Preliminary

Operating and user manual

QS-4A60 - QS-2A120

Adimec

About Adimec

Adimec is the leading supplier of high-performance digital camera modules and camera-lens assemblies for use in three market segments: machine vision, medical imaging, and applications for government purposes such as traffic and defense systems. In developing our products as a partner to major OEMs around the world, we utilize the synergy between these segments to shine in terms of image quality, speed, dynamic range and reliability.

Adimec is the only company in the market that weds the specific needs of its highly demanding customers to its technological inventiveness, generating vision solutions of exceptional quality. These industry-leading customer specials are the models for our standard products.

Thanks to this unique approach, Adimec's solutions add crucial competitive value to our customers' high-end systems and their applications, as they yield brilliant results to the users of those systems.

The Netherlands-based holding company has business offices in Europe, the United States, Japan, and Singapore. For more detailed information about Adimec and our products you can visit our website www.adimec.com or you can contact your local dealer or the business offices in your region:

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1. General introduction

The Qs-4A60m, Qs-4A60c, Qs-2A120m and Qs-2A120c are members of a family of high resolution CMOS cameras that offer a unique combination of high speed, global shutter operation, CCD like image quality and reliability. Unlike competitors who are offering general purpose cameras, our products are developed with the specific needs of OEMs and their applications in mind.

1.1 Product Highlights

The Qs-4A60 and Qs-2A120 cameras offer the following features:

- Up to 2048 x 2048 maximum image resolution
- High quality images on account of sophisticated internal processing
- Full a-synchronous image capture
- Lowest noise attainable to global shutter CMOS sensor
- Programmable interface speed
- Programmable region of interest
- Camera Link Base interface

1.2 About this manual

This manual provides the necessary information for setting up, operating and troubleshooting the camera.

We strongly recommend reading this manual before you unpack or operate the camera.

The manual is applicable to both Qs-4A60 and Qs-2A120 Camera Link models, color as well as monochrome, unless stated differently.

In this manual we use the following standard symbols in the left margin to draw your attention:

 Command syntax

 Return message

NOTE Practical tip or note

1.3 Standards

Camera Link – Specification of Camera Link Interface Standard for Digital Cameras and Frame Grabbers – Version 1.1 - January 2004.

1.4 Liability

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2. Precautions

NOTE: It is advised to include the text of this chapter in the assembly documents of the system in which the camera is used.

A CMOS sensor camera is a sensitive device. Please read the following precautions carefully before you continue unpacking or operating the camera.

2.1 Safety precautions

2.1.1. General

It is advised to unpack and handle the camera in a clean, ESD protected working area.

It is advised to read the whole manual before using the camera.

2.1.2. Safety symbols

The following safety symbols are applicable to and indicated on the camera.

Symbol for “Conformiteé European”

The exclamation mark within an equilateral triangle is intended to alert the user to the presence of important operating and maintenance (servicing) instructions in the literature accompanying the instrument.

2.2 Handling

2.2.1. General

In order to prevent damage to the camera and to keep the CMOS sensor clean, please take the following precautions.

- Always keep the sensor cap in place, as long as no lens is attached.
- Remove the lens cap just before the lens is screwed on the camera. It is advised to perform this operation in a clean room or clean bench.
- Never touch the CMOS sensor surface. The cover glass is easily damaged and the CMOS sensor can be damaged by ESD (electrostatic discharge).

2.2.2. Cleaning of the CMOS sensor

Cleaning of a CMOS sensor is a rather difficult task. Depending on the aperture of the lens used, any dust particles with a size of 10µ and larger can show up in your image.

All cameras are checked for cleanliness in our factory before shipment. Proper handling instructions during system assembly can prevent the CMOS sensor from getting contaminated.

Should cleaning of the CMOS sensor be necessary follow the instruction below.

NOTE: that damage of the CMOS sensor due to scratches on the cover glass or electrostatic discharge (ESD) is not covered by warranty!

The correct working environment for cleaning is essential in order to ease cleaning and to prevent damage of the CMOS sensor.

Precautions:

- Take precautions to prevent ESD that can damage the CMOS sensor.
- Cleaning of the CMOS sensor, and assembly of the lens is preferably performed in a clean room or clean bench.
- Never try to clean the CMOS sensor at a relative humidity lower than 30 %. A relative humidity of 40 % or higher is preferred in order to minimize the chance of damage due to ESD.
- It is advisable to use an ionizer, in order to minimize the built-up of ESD.
- Be sure to clean the lensmount of the lens before assembly.
- Use non-fluffing Q-tips and Alcohol (or Hexane) for cleaning. De-ionized water may be necessary to remove ionic contaminants like salts.
- Any Q-tip should be used only once - you will otherwise move dirt from one place to another.
- Never dry rub the window. This may cause static charges or scratches that can destroy the CMOS sensor.

Cleaning instructions:

1. First try to remove the contamination by using clean, dry air. (Use an ultra-filtered, non-residue dust remover spray). Avoid blowing air into the screw thread of the lensmount, because this may cause contamination on the CMOS sensor due to loose particles and traces of oil or grease.

If this step does not result in an acceptable result, continue with step 2.

2. Remove the lensmount by unscrewing the 4 crosshead screws that hold the lensmount (see figure 2.1)

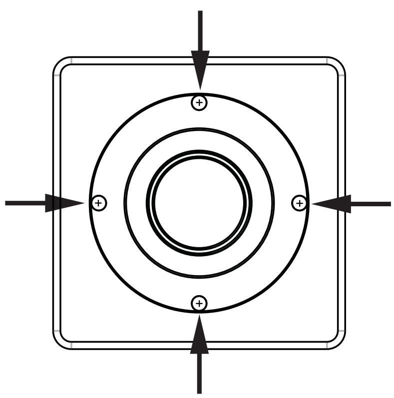


Figure 2.1: Crosshead screws that hold the lensmount (front view of the camera).

3. Clean the inner screw thread of the lensmount using Alcohol or Hexane and a Q-tip.
4. Clean the CMOS sensor cover glass using Alcohol or Hexane and a Q-tip.
   Gently and carefully rub the window always in the same direction, e.g. top to down.
5. Install the lensmount back on the camera front.
   Maximum tightening force may not exceed 0.3 Nm.
6. Install a lens, power up the camera, set the lens at a small aperture (F16) and point the lens at a bright source. Adjust gain and integration time if necessary.
7. Check the image on the monitor for dark spots and stripes caused by contamination on the CMOS sensor cover glass. (Note that the image on the monitor should not saturate due to over exposure - if necessary close the iris even further).
8. If the CMOS sensor is not clean, repeat steps 4 - 7 using a new Q-tip. After three unsuccessful tries, it is advised to wait a few minutes before a new attempt is made to clean the CMOS sensor. (The waiting time allows the electric charge that has been built up during cleaning to neutralize).

2.2.3. Cleaning of the camera

The camera shall NEVER be immersed in water or any other fluid. For cleaning, only use a light moist tissue.

2.2.4. Maintenance

No specific maintenance other than cleaning is applicable.

2.2.5. Repair and modification

Repair, modification and replacement of parts shall be done only by Adimec to maintain compliance with the directive 89/336/EEC electromagnetic compatibility and directive 72/23/EEC low voltage directive and the international standards.

2.2.6. Peripheral equipment

For safety, use an external SELV qualified power supply. Maximum current 1 A.

For safety, peripheral equipment must either be double isolated or SELV qualified.

2.2.7. Mounting / Mechanical

Connectors

Take care during handling of the camera. The Camera Link connector and the power connector should not be damaged.
The maximum tightening torque for the Camera Link connector may not exceed 0.26 Nm.
Prevent the entry of foreign objects or dirt into the connectors, as this will result in unreliable operation or damage.

Mounting screws

Take notice of the maximum length of the screws that may be used for mounting of the camera. Using screws too long can cause damage to the camera. Maximum screw length: 5 mm.

3. Installation

In this chapter all three electrical interfaces as well as the mechanical and optical interface are described. If a lens and all interfaces are available, it is possible to refer to the quick start paragraph at the end of this chapter. The other paragraphs describe the interfaces in detail.

3.1 Electrical interface - power

Chassis part

- Binder series 712 type 09-0403-30-02

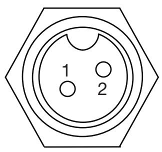


Figure 3.1: Camera male power connector

PIN	FUNCTION
1	10 to 24 +/- 10% Vdc
2	GND

Table 3.1: Power pin configuration.

Qs-4A60m/c and Qs-2A120m/c
Typically 4.5 Watt @12 Volt

Table 3.2: Power requirement.

NOTE: The supply is reverse voltage protected. When applying power to the camera with the wrong polarity it will not operate, but will not be damaged.

Mating cable connector:

- Binder series 711 type 99-0072-100-02 (straight)
- Binder series 712 type 99-0402-00-02 (straight)
- Binder series 712 type 99-0402-70-02 (90 degrees angle)

3.2 Electrical interface - strobe and trigger

An input for external triggering of the camera is available at the I/O connector.

Also a trigger output signal from the camera to control an external flash light is available at this connector. The input and output are fully programmable. For reference see paragraph 7.5.

The input and output are galvanic isolated from the internal camera electronics by means of an optocoupler.

Chassis part

- Binder series 712 type 09-0412-30-04

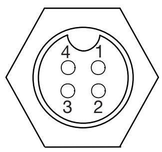


Figure 3.2: Camera female I/O connector

PIN NO.	SIGNAL NAME	DIRECTION	LEVEL	AT THE PIN
1	Flash strobe out	Output		Open collector of optocoupler
2	Trigger in	Input	10..20 mA	Anode of optocoupler(*)
3	Trigger return	Input	Isolated gnd	Cathode of optocoupler
4	Flash strobe return	Output	Isolated gnd	Emitter of optocoupler

(*) serial resistors 470 Ω inside camera, see figure 3.3.

Table 3.3: Pinning I/O connector

Mating cable connector

- Binder series 711 type 99-0079-100-04 (straight)
- Binder series 712 type 99-0409-00-04 (straight)
- Binder series 712 type 99-0409-70-04 (90 degrees angle)

NOTE: The delay from non-conductive to conductive state of the phototransistor is less than 1.5 µs. The delay from conductive to non-conductive state of the phototransistor is less than 10 µs.

The recommended termination circuitry is drawn in Figure 3.3.

A current of 2.5 mA is recommended for the Flash output. For the trigger input, a current of 10 mA is recommended. These current recommendations translate to the recommended resistor values in table 3.4.

