=3, typical)
First delay to end-of-charge-transfer	$t_{TD2} = (N + 2) * t_L$
Trigger to end-of-charge-transfer <i>jitter</i>	$t_{TJ} < 25 \text{ ns}$
End-of-charge-transfer to sync <i>delay</i>	$t_{S1} = 800 \text{ ns}$ (@ T=2, typical) $t_{S1} = 700 \text{ ns}$ (@ T=3, typical)
Readout start to sync	$t_{S2} = 700 \text{ ns}$ typical
Guard interval 1	t_{G1} : t.b.d. (expected: $t_{G1} < 350 \text{ ns}$ typical)
Guard interval 2	t_{G2} : t.b.d. (expected: $t_{G2} < 350 \text{ ns}$ typical)

Table 17: PIV mode timing parameters not depending on the setting of other parameters.

Exposure feature mode (bit group f)

The exposure feature mode allows to switch between Standard mode, Enhanced full well mode and Permanent exposure mode.

Weight (hexadecimal)	Usage
0	Standard mode
16	Enhanced full well (3T) mode
32	Permanent exposure mode
48	(Reserved value)

Table 18: Exposure feature mode: possible values

Standard mode

Bit group: f

Weight: 0

Enhanced full well (3T) mode

Bit group: f

Weight: 10

The full image shutter is not available in this mode. Instead, the sensor operates in rolling shutter mode, the effective shutter time equals the image duration. For that reason, a synchronized strobe light is recommended.

Consequently, any exposure time setting controlled by Parameter **E** or by external signal is ignored.

The light should flash between two image readouts, which may be the duration of one line at highest possible image rate.

Decrease the image rate accordingly, if longer exposure times are needed. Use the sync output (RS232 driver at pin 6) for synchronization.

Permanent exposure mode

Bit group: f

Weight: 20

Use this mode to maximize the exposure time.

If activated, the exposure time equals the image duration.

Consequently, any exposure time setting controlled by parameter **E** or by external signal is ignored.

Number of lines (N)

The number of lines per frame is controlled with **N**. The actual line count is $N+1$, the default of **N=6BD** results into 1726 output lines. If the double ROI mode is active (**D=1**) the actual line count is doubled: $(N + 1) * 2$.

Parameter **N** also has an influence on the number of frames per second possible. Use the following formula to calculate the exact number:

- $\text{Max fps} = 1 / ((D + 1) * (N + 1) + 1 + \text{IOD}) * t_L$;

the parameters are explained in the table below

Parameter	Value
D	Parameter D
N	Parameter N

Table 19: Parameters for fps calculation

Parameter	Value
IOD	IOD=0 if Continuous mode (e.g. M=0), IOD=1 if not in Continuous mode
t_L	$t_L = 3 \mu\text{s}$ in single CL channel mode (e.g. S=0), $t_L = 1.5 \mu\text{s}$ in dual CL channel mode (e.g. S=1)

Table 19: Parameters for fps calculation

Range From 0 to **6BD**
Default **6BD**
Related Parameters **A**, **B**, **D**, **I**, and **M**
Example 1 **M=0**

S=0 [$t_L = 3 \mu\text{s}$]

D=0 (not for Bonito CL-400B/C 200fps cameras)

N (see table on next page)

Setting	No. of lines	Minimum frame duration t_{FDmin}	Frame rate/fps
N=6BD	1726	5.181 ms	193.01
N=681	1666	5.001 ms	199.96
N=14B	332	0.999 ms	1001.0
N=1F	32	0.099 ms	10101
N=0	1	0.006 ms	166667

Table 20: Timing examples (M=0, S=0, D=0)

Example 2 **M=0**

S=1 [$t_L = 1.5 \mu\text{s}$]

D=0 (not for Bonito CL-400B/C 200fps cameras)

N (see table below)

Setting	No. of lines	Minimum frame duration t_{FDmin}	Frame rate/fps
N=6BD	1726	2.5905 ms	386.03
N=681	1666	2.5005 ms	399.92
N=14B	332	0.4995 ms	2002.0
N=1F	32	0.0495 ms	20202
N=0	1	0.0030 ms	333333

Table 21: Timing examples (M=0, S=1, D=0)

Note

- Consider the number of lines in minimum frame duration calculations for the image on demand (IOD) mode.
- For more information about calculation of the minimum frame duration and dependent IOD mode timing constraints, see chapter [Exposure control mode \(M\)](#) on page 45.

