Operating and user manual

Q-12A180F

rev1.0

Excellence in Imaging

192930

ABOUT ADIMEC

Adimec designs, manufactures, and markets high performance industrial cameras for equipment manufacturers in:

- Machine Vision
- Healthcare
- Global Security

Our high resolution cameras offer a unique combination of excellence in image quality, speed, and reliability. With optimized functionality for the needs of specific applications, Adimec cameras exceed general purpose.

Adimec is a reliable partner with a focus on establishing long term relationships through a worldwide network of highly qualified engineers.

Adimec aligns its roadmap in close cooperation with industry leaders and monitors the market for the latest technology to continuously provide innovative cameras that enhance our customers' competitiveness. With our capabilities, modular designs, process control and commitment to partnership, we can tailor to the exact solution required in a short time to market and with low risk.

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1 GENERAL INTRODUCTION

The Quartz CMOS camera described in this manual provides 12Mp resolution through a CoaXPress interface. The sensor has a global shutter architecture, combined with 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

- 12 Megapixels up to 187 fps
- True Global Shutter CMOS
- Column based DSNU and PRNU corrections
- Configurable 1,2 or 4 lane CXP3 - 6 interface.
- M12 I/O connector optional
- CoaXPress V1.1 compliant
- CoaXPress V1.0 compatible

1.2 About this manual

This manual describes the Q-12A180F camera.

All specifications in this document apply to the products listed above unless stated otherwise.
Practical tips or notes are indicated by the "**NOTE:**" sign.

1.3 Standards

- CoaXPress Standard Version 1.1 – JIIA CXP-001-2013
- CoaXPress Standard Version 1.0 – JIIA CXP-001-2010
- GenICam V2.3.1
- SFNC V2.0

1.4 Waste Electrical and Electronic Equipment

With regard to waste electrical and electronic equipment (WEEE), Adimec wishes to follow the Directive 2002/96/EC of the European Parliament and of the Council. The purpose of this Directive is, as a first priority, the prevention of waste electrical and electronic equipment (WEEE), and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment, e.g. producers, distributors and consumers and in particular those operators directly involved in the treatment of waste electrical and electronic equipment.

Separate collection for electronic equipment in your area is recommended in order to minimize the disposal of WEEE as unsorted municipal waste and to achieve a high level of separate collection of WEEE.

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2 PRECAUTIONS

NOTE: In case the camera is used as a subsystem, it is advised to include the text of this chapter in the assembly documents of the main system.

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 CE symbol

The following symbol for “Conformité Européenne” is applicable to and indicated on the camera.

2.2 Handling precautions

2.2.1 Preventing dirt on and damage of the CMOS sensor

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 10 µm 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: 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 lens mount 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 screws (m3x6 screws; torx10) that hold the lensmount (see figure 2.1).

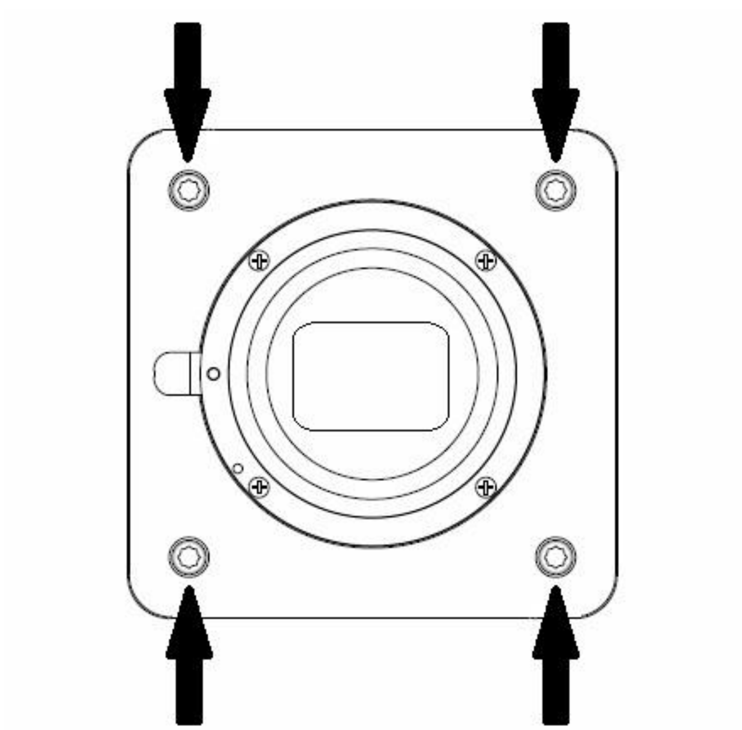

Figure 2-1: Lensmount fixation points

3. 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 - down.

4. Install the lensmount back on the camera front.
   Maximum tightening force may not exceed 0.6 Nm.

5. 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 exposure time if necessary.

6. 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).

7. 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. For repair and modification contact contact your local dealer or the business offices in your region.

2.2.6 Mounting / Mechanical

Connectors

Take care during handling of the camera. Connectors should not be damaged.
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. M4 screws should be used with a maximum screw depth of 5 mm. The recommended tightening torque is 108 cNm.

3 INSTALLATION HARDWARE

In this chapter the electrical interfaces as well as the optical interface are described. If a lens, cabling and frame grabber is available and installed, one may refer directly to the quick start section at the end of this chapter. The other sections describe the interfaces in detail.

3.1 Connector overview

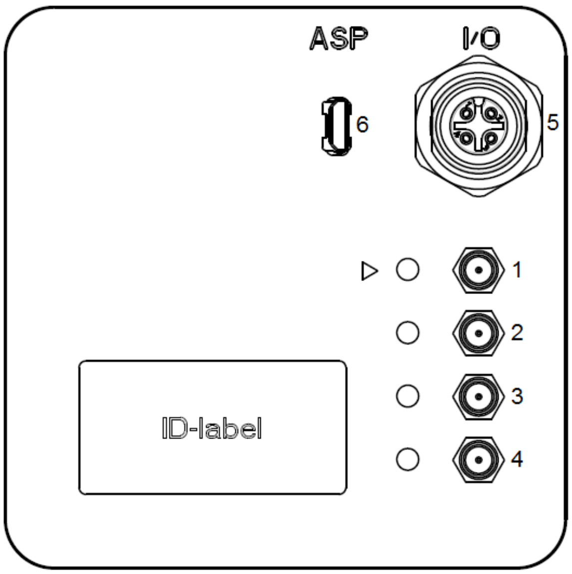

Figure 3-1: Camera back overview

Connector number	*Connector type*	*Description*	*Mating connector*
1	DIN 1.0/2.3	CXP connection 0 (Master connection)	DIN 1.0/2.3[1]
2	DIN 1.0/2.3	CXP connection 1 (Extension, Dual)[2]	DIN 1.0/2.3[1]
3	DIN 1.0/2.3	CXP connection 2 (Extension, Quad)[3]	DIN 1.0/2.3[1]
4	DIN 1.0/2.3	CXP connection 3 (Extension, Quad)[3]	DIN 1.0/2.3[1]
5	Binder M12 type 09-3432-216-04	I/O connector	Binder M12 type 79-3529-13-04
6	Micro USB, type B (Socket)	Adimec Service Port	Micro USB, type B (Plug)

Table 3-1: Camera connections

Note:
[1] Single DIN cables and multi DIN cables supported
[2] Dual: CXP connection 0, 1 are used
[3] Quad: CXP connection 0, 1, 2, 3 are used

3.2 Electrical interface - CoaXPress

The camera has 4 DIN1.0/2.3 connectors for the CoaXPress interface which serve the purposes listed in the table below. Refer to Table 3-3 for details on the CXP data rate configurations.

CXP connection	*Interface functions*
0	Video, power, control, triggering
1	Video
2	Video
3	Video

Table 3-2: Functionality per CXP connection

3.2.1 Power

Power is supplied over the master coax connection (PoCXP) with a maximum of 13 Watt according to the CoaXPress standard. The dissipation of the Q-12A180 is <9 Watt @ 24 Volt (with maximum frame speed at full resolution).

3.2.2 Video, control and trigger

The CoaXPress interface is designed to transfer video from camera to the frame grabber as well as control data, triggering and power from the frame grabber to the camera.

The maximum cable length depends on the used cabling and CXP configuration. See an overview in the table below.

CXP speed (Gbps)	*Maximum cable length (cable Belden 1694A)*
3.125	105 m
6.25	45 m

Table 3-3: Maximum cable length per CXP configuration

For a complete description of the CoaXPress interface please refer to the CoaXPress specification.

3.2.3 Adimec Service Port

The Adimec Service Port (ASP) interface is available for firmware uploads to the camera.
USB driver XR21x141x is required to support communication via the ASP port.