VEXT [V]	R1 EXT [Ω]	R2 EXT [Ω]
3.3	1000	Do not apply
5.0	2000	0
12	4700	470

Table 3.4: Recommended series resistor for trigger input

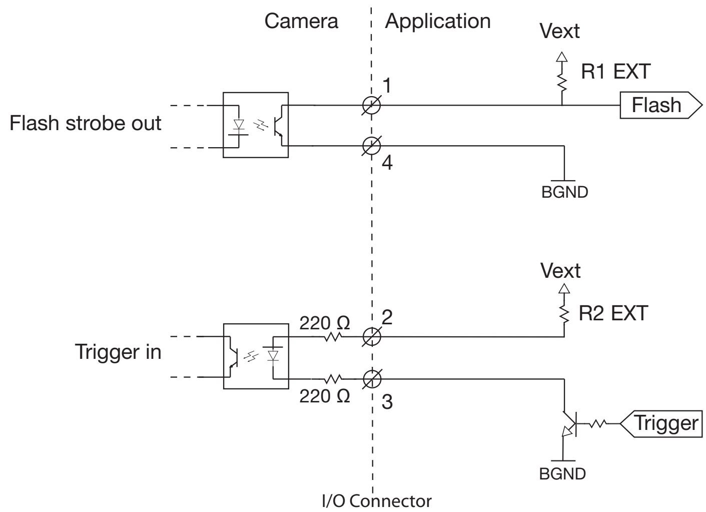


Figure 3.3: Recommended terminations of strobe output and trigger input.

3.3 Electrical interface - Video and Data.

The Camera Link interface is designed to connect the camera to a frame grabber in order to transfer video to the grabber as well as control data from the grabber to the camera. The maximum cable length is 10 meter, for a 85MHz interface however 5 meter is recommended.

For a description of the Camera Link interface please refer to the Camera Link specification.

NOTE: PoCL (Power over Camera Link) is not supported. When connecting the camera to a PoCL-compliant frame grabber, the PoCL-function must be disabled.

Interface connectors: 3M MDR 26-pins.
Standard Camera Link cables can be ordered at Adimec.

The Camera Link ports assignment is described in chapter 11.

3.4 Quick start

- Mount a lens on the camera and adjust the iris for F5.6.
- Connect the Camera Link cables to the camera and frame grabber.
- Boot up the PC and start the frame grabber application.
- Connect the power cable to the camera and power up the camera with 12 Vdc.
- Configure the framegrabber to 10 bit pixel depth resolution, 2 taps interleaved and 85 MHz pixelclock.

Factory default settings of the Qs-4A60 and Qs-2A120 camera series.

	Qs-4A60m/c and Qs-2A120m/c
Operation Mode	Continuous
Frame Rate 2-taps	40 fps
Output Resolution	10 bit

Table 3.5: Factory default interface settings

4. Functional description

This chapter contains a functional description of the Qs-4A60 and Qs-2A120 cameras. It describes the main functions and features of the camera using a simplified block diagram.

4.1 Block diagram

The diagram below shows the main functional blocks of the Qs-4A60 and Qs-2A120 cameras.

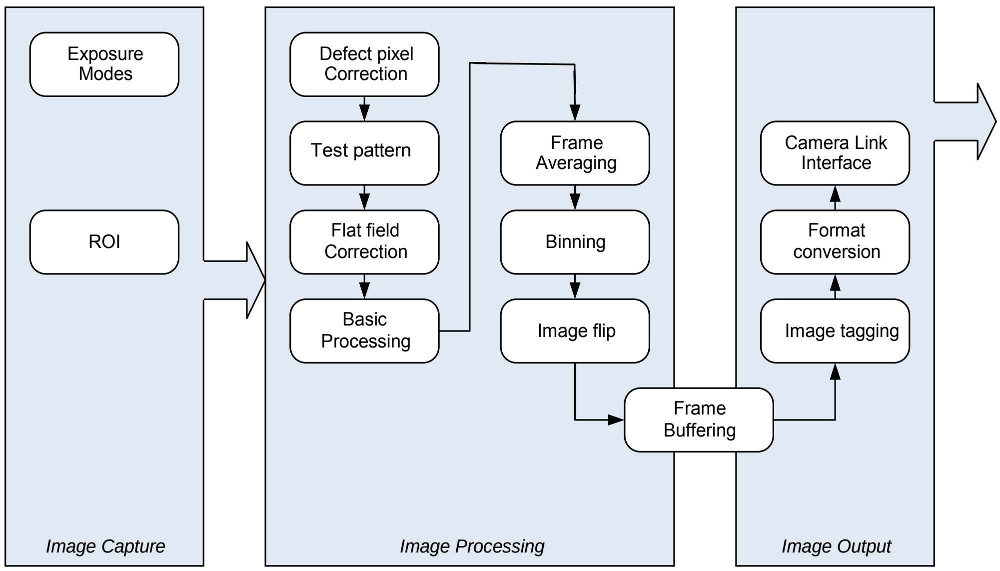


Figure 4.1: Block diagram of the camera

The CMOS image sensor is equipped with one analog to digital converter per pixel column.

A programmable Region Of Interest (ROI block) is available. The camera will only output video information from a rectangular subframe, programmed through the ROI command. This reduces the amount of data and thus increases the possible throughput.

The defect pixel correction function can be enabled and disabled on demand.

For functional testing of the camera and frame grabber chain, a test pattern generator is available. The test pattern generator can also be enabled and disabled on demand.

Flat field correction allows for correction of shading.

Digital Gain is applied within the basic processing block. An output look-up table is available; this table allows real-time conversion of the video levels from the processing chain according to a user programmable curve (e.g. Gamma-function).

The camera is able to average a number of images before they are output over the interface. This increases signal to noise ratio.

Horizontal binning and vertical binning digitally averages a number of pixels into a single pixel. The used method is suitable to increase sensitivity.

The output image can be mirrored horizontally and vertically.

All images pass through a real-time dual ported frame memory, referred to as image FIFO. This FIFO (first-in-first-out memory) allows for temporary buffering of the images if acquisition of frames is done faster than the Camera Link interface allows. Data will be readout immediately after it is written if buffering is not necessary, leading to minimal delay between acquisition and camera output.

Image tagging allows for identification of each frame at the output. The camera has a build-in framecounter. A digital representation of this framecounter can be made visible as either overlaying the actual video data or added as an extra video line tag.

The video data from the User OLUT stage is mapped to the Camera Link ports. The output resolution can be set to 8 bit or 10 bit by user command. The output format can be set by user command.

The camera is equipped with a flash strobe output signal on the I/O connector. The active state of the flash strobe output can be inverted to adapt to the application requirements. The flash strobe output can be operated in two different modes, which are set through a user command.

- The automatic mode: The flash strobe will become active after the sensor is reset and a configurable delay time is expired. The strobe will deactivate when the acquisition is completed.
- The programmed mode; Both delay time after a sensor reset as well as the duration of the active state can be programmed.

5. Control of the camera

5.1 Introduction

The Qs-4A60 and Qs-2A120 cameras are fully software controlled via the Camera Link serial channel using a simple ASCII based protocol.

It is possible to save settings as 'power-up default settings' in the camera.

A command line control application is available to interactively control the camera settings.
Please contact your local Business Office to obtain a copy of the latest release.

Although this is an easy way of changing camera settings, it is also possible to communicate with the camera using self deployed software. Please refer to chapter 5.2 for the communication protocol.
Use chapters 6 to 10 as a detailed reference of the control commands.

5.2 Communication protocol

The camera is controlled by a host system connected to the Camera Link interface using the serial communication link of the Camera Link. Commands and resulting data are transferred between the host system and the camera by means of a communication protocol. The host system is the master in the communication link. All actions are initiated by the host system. The camera only replies to a message received from the host system.

5.2.1. Data link settings

The data link settings that shall be used for communication with the camera are:

Baud rate	57600 baud
stop bit	1
data bit	8
parity	none
handshaking	none

5.2.2. Data flow characters

The communication protocol uses data flow control characters to identify a message and for acknowledgement.
The following data flow characters are defined:

CHAR	DEC	DESCRIPTION
NUL	0	NUL character, is ignored
STX	64	start of message identifier
ETX	13	end of message identifier
ACK	6	positive acknowledgement
NAK	21	negative acknowledgement

5.2.3. Message Format

Command and data are packed in a message. A message starts with the STX character followed by the message content. The message ends with an ETX character. The characters allowed in the message content range from decimal 32 to 255.
Format: STX <message content> ETX

5.2.4. Message acknowledgement

After receiving a message, the camera responds with an acknowledgement character. This can be an ACK character (positive acknowledgement) or a NAK character (negative acknowledgement). The ACK response is given when the received message was understood (the content of the message is not considered).
The NAK response is given when the received message was not understood, which may be the case when invalid characters are received as message content, or the message overruns the camera receiver buffer capacity.

5.2.5. Reply messages

When a message is sent to the camera that requires data to be transmitted back to the host system, this data is packed in a message and is sent to the host system after the positive acknowledgement (ACK) character. When the camera responds with a NAK character no data is send back to the host system.

5.2.6. Communication timing

The time between the successive characters making up a message is not limited. The camera however, when transmitting a message to the host system, has a time interval between successive characters of less than the time required for a single character to be transmitted.

5.2.7. Host system requirements

After transmitting a message to the camera, the host system must wait for the camera to reply with an ACK or NAK character. To prevent lock-up, the wait time for the response must be limited by a time-out period. After not receiving an ACK or NAK character after the time-out period has elapsed, the host system must consider the transmitted message as not being received.
The time-out time to be used for the camera should be at least 200 ms.
Under normal conditions, a NAK or no response from the camera results from damage of the transmitted characters due to noise or communication link hardware problems. In such case, the host system should transmit the message again. The number of repeated transmissions after a NAK response or no response must be limited by a retry count to prevent lock-up. If the camera is still responding with a NAK character after the maximum number of retries of the transmitted message have been sent, the communications channel should be considered malfunctioning or too noisy. When the maximum number of retries of the transmitted message has been reached and the camera is still not responding, the communication channel should be considered disconnected or the camera not being powered or malfunctioning.

5.3 Camera Link interface standard

5.3.1. Introduction

Without getting into detail on the Camera Link standard, this section discusses the mechanics of the serial communication channel. Available Camera Link serial software enhancements in the form of Dynamic Link Library files will greatly simplify the setup of a communication channel. Both camera manufacturers and frame grabber vendors have issued these DLL files which will provide standard C, API and native Visual Basic support, so that applications written in C or Visual Basic can communicate serially with Camera Link cameras.