Camera Link output mode setting (S)

The parameter **S** controls how the camera outputs pixel data to the Camera Link interface.

- For more information about how the resulting image is reconstructed in the various modes, see chapter [Pixel order](#) on page 33.
- For more information about pixel output timing, see chapter [Timing \(FVAL, LVAL, PCLK\)](#) on page 35.

Valid values: Either 0, 1, 3, 5, or 7

Default 0

Related Parameters **s**, **T**

Examples (see settings table below.)

Setting	Function
S=0	<ul style="list-style-type: none"> • Mode: Single channel mode • Frame rate: 193 fps • Line length: 2320 pixels • The camera utilizes one Camera Link 80-bit channel in 10-tap configuration. It allows only half of the maximum frame rate but also produces less noise in the image because the sensor clock frequency is reduced. (To be continued on next page.)
S=0	(Continued from previous page.) The preferred Camera Link connector pair for this mode is the left channel 02 / 01, but the other pair (04 / 03) also outputs all pixel data. The CC signals and SerTC / SerTFG are handled separately per channel. That means for example the trigger source selection (T) and serial port configuration (s) might need adjustments if 04 / 03 are used. The Bonito CL-400B/C 200fps provides only one channel at the connectors CL1/CL2.

Table 22: Camera Link output settings.

Setting	Function
S=1	<ul style="list-style-type: none"> • Mode: Dual channel mode (not for Bonito CL-400B/C 200fps) • Frame rate: 386 fps • Line length: 2 x 1160 = 2320 pixels <p>The image is split vertically into a left and a right half. Each half has a horizontal size of 1160 pixels and is output separately via its own Camera Link 80-bit channel. The left half travels via the left Camera Link channel at the connectors 02 / 01 and the right half travels via 04 / 03 respectively.</p>
S=3	<ul style="list-style-type: none"> • Mode: Dual channel mode (not for Bonito CL-400B/C 200fps) • Frame rate: 386 fps • Line length: 2 x 1120 = 2240 pixels <p>This mode is the same as S=1, with the difference of a shortened line length. For frame grabber compatibility reasons 40 pixel columns at the left and right side of the full image are dropped so that the line length of each image half is divisible by 16.</p>
S=5	Same as S=1 , but with right image half via 02/01 and left image half via 04/03 (if available).
S=7	Same as S=3 , but with right image half via 02/01 and left image half via 04/03 (if available).
(Others)	Reserved for future use.

Table 22: Camera Link output settings.

Trigger source selection (T)

This parameter selects the signal source for triggering and exposure control.

For more information about usage of the selected signals: see chapter [Exposure control mode \(M\)](#) on page 45.

Range	Either 0, 2, 3, or 4
Default	3
Related	Parameter M
Example	T=2 Select the optocoupler input at pins 10 and 11 of the I/O connector as trigger source

Setting	Function
T=0	No input selected.
T=2	Optocoupler OK1 at pins 10 and 11 of the control connector.
T=3	CC1 at the Camera Link connector 02 or CL1 (default).
T=4	CC1 at the Camera Link connector 04.
(Others)	Reserved for future use.

Table 23: Trigger source selection (T)

Note

For more information:
 see chapter [Trigger input \(pin 10-11\)](#) on page 27
 and chapter [Trigger inputs \(CC1\)](#) on page 32.

Metadata overlay and test image generator (U)

The Bonito can overlay the image's first pixels with some bytes of metadata, such as a hardware frame counter. The frame counter increments for each image read out from the sensor. This helps to increase system reliability by detecting missing frames on the host system. In dual channel mode (**S=1** or **S=3**) it can also be used to join the two related image halves because they have the same counter value.

Furthermore, to test the Camera Link cabling and frame grabber operability, a test image generator is available. It forces the camera to output an almost fixed test image containing grey wedges, black and white stripes with various frequencies and edge markers.

Range	Either 0 , 1 , 10 , or 11
Default	0
Related	Parameters C , D , G , N , and M
Examples	(see settings table below.)

Setting	Function
U=0	Normal image output.