3.2.4 Electrical interface – strobe and trigger

A fully programmable trigger input and flash strobe output are available at the I/O connector.
The trigger input and output are galvanic isolated from the internal camera electronics by means of an optocoupler. (Avago ACPL-M50L).

Connector view backside of the camera:

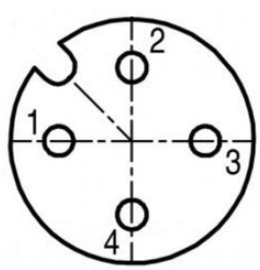

Figure 3-2: Camera female I/O connector

Connector pinning:

Pin	*Signal name*	*Type*	*Level*	*Description*
1	Trigger in	Input	10..20 mA	Anode of opto-coupler*
2	Flash strobe out	Output		Open collector of opto-coupler photo transistor.
3	Flash strobe return	Output	Isolated gnd	Emitter of opto-coupler photo transistor.
4	Trigger return	Input	Isolated gnd	Cathode of opto-coupler

Table 3-4: Connector pinning

* serial resistors 2x 220 Ω inside camera.

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 3-5.

Vext [V]	*R1E ext [Ω]*	*R2E ext [Ω]*
3.3	1000	Do not apply
5.0	2000	0
12	4700	470

Table 3-5: Recommended register values

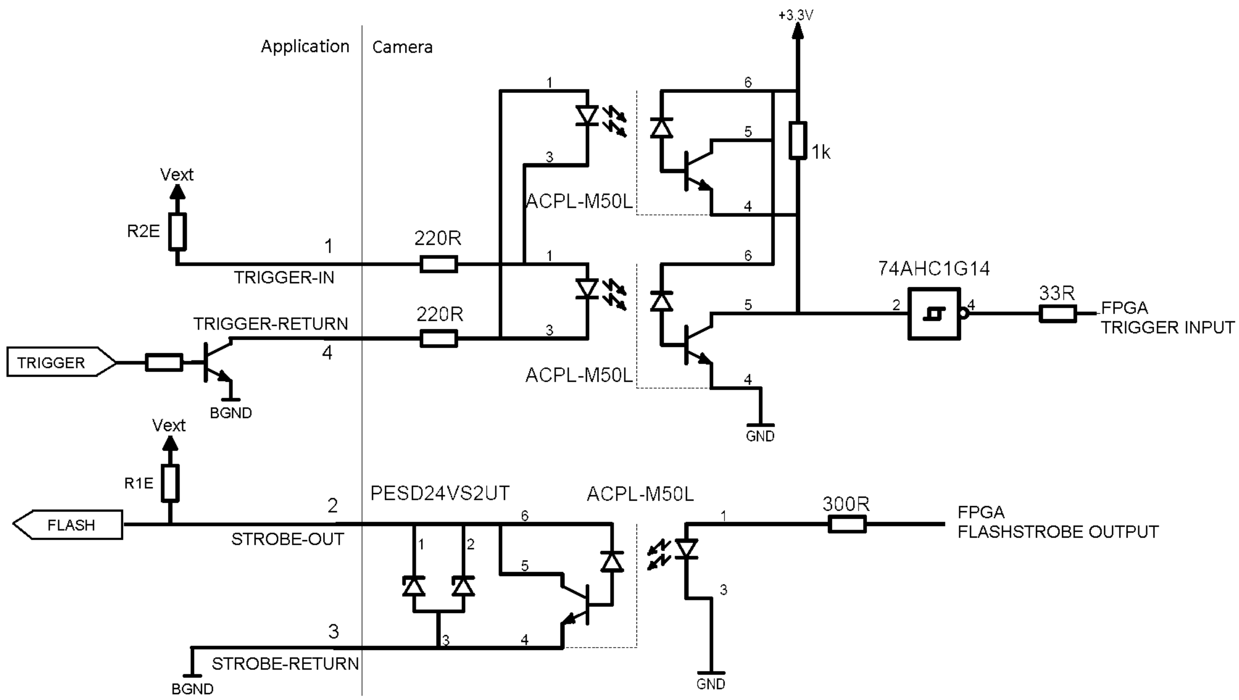

Figure 3-3: Recommended terminations strobe output and trigger input

3.2.5 Lensmount overview

Table 3-6 gives an overview of the available lensmounts for the Q-12A180 camera with the corresponding Adimec article code.

Lensmount type	*Adimec article code*
Fixed F-mount	187490
Fixed M42-mount	191540
Fixed T2-mount	189080
Fixed TFL2-mount	188230
Adjustable TFL2-mount	189590

Table 3-6: Lensmount overview

3.3 LED indicators

Next to each DIN1.0/2.3 connector is a multi-color LED indicator.
The meaning for each LED indication is shown in the table below.

LED indication		*Camera / interface state*
	Off	No power
	Solid orange	System booting
	Slow pulse orange	Device / Host connected, waiting for event (e.g. trigger, exposure pulse)
	500 ms red pulse In case of multiple errors, there shall be at least two green fast flash pulses before the next error is indicated	Error during data transfer (e.g. CRC error, single bit error detected)
	Fast flash red	System error (e.g. internal error)
	Solid green	Device / Host connected, but no data being transferred
	Fast flash green	Device / Host connected, data being transferred
	Fast flash alternate green / orange Shown for a minimum of 1s even if the connection detection is faster	Connection detection in progress, PoCXP active
	Slow flash alternate green / orange	Connection test packets being sent
	Slow flash alternate red / green / orange	Compliance test mode enabled (Device only)

Table 3-7: Led indication states

Led indication	*Timing*
Fast flash	12.5 Hz
Slow flash	0.5 Hz
Slow flash	1 Hz

Table 3-8: Led indication flash timing

3.4 Quick start

- Mount a lens on the camera and adjust the iris for F5.6
- Connect the CXP cables to the camera and the frame grabber
- Start the PC and start the frame grabber application
- Perform a camera discovery with the frame grabber and start acquisition

Default factory settings of the Q-12A180 camera:

Function	*Setting*
CoaXPress revision	1.1
Connection configuration	CXP3_X1
Exposure mode	Continuous
Output resolution	10 bit

Table 3-9: Factory default interface settings

Note: Contact Adimec for more detailed information about above procedure if required. There are quick install guides available for a couple of frame grabber manufacturers.

4 FUNCTIONAL DESCRIPTION

This chapter contains a functional description of the Q-12A180 camera. It briefly describes the main functions and features of the camera using a simplified block diagram.

More in-depth explanations on these functions as well as descriptions on how to control them are in the next chapters of this manual.

4.1 Block diagram

The diagram below shows the main functional blocks of the Q-12A180 camera.

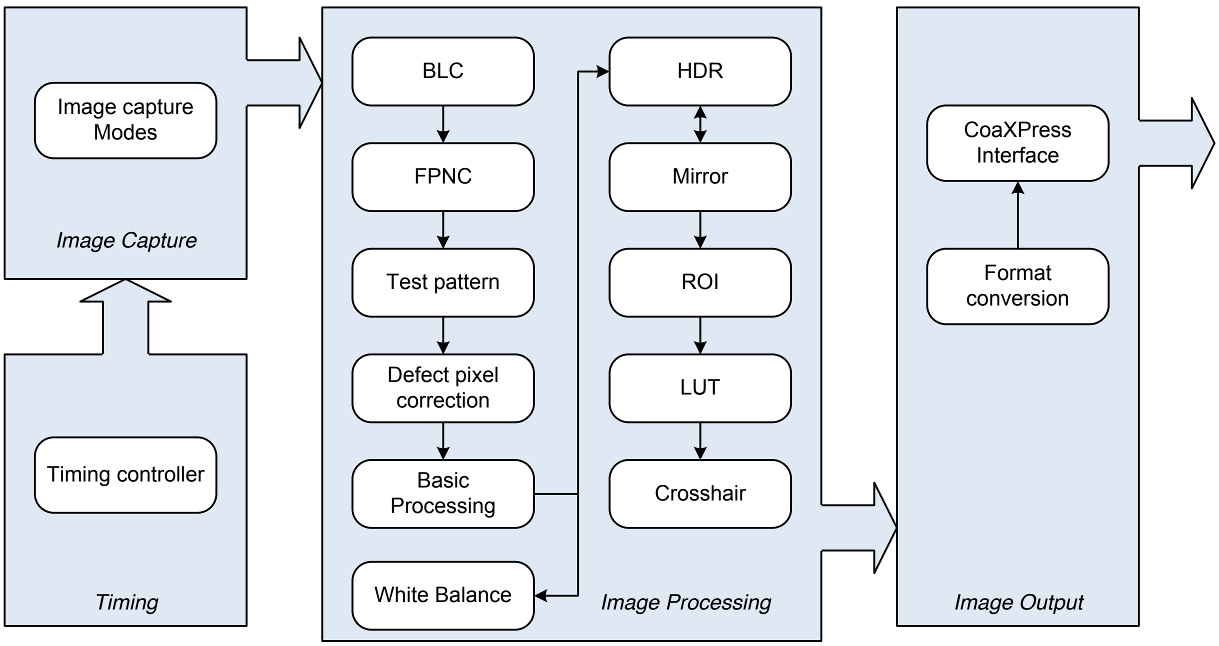

Figure 4-1: Block diagram of the camera

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

The acquisition rate and exposure time can be controlled externally via a selectable trigger input or the camera can operate in free run mode where the camera generates the timing.