5.3.2. Overview

The user application calls into the generic clserial.dll, which dynamically loads the.dll file(s) specific to the frame grabber(s) referred to by the application. It then routes all calls to that .dll file. The following diagram illustrates this sequence:

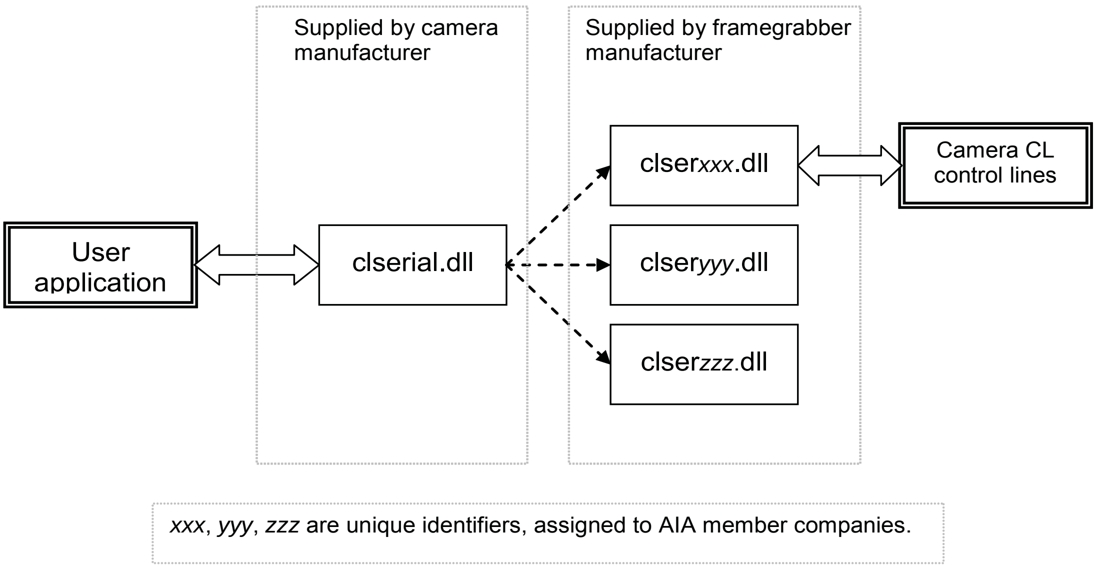


Figure 5.1: Mechanics of communication per Camera link serial channel

Features Provided by clserial.dll

- Simultaneous, multi-port (including cross vendor) support
- Support for binary or text based data transfers
- Common API across vendors
- Common error codes across vendors
- Common error text across vendors
- Strict, well defined behavior of all functions in specification
- Openness to vendor specific error codes and text
- Ability to enumerate ports on sytem
- Inquireable/adjustable baud rate for ports
- Win 32 support (open source for port to other platforms)
- C/C++ support through import library
- VisualBasic support through type library
- Backwards compatibility with recommended specification of October 2000
- Standard default communication settings for serial port

5.3.3. Mechanics of clserial.dll

When clserial.dll loads, it searches the operating system's system directory (for example, C:\windows\system or c:\winnt\system) for all files that use the naming convention clserxxx.dll (xxx is uniquely assigned to AIA member companies). Clserial.dll then dynamically loads those .dll files and queries each one for its manufacturer name and port names. This action produces a list of all possible ports.

The application can then select which port or ports it would like to communicate through. The required manufacturer specific .dll files will be loaded and clserial.dll will manage passing the application calls to the appropriate .dll for the application specified port.

Further details can be found in the Camera Link – Specification of Camera Link Interface Standard for Digital Cameras and Frame Grabbers – Version 1.1 - January 2004.

6. Managing camera settings

This chapter describes the individual camera functions and settings. The specific commands and their effect on the camera operation are described in detail.

6.1 Command parameters

All commands are composed of a command keyword and the required parameters for that specific command. Parameters for the camera command set are signed integer values. Negative values must start with a negative (–) character. Positive values do not need a preceding character but may optionally start with a positive (+) character. The integer values are transmitted as text using the characters '0' … '9'.In case of more than one parameter, the parameter values are separated by a semicolon ";". In addition, a string is possible as a command (one parameter string).

NOTE: Everything after " is part of the string.

6.2 Command response messages

Parameter(s) regarding the settings of the camera can be set by command. Each command ending with a question mark (?) is a query command. After the acknowledgement, the camera sends the query value(s) for that command. In case of more than one value, the returned values are separated with a semicolon (;). Values are preceded with negative (–) character when negative and a positive (+) character when positive.

For example: OR? returns a message for example +10 as the current output resolution.

OFRM? returns a message like +2;+8

6.3 Command description

6.3.1. Identification commands

Build state of the camera

This command returns a string of numbers that exactly describes the camera build state.

```
Command format: BS?
Return Message: ″x.xx;y.yy;z.zz
```

Where x.xx indicates the issue of the camera. Minor changes in the camera will increase the part after the decimal point. Major changes in the camera will increase the first digit. Cameras with the same major issue number are fully interchangeable.
Where y.yy indicates the microcontroller firmware version (*)
Where z.zz indicates the programmable logic firmware version (*)

*: These values are retrieved from the devices. They are of low importance to a user. A change that will influence the functionality of the camera will result in a camera issue change.

Camera identification string

The camera identification string is stored in the camera and can be read with the ID? command.

```
Command format: ID?
Return Message: "Qs-4A60x/CL S/N:yyyyyy
```

or

```
Return Message: "Qs-2A120x/CL S/N:yyyyyy
```

where x indicate the type

CAMERA TYPE	X
Monochrome	m
Color	c

and yyyyyy is the serial number of the camera.

Serial number of the camera

Each camera has a unique serial number. It is stored in the camera and can be read with the SN? command.

```
Command format: SN?
Return Message: "yyyyyy
```

where yyyyyy is the serial number of the camera.

6.3.2. Camera settings and user data commands

Load factory defaults

At delivery, the factory settings are stored as the power-up default settings. The user may however change the power-up settings without losing the factory default settings. A copy of the factory default settings is stored in the camera. The camera settings are set to the copy of the factory defaults by means of the FD command (Factory Defaults).

```
Command format: FD
```

After restoring the factory settings (FD), the settings may be saved again as the power-up defaults by executing the SC.

Save camera settings

Camera settings are directly set by the individual commands for these settings. When the settings performed are satisfactory, they may be used as the settings to be used by the camera after power-up. The settings are saved as power-up defaults using the SC command (Save Configuration).

```
Command format: SC
```

Load camera settings

The camera power-up settings are restored after power-up but can also be restored during camera operation with the LC command (Load Configuration)

`Command format: LC`

User storage

16 signed integers and 16 character strings can be stored in the camera for user purposes. These values do not influence camera operation.

`Command format: USIx;y`

`Command format: USI?x`
`Return Message: y`

where x = 0 … 15, stores / reads back the xth user signed integer, being y.

`Command format: USSx;”y`

`Command format: USS?x`
`Return Message: ”y`

where x = 0 … 15, stores / reads back the xth user string, being y.

A user string always consists of 32 characters maximum. If a string longer than 32 characters is set, only the first 32 characters will be programmed.

6.4 Camera command set overview

Identification commands

SYNTAX	DESCRIPTION
BS?	Get the build state of the camera
ID?	Get the camera indentification string + serial number
SN?	Get the serial number of the camera

Camera Status commands

SYNTAX	DESCRIPTION
BIT?	Get the built-in self test status code
ERR?	Get the last error result
TM?	Get temperature

In the tables below, the distinction is made between 2 Camera Link clock frequencies 66MHz and 85MHz. This frequency is controllable with the CLC command (see section 9.6.5).

Camera Settings and User Data commands.

SYNTAX	DESCRIPTION	DEFAULT VALUE	
		CLC2 (66 MHZ)	CLC3 (85 MHZ)
FD	Load the factory default camera settings		
SC	Save all current settings as camera power up settings		
LC	Load the camera power up settings		
USI	Save a user-defined signed integer	0	0
USI?	Recall a user-defined signed integer		
USS	Save a user-defined signed character string	empty	empty
USS?	Recall a user-defined signed character string		

Image Acquisition commands

SYNTAX	DESCRIPTION	DEFAULT VALUE	
		CLC2 (66 MHZ)	CLC3 (85 MHZ)
CCE	Set trigger input and polarity		
CCE?	Get trigger input and polaroty		
CCREQ	Set image request trigger and polarity		
CCREQ?	Get image request trigger and polarity		
MO	Set the acquisition mode	0	0
MO?	Get the current acquisition mode		
IT	Set the integration time for continuous mode	2000	2000
IT?	Get the current integration time for continuous mode		
FP	Set the frame period time for continuous mode	40000	40000
FP?	Get the current frame period time for continuous mode		

Image Output commands

SYNTAX	DESCRIPTION	DEFAULT VALUE	
		CLC2 (66 MHZ)	CLC3 (85 MHZ)
RQM	Set the output request mode	0	0
RQM?	Get the output request mode		
BCNT?	Get the actual number of images in image FIFO		
RQSIZE	Set the number of required images in burst mode	1	1
RQSIZE?	Get the number of required images in burst mode		
RQ	Request acquired images in burst mode 2		
BO?	Get buffer overflow status		
FB	Flush buffer		

Strobe commands

SYNTAX	DESCRIPTION	DEFAULT VALUE	
		CLC2 (66 MHZ)	CLC3 (85 MHZ)
FSE	Enable flash strobe	1	1
FSE?	get flash strobe status		
FSP	Set flash strobe polarity	1	1
FSP?	Get flash strobe polarity		
FSM	Set flash strobe mode	0	0
FSM?	Get flash strobe mode		
FST	Set flash output timing	0;2500	0;2500
FST?	Get flash strobe output timing		

Post Processing and Output commands

SYNTAX	DESCRIPTION	DEFAULT VALUE	
		CLC2 (66 MHZ)	CLC3 (85 MHZ)
BL	Set the black level (monochrome only)	20	20
BL?	Get the black level (monochrome only)		
CCHDR	Set multislope trigger input selection		
CCHDR?	Get multislope trigger input selection		
CLC	Set pixelclock speed	2	3
CLC?	Get pixelclock speed		
OFS	Set output offset (color only)	20	20
OFS?	Set output offset (color only)		
FCR	Reset frame counter		
FVALGAP	Set gap time between two consecutive frames	12	12
FVALGAP?	Get gap time between two consecutive frames		
GA	Set the digital fine gain	100	100
GA?	Get the current digital fine gain		
WB	Set white balance gain (color only)	100;100;100	100;100;100
WB?	Get the current white balance gain (color only)		
MI	Set the image output to mirrored	0	0
MI?	Get the current mirror state		
MS	Set number of slopes (multislope)	1	1
MS?	Get number of slopes (multislope)		
MSL	Set multislope levels	50;70	50;70
MSL?	Get multislope levels		
MST	Set multislope timing	80;95	80;95
MST?	Get multislope timing		
OR	Set the camera output resolution	10	10
OR?	Get the current camera output resolution		
ROI	Set the Region of Interest	[Full res]	[Full res]
ROI?	Get the Region of Interest		
TPLVL	Set uniform test pattern video level		
TPLVL?	Get uniform test pattern video level		

SYNTAX	DESCRIPTION	DEFAULT VALUE	
		CLC2 (66 MHZ)	CLC3 (85 MHZ)
OLUTBGN	Prepares the camera to receive entries for the output LUT		
OLUT	Provides one entry for the output LUT		
OLUT?	Retrieve one entry from the output LUT		
OLUTEND	Finalize the output LUT filling operation		
OLUTE	Enable/disable the output LUT	0	0
OLUTE?	Get the enable status of the output LUT		
OFRM	Set the output format	2;8	2;8
OFRM?	Get the output format		
OVL	Set image overlay	0	0
OVL?	Get image overlay		
TP	Set test pattern	0	0
TP?	Get test pattern		
HBIN	Set horizontal binning (values 1, 2 or 4)	1	1
HBIN?	Get horizontal binning		
VBIN	Set vertical binning (values 1, 2 or 4)	1	1
VBIN?	Get horizontal binning		
AVG	Set averaging mode (values 1-10)	1	1
AVG?	Get averaging mode		