Table 24: Trigger source selection (T)

Setting	Function
U=1	Enable metadata overlay The overlay occupies the first (top left) 8 pixels of each frame. Metadata format for the left Camera Link channel (connectors 02/01 or CL1/CL2): <ul style="list-style-type: none"> Pixel offset 0–3 (4 bytes): constant ASCII characters <i>CM4L</i> Pixel offset 4–7 (4 bytes): 32-bit frame counter, LSB first (Intel format) Metadata format for the right Camera Link channel (connectors 04/03): <ul style="list-style-type: none"> Pixel offset 0–3 (4 bytes): constant ASCII characters <i>CM4R</i> Pixel offset 4–7 (4 bytes): 32-bit frame counter, LSB first (Intel format)
U=10	Enable test image generator. Full test image appears with N=6BD , I=1 , G=0 and D=0 .
U=11	Enable metadata overlay and test image generator.
(Others)	Reserved for future use

Table 24: Trigger source selection (T)

Note

- The effective image size and also the frame rate depend on the corresponding camera settings such as e.g. **D**, **N** or **M**. Edge markers are only fully visible if all 1726 active lines are output.
- The digital gain setting **G** also applies to the test image, but the FPN correction **c** is temporary disabled.

Dark value offset (**W**)

Dark value offset is an 8-bit parameter that is added to the pixel data. It adjusts the dark level and avoids clipping of pixels to black in low-light situations. The eight bits are aligned to the lowest significant bit of the 10-bit raw pixel data from the sensor.

If the digital gain is not active (**G=0**), each increment of four increases the output grey level just by one count.

Version information (**V**)

The command **v** displays information about the camera model and firmware version.

```
>v
Bonito CMOS High-Speed Camera
Version: CMC.040.xx.yy
>
```

Save parameters (X)

Use the command **x=1** to store all parameter values into the embedded flash memory. After a re-start they are automatically restored.

Note Acquired FPN correction data is not stored and is, therefore, lost after switch-off.



See chapter [Fixed pattern noise \(FPN\) correction \(C\)](#) on page 39.

Parameter summary (Y)

The command **y** shows a summary of all current parameter value settings.

Reset to factory defaults (Z)

The command **z=1** sets the camera into a factory default state. To save the new parameter configuration, the command **x=1** has to be executed afterwards.

The default settings are:

```
A=0000
B=0000
C=00
D=00
E=000006BE
F=000006BF
G=00
I=01
J=01
K=A7
M=00
N=06BD
S=00
```


T=03**U=00****W=18****s=2A**

>

Note

The serial interfaces are not reinitialized by **z=1**. The baud rate does not change until re-start of the camera or explicitly writing a new value to the serial interface configuration parameter **s**.

Serial number (a)

The camera's serial number is stored as 16-bit value. Use the command **a** to read it.

Product variant code (b)

The product variant code is a 16-bit number unambiguously identifying the camera variant. Use command **b** to read it.

b	Article number	Camera variant
0000	1064000	CMC-4000 / C-Mount
0001	1064001	CMC-4000 / F-Mount
0002	1064002	CMC-4000 / EF-Mount
0010	1064010	CMC-4000C / C-Mount
0011	1064011	CMC-4000C / F-Mount
0012	1064012	CMC-4000C / EF-Mount
4000	4064000	Bonito CL-400B
4001	4064001	Bonito CL-400B F-Mount
4002	4064002	Bonito CL-400B EF-Mount
4010	4064010	Bonito CL-400C
4011	4064011	Bonito CL-400C F-Mount
4012	4064012	Bonito CL-400C EF-Mount
4020	4064020	Bonito CL-400B 200fps
4021	4064021	Bonito CL-400B F-Mount 200fps

Table 25: Product variant code (b)

b	Article number	Camera variant
4022	4064022	Bonito CL-400B EF-Mount 200fps
4030	4064030	Bonito CL-400C 200fps
4031	4064031	Bonito CL-400C F-Mount 200fps
4032	4064032	Bonito CL-400C EF-Mount 200fps
4100	4064100	Bonito CL-400BS
FFFF	-	Unknown / test / prototype

Table 25: Product variant code (b)

Serial control interface configuration (s)

Use parameter **s** to set up the serial control interface of the camera, such as baud rate, enable state, or echo mode.

- Range** From **0** to **FFFF**.
 Since the parameter **s** is divided into three different sub-fields (see further below), the following ranges cover all possible uses of this parameter. It is recommended not to use parameters that are outside the defined ranges.
0 to A, 20 to 2A, 40 to 4A, 60 to 6A, 80 to 8A, A0 to AA, C0 to CA, E0 to EA.
- Default** **2A** (115,200 Baud, additionally activates second channel via Camera Link connector 02, each character received from the host is echoed back to it.)
- Related** Three sub-fields are available to control the serial control interface, of the **Bonito CL-400B/C**:
- Baud rate of the serial ports
 - Echo mode
 - Enable state of the serial ports

All of these sub-fields are controlled by the parameter **s**, however, each of them works independently from the other sub-fields. The sub-fields are represented by bit groups of different size within the parameter **s**.