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.

The delay time between the sensor reset operation in the active state of the flash strobe, as well as the duration of the flash strobe if the camera is in programmed strobe timing mode, can be user programmed.

Black Level Clamp (BLC): The Black Level Clamp function clamps the black level per line using the dark reference columns if this function is enabled.

Fixed Pattern Noise Correction (FPNC): Dark field and bright field column based corrections allows for correction of column based fixed pattern noise. Calibration of these functions can be performed in the field.

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

The defect pixel correction function can be enabled and disabled on demand. Also, defect pixels can be added to the list or removed by the user.

The basic processing block consist of several functions, like:

- Digital fine gain addition.
- RGB gain addition (only color)
- Black level offset.

HDR: High Dynamic Range function. With this function an optical high dynamic range can be realized by using the multi slope feature or the interleaved exposure mode of the sensor.

The output image can be mirrored horizontally and vertically.

A Region Of Interest (ROI block) is available. The camera will only output video information from a programmable rectangular sub frame. This reduces the amount of data and can increase the frame rate.

An output look-up table (LUT) 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).

A crosshair overlay can be enabled. This function can be used for the optical alignment of the optics.

The video data is mapped into the packed CXP format for sending data according to the CXP protocol. The output resolution can be set to 8 bit or 10 bit by user command. The output format can be set by user command. Both CXP 1.0 and 1.1 formats are supported and can be configured.

5 CONTROL OF THE CAMERA

5.1 Introduction CoaXPress and GenICam

The CoaXPress interface is register-based and GenICam compliant. The former means in practice that if a setting is changed or queried, a value is written to or obtained from a camera register with an address. The exact address and interpretation of this value is camera specific.

GenICam (Generic Interface for Cameras) is designed to bridge this. With CoaXPress frame grabbers a GenICam Application Programming Interface (GenAPI) is provided. This is a software layer that maps generic programming syntax onto the camera registers, using a description XML file. The programming syntax complies to the GenICam SFNC (Standard Features Naming Convention).

The description XML file is stored in the camera. Upon camera startup, most frame grabbers will automatically download the description XML file from the camera.

Communication between application and camera through SFNC, GenAPI and CoaXPress is schematically shown in Figure 5-1.

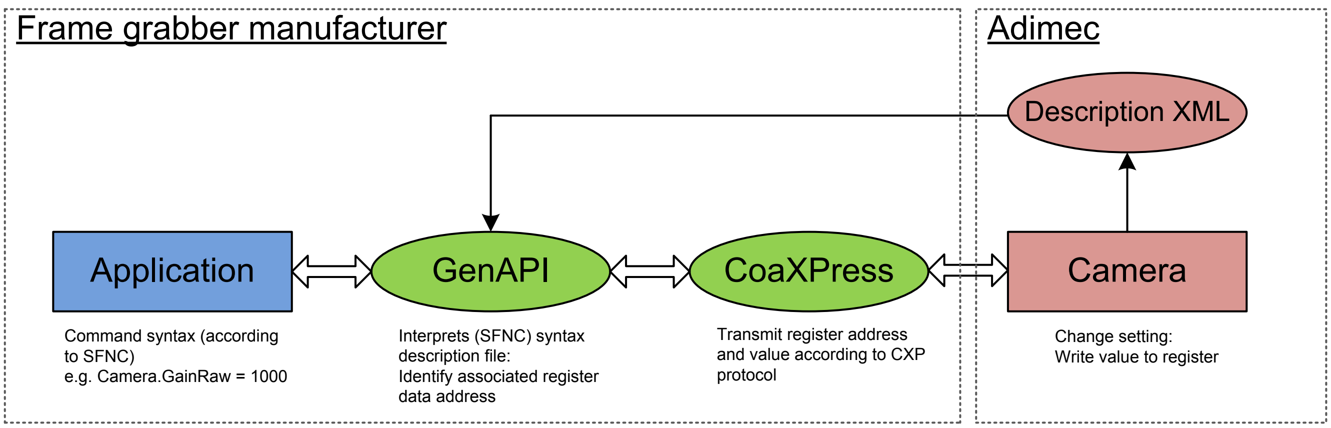

Figure 5-1: Schematic view of communication between application and camera through SFNC, GenAPI and CoaXPress

In practice the camera is controlled as follows. If a user would like to change a camera setting, for example gain, GenICam (SFNC) prescribes a standardized syntax.

```
if( IsAvailable(Camera.GainRaw) )
        Camera.GainRaw = 1000;
```

GenAPI can interpret such commands by the description file, and for example figure out that in order to set the gain to ‘1000’, a value of 3E8 (HEX) must be written to a register located at address 0x0815 (HEX). Other tasks involved might be to check in advance whether the camera possesses a Gain feature and to check whether the new value is consistent with the allowed Gain range.

This register message is transmitted via the CoaXPress protocol and interpreted and applied inside the camera.

5.2 Structure of camera control

The practical way to control the camera is closely dependant on the frame grabber manufacturers' software implementation and SDK.

Most frame grabber manufacturers' software provide a Graphical User Interface (GUI) that is automatically generated from the XML file.

This manual focuses on the camera functionality. The specific commands and their effect on the camera operation are described in detail.

Of each GenAPI parameter its name, interface, access, visibility, description, range and default are listed.

5.2.1 Register name

Each parameter is identified by a unique name.

Most names are part of the Standard Features Naming Convention SFNC. For some Q-12A180 functions no SFNC equivalent was available, for these functions, names outside SFNC are introduced.

5.2.2 Register address

This parameter indicates the address value (decimal format) of the register.

5.2.3 Register size

This parameter indicates the register value size in units of bytes.

5.2.4 Register interface

The parameter interface indicates the type of the parameter. This is mainly used in the frame grabbers' GUI to assign a display type to the Parameter.

Interface	*Table interface name*	*GUI display type*
Integer	I	Slider with value, min, max and increment
Float	F	Slider with value, min, max and physical unit
String	S	Edit box showing a string
Enumeration	E	Drop down box
Command	C	Command button
Boolean	B	Check box
Category	C	Entry in a tree, structuring the camera features in the XML file. The features are categorized and grouped according to Categories.

Table 5-1: Overview of parameter interfaces

5.2.5 Parameter access

This parameter indicates if the user can Read (RO), Write (WO) or Read/Write (RW) the parameter.

5.2.6 Parameter visibility

Each parameter has a visibility level assigned to it: Beginner, Expert and Guru (increasing in complexity).
The visibility does not affect the functionality of the features but is merely used by the frame grabber manufacturers' GUI to decide which features to display based on the current user level.
The purpose is mainly to insure that the GUI is not cluttered with information that is not intended at the current user level.

The following criteria's have been used for the assignment of recommended visibility:

- B: beginner - features that should be visible for all users via the GUI and API. The number of features with "beginner" visibility is limited to all basic features of the devices so the GUI display is well-arranged and is easy to use.
- E: expert - features that require a more in-depth knowledge of the camera functionality. This is the visibility level for all advanced features in the cameras.
- G: guru – advanced features that might bring the cameras into a state where it will not work properly anymore if it is set incorrectly for the cameras current mode of operation.The guru parameters mainly have use in debugging.

NOTE: not all the guru level parameters are described in this manual. In case the user needs to control them, please contact your local support.

In this manual, for each setting and function the visibility is indicated by the letter B (beginner), E (expert) or G (guru).

5.2.7 Parameter default and range

For each parameter the range and default value is listened.
NOTE: The default value is not stored in the XML file but in the camera itself.

5.2.8 Register setting synchronization

Some register setting changes require the camera acquisition to be stopped. To easily control also these registers while acquisition is running the camera automatically performs a sequence of acquisition stop, setting change and acquisition start. It could occur that during this sequence frames being dropped. Table 5-2 gives an overview of the registers which required acquisition to be stopped.

Chapter	*Register name*	*Description*
BootstrapCoaXPress	ConnectionConfig	Holds a valid combination of Device connection speed and number of active connections.
ImageFormatControl	Width	Width of the Image provided by the device (in pixels).
	Height	Height of the image provided by the device (in pixels).
	OffsetX	Horizontal offset from the origin to the region of interest (in pixels).
	OffsetY	Vertical offset from the origin to the region of interest (in pixels).
	ReverseX	Flip horizontally the image sent by the device. The Region of interest is applied after the flipping.
	ReverseY	Flip vertically the image sent by the device. The Region of interest is applied after the flipping.
	PixelFormat	Format of the pixel to use for acquisition.
AcquisitionControl	TriggerSource	Specifies the internal signal or physical input Line to use as the trigger source.
	ExposureMode	Sets the operation mode of the Exposure (or shutter).
UserSetControl	UserSetLoad	Loads the User Set specified by *UserSetSelector* to the device and makes it active.