User Calibration and Correction commands

SYNTAX	DESCRIPTION	DEFAULT VALUE	
		CLC2 (66 MHZ)	CLC3 (85 MHZ)
CCFFSEL	Set flat field input selection	2;3	2;3
CCFFSEL?	Get flat field input selection		
DP	Add defect pixel to the defect pixel list		
DP?	Get defect pixel info from defect pixel list		
DPC	Clear defect pixel list		
DPE	Set defect pixel correction on / off	1	1
DPE?	Get the current defect pixel correction		
DPFD	Restore factory default defect pixel list		
DPR	Remove defect pixel		
DPT	Defect pixel test mode enable	0	0
DPT?	Get defect pixel test mode		
BLCAL	Calibrate black level		
FFCAL	Preform flat field (offset or gain) calibration		
FFERR?	Get flat field calibration error		
FFMINMAX?	Get flat field minimum and maximum video levels		
FFSTA?	Get status of flat field (offset or gain) calibration		
FFSEL	Set gain calibration set (also determines which set is used in calibration)	1	1
FFSEL?	Get gain calibration set		
FFP	Set flat field correction parameter		
FFP?	Get flat field correction parameter		
FFLC	Retrieve a calibration ref. image from non volatile memory		
FFSC	Store a calibration ref. image in non volatile memory		

7. Acquisition modes

7.1 Modes of operation

The camera operates in one of the four acquisition modes, selectable by the MO command (section 7.4.1).

In this chapter each mode is described. Basic formulas for sensor readout and frame readout over Camera Link are presented below.

Inbetween acquisition from sensor and image transfer through the Camera Link interface, there is a buffer memory, which enables decoupling of sensor image acquisition and interface data transmission.

- The time needed to read a single line from the sensor (Applicable to all cameras in this manual):

$$t_{row,sensor} = 5.375\mu s$$

- The time needed to read an image from the sensor:

$$t_{IMG,sensor} = ROI_{height} \cdot t_{row,sensor} + 64\mu s \qquad \text{Qs-4A60}$$

$$t_{IMG,sensor} = ROI_{height} \cdot t_{row,sensor} + 37\mu s \qquad \text{Qs-2A120}$$

During the additional 37 and 64 μs the sampling mechanisms take place. The Qs-4A460 and Qs-2A120 are photosensitive during the first 17 μs and 23 μs, respectively.

The time needed to output an image over the Camera Link interface:

$$t_{IMG,Interface} = \frac{ROI_{height} \cdot \left(\frac{ROI_{width}}{\#_{CameraLinkTaps}} + LVal_{GapSize} \right) + LVal_{GapSize}}{f_{CameraLinkPixelClock}} + FVal_{GapSize} + 10\mu s$$

Where FVALGap is the set frame delay time by command FVALGAP and LVALGap is the set line delay time by command LVALGAP.

OVL_h equals 1 if the image overlay is configured to output an extra line (commands OVL2 or OVL3), else 0.

NOTE: If either LVALgap or FVALgap does not meet the required time to output a video line at the Camera Link output, the set value will be increased automatically to the minimum valid value. See also section 7.2 Continuous mode for further elaboration.

NOTE: If the on-camera frame averaging is enabled, this natually reduces the datarate over the interface by a factor equal to the number of averaged frames.

7.1.1. Burst and Request Mode

The decoupling of image acquisition and interface data transmission enables capturing a burst of images at a higher acquisition rate than the interface frame rate. The camera FIFO memory buffer is filled up. Bursts are possible in all of the camera's control modes.

In addition, the moment of interface data transmission can be controlled precisely by the Request Mode command (section 7.6.2).

After the Integration has finished, the image will be output immediately when Request Mode is set to 0 (RQM0).

If the request mode is set to 1 (RQM1), a preset number of images are released from buffer memory upon receiving a soft- or hardware trigger.
If the request mode is set to 2 (RQM2), all images are released from buffer memory directly or upon receiving a soft- or hardware trigger. If multiple images are requested, they are output at the maximum speed.

7.2 Continuous mode

The continuous mode is the most basic mode of operation. In continuous mode, the camera captures images with an integration time set by the user and a frame period set by the user.

Acquisition of images will take place continuous, regardless of trigger signals.

To prevent buffer overflow, the request mode must be set to 0 (images are output immediately after acquisition). Also, the frame speed must be chosen lower than, or equal to the speed that can be handled by the Camera Link interface. The camera link interface speed is dependent of five parameters:

- Interface clock
- ROI size
- Overlay enabled/disabled
- Duration of the Lval gap
- Duration of the Fval gap

For a full frame image (ROI at its maximum), a Fval gap of 2 and a Lval gap of 2, the maximum sustained frame rates are indicated in the tables below.

Qs-4A60

I/F CLOCK [MHZ]	CL 2 TAPS	CL 3 TAPS
66	31	47
85	40	60

Qs-2A120

I/F CLOCK [MHZ]	CL 2 TAPS	CL 3 TAPS
66	59	88
85	76	114

Table 7.1: Maximum frame speeds at different Camera Link interface properties in continuous mode.

In continuous mode, the camera output can only run in RQM0 (automatic image output).

Depending on the width of the ROI and the CameraLink interface configuration, the continuous mode frame rate is either limited by the sensor readout speed or the Camera Link throughput:

$$FP_{\min} = MAX(t_{IMG,sensor}, t_{IMG,interface})$$

7.3 Control mode

Three control modes are possible in the camera.
If the Request mode is set to output the images immediately after acquisition (RQM0) and the acquisition trigger rate does not exceed the rate at which the CameraLink Interface configuration can output the images, the camera outputs the images normally.

Minimum frame periods (and corresponding trigger frequency) can be computed with the equations in section 7.1. As another reference the tables in section 7.2 may be used.

7.3.1. Normal control mode

The control mode (MO1) is used in basic control applications. The state of the external control pulse (section 7.4.4) determines start of integration and readout.

7.3.2. Sync Control mode

In sync control mode (MO2), the start and stop of acquisition is controlled by the rising edge of the external control pulse (section 7.4.4). The falling edge of CC1 does not trigger any event. The integration time is equal to the frame period. Sensor readout (image n) and sensor reset (image n+1) occur simultaneously at the rising edge of CC1.

7.3.3. Triggered Control mode

In triggered control mode (MO3), the acquisition is started by a hardware trigger. The length of the exposure is determined by camera parameter IT.

7.4 Image Acquisition commands

7.4.1. Camera acquisition mode

The camera acquisition mode is set by the MO command.

```
Command format: MOx
```

```
Command format: MO?
Return Message: x
```

where x is one of the values shown in the table below. Other values for x are not allowed.

X	MODE OF OPERATION
0	Continuous mode
1	Normal control mode
2	Sync control mode
3	Triggered mode

See sections 7.2 and 7.3 for a description of each mode.

7.4.2. Integration time

The integration time in continuous mode is set by means of the IT command.

```
Command format: ITx
```

```
Command format: IT?
Return Message: x
```

where x is the integration time in units of 1 μs. The minimum allowed value for x is 1 and the maximum value allowed for x is 100,000 (= 100 ms).
The sensor design dictates a minimum integration time. This is not included in the ITx command and will be added to that set value.

Qs-4A60:

Continuous mode:	Actual_integration_time = x + 23 μs.
Normal control mode:	Actual_integration_time = cc1_pulse_length + 23 μs.
Syncontrol mode:	Actual_integration_time = Frame_time; Latency of 23 μs.
Triggered Mode:	Actual_integration_time = x + 23 μs.

Qs-2A120:

Continuous mode:	Actual_integration_time = x + 17 μs.
Normal control mode:	Actual_integration_time = cc1_pulse_length + 17 μs.
Syncontrol mode:	Actual_integration_time = Frame_time; Latency of 17 μs.
Triggered Mode:	Actual_integration_time = x + 17 μs.

The camera automatically checks the specified integration time. When the set value of IT is too large for the current frame period time, the integration time is limited to the maximum possible value. The maximum possible integration time in continuous mode is automatically obtained when x is set to 100000.

7.4.3. Frame period

The frame period in continuous mode is set by means of the FP command.

```
Command format: FPx
```

```
Command format: FP?
Return Message: x
```

where x is the frame period in units of 1μs. The minimum allowed value for x depends on various parameters (Camera Link configuration, ROI), the maximum allowed value for x is 100,000 (= 100 ms).

If the frame period is decreased, the camera checks the integration time and adjusts it to the maximum possible if necessary.

The minimum possible frame period in continuous mode is automatically set if x is set to 0.

If required the integration time will be decreased to fit within the frame period.

NOTE: The FP command only effects the frame period in the continuous mode. When working in another mode, the command is still available and the settings become active when the mode is set to continuous mode.

7.4.4. Acquisition trigger input and polarity selection

In case the camera is running in control mode, an image acquisition trigger can be fed to either a CC pulse or the electrically isolated external input. Furthermore this command selects the polarity of the input signal.

```
Command format: CCEx;y
```

```
Command format: CCE?
Return Message: x;y
```

Where parameter x selects the input:

X	INPUT
0	CC1
1	CC2
2	CC3
3	CC4
4	I/O- connector

Parameter y sets the signal polarity: y=1 starts image acquisition on the rising edge and image readout on the falling edge in normal control mode.

7.5 Flash Strobe commands

7.5.1. Flash strobe enable

The camera is equipped with strobe output signal on the I/O connector. The strobe can be switched on or off by means of the FSE command.

```
Command format: FSEx
```

```
Command format: FSE?
Return Message: x
```

where x is set to 0 to disable the strobe output and x is set to 1 to enable the strobe output. The definition of the active state depends on the strobe polarity.

7.5.2. Flash strobe polarity

The active state of the strobe output can be inverted to adapt to the application requirements.

```
Command format: FSPx
```

```
Command format: FSP?
Return Message: x
```

where x is set to 1 for the normal polarity: in this polarity configuration the photo transistor at the camera output is conductive during the active state of the strobe.

If x is set to 0 the strobe photo transistor is non-conductive during the active state of the strobe.

7.5.3. Output Mode setting

The strobe output can be operated in two different modes, which are set through the FSM command.

```
Command format: FSMx
```

```
Command format: FSM?
Return Message: x
```

where x is set to 0 for the automatic mode: The strobe will become active after the sensor is reset and a configurable delay time is expired. The strobe will deactivate when the acquisition is completed.