Bit group	Sub-field description
x	Controls the baud rate of the serial ports.
a	Controls the enable state of the serial ports.
e	Controls the echo mode.

Table 26: Attribution of bit groups and sub-fields

F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-	e	a	a	-	x	x	x	x
-	-	-	-	-	-	-	-	rw	rw	rw		rw	rw	rw	rw

Table 27: Order of bit groups within parameter **s**

To set a sub-field to a certain value, modify the associated bit group by allocating **s** to the appropriate hexadecimal number.

Since all of the sub-fields are set using the parameter **s**, it is only possible to set all of them at the same time. The value of **s** is calculated as the aggregate sum of the hexadecimal values that are set to each of the three sub-fields.

The table below shows the hexadecimal values that can be set for each sub-field. To work out the final value for **s**, select the usage for each sub-field, then add the corresponding hexadecimal values.

Bit values	Settings	Weight (hexadecimal)
Baud rate of the serial ports		
xxx-0000	110 Baud *	0
xxx-0001	300 Baud *	1
xxx-0010	600 Baud *	2
xxx-0011	1,200 Baud *	3
xxx-0100	2,400 Baud *	4
xxx-0101	4,800 Baud *	5
* Baud rates up to 4,800 Baud are not available via Camera Link.		
xxx-0110	9,600 Baud	6
xxx-0111	19,200 Baud	7
xxx-1000	38,400 Baud	8
xxx-1001	57,600 Baud	9
xxx-1010	115,200 Baud	A
Enable state of the serial ports		
x00-xxxx	RS232 via 15-pin D-sub connector only.	0
x01-xxxx	Additionally activates second channel via Camera Link connector 02.	20
x10-xxxx	Additionally activates second channel via Camera Link connector 04.	40
x11-xxxx	Additionally activates second channel via Camera Link connector 02 and 04.	60

Table 28: Baud rate: hexadecimal weights for each setting

Bit values	Settings	Weight (hexadecimal)
Echo mode		
0xx-xxxx	Each character received from the host is echoed back to it.	0
1xx-xxxx	No echo	80

Table 28: Baud rate: hexadecimal weights for each setting

Example 1 **s=29**

(**0x29 = bx101001**), sets the bit field to „0 0 1 - 1 0 0 1“

- Sets the baud rate to 57,600 Baud (weight = **9**)
- Activates second channel via Camera Link connector 02 (weight = **20**)
- Each character received from the host is echoed back to it (weight = **0**)

Example 2 **s=16**

(**0x16 = bx10110**), sets the bit field to „0 0 1 - 0 1 1 0“

- Sets the baud rate to 9,600 Baud (weight = **6**)
- Activates second channel via Camera Link connector 02 (weight = **20**)
- Each character received from the host is echoed back to it (weight = **0**)

Example 3 **s=AA**

(**0xAA = bx10101010**), sets the bit field to „1 0 1 - 1 0 1 0“

- Sets the baud rate to 115,200 Baud (weight = **A**)
- Activates second channel via Camera Link connector 02 (weight = **20**)
- No echo (weight = **80**)

Show Help text (?)

The command ? shows an embedded command reference text at the serial terminal. It lists a short description for each command available in the firmware.

Bayer filter mosaic pattern

The color variants of the Bonito are equipped with a Bayer filter mosaic on the image sensor that is aligned to the top left corner of the sensor as shown in the following pattern:

G	R	G	R	...
B	G	B	G	...
G	R	G	R	...
B	G	B	G	...
...

Changing the output mode (parameter **S**) does not affect the pattern alignment in the output image. On the other hand, modifying the ROI settings (**A**, **B**, **D**, **I**, **N**) may lead to misalignments. Observe consistent mapping of even and odd sensor rows to even and odd rows in the output image when changing the ROI settings.

Appendix

Command reference

This chapter describes the general command reference of the **Bonito CL-400B/C** firmware. It can be output to the camera's serial interface by sending the command **?=1**.

Bonito CL-400 and CMC-4000 Series Command Reference

=====

Referenced Firmware...: CMC.040.01.07
Document Version.....: 06 / 02.02.2012

(C) Allied Vision Technologies GmbH

General Information

Each command consists of a command letter, optionally followed by an equality sign and a parameter value in hexadecimal number representation. The command letter is case sensitive. Hexadecimal values are always upper case and are 1 to 8 digits long. The command is activated by sending a carriage return character ([CR], ASCII character number 0x0D). Serial communication operates in echo mode by default. This means that each character received by the module is echoed back to the PC.