Table 5-2: Register which require acquisition stop after setting change

5.2.9 Bootstrap CoaXPress registers

Register name	Address	Size (bytes)	Interface	Access	Visibility	Description	Default	Range
Standard	0	4	I	RO	B	Unique Identification of the CoaXPress Standard.	0	-
Revision	4	4	I	RO	B	Revision of the CoaXPress specifciation implemented.	0	-
XmlManifestSize	8	4	I	RO	G	The number of XML manifests available.	0	-
XmlManifestSelector	12	4	I	RW	G	Selects the XML manifest entry.	0	-
XmlVersion	16	4	I	RO	G	Indicates the version of the XML file referenced by the XmlManifestSelector.	0	-
XmlSchemeVersion	20	4	I	RO	G	Indicates the scheme version of the XML file referenced by the XmlManifestSelector.	0	-
XmlUrlAddress	24	4	I	RO	G	Indicates the start of the URL string referenced by the XmlManifestSelector.	0	-
Iidc2Address	28	4	I	RO	G	If the Device supports the IIDC2 protocol, then this register shall provide the address of the start of the IIDC2 register space.	0	-
ConnectionReset	16384	4	I	RW	G	Resets all connections of the Device.	0	-
DeviceConnectionID	16388	4	I	RO	G	Provides the ID of the Device connection via which this register is read.	0	-
MasterHostConnectionID	16392	4	I	RW	G	Holds the Host Connection ID of the Host connection connected to the Device Master connection.	0	-
ControlPacketSizeMax	16396	4	I	RO	G	Provides the maximum control packet data size. The size is defined in bytes, and shall be a multiple of 4 bytes.	0	-
StreamPacketSizeMax	16400	4	I	RW	G	Provides the maximum stream packet data size the Host can accept. The size is defined in bytes, and shall be a multiple of 4 bytes.	0	-
ConnectionConfig	16404	4	E	RW	B	Holds a valid combination of Device connection speed and number of active connections.	0x10038	CXP3_X1 = 0x10038(65592) CXP6_X1 = 0x10048(65608) CXP3_X2 = 0x20038(131128) CXP6_X2 = 0x20048(131144) CXP3_X4 = 0x40038(262200) CXP6_X4 = 0x40048(262216)
ConnectionConfigDefault	16408	4	E	RO	B	Holds a valid default mode combination of Device connection speed and number of active connections.	0x10038	CXP3_X1 = 0x10038(65592) CXP6_X1 = 0x10048(65608) CXP3_X2 = 0x20038(131128) CXP6_X2 = 0x20048(131144) CXP3_X4 = 0x40038(262200) CXP6_X4 = 0x40048(262216)
TestMode	16412	4	E	RW	G	Enables test packet transmission from Device to Host.	0	Off = 0x0(0) Mode1 = 0x1(1)
TestErrorCountSelector	16416	4	I	RW	G	Selects the TestErrorCount register. Selection shall be a valid Device Connection ID.	0	0 to 3 (increment: 1)
TestErrorCount	16420	4	I	RW	G	Current connection error count selected by TestErrorCountSelector.	0	-
TestPacketCountTx	16424	8	I	RW	G	Current connection test transmit packet count selected by TestErrorCountSelector.	0	-
TestPacketCountRx	16432	8	I	RW	G	Current connection test receive packet count selected by TestErrorCountSelector.	0	-
ElectricalCompliancyTest	16440	4	E	RW	G	Supports the formal electrical compliancy testing of the Device.	0	NormalOperatingMode = 0x0(0) CXP3_X1 = 0x10038(65592) CXP6_X1 = 0x10048(65608) CXP3_X2 = 0x20038(131128) CXP6_X2 = 0x20048(131144) CXP3_X4 = 0x40038(262200) CXP6_X4 = 0x40048(262216)
WidthAddress	12288	4	I	RW	G	Provides the address in the manufacturer-specific register space of the feature with the corresponding name.	0	-
HeightAddress	12292	4	I	RW	G	Provides the address in the manufacturer-specific register space of the feature with the corresponding name.	0	-
AcquisitionModeAddress	12296	4	I	RW	G	Provides the address in the manufacturer-specific register space of the feature with the corresponding name.	0	-

Table 5-3: Bootstrap CoaXPress registers

5.2.9.1 ConnectionConfig

The CXP link configuration is programmable. The number of links can be programmed to be 1, 2 or 4. Independently the bit rate (applies to all active links) can be programmed to be 3.125 Gbps or 6.25 Gbps.

Configuration	*Number of links*	*Configuration speed (Gbps)*
CXP3_X1	1	3.125
CXP6_X1	1	6.25
CXP3_X2	2	3.125
CXP6_X2	2	6.25
CXP3_X4	4	3.125
CXP6_X4	4	6.25

Table 5-4: Link configuration options

Connection config characteristics:

- Acquisition must be stopped before changing the link configuration.
- Depending on the CXP link configuration the camera is optimized for minimum power dissipation.
- For each SensorBitDepth and ProgrammableGainAmplifier configuration option a different dark field and bright field set is selected due to a change in sensor characteristics. Each set can be recalibrated to optimize for the environmental conditions.

Detailed information about the bootstrap CoaXPress registers can be found in the JIIA CoaXPress standard document.

5.2.10 Device control registers

Register name	Address	Size (bytes)	Interface	Access	Visibility	Description	Default	Range
DeviceVendorName	8192	32	S	RO	B	Name of the manufacturer of the device.	-	-
DeviceModelName	8224	32	S	RO	B	Model of the device.	-	-
DeviceManufacturerInfo	8256	48	S	RO	B	Manufacturer information about the device.	-	-
DeviceVersion	8304	32	S	RW	B	Version of the device (user read only).	-	-
DeviceFirmwareVersion	8336	32	S	RO	B	Version of the firmware in the device.	-	-
DeviceSerialNumber	8368	16	S	RW	E	Device serial number (identifier, user read only).	-	-
DeviceUserID	8384	16	S	RW	B	User-programmable device identifier.	-	-
DeviceIndicatorMode	33672	4	E	RW	E	Controls the behavior of the indicators (such as LEDs) showing the status of the Device.	-	Inactive = 0x0(0) ⍰ Active = 0x1(1) ⍰ ErrorStatus = 0x2(2) ⍰
BuiltInTest	41004	4	I	RO	E	Returns the Built In Test status of the camera.	0	-
SensorTemperature	41012	4	I	RO	E	Returns the temperature of the sensor.	0	-

Table 5-5: Device control registers

The status and firmware versions of the camera can be read back in the device control registers group. It's possible for the user to disable the LED status indicators with the *DeviceIndicatorMode* register.

5.2.10.1 Built-in test

The built-in test register returns the basic status of the camera. When no failures are detected the built-in test result code is 0. Some of these tests are run at camera start-up, others run continuously. Table 5-6 gives an overview of the built-in test failure bit masks.

Failure condition	*Mask value (Hex)*	*When tested*
FPGA not booted	0x00000001	At start-up
Flash not recognized	0x00000002	At start-up
Factory settings corrupt	0x00000004	When data is read from flash
User settings corrupt	0x00000008	When data is read from flash
Factory defect pixel data corrupt	0x00000010	When data is read from flash
User defect pixel data corrupt	0x00000020	When data is read from flash
Calibration corrupt	0x00000040	When data is read from flash
5V power supply error	0x00000080	At start-up
1.8V power supply error	0x00000100	At start-up
1.2V power supply error	0x00000200	At start-up
1V Power supply error	0x00000400	At start-up
Camera configuration corrupt (m/c, Bayer phase)	0x00000800	At start-up
Look-Up Table corrupt	0x00001000	When data is read from flash
Device Names corrupt	0x00002000	At start-up
Sensor data alignment failed	0x00004000	Continuous; actual status is updated on a 1 sec. interval.