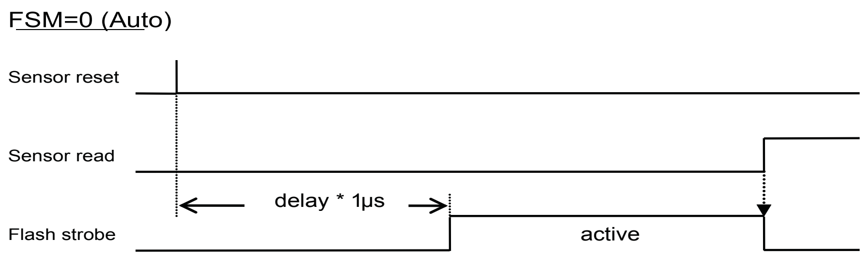


Figure 7.1: Timing diagram strobe output (auto mode).

If x is set to 1 the strobe will operate in programmed mode; both delay time after a sensor reset as well as the duration of the active state is programmed. A new flash window can only start after the completion of the previous flash strobe window.

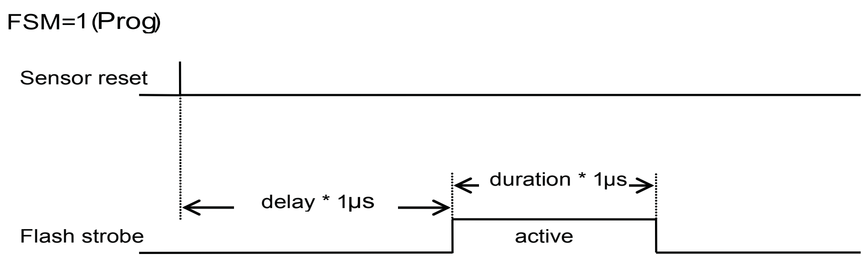


Figure 7.2: Timing diagram strobe output (programmed mode).

7.5.4. Flash strobe timing

The strobe output timing can be programmed through the FST command.

```
Command format: FSTx;y
```

```
Command format: FST?
Return Message: x;y
```

where x indicates the delay time between the sensor reset operation and the active state of the strobe.

y indicates the duration of the strobe if the camera is in programmed strobe timing mode. Note the duration parameter is ignored in automatic strobe mode.

Valid ranges for both x and y are 0 … 100000. Both x- and y-values are in units of 1µs.

7.6 Memory control commands

7.6.1. Burst count

The number of images currently stored in the buffer (during burst mode) can be requested from the camera by the BCNT? command.

```
Command format: BCNT?
Return Message: n
```

where n is the actual number of images available.

The image FIFO size is 0.5Gb. Images are stored in the memory at 10bits per pixel. At full resolution for the 2 and 4 Mp cameras, 24 and 12 frames can be stored respectively. This number scales with ROI.

For a given ROI where ROI width indicates the width of the ROI and ROI height indicates the height, the maximum burst size nmax equals:

$$n_{\max} = Floor\left(\frac{Memsize}{ROI_{width} \cdot ROI_{height}}\right)$$

where:
nmax = number of frames
Memsize = 2^{29} (bit) / 10 (bit/pixel), which is approximately 54Mpix

NOTE: ROI width is subject to restriction, see the ROI section.
nmax is limited to 255.

7.6.2. Request mode

The camera can transmit the captured data over the interface directly or upon request. This is selected by means of the Request Mode command.

```
Command format: RQMx
```

```
Command format: RQM?
Return Message: x
```

where x indicates the Request Mode according to the following table.

X	REQUEST MODE
0	Images are output immediately after acquisition. If acquisition takes place at a speed that the Camera Link interface can manage the FIFO will not fill up and cause a delay. If acquisition runs faster than the Camera Link output allows, images will temporarily be stored, but output immediately once the interface is ready for them.
1	A fixed number of images is output upon receiving a request pulse or an RQ command. The number of images is set by means of the RQSIZE command
2	All images available are output upon receiving a request pulse or an RQ command.

In RQM2 and RQM3, the request can be made via a command, CC pulse or hardware trigger (see section 7.6.4).

NOTE: A situation of acquisition speed exceeding the maximum Camera Link speed can only be maintained for a limited amount of time (burst mode). Else, the buffer will overflow.

7.6.3. Request image output

In RQM2 and RQM3, image transmission is initiated by the Request image command (or a pulse, configurable with CCREQ).

`Command format: RQ`

7.6.4. Image request trigger selection

If the camera is configured to output the images on a request pulse, the input used for applying this pulse is selected by command:

`Command format: CCREQx;y`

`Command format: CCREQ?`
`Return Message: x;y`

Where parameter x selects the input:

X	INPUT
0	CC1
1	CC2
2	CC3
3	CC4
4	I/O- connector

Parameter y sets the signal polarity: y=1 request active on the rising edge, y=0 request active on the falling edge.

7.6.5. Request size

The number of images to be output on the RQ command can be set by means of the RQSIZE command.

`Command format: RQSIZEx`

`Command format: RQSIZE?`
`Return Message: x`

where x = the number of images programmed to be output upon an RQ command.

7.6.6. Request buffer overflow

If the image memory is full and another image is acquired, an error situation occurs. This error status is flagged and can be queried by means of the Buffer Overflow command:

```
Command format: BO?
Return Message: x
```

Return value 0 indicates no overflow.

If value 1 is returned, the buffer reached the overflow status. Images present in memory can no longer be retrieved (the number of images in memory is reset to 0). A Flush Buffer command clears the overflow error status.

7.6.7. Flush burst buffer

The image memory can be cleared by a flush buffer command:

```
Command format: FB
```

The number of acquired images will be reset to 0 (BCNT? returns 0) and a possible buffer overflow flag cleared.

8. Calibrations and corrections

8.1 Defect pixel correction commands

8.1.1. Introduction

In Quartz series cameras defect pixels are corrected in real time.

Adimec does not release cameras with more than 1 adjecant defect pixel upon delivery. However, additional defect pixes can be user-programmed.

Up to 2 adjacent pixels can be corrected. More than 2 adjacent defect pixels can be user programmed, but will not result in a reliable correction.
Correction is done by interpolation of the adjacent pixels according to the methode illustrated in figures 8.1 and 8.2

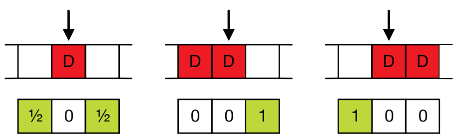


Figure 8.1: Defect pixel correction method on monochrome cameras.

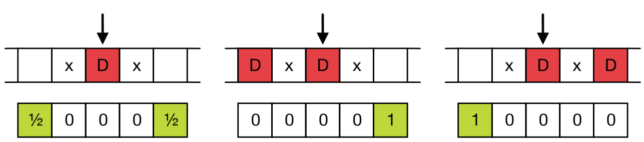


Figure 8.2: Defect pixel correction method on color cameras.

8.1.2. Defect pixel correction

The pixel correction can be enabled or disabled by means of the DPE command.

`Command format: DPEx`

`Command format: DPE?`
`Return Message: x`

Where x is set to 0 to disable the pixel correction and x is set to 1 to enable the pixel correction.

8.1.3. Add a defect pixel to the defect pixel list

The camera is equipped with a pixel correction function. The defect pixel correction is maintained by a defect pixel list. An additional defect pixel can be added to this list by means of the DP command.

`Command format: DPx;y`
`Return Message: x;y`

Where x and y are the origin (1, 1) base coordinates of the defect pixel.

Defect pixels can be queried as follows:

`Command format: DPn?`

Parameter n indicates the index of the defect pixel list for querying defect coordinates.

If n=0 is queried, the number of defects in the list is returned.

8.1.4. Remove defect pixel

Defect pixels can be removed from the defect pixel list by means of the DPR command.

`Command format: DPRx;y`

Where x and y are the origin (1, 1) base coordinates of the defect pixel.
If the coordinate does not exist in the list, error 7 (parameter out of range) is issued.

8.1.5. Clear defect pixel list

The defect pixel list can be cleared:

`Command format: DPC`

8.1.6. Restore factory default defect pixel list

The defect pixel list can be restored to its factory default by means of the DPFD command:

`Command format: DPFD`

NOTE: The existing coordinates in the defect pixel list will be lost.

8.1.7. Defect pixel test mode

The camera is able to display the defect pixel map as an overlay on the image.

This is an aid to visualize the defect pixel list in the image.

`Command format: DPTn`

`Command format: DPT?`
`Return Message: n`

Where n indicates the defect pixel test mode according to the following table:

N	DEFECT PIXEL TEST MODE
0	Test mode disabled, normal image input
1	Mark defects white on video
2	Mark defects black on video
3	Show defects as white on black background

8.2 Black level control

Because there are no reference black pixels in the sensor design, there is no ability to continuously maintain a certain black level. In order to compensate for thermal drift, it is advised to calibrate the average black level of the camera on a regular interval. The desired black level can be set by the BL and OFS command for mono and color cameras respectively. Calibration shifts the black level to the set value.

8.2.1. Executing black level calibration

The calibration requires a dark scene.

```
Command format: BLCAL
```

8.2.2. Black level (only for monochrome)

In monochrome cameras the average black level of the camera can be set with the BL command.

```
Command format: BLx
```

```
Command format: BL?
Return Message: x
```

Where x indicates the black level (value in 10 bit output resolution).

NOTE: The black level in the video output is amplified by the gain setting of the camera.

8.2.3. Offset (only for color)

In order to enable all captured information to be displayed within the digital domain an offset is applied on the camera output data. Black is not represented by 0, but by the value programmed with the offset command.

This ensures that all noise information, even in a dark image, is quantized and reproduced on the output

```
Command syntax: OFSx
```

```
Command format: OFS?
Return Message: x
```

Where x indicates the offset (value in 10 bit output resolution).

8.3 Flat field calibration

8.3.1. Introduction

The pixels of the CMOS sensor show offset and gain variations in their response to light.
In the Qs-4A60, Qs-2A120 these deviations are per-pixel corrected for.

- The offset correction is referred to as dark field correction.
- The gain correction is referred to as bright field correction. It comes in two flavours, local and global.
  In local flat field gain correction, a particular pixel is ‘flat fielded’ with respect to it’s near environment.
  In global flat field gain correction, the entire image is ‘flat fielded’ towards the same response (this can be used to compensate for e.g. shading due to optics).

The offset and local gain flat field corrections are pre-calibrated in the factory. The user is able to do recalibrate in the field. Calibrations may take up to several seconds.

Up to 3 gain calibrations may be saved for use.

8.3.2. Enable/disable flat field corrections

Offset and gain corrections may be enabled or disabled. Furthermore, for gain corrections local or global correction may be applied. In local gain correction a particular pixel is 'flat fielded' with respect to it's near environment. In global gain correction the entire image is 'flat fielded' towards the same response.

```
Command format: FFPn;x
```

```
Command format: FFP?n
Return Message: n
```

Where n indicates the parameter number and x the value of the parameter.
For clarity, the dark field related parameters start at 0 and all gain related parameters at 100.