Example (set Baudrate to 115200 Baud, RS-232 only):
s=A[CR]

After successful execution of the command, the command prompt character ">" is output. If any error occurred, somewhere previous to the prompt a question mark character "?" is displayed.

To query a parameter value, send the corresponding command letter followed by the equality sign and a question mark character:
s=?[CR]

If the intended action does not need any parameter, it is also sufficient - as a shortcut - to send the command letter only, directly followed by [CR].

At the beginning of a command sequence it is good practice to check the serial communication by sending just a [CR] to the camera and verify that the command prompt ">" is returned. There is an input buffer holding a few characters but no hardware handshake. a sequence of commands should not be send to the camera without awaiting the intermediate input prompts. Otherwise the camera's serial input buffer may overflow.

How to use Help

To see this help text type the following command:
?[CR]

Conventions

<p8> : 8 bits long parameter value (1 to 2 Hex characters)
 <p16> : 16 bits long parameter value (1 to 4 Hex characters)
 <p32> : 32 bits long parameter value (1 to 8 Hex characters)
 <aa**_bcbb> : 8 bits long parameter (resulting in two hex chars) consisting of bit fields. The function of each bit field is described, like this:

- "aa" : Lower case letters label the bits of interest.
- "**" : Reserved, should be written as "0", read undefined.
- "_" : Separation character for readability.
- "bcbb" : Bit fields may have any length and can be split up.

(*) : Some commands are only accessible in a special password protected service mode.

Command and Parameter Overview - Service Mode

a=<p16> : Set the serial number A and save it to flash. In user mode read access to this value is available. (*)

b=<p16> : Set the product variant code and save it to flash. In user mode read access to this value is available. (*)

c=<p8> : Configure the FPGA with data from the specified file number. (*)

d=<p8> : Delete the file with the specified file number. (*)

e=<p8> : Erase the flash. (*)

- e=0 : Erase used blocks only.
- e=FF : Erase all blocks.
- Other Values: Reserved / undefined.

f=<p16> : Write a data byte to an FPGA register. (*)

- High Byte : Data value to write, 0 if omitted.
- Low Byte : Address of the register.

g=<p16> : Read data bytes from FPGA registers at specified address. (*)

- High Byte : Number of sequential bytes to read. Set the most significant bit in order to reverse the byte output order. If high byte is omitted, a default count value of 1 is assumed.
- Low Byte : Base address to read from. On forward byte order the address is incremented until it reaches [base]+[count]-1. On reverse byte order the output starts at [base]+[count]-1 and is decremented down to [base].

l=1 : List contents of the flash file directory. (*)

v=<p8> : View contents of the specified file. (*)

```

z=1          : Reload parameters from file. (*)

O=<p8>       : File number of the file containing the FPGA configuration
              data. (*)

P=1         : Upload a new FPGA configuration file via the serial
              interface and store it in the flash memory. After issuing
              <CR> a special transfer protocol is processed. A currently
              existing file will be overwritten. (*)

Q=<p8>       : Upload a general file via the serial interface and store
              it in the flash memory using the specified file number.
              After issuing <CR> a special transfer protocol is processed.
              A currently existing file will be overwritten. (*)

```

Command and Parameter Overview - User Mode (Lower Case)

```

-----

p=<p16>      : Internal system parameter. Change this setting only if you
              know what you are doing!
              <ssss_ssss_cccc_cccc>
              \_____| \_____|
              |           +---c: Camera Link clock phase. Modify
              |           |           this byte value a few steps up or
              |           |           down to optimize the phase of the
              |           |           Camera Link clock. It may
              |           |           eventually improve data
              |           |           transmission reliability with
              |           |           long cable runs in some cases.
              |           +-----s: Internal system parameter. Do not
              |           |           change this byte at all. To modify
              |           |           the other bitfield "c" please first
              |           |           read all bits of p=<p16> from the
              |           |           camera, modify only the bits of "c"
              |           |           and write back the complete value
              |           |           including the "s"-bits unchanged.

s=<p8>       : Configure the UART(s) for serial communications. Changes are
              activated immediately.
              <eaa*_bbbb>
              |\| \__|
              ||      +---b: Baud rate of the main RS-232 UART available
              ||      |           at the 15-pin D-sub connector and the second
              ||      |           channel UART via Camera Link. The second
              ||      |           channel UART supports 9600 to 115200 Baud
              ||      |           only (x). Both channels share the same
              ||      |           receive buffer and output characters are
              ||      |           always sent to both. the two channels
              ||      |           are not intended for completely concurrent
              ||      |           use.
              ||      |           0 -> 110 Baud.
              ||      |           1 -> 300 Baud.
              ||      |           2 -> 600 Baud.
              ||      |           3 -> 1200 Baud.
              ||      |           4 -> 2400 Baud.
              ||      |           5 -> 4800 Baud.
              ||      |           6 -> 9600 Baud. (x)