Table 5-6: Built-in test failure bit mask

5.2.11 Image format control registers

Register name	**Address**	**Size**	**Interface**	**Access**	**Visibility**	**Description**	**Default**	**Range**
Width	33048	4	I	RW	B	Width of the image provided by the device (in pixels).	4096	32 to SensorWidth (increment: 32)
Height	33052	4	I	RW	B	Height of the image provided by the device (in pixels).	3072	32 to SensorHeight (increment: 4)
SensorWidth	33024	4	I	RO	E	Effective width of the sensor in pixels.	4096	-
SensorHeight	33028	4	I	RO	E	Effective height of the sensor in pixels.	3072	-
WidthMax	-	4	I	-	E	Maximum width (in pixels) of the image.	-	-
HeightMax	-	4	I	-	E	Maximum height (in pixels) of the image.	-	-
OffsetX	33056	4	I	RW	B	Horizontal offset from the origin to the region of interest (in pixels).	0	0 to SensorWidth-16 (increment: 16)
OffsetY	33060	4	I	RW	B	Vertical offset from the origin to the region of interest (in pixels).	0	0 to SensorHeight-4 (increment: 4)
ReverseX	33084	4	B	RW	E	Flip horizontally the image sent by the device. The Region of interest is applied after the flipping.	-	-
ReverseY	33088	4	B	RW	E	Flip vertically the image sent by the device. The Region of interest is applied after the flipping.	-	-
PixelFormat	33092	4	E	RW	B	Format of the pixel to use for acquisition. Pixelformat can only be changed if there is no acquisition active. V1.1.	-	Chapter 5.2.11.1
TestImageSelector	33116	4	E	RW	B	Selects the type of test image that is sent by the camera.	0	Chapter 5.2.11.2
TestImageVideoLevel	33132	4	I	RW	B	Sets the video level if UniformVideoLevel is selected. Video level is always in 10 bit.	512	0 to 1023 (increment: 1)
DeviceTapGeometry	33120	4	E	RO	E	Tap geometry to be used by streams of the Device.	0	Geometry_1X_1Y = 0x0(0) □
Image1StreamID	33124	4	I	RO	G	Identification of stream 1.	0	-
CrosshairOverlay	33096	4	B	RW	E	Add a crosshair overlay to the image sent by the device. The crosshair is centered in the output image.	-	-

Table 5-7: Image format control registers

5.2.11.1 PixelFormat

Depending on the camera type monochrome or Bayer pixel formats can be selected.

Camera type	*Format name*	*Bits per pixel*	*Register value*
Monochrome	Mono8	8	0x1080001(17301505)
	Mono10	10	0x1100003(17825795)
Color	BayerRG8	8	0x1080009(17301513)
	BayerGB8	8	0x108000A(17301514)
	BayerGR8	8	0x1080008(17301512)
	BayerBG8	8	0x108000B(17301515)
	BayerRG10	10	0x110000D(17825805)
	BayerGB10	10	0x110000E(17825806)
	BayerGR10	10	0x110000C(17825804)
	BayerBG10	10	0x110000F(17825807)

Table 5-8: Pixel formats

Acquisition must be stopped when changing the pixel format.

Note: Selection of one of the 4 Bayer phases is arbitrary. The PixelFormat register in the CXP image header stream however will report the code for correct phase to be used by the host for color decoding. For example, the format changes when *ReverseX* and/or *ReverseY are enabled*.

The Bayer phase of the color camera with deactivated ReverseX and ReverseY functions is defined in Figure 5-2.

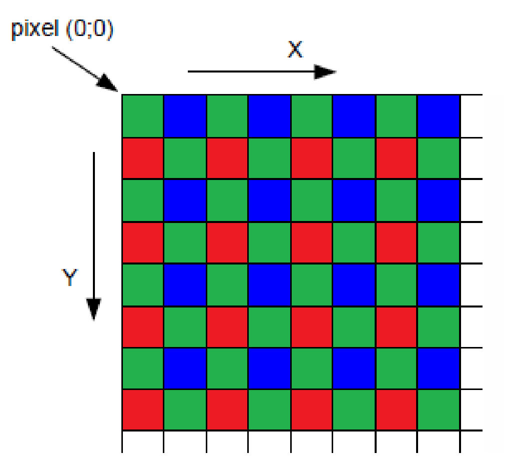

Figure 5-2: Bayer pattern for color camera

Pixel(0;0) is the first pixel from the camera (left-top pixel in image), the corresponding Bayer phase is GBRG.
If the *ReverseX* and *ReverseY* functions are activated, the Bayer phase changes (*PixelFormat*) according to the table below.

ReverseX	*ReverseY*	*Bayer phase*	*PixelFormat*
Off	Off	GBRG	BayerGB8 / BayerGB10
Off	On	RGGB	BayerRG8 / BayerRG10
On	Off	BGGR	BayerBG8 / BayerBG10
On	On	GRBG	BayerGR8 / BayerGR10

Table 5-9: The influence of the ReverseX and ReverseY register on PixelFormat.

5.2.11.2 TestImageSelector

The camera can generate test patterns in all its working modes. The camera will continue to work in the selected mode, but instead of the usual image an artificial image is displayed. This test pattern mode is implemented for service purposes.

Selected test image	*Test pattern description*	*Register value*
Off	In this mode the test pattern is disabled	0x0(0)
AdimecTestPattern	Specific Adimec test pattern with grey bars, color bars (only active in a color camera) and contour lines	0x10000(65536)
UniformVideoLevel	Uniform test pattern to verify corrections	0x10002(65538)
DiagonalPattern	Test pattern with a grey ramp in the diagonal direction	0x10003(65539)

Table 5-10: Test image selector

Note:
- The test patterns are not amplified with the set gain.
- The test image is reshaped when a different width and/or height is set

In the figure below the Adimec test pattern is defined in 10 bit per pixel resolution with black is 0 and white is 1023.

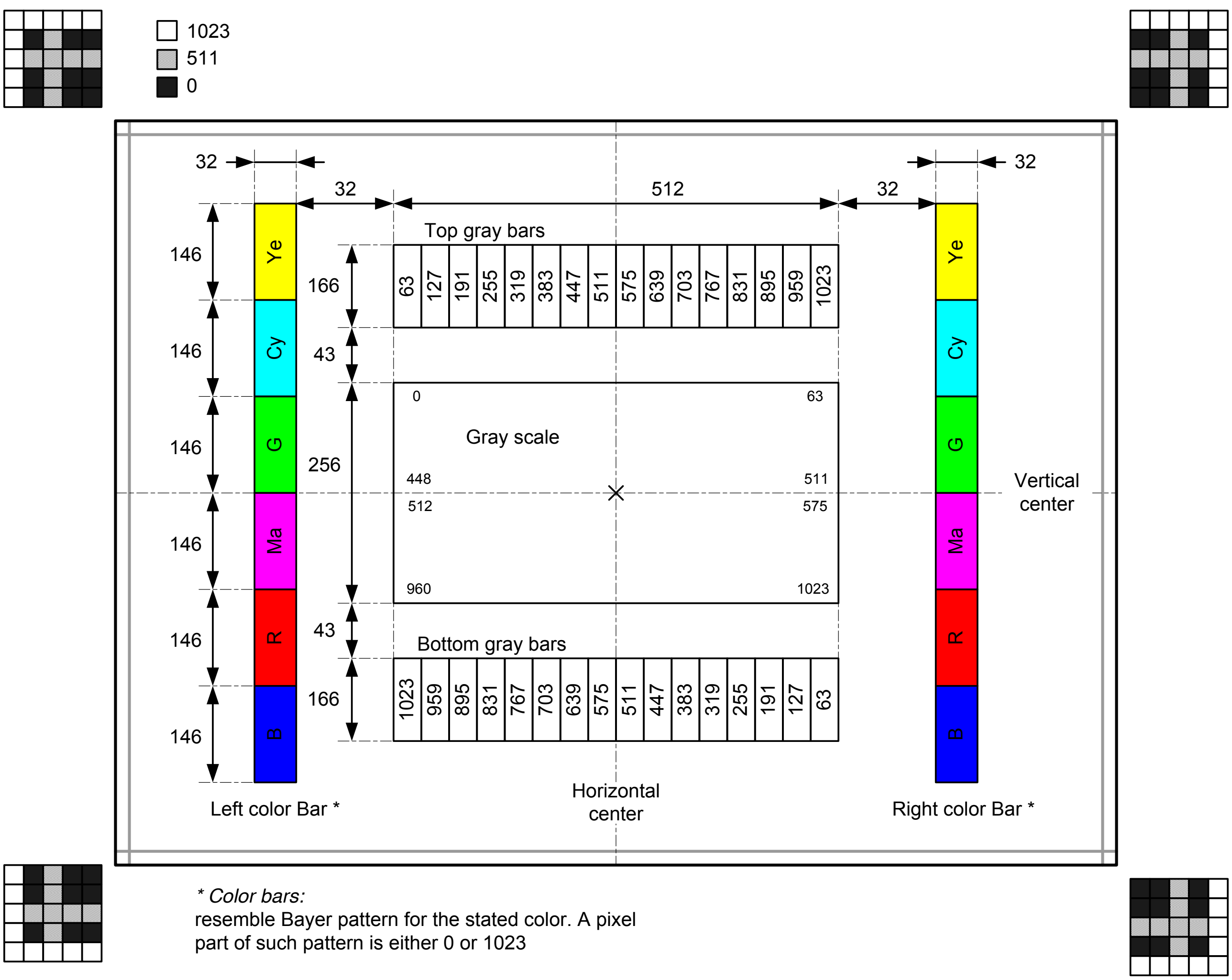

Figure 5-3: Adimec Test Pattern visualization

Figure 5-4 shows the diagonal test patterns in 8 (a) and 10 (b) bit per pixel resolution (ramp 0-255 and 0-1023).