N	RANGE X	DESCRIPTION
0	0,1	Disable (x=0) or enable (x=1) dark field fixed pattern (offset) correction.
100	0,1	Disable (x=0) or enable (x=1) gain correction.
101	0,1	Local (x=0) or global (x=1) gain correction.
102	0,1	Disable (x=0) or enable (x=1) automatic exposure adjustment during gain calibrations.
103	50..1023	Set target exposure level if FFP102 is set to 1. Default value is 700 (DN).

Settings 101 and 102 are related to the calibration of the corrections and do not play a role during operation of the camera (see section 8.3.5).

8.3.3. Gain flat field calibration set selection

There are 3 gain calibrations storable. This enables storing various sets for e.g. various optics. Selection of the calibration used can be configured by the command:

```
Command format: FFSELn
```

Where n = 1…3 representing the selected set n.

NOTE: The selected set also determines which set is used during gain calibration (FFCAL3, section 8.3.5).

If n=0, the selection is hardware controlled by 2 input signals. The routing of the 2 signals is selected by command CCFFSEL.

NOTE: If n=0, FFCAL3 results in FFERR 110; calibration may only be performed with set selection under software control.

Since the dark field offset image is not dependent on optics, the camera only allows for single offset calibration.

8.3.4. Gain flat field set input selection

If the flat field selection is hardware controlled (FFSEL=0), the inputs used are configured by command:

```
Command format: CCFFSELn;m
```

```
Command format: CCFFSEL?
Return Message: x
```

Where x indicates the selection according to the following table:

N, M	BIT1	BIT0
0	CC1	CC1
1	CC2	CC2
2	CC3	CC3
3	CC4	CC4
4	I/O-connector	I/O-connector

8.3.5. Calibration of flat field corrections

```
Command format: FFCALx
```

X	FUNCTION
0	Abort a pending calibration. The termination may take a few milliseconds. Termination is completed if FFSTA? returns 0.
1	Perform a full dark field offset calibration based on multiple images. This calibration requires a dark scene. Furthermore no specific camera settings are required. The camera will autonomously acquire the images at the user programmed integration time (IT). During calibration no images will be output over the interface.
2	Perform an incremental dark field offset calibration. The calibration takes minimal time, only one image is captured at a time. Only a minor adjustment to previously stored correction image takes place. The same requirements are valid as those described for FFCAL1.
3	Perform a full gain calibration. The gain set used (1…3) is configured by the FFSELn command. Selection between local and global non uniformity calibration is selected by a Flat Field Parameter command (FFP101;x). If the camera is not running in continuous mode, the camera should be triggered externally at a rate less than 50 fps. If FFP102;1 and the camera is running in continuous mode, the exposure will be adjusted automatically in advance of the calibration. The camera target exposure is configurable with FFP103;x.

8.3.6. Flat field calibration status

The status of a pending calibration can be queried by issuing command:

```
Command format: FFSTA?
Return Message: x
```

Where x indicates the status according to the following table:

X	CALIBRATION STATUS
0	Done
1	Full dark field offset calibration pending
2	Incremental dark field offset calibration pending
3	Gain calibration pending
10	Load or save calibration pending

No calibration can be started if the calibration status is unequal 0.

8.3.7. Flat field calibration error result

During the process of flat field calibration (FFCAL), storage or retrieval of flat field data (FFSC, FFLC) the error status can be queried by command:

```
Command format: FFERR?
Return Message: x
```

Where x indicates the status according to the following table:

#	DEFINITION
0	No error
1	Starting a calibration action while a calibration is still pending
2	Non volatile storage CRC error during read of flat field data
100	Ratio of maximum over minimum video level more than 4x or minimum video in image below 5% of full-scale during global gain calibration (FFCAL3 & FFP101;1). No calibration will be generated. If this error occurs, use command FFMINMAX? to retrieve the detected video levels.
101	FFCAL3 started with auto exposure adjustment (FFP102;1), but acquisition mode of camera is not continuous
102	Auto exposure adjustment failed, sensor exposure too low
103	Auto exposure adjustment failed, sensor exposure too high
104	Auto exposure adjustment failed, sensor exposure instable
110	FFCAL=3 not allowed in combination with FFSEL=0
500	Internal camera error (e.g. time out of internal process)

The error status will be cleared at the start of a flat field calibration or storage command.

8.3.8. Flat field minimum and maximum video levels

During global non-uniformity flat field calibration (FFCAL), the minimum and maximum video levels are measured and stored. These video level values can be queried by command:

```
Command format: FFMINMAX?
Return Message: x;y
```

Where x and y indicate respectively the minimum level and maximum level.
Returned values are in 10-bit resolution and without the offset as configured by the BL or OFS command.

8.3.9. Flat field calibration load calibration

The result of a stored calibration can be retrieved.

```
Command format: FFLCn
Return Message: n
```

Where n = 0 indicates the offset reference image
n = 1…3 indicate one of the available gain calibrations.

9. Image data formatting

9.1 Introduction

The video-processing, which translates the sensor signal to the digital Camera Link output can be configured. It is possible to select the number of bits on the output, there is the possibility to set a digital gain and there is a possibility to change the output offset. Horizontal and vertical mirror can be applied on demand.

Although the sensor in the camera has a fixed format, there are several possibilities to change the way the sensor is read-out. It is possible to limit the amount of lines read from the sensor. This can be achieved either by binning 2 or more pixels or skipping the readout of lines by selecting a region of interest.

A users programmable output look up table can be configured to translate each pixel value to a user defined value. This can be useful to implement, for instance, a gamma correction.

Furthermore, the Camera Link output parameters can be set by command to meet the required interface.

9.2 Processing commands

9.2.1. Digital gain

The digital gain of the camera can be set by means of the GA command.

```
Command format: GAx
```

```
Command format: GA?
Return Message: x
```

Where x is 100 ... 800.
100=1x gain, 250=2.5x gain, etc.

9.2.2. White Balance (only for color)

To correct for different illumination colors it is possible to program additional gain per color channel.

```
Command syntax: WBr;g;b
```

Where r = 100..399, representing a gain in the red channel of 1.00x .. 3.99x
g = 100..399, representing a gain in the green channel of 1.00x .. 3.99x
b = 100..399, representing a gain in the blue channel of 1.00x .. 3.99x

The actual white balance setting can be read back from the camera.

```
Command syntax: WB?
Reply message:  r;g;b
```

Where r,g,b are as above.

NOTE: The total gain per color can not be greater that 32x. So the product of digital gain (par 9.2.1) and white balance gain is clipped to 32x.

9.2.3. Mirror

The output image can be mirrored horizontally, vertically and a combination of both.

```
Command format: MIx
```

```
Command format: MI?
Return Message: x
```

Where x indicates the state of operation:

X	MIRROR FUNCTION
0	No mirror
1	Horizontal mirror
2	Vertical mirror
3	Horizontal and vertical mirror

In the processing order, the mirror function is applied after the ROI function has been performed.

9.2.4. Output resolution

The output resolution is set by the OR command to be 8 bit or 10 bit.

```
Command format: ORx
```

```
Command format: OR?
Return Message: x
```

where x is 8 or 10, indicating number of bits.

9.2.5. Region Of Interest

The actual region of the sensor that is output to the interface can be configured.

The image format is set by the ROI command.

```
Command format: ROIl;t;w;h
```

```
Command format: ROI?
Return Message: l;t;w;h
```

where l is the left most pixel.
t is the top pixel
w is the width of the ROI
h is the height of the ROI

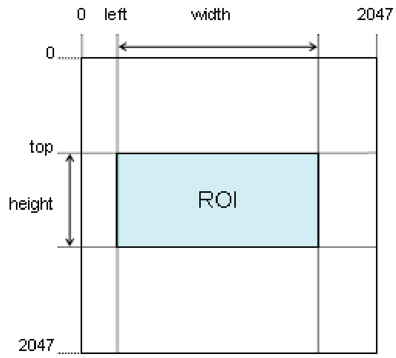


Figure 9.1: Representation of a Region Of Interest.

Reset of the ROI is done by command ROI0;0;2048;2048

When selecting a new ROI, the frame period is checked. If the frame period is too small, it is set to the minimum value allowed.

NOTE: In 2 tap output, the camera rounds the values of l and l+w to the nearest integer factor of 8 pixels.
In 3 tap output, the camera rounds the values of l and l+w to the nearest integer factor of 24 pixels.

NOTE: In case of a color camera, the values of t and h will be rounded down to the nearest multiple of 2 rows.

NOTE: Automatic centering of the ROI:
    If l = -1 the ROI will be centered in horizontal direction.
    If t = -1 the ROI will be centered in vertical direction.

if -1 is used for centering the ROI, command ROI? will not return -1, but the actual ROI value.

9.2.6. Binning

In certain circumstances it might be preferable to sum 2 or more pixels. This process is called binning. If two or more pixels are binned, the combination of those pixels can be regarded as one larger “binpixel”.
If the consequences of binning are known, it can be determined whether binning is preferred.

Binning at the Quartz camera is performed ‘off chip’. This means two or more adjecent pixels are digitally summed. The result is then divided by the binning factor. Binning at this method does not improve sensitivity.

Although the binned pixel value is represented as integer value, the decimal places are tracked internally and will be accounted for when digital gain is applied.
By applying digital gain while binning, the result can be considered as an increased sensitivity without missing codes.

Horizontal binning digitally adds a number of (horizontally adjacent) pixels into a single pixel.
Vertical binning digitally adds a number of (vertically adjacent) pixels into a single pixel.For a thorough understanding, of the concept please find some properties of the possibilities in the table below.

HBIN SETTING	VBIN SETTING	HBIN FACTOR	VBIN FACTOR	BINNED PIXEL CHARGE CORRESPONDING WITH FULL SCALE CAMERA OUTPUT [KEL]
1	1	1x	1x	13.5
1	2	1x	2x	27
1	4	1x	4x	54
2	1	2x	1x	27
2	2	2x	2x	54
2	4	2x	4x	108
4	1	4x	1x	54
4	2	4x	2x	108
4	4	4x	4x	216

Table 9.1: Theoretical charge values of camera in binning modes.

```
Command format:    HBINx

Command format:    HBIN?
Return Message:    x
```

Where x indicates number of pixels to bin; valid entries for x are 1, 2 or 4.

```
Command format:    VBINy

Command format:    VBIN?
Return Message:    y
```

Where y indicates number of pixels to bin; valid entries for y are 1, 2 or 4.

NOTE: that the ROI functions precedes the binning function, i.e. regions of interest are defined in the unbinned field of view.

The height of the ROI is truncated to the nearest multiple of the Vbin factor.
NB: digital binning does not allow higher *sensor* framerates.

NOTE: digital binning does not allow higher sensor framerates.

9.3 HiQ mode - Image averaging

The camera is able to average a number of images before they are output over the interface. Averaging N images reduces the temporal noise and increases the signal to noise ratio by a factor $\sqrt{N}$.