```



```

| |          7 -> 19200 Baud. (x)
| |          8 -> 38400 Baud. (x)
| |          9 -> 57600 Baud. (x)
| |          A -> 115200 Baud. (x)
| +-----a: Second channel UART port selection.
|           00 -> Second channel UART off.
|           01 -> Activate second channel via Camera
|                   Link connector O2 (or CL1).
|           10 -> Activate second channel via Camera
|                   Link connector O4 (if available).
|           11 -> Activate second channel via Camera
|                   Link connector O2 (or CL1) and O4.
+-----e: Echo suppression.
           0 -> Each character received from the host
               is echoed back to it.
           1 -> No echo.

```

Command and Parameter Overview - User Mode (Upper Case)

A=<p16> : Start value for line address counter A. It sets the line address of the image's first line read out from the image sensor. After processing each line the address is incremented by the amount specified by I=<p8>. See N=<p16> for number of lines per image. Valid range 0...6BF (decimal: 0...1727).

B=<p16> : Start value for line address counter B. It sets the line address of the second ROI's first line read out from the image sensor. After processing each line the address is incremented by the amount specified by I=<p8>. See N=<p16> for number of lines per image. This parameter is only used in double ROI mode. Please see command D=<p8> for details. Range 0...6BF (decimal: 0...1727).

C=<p8> : Mode and control of the fixed pattern noise (FPN) correction. Please note that correction data is volatile and has to explicitly be acquired at least once after switching on the camera.

```

<****_**sm>
| |
| +-m: Mode of fixed pattern noise correction.
|     0: No correction is applied.
|     1: Acquire new fixed pattern noise correction
|         data and apply it to the image. To
|         successfully complete the procedure ensure
|         continous image output by e.g. setting
|         M=0. For optimum quality please totally
|         darken the sensor during data acquisition.
|         Avoiding bright light sources might also
|         be sufficient, but a residual image may
|         occur. Please note that saving the
|         correction state with X=<p8> will activate
|         the correction at start of the camera
|         without correction data. This leads to an
|         uncorrected image until new correction
|         data has explicitly been reacquired.