Depending on the interface bit depth the following formulas for the diagonal pattern grey values will be valid:

- 10 bit per pixel interface setting: Video level = (column number + row number) modulo 1024
- 8 bit per pixel interface setting: Video level = (column number + row number) modulo 256

(a) (b)

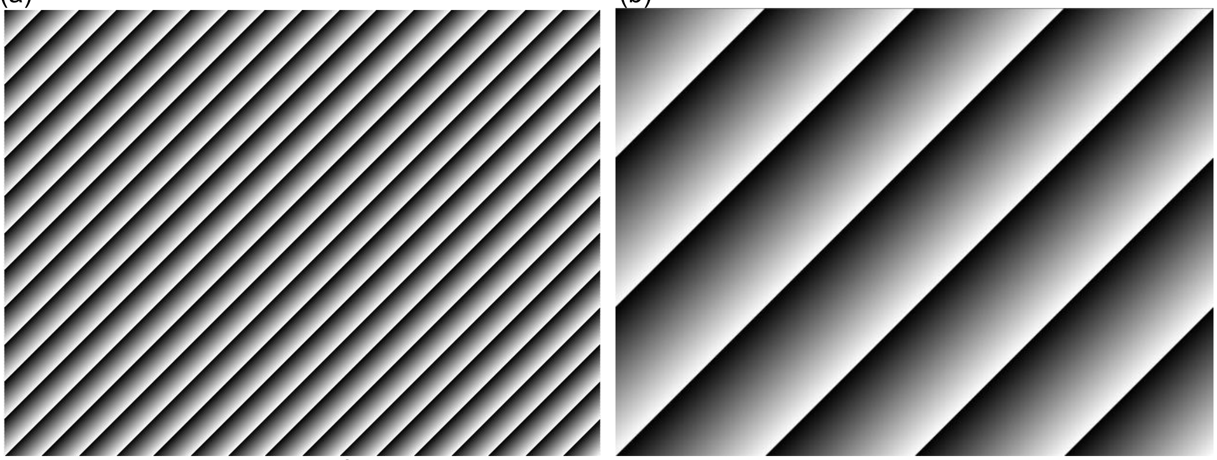

Figure 5-4: Visualization of the diagonal test pattern in 8 bit per pixel resolution (a) and 10 bit per pixel resolution (b)

5.2.12 Acquisition control

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
AcquisitionMode	33280	4	E	RW	B	Sets the acquisition mode of the device.	0	Continuous = 0x0(0) ⍰
AcquisitionStart	33284	4	C	RW	B	Starts the Acquisition of the device.	0	-
AcquisitionStop	33288	4	C	RW	B	Stops the Acquisition of the device at the end of the current Frame.	0	-
AcquisitionFrameRate	-	4	F	-	B	Controls the acquisition rate (in Hertz) at which the frames are captured.	-	1 to 100000 (increment: undefined)
AcquisitionFramePeriod	-	4	F	-	B	Controls the acquisition rate (in 1us steps) at which the frames are captured.	-	1 to 1e+06 (increment: undefined)
AcquisitionFramePeriodRaw	33312	4	I	RW	B	Controls the acquisition rate (in 1us steps) at which the frames are captured.	-	16 to 1000000 (increment: 1)
AcquisitionMaxFrameRate	33316	4	C	WO	B	Sets the camera to the maximum frame rate, with respect to the given settings	-	-
TriggerSource	33336	4	E	RW	B	Specifies the internal signal or physical input Line to use as the trigger source.	0x10	Chapter 5.2.12.2
TriggerActivation	33340	4	E	RW	B	Specifies the activation mode of the trigger.	0x01	Chapter 5.2.12.3
ExposureMode	33360	4	E	RW	B	Sets the operation mode of the Exposure (or shutter).	1	Chapter 5.2.12.4
ExposureTime	-	4	F	-	B	Sets the Exposure time (in 1us steps)	-	1 to 100000 (increment: undefined)
ExposureTimeRaw	33368	4	I	RW	B	Sets the Exposure time (in 1us steps).	-	1 to 100000 (increment: 1)
InterfaceUtilization	33376	4	I	RW	B	Decreases the line rate of the sensor in order to prevent the framegrabber from being overrun.	100	Chapter 5.2.12.6

Table 5-11: Acquisition control registers

5.2.12.1 AquisitionMaxFrameRate

The *AcquisitionMaxFrameRate* calculates and sets the maximum achievable frame rate in the set camera configuration. This function could be also used to calculate the maximum achievable frame rate in case the camera is set in a slave exposure mode.

NOTE: It is required to configure the sensor to 8 bit per pixel (register *SensorBitDepth* (chapter *Sensor*)) to achieve the maximum frame rate of 187 fps at full image resolution.

5.2.12.2 TriggerSource

In the control modes (TriggerWidth, SyncControlMode or TimedTriggerControl) the trigger can be either the CXP trigger input (Trigger) or the IO connector (IO_Connector) trigger input.

TriggerSource range	*Description*	*Register value*
Trigger	Acquisition triggered via CXP trigger input	0x10(16)
IO_connector	Acquisition triggered via IO connector	0x10000(65536)

Table 5-12: TriggerSource

5.2.12.3 Trigger activation

TriggerActivation range	*Description*	*Register value*
FallingEdge	Falling edge triggers start of exposure, rising edge triggers start of image readout	0x0(0)
RisingEdge	Rising edge triggers start of exposure, falling edge triggers start of image readout	0x1(1)

Table 5-13: Trigger activation

A deglitch filter is added to handle glitches on possible heavily disturbed external trigger signals. This deglitch circuit will prevent short glitches to be interpreted as trigger signals. Pulses shorter than 133.33 ns are rejected with this filter.

5.2.12.4 ExposureMode

The camera can be operated in one of the 3 control modes or in free run (timed) mode. Refer to Table 5-14 and Figure 5-6 for a description of these modes.

ExposureMode range	*Description*	*Register value*
Timed	Free run mode. Camera is master: frame period and exposure time are both fixed and controllable via the *AcquisitionFramePeriod* respectively *ExposureTime* registers.	0x0(0)
TriggerWidth	Camera is slave: Both frame period and exposure time are determined by the trigger pulse	0x1(1)
SyncControlMode	Camera is slave: Start and stop of exposure time are determined by the start of the trigger. The frame period equals the exposure time.	0x100(256)
TimedTriggerControl	Camera is slave: Start of exposure time is determined by the start of the trigger, the exposure time is fixed and can be controlled via the *ExposureTime* register.	0x200(512)
TimedSync	Camera is slave but timing should be synchronized with internal camera timing. In this exposure mode the frame sequence is synchronized to the edge of the external trigger signal. The exposure time is fixed and can be controlled via the *ExposureTime* register. Characteristics: - The *AcquisitionFramePeriod* must be set slightly smaller than the external sync period time. (Take into account that the absolute camera timing has a deviation of ±120 ppm). - When locked the camera frame rate equals the applied external sync signal frequency.	0x300(768)