The averaging of images can be enabled by command AVG.

```
Command format: AVGx

Command format: AVG?
Return Message: x
```

Where x indicates number of images to average; $1 \leq x \leq 6$. x = 1 is the normal, non-averaged camera operation.

9.4 HDR mode - Multislope

Introduction

In the camera, a high optical dynamic range can be realized by using a multiple slope feature. For high exposures, this ensures contrast in bright part of the scene that would otherwise saturate.

The underlying principle is in varying the pixel charge capacity of the sensor in steps. This can be done up to 3 times within one exposure time to achieve a maximum of 3 exposure slopes. This is illustrated in the figures 9.2 and 9.3.

The multi slope levels Vhigh and Vlow1 in figure 9.2, correspond to pixel reset and normal 'single slope' sensor charge capacity respectively. The levels Vlow2 and Vlow3 are added in multi slope. The red and blue curves illustrate the effect of the additional steps.

The red curve represents a pixel that receives a bright illumination. The blue curve represents a pixel which is illuminated lower. As shown in the figure, the brightly lit pixel is affected twice by the intermediate voltage steps that effectively temporarily limit the pixel capacity. Eventually after the total exposure time this prevents the pixel from saturating. The darker pixel is not influenced by this multiple slope and will have a normal response. The pixel under bright illumination in figure 9.2 shows parts (horizontal lines) where the charge is constant. Basically, this is intermediate pixel saturation. The saturation comes with additional fixed pattern for which is not corrected for in the present camera.

The levels and exposure times are programmable via a command set as described below. This feature results in a multi slope (piece wise linear) response curve as in figure 9.3. The placement of the knee points in this image depends on the specific Voltage and Timing programming.

The multiscope can be used in both continuous as the various control modes. How the trigger the multiscope is explained in section 9.4.3.

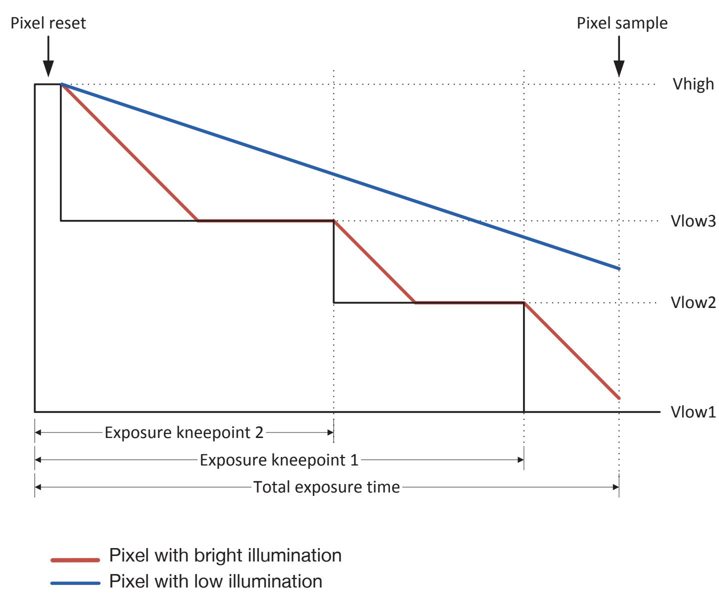


Figure 9.2: Multislope priciple

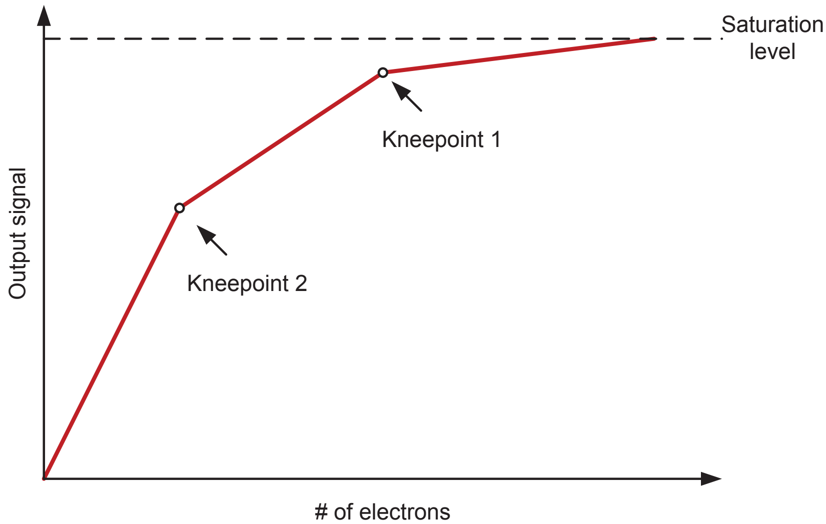


Figure 9.3: Multislope response curve

9.4.1. Set number of slopes

The number of multislopes is set witht he MS command.

```
Command format:    MSx

Command format:    MS?
Return message:    x
```

x can be 1, 2 of 3 and represents the number of slopes. For x = 1, the multislope functionality is disabled (single slope).

9.4.2. Set Multislope Levels

The levels are varied in percentage of the Single slope level Vlow1.

```
Command format:    MSLx;y

Command format:    MSL?
Return message:    x;y
```

Where $0 < x < y < 100$

In case of 2 slopes and y is entered smaller than x, y is automatically set to x + 1.

Default values are 50;70.

9.4.3. Set Multislope Timing steps

The timing of the exposure steps is set as a percentage of the total IT.

```
Command format:   MSTx;y
```

```
Command format:   MST?
Return message:   x;y
```

In case of 3 slopes, y must exceed x. Else an error will occur.

In case of 2 slopes and y < x, y is be adjusted automatically to exceed x by 1.

Default values are 80;95.

The MST command is only applicable to continuous mode (MO0) and triggered mode (MO3), where the IT is set with the ITx command.
For the control mode (MO1) and sync control mode (MO2), the multislope timings can be controlled by an additional CC trigger pulse. This can be programmed with the CCHDR command.

NOTE: the total exposure time is not equal to the integration time set by the ITx command (manual section 7.4.2). Instead, the actual integration time in the camera depends on the mode of operation.

9.4.4. Multislope timing trigger input and polarity selection

In case in the camera multislope is enabled and it is running in (sync) control mode (MO1/MO3), a second trigger must be fed to the camera to define the multislope exposure timing of figure 9.2. The CCHDR command sets the trigger input, as well as its polarity:

```
Command format: CCHDRx;y
```

```
Command format: CCHDR?
Return Message: x;y
```

Where parameter x selects the input:

X	INPUT
0	CC1
1	CC2
2	CC3
3	CC4
4	I/O-connector

Parameter y sets the signal polarity: y=1 triggers the new multislope levels (MSL) on the rising edge, y=0 triggers on falling edge.

In case of 2 slopes (MS2), one CCHDR trigger is required during a single exposure. In case of 3 slopes (MS3), two CCHDR triggers are required during a single exposure.

9.5 Output look-up table commands

9.5.1. Output look-up table begin

In order to load the output look-up table OLUT values, the camera should be prepared to receive the values. This is done through the OLUTBGN command.

`Command format: OLUTBGN`

If an OLUTBGN command is received when the OLUT is already opened and/or the OLUT is already (partly) filled, error 120 is issued and the OLUT-status is reset.

9.5.2. Output look-up table content

The user look-up table is loaded by command OLUT and entries can be retrieved by OLUT?

`Command format: OLUTy`

`Command format: OLUT?x`
`Return Message: y`

where x indicates the video level (in GL) from the processing core and y represents the resulting video level (in GL) at the camera output.

$0 \leq x \leq 1023$,

$0 \leq y \leq 1023$

To fill the OLUT, it should first be opened through the OLUTBGN command. If an OLUTy command is received without the OLUT being opened, error 121 is issued.
Then the 1024 LUT entries should be provided by sending 1024 OLUTy commands. If more then 1024 OLUTy commands are received, error 123 is issued and the OLUT-status is reset.

The full-scale range of the OLUT is always 1023. Optional down-scaling the output resolution to 8 bit is done after the OLUT.

9.5.3. Output look-up table end

After filling the output look-up table with 1024 values, the table should be closed. This is done through the OLUTEND command.

`Command format: OLUTEND`

If the camera did not receive exactly 1024 entries, error 122 is issued and the OLUT-status is reset.

9.5.4. Output look-up table enable

The user look-up table can be enabled or disabled by means of the OLUTE command.

`Command format: OLUTEx`

`Command format: OLUTE?`
`Return Message: x`

Where x is set to 1 for enabling the OLUT and 0 to disable the OLUT.

9.6 Camera Link parameter settings

9.6.1. Introduction

The active period for each line expressed in the number of clock cycles equals the number of pixels in a line (Image Width) divided by the number of taps. The number of pixels is programmed by means of the ROI command. At full resolution the Image Width equals 2048 pixels. Expressed in seconds the active time can be calculated with the formula:

$$t_{Active} = \frac{ROI\_width}{f_{clk} \cdot Taps}$$

The inactive period (t_{GAP} in figure 9.4) is the Lval gap time which is programmed as the second parameter of the OFRM command. t_{GAP} = Lval gap / f_{clk}

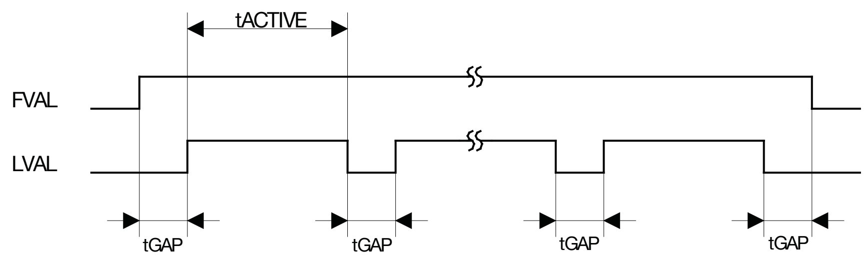
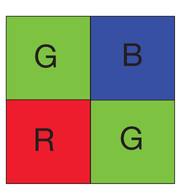


Figure 9.4: Timing diagram Camera Link.

Fval gap time can be programmed by the FVALGAP command in case it is needed to interface the camera with a slower framegrabber.

9.6.2. Bayer pattern (color cameras)

The Quartz color cameras use the following Bayer pattern for color encoding:



The green left top pixel is the first to be output by the camera.
When using the horizontal and/or vertical flip functions, the Bayer pattern will also be mirrored.