```

- +--s: Suppression of new data acquisition. This bit is write-only and reads always 0. Write C=3 to reactivate the fixed pattern noise correction from the state C=0 without the correction data being reacquired as C=1 would do.
- D=<p8> : Double ROI mode. Can be used to read out two independent areas of the same size into one output image. This is useful to gain speed due to dropping unneeded lines between two areas of interest. Also field separation for interlaced mode can be obtained. The top half of the output image consists of the lines A, A+I, A+2*I, ..., A+N*I and the bottom half consists of the lines B, B+I, B+2*I, ..., B+N*I. the resulting image size is (N+1)*2. Please see parameters A=<p16>, B=<p16>, I=<p8> and N=<p16> for more details.
- 0: Single ROI mode. Image size is (N+1) lines.
 - 1: Double ROI mode. Image size is (N+1)*2 lines.
- Parameter B=<p16> specifies the address of the first line of the second half. Please note that due to the increased image size (N+1)*2 also the minimum frame duration increases from (N+1) + 1 to (N+1)*2 + 1.
- E=<p32> : Exposure time. The time resolution depends on the prescale value K=<p16>. Please note that the exposure time is only active when the trigger mode M=<p8> is set accordingly.
- F=<p32> : Frame duration. The time resolution depends on the prescale value K=<p16>. Please note that the frame duration is only active when the trigger mode M=<p8> is set accordingly.
- G=<p8> : Digital gain.
- 0: Gain factor 1.
 - 1: Gain factor 2.
 - 2: Gain factor 4.
- I=<p8> : Increment value of the line address counters A and B. After processing each line this value is added to the current line address. Valid range 1...FF (decimal: 1...255).
- J=<p8> : Configuration of synchronization output at pin 6 of the control connector. This pin delivers RS232 voltage levels (+/- 6 volts) with a delay of less than 800 ns. The logic is negative, meaning +6 V = LOW and -6 V = HIGH.
- ```
<****_n*ss>
| \ |
| +--s: Signal source selection.
| 0: Effective sensor exposure.
| 1: Charge transfer pulse. Active for one line
| duration at the end of exposure, end of
| this pulse marks the end of exposure and
| at the same time start of sensor readout.
| In PIV mode (see M=<p8>) this pulse occurs
| at the exposure end of only the first
| image of each PIV pair.
| 2: Effective sensor readout.
| 3: Exposure phase. Contrary to 0 this setting
| shows the "exposure phase" of the state
| machine and not the effective exposure
```

```

| of the sensor. This allows to synchronize
| external devices even if the sensor is in
| permanent exposure mode. See M=<p8> for
| details about permanent exposure.
+-----n: Invert the logic levels of the sync output.

K=<p16> : Timer prescale value. The basic clock frequency of 56 MHz is
 divided by the prescale value (K+1) to generate the time base
 for exposure time E=<p32> and frame duration F=<p32>. A value
 of K=37 (decimal: 55) leads to a timer resolution of 1µs, for
 example. To minimize jitter effects it is recommended to set
 this value to a multiple of the current line duration, which
 is K=A7 for single channel mode (e. g. S=0) or K=53 for
 dual channel mode (e. g. S=3).

M=<p8> : Exposure control.
<***ff_*pee>
 \ | | \ |
 + | +-e: Exposure timing mode.
 | | 0: Continuous mode. The camera outputs images
 | | as fast as possible in a free running
 | | mode. The gap between two images is only
 | | one line, the total frame duration
 | | takes N+2 lines (or (N+1)*2 + 1, if double
 | | ROI mode is active). The exposure time is
 | | nearly equal to the frame duration.
 | | 1: Image on demand mode (IOD). The exposure
 | | is directly controlled by an externally
 | | applied signal. Use parameter T=<p8> to
 | | select the signal source. A rising edge at
 | | the corresponding input starts exposure
 | | synchronized to the line after the next.
 | | If the rising edge occurs during idle (the
 | | camera is not transmitting an image), then
 | | the jitter is reduced. In this case
 | | exposure will start with a constant delay
 | | of about two line durations. The following
 | | falling edge stops exposure in any case
 | | and starts output of the image
 | | synchronized to the next line. The next
 | | exposure must start later than
 | | (N+1)+1 line periods after the previous
 | | rising edge. To be safe consider one line
 | | jitter reserve, i.e. (N+1)+2. With D=1
 | | setting replace the term (N+1) by (N+1)*2.
 | | 2: Image on demand mode (IOD) with exposure
 | | timer. The exposure time is controlled by
 | | the parameter E=<p32>. Each rising edge of
 | | an externally applied signal starts the
 | | exposure. Use
 | | parameter T=<p8> to select the signal
 | | source. The next rising edge must
 | | arrive later than (N+1)+1 line periods
 | | after the previous rising edge. To be safe
 | | consider one line jitter reserve, i.e.
 | | (N+1)+2. With D=1 setting replace the term
 | | (N+1) by (N+1)*2.
 | | 3: Image on demand mode (IOD) with exposure

```

```

| | timer and frame duration timer. The
| | exposure time is controlled by the
| | parameter E=<p32>. The frame duration is
| | controlled by the parameter F=<p32>. Start
| | of the exposure can be synchronized to the
| | rising edge of an externally applied
| | signal. Use parameter T=<p8> to select the
| | signal source. Frame duration F=<p32> must
| | not be less than (N+1)+1 line periods
| | after the previous rising edge. To be safe
| | consider one line jitter reserve, i.e.
| | (N+1)+2. In the special case of K=A7 a
| | jitter reserve is not necessary, because
| | timer resolution is exactly one line
| | period. With D=1 setting replace the term
| | (N+1) by (N+1)*2.
+---p: Particle Image Velocimetry (PIV) mode. If
| enabled, the camera outputs two images per
| trigger event. If not in continuous mode the
| time between two rising edges must exceed
| 1+2*((N+1)+1) line durations. The trigger
| high duration should be less than N+1 line
| durations, but at least 500 ns. After a delay
| of one line duration plus 150 ... 250 ns
| (depending on the used trigger input type) from
| rising edge of the trigger input, the exposure
| of the first PIV image ends and its readout
| process begins. The exposure is permanently
| active in this mode, for a usual PIV
| application the first light strobe can also
| start before the trigger input event. In any
| case it should end a few 100 ns before start of
| readout. After a guard interval of a few 100 ns
| ... 1000 ns the second light strobe may begin.
| The exact position and length of the guard
| interval depends on the allowable crosstalk
| for the application and should be tested
| individually. See J=<p8> for synchronization
| output.
+-----f: Exposure feature mode.
| 0: Standard mode.
| 1: Enhanced full well (3T) mode. The full
| frame shutter is not available in this
| mode. Instead, the sensor operates in
| rolling shutter mode with an effective
| shutter time equaling the frame duration.
| a synchronized strobe light is
| recommended. Consequently any exposure
| time setting, controlled by E=<p32> or by
| external signal, is ignored. The light
| should flash between two
| image readout operations, which may be the
| duration of one line at highest possible
| frame rate. Decrease the frame rate
| accordingly, if longer exposure times are
| needed. Use exposure output (opto coupler
| at pins 12/13) or sync output (RS232
| driver at pin 6) for synchronization.