Table 5-14: Exposure modes

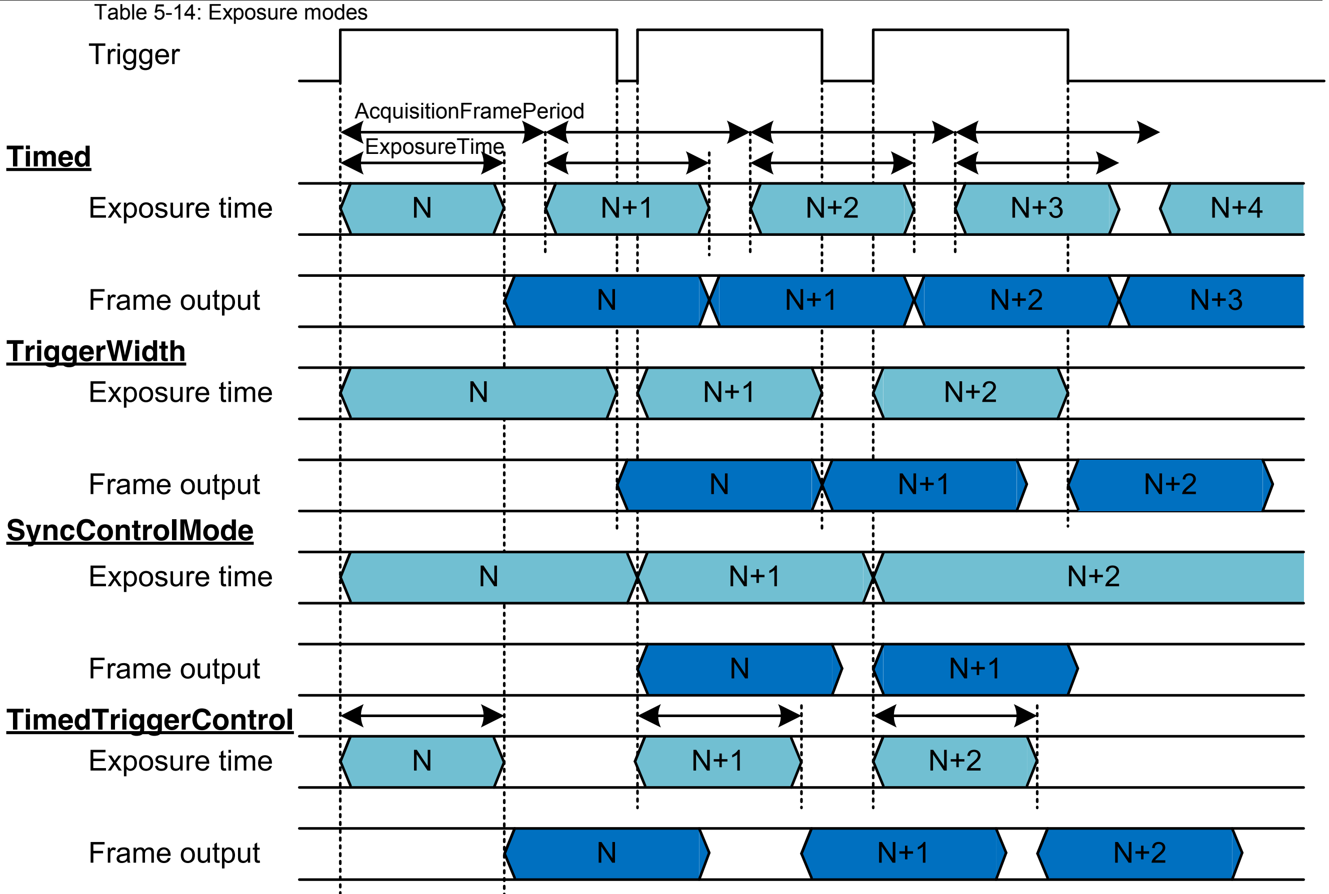

Figure 5-5: Exposure modes timing diagram 1/2

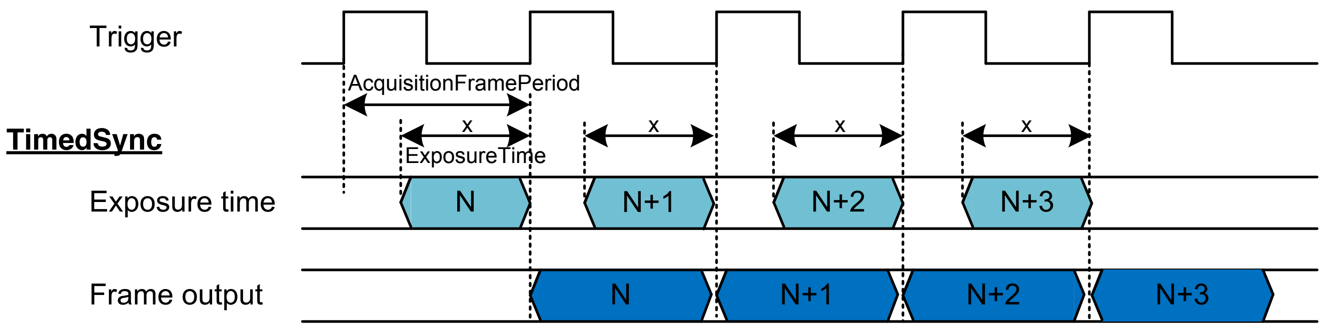

Figure 5-6: Exposure modes timing diagram 2/2

5.2.12.5 Exposure time and latency during Frame Overhead Time

Figure 5-8 shows the additional Frame Overhead Time (FOT) at the end of the exposure time. The FOT is required for a couple of processing steps within the image sensor. The period *t_sens* in Figure 5-8 and Figure 5-8 is the extra time for which the sensor remains light sensitive. This means that the minimum exposure time equals the configured exposure time + *t_sens*. Table 5-15 shows the minimum exposure time in combination with the *t_sens* period depending on the set *SensorBitDepth*.
The total FOT period is 44 µs. In a situation where the exposure time equals the frame period (for example *SyncControlMode* situation in Figure 5-8), the exposure time will have a latency with the duration of the FOT. In this case the maximum exposure time will be: frame period – FOT + *t_sens*.
In the situation where the exposure time is shorter than the frame period – FOT the configured start of exposure is well aligned with the actual start of exposure of the image sensor (see example *TriggerWidth* mode in Figure 5-8). The difference of 44 µs in *Timed* mode between the set minimum frame period and maximum *ExposureTime* is related to the FOT duration.

SensorBitDepth configuration	*t_sens period (µs)*	*Minimum exposure time (µs) (ExposureTime set to the minimum of 1 µs)*
8	15.41	15.41 + 1 = 16.41
10	15.3	15.3 + 1 = 16.3