10. Service and maintenance

10.1 Camera status commands

10.1.1. Built-in test

The built-in test command returns the basic status of the camera.

```
Command format: BIT?
Return Message: x
```

Where x indicates the addition of the actual error codes:

CODE	DESCRIPTION
0	All tests are passed
1	FPGA boot failed
2	FPGA not running
4	Configuration data corrupt
8	Setting data corrupt
128	Output look-up table data corrupt
256	Sensor data alignment error

10.1.2. Error diagnosis

Since the communication protocol does not check the message content, the error result of a command must be obtained by the ERR? query command.

```
Command format: ERR?
Return Message: x
```

The ERR? command returns a single integer value x, the error code of the last executed command (The ERR? command itself when executed successfully does not effect the last error result).
A list of all possible error values and the cause of the error code are shown below:

CODE	CAUSE
0	Last command executed with success
1	Unknown command received
2	Parameter expected after command keyword
3	Invalid parameter syntax in last command
4	Too many parameters in last command
5	Not enough parameters in last command
7	Invalid parameter values in last command
100	LC command failed, no power-up defaults found. This indicates an internal NVRAM failure.
101	FD command failed, no valid factory defaults found. This indicates an internal NVRAM failure.
120	LUTBGN operation failed: LUT transactions already pending
121	Trying to add LUT elements or end LUT, but not opened
122	LUTEND, while too few elements were received
123	Adding more elements than allowed

NOTE: If no invalid commands or command parameter values are sent to the camera it is not necessary to obtain the error result after each command. However to increase the reliability of the whole system (camera + host system), it is good practice to check each command by obtaining the error result or use a query command to obtain the value of the last setting performed and check whether the setting is actually done.

10.1.3. Camera temperature

The camera is equipped with a temperature sensor on a PCB in the sensor.
The temperature measured can be read.

```
Command format: TM?
Return Message: x
```

Where x = the temperature in °C.

Valid range : 0 … +90 = 0 … 90°C; resolution: 1°C

NOTE: the temperature readout is subject to deviations and should be used for indicative purpose only.

10.2 Diagnostics

10.2.1. Test pattern

The camera can generate a test pattern in the mode the camera is currently working. The camera will continue working in the selected mode, but instead of the usual image, an artificial image is displayed.

The test pattern is built in for service and calibration purposes.

NOTE: This image is inserted in front of the digital gain stage. It represents full bitdepth when the gain command is set to 100, e.g. 1 time gain (GA? returns 100).

```
Command format: TPx
```

```
Command format: TP?
Return Message: x
```

Where x indicates the state of operation;

X	TEST PATTERN FUNCTION
0	Normal operation (No test pattern)
1	Test pattern is displayed (see figure 6.2)
2	Displays white cross hairs in normal image
3	Grey image, grey value to be set with command TPLVL. This test pattern can e.g. be used to visualize flat field corrections (command FFP).

Depending on the chosen camera resolution the test pattern is 8 or 10 bit.

NOTE: The normal test pattern (TP1) cannot be mirrored vertically (MI2, described section 9.2.3). Horizontal mirroring is possible.

NOTE: it is not possible to perform vertical mirror on the test pattern.

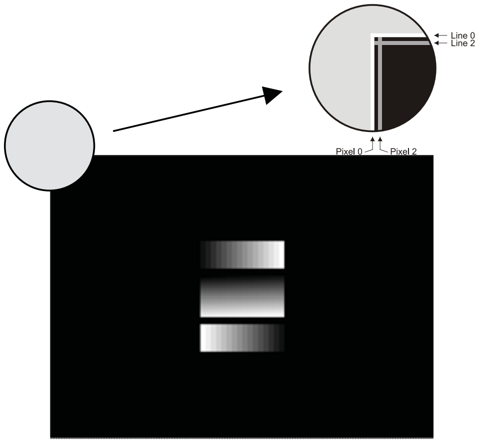


Figure 10.1: Representation of the test pattern gray levels

The exact gray levels, expressed in 10 bit output, are as presented on the next page. For 8 bit output resolution the values are truncated as follows:

10 BIT	8 BIT
0	0
1	0
2	0
3	0
4	1
...	
15	
16	
...	
511	127
...	
1023	255

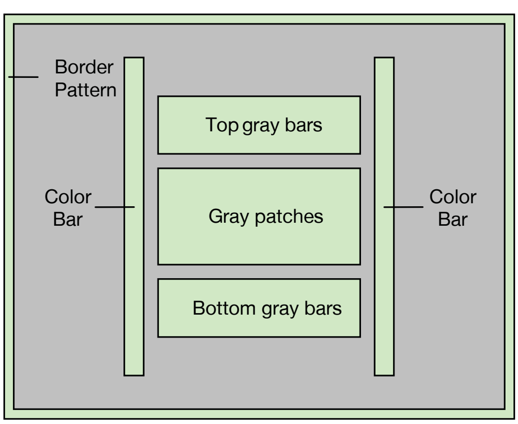


Figure 10.2: Test pattern layout.

NOTE: that the ROI function does not cut-out a part of the test pattern, but the test image is reshaped:

- The gradient objects are centered in the ROI-output-image, size and distance remain the same,
- The ROI output image has the contour lines (white and middle-gray) in the outer pixels.

Border pattern

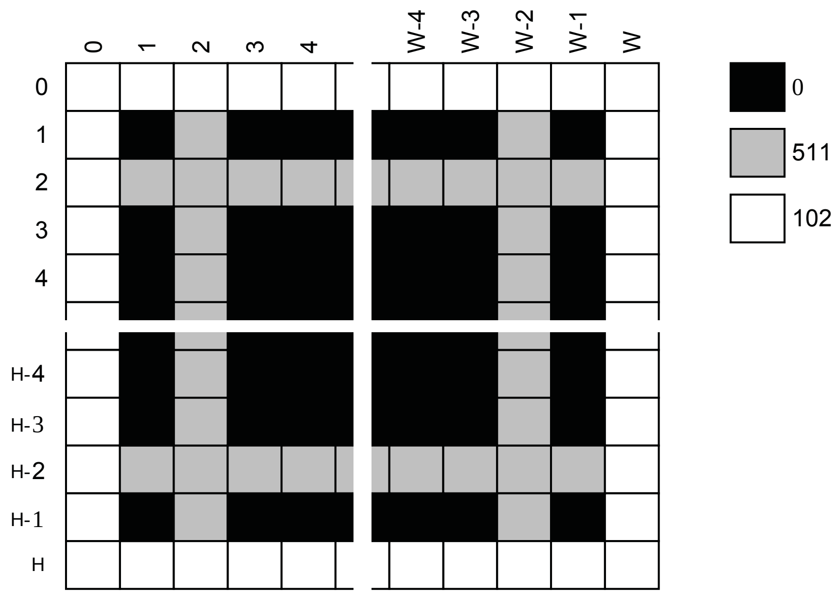


Figure 10.3: Test pattern border illustration

Top gray bars

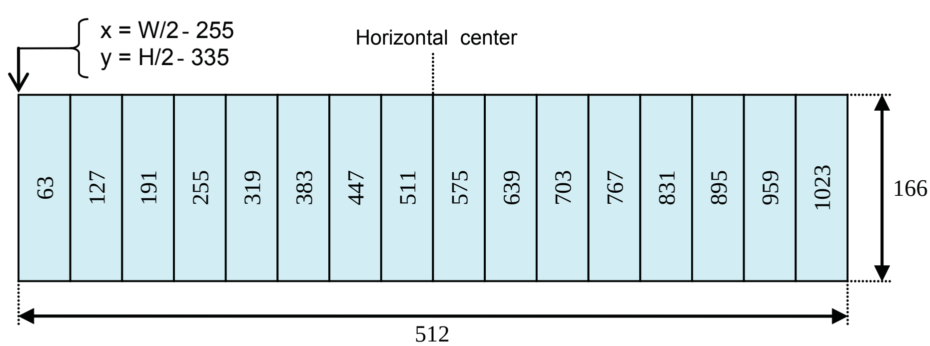


Figure 10.4: Top gray bars illustration

Gray patches

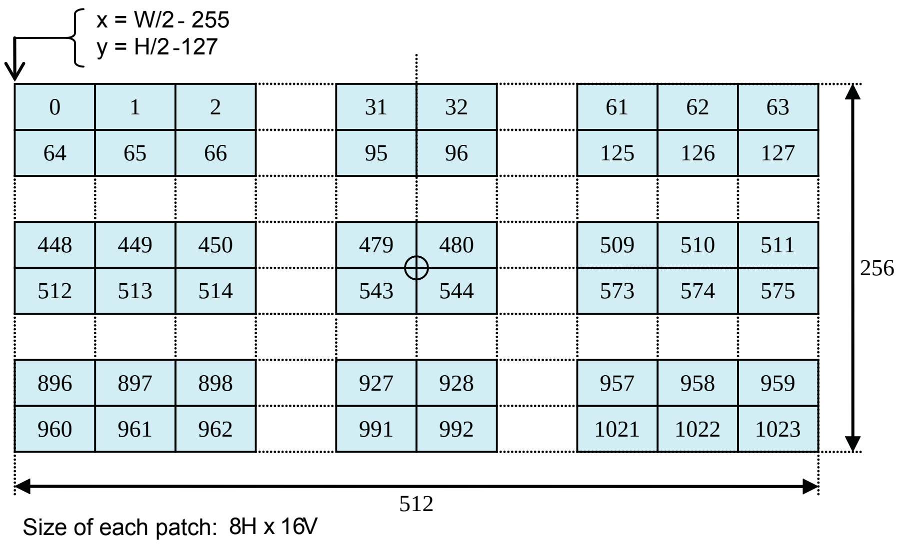


Figure 10.5: Middle section grey patches illustration

Bottom gray bars

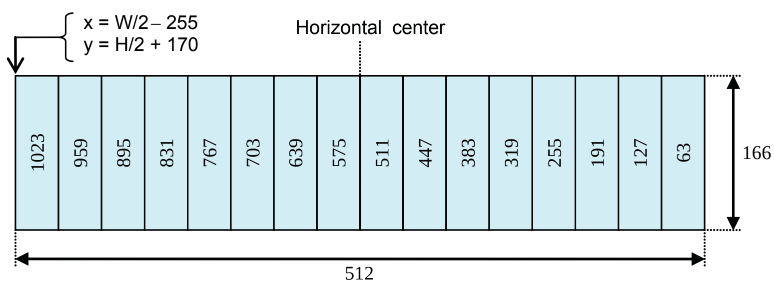


Figure 10.6: Bottom grey bars illustration

10.2.2. Video level of uniform test pattern

When test pattern 3 is selected, the output will be a uniform video level.
This can be a practical help in checking transmission paths when, for instance, cable crosstalk errors occur.

When (offset and/or gain) flat field correction is enabled, the output will visualize the magnitude of these corrections in the image.

The video level for test pattern 3 can be configured with command:

```
Command format:    TPLVLx
                   TPLVL?
```

where: x is the video level. The video level is always in 10-bit; 0 < x < 1023.

11. Camera Link ports assignment

The Camera Link configuration used is the base and medium configuration.

See table below and refer to the Camera Link specification, appendix C.

	2-TAP (OFRM2;X)	3-TAP (OFRM3;X)
OR8	Base Configuration (Table C-1) 8 bit x 2	Base Configuration (Table C-1) 8 bit x 3
OR10	Base Configuration (Table C-1) 10 bit x 2	-

Table 11.1: Camera Link configurations at different output formats