```

- 2: Permanent exposure mode. Used to maximize the exposure time. If activated, the exposure time equals the frame duration. Consequently any exposure time setting, controlled by E=<p32> or by external signal, is ignored.
- 3: Reserved.
- N=<p16> : This parameter sets the number of lines per frame. The actual line count is N+1, the default of N=6BD results into 1726 lines. If the double ROI mode is active (D=1) the actual line count is (N+1)\*2. Please consider this in minimum frame duration calculations for the image on demand (IOD) mode (see M=<p8>). See also parameters A=<p16>, B=<p16>, D=<p8> and I=<p8> for more information regarding sensor line addressing. Valid range 0...6BF (1 to 1728 lines).
- S=<p8> : Sensor mode control.  
 <\*\*\*\*\_ \*ccc>  
 \\_ |  
 +-c: Channel mode configuration.
- 0: Single channel mode (half pixel clock speed). Full line length of 2320 pixels is output at the Camera Link connectors O2/O1 (or CL1/CL2). The data is mirrored at O4/O3 (not available in all variants), but note that the CC signals and SerTC/SerTFG are handled separately. e.g. the trigger source selection (T=<p8>) and serial port configuration (s=<p8>) might need adjustments if only the connectors O4/O3 are connected to a frame grabber.
  - 1: Dual channel mode (full pixel clock speed). The image is split vertically into a left and a right half. each half has a horizontal size of 1160 pixels and is output separately on its own Camera Link 10-tap channel. The left half travels via the left Camera Link channel at the connectors O2/O1 (or CL1/CL2) and the right half travels via O4/O3 (not available in all variants) respectively.
  - 3: Dual channel compatibility mode (full pixel clock speed). This mode basically is the same as S=1. For frame grabber compatibility reasons 40 pixel columns at the left and right side (of the full image) are dropped so that the line length of each half image is divisible by 16. The effective line length in this mode is 2 x 1120 = 2240 pixels.
  - 5: Same as mode 1, but with right image half via O2/O1 (or CL1/CL2) and left image half via O4/O3 (if available).
  - 7: Same as mode 3, but with right image half via O2/O1 (or CL1/CL2) and left image half via O4/O3 (if available).

All other values are reserved.

- T=<p8> : Trigger source selection.  
 0: None.  
 2: OK1 at control connector.  
 3: CC1 at O2 connector (or CL1).  
 4: CC1 at O4 connector (if available).  
 All other values are reserved.
- U=<p8> : Metadata overlay and test image.  
 <\*\*\*t\_\*\*\*m>  
 | |  
 | +-m: Metadata overlay mode.  
 | 0: No overlay.  
 | 1: Show metadata in each frame starting at  
 | the first pixel of the first line.  
 +-----t: Test image generator.  
 0: Normal image output.  
 1: Test image generator is active.
- V=1 : Show model and firmware version information. Use V=2 for a more detailed output.
- W=<p8> : Dark value offset. This value is added to the pixel data. It is used to adjust the dark level and avoid clipping of pixels to black in low light situations. The eight bits are aligned to the lowest significant bit of the 10-bit raw pixel data from the sensor. If the digital gain is not active (G=0), each increment of four increases the output grey level just for one count.
- X=1 : Store the current parameter configuration to the flash.
- Y=1 : Show the current parameter configuration.
- Z=1 : Load the factory default parameter configuration. The saved configuration is only affected if you store the reset parameter values with X=1 afterwards.

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