Table 5-15: Minimum exposure time

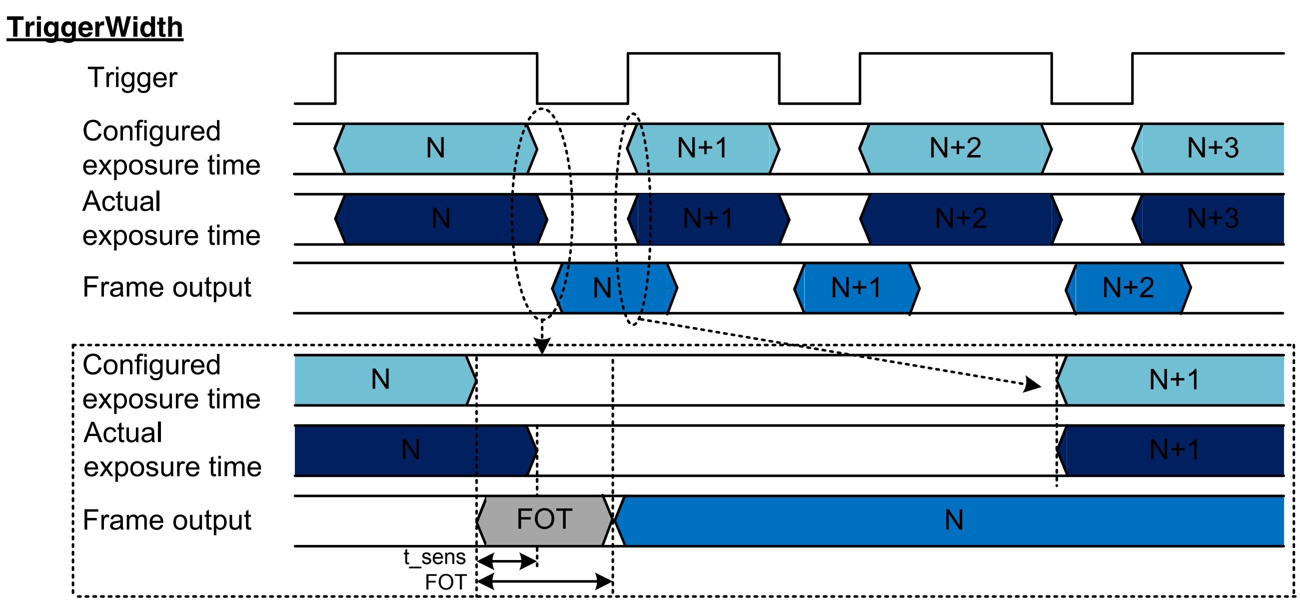

Figure 5-7: Exposure timing and latency during FOT in TriggerWidth mode

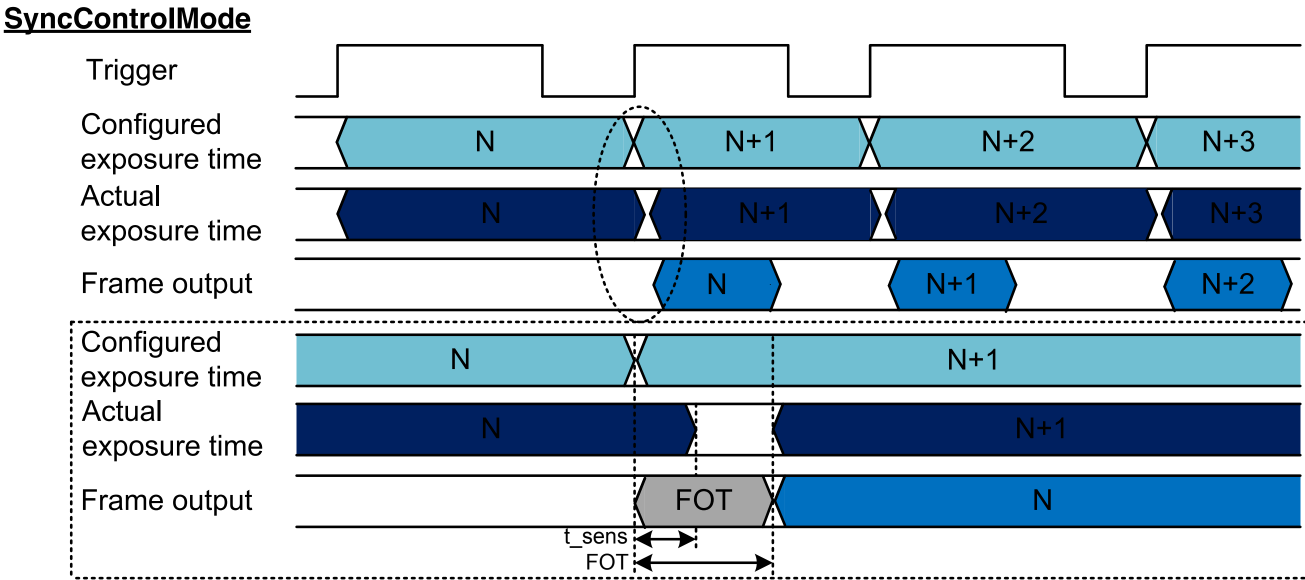

Figure 5-8: Exposure timing and latency during FOT in SyncControlMode

5.2.12.6 InterfaceUtilization

The interface utilization parameter is available to decrease the data throughput in case the host system cannot sustain the data rate. The utilization factor does not change the interface configuration (*ConnectionConfig*) but creates an empty period in between the readout of lines. Examples of the utilization factor are shown in Figure 5-9. When lowering the utilization factor the line readout period will increase which directly influences the duration of the frame output. The maximum achievable frame rate after changing the utilization factor can be requested with via the *AcquisitionMaxFramerate* register.

The relation between the utilization factor and line readout time is as follows:

$$new\ readout\ line\ time\ (\mu s) = \frac{line\ time\ @\ 100\%\ InterfaceUtilization}{InterfaceUtilization} \times 100\%$$

Example: 50% utilization factor is a doubling of the readout time of one line with respect to the fastest line readout period (100%).

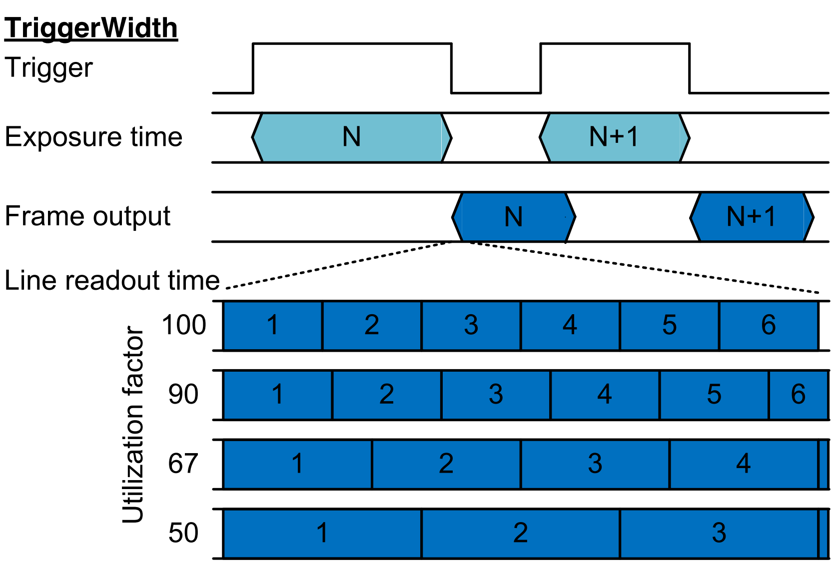

Figure 5-9: Impact of utilization factor on line readout timing

5.2.13 Frame skipping due to over triggering

In the triggered mode, the sensor can be over triggered; in this case a new image is requested from the sensor, while it is still busy outputting an image frame. In this case the requested frame is being delayed according to Figure 5-10.

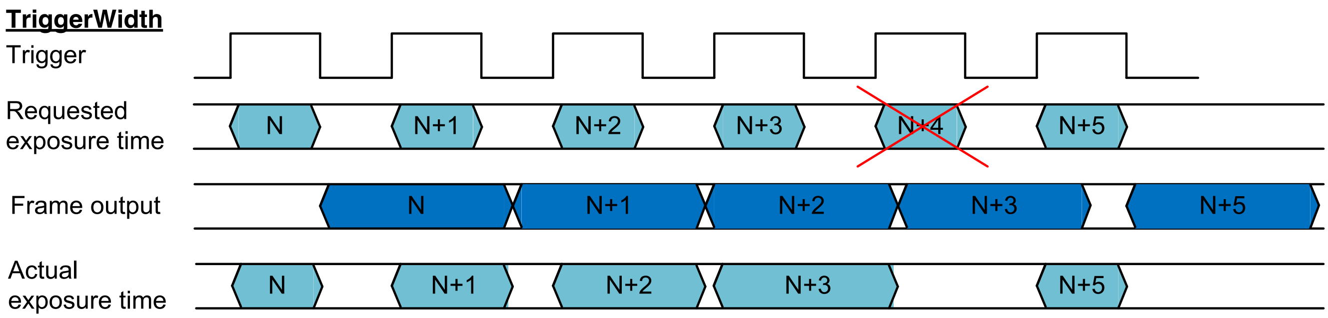

Figure 5-10: Over triggering behavior

5.2.14 Counter and timer control

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
FlashStrobeMode	33868	4	E	RW	B	Selects the mode of the flashstrobe.	0	Chapter 5.2.14.1
FlashStrobeDuration	-	4	F	-	B	Controls the duration of the flash strobe in us.	-	-
FlashStrobeDurationRaw	33876	4	I	RW	B	Controls the duration of the flash strobe in steps of 1us.	0	0 to 65535 (increment: 1)
FlashStrobeDelay	-	4	F	-	B	Controls the delay of the flashstrobe in us.	-	-
FlashStrobeDelayRaw	33884	4	I	RW	B	Controls the delay of the flashstrobe in steps of 1us.	0	0 to 65535 (increment: 1)
FlashStrobeActiveState	33888	4	E	RW	B	The active state of the flash strobe output	1	Chapter 5.2.14.2

Table 5-16: Counter and timer control registers

5.2.14.1 Flash strobe mode

The camera is equipped with a strobe output signal on the I/O connector. This strobe output is active during the period that the target should be lit. The strobe output can be operated in two different modes, which are explained in Table 5-17.

Flash strobe mode	*Description*	*Register value*
Disabled	Flash stobe inactive, inactive state selectable via FlashStrobeActiveState	0x0(0)
Automatic	The flash strobe output will become active during the exposure time (regardless exposure mode)	0x1(1)
Programmed	In this mode both delay time after start of exposure (FlashStrobeDelay) as well as the duration of the active state (FlashStrobeDuration) is programmed.	0x2(2)

Table 5-17: Flash strobe mode

5.2.14.2 Flash strobe active state

The polarity of the flash strobe output can be programmed to adapt to the application requirements.

Flash strobe active state	*Description*	*Register value*
NonConducting	The photo transistor at the camera output is non conductive during the strobe active time	0x0(0)
Conducting	The photo transistor at the camera output is conductive during the strobe active time	0x1(1)

Table 5-18: Flash strobe active state

5.2.15 HDR: High Dynamic Range

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
HDR_Mode	33296	4	E	RW	E	-	-	Off = 0x0(0) ⍰ MultiSlope2Slopes = 0x20(32) ⍰ MultiSlope3Slopes = 0x21(33) ⍰
SecondExposureTimeRaw	33372	4	I	RW	-	Sets the second Exposure time for Interleaved mode (in 1us steps).	10000	10 to 100000 (increment: 1)
SecondExposureTime	-	4	F	-	-	Controls the Exposure time (in 1us steps)	-	10 to 1e+05⍰ (increment: undefined)
MultiSlopeNodeSelector	41784	4	I	RW	E	Selects the node of the multislope curve.	1	1 to 2 (increment: 1)
MultiSlopeLevel	41788	4	I	RW	E	Sets the level of the multislope node.	1	1 to 100 (increment: 1)
MultiSlopeTime	41792	4	I	RW	E	Sets the time of the multislope node.	1	1 to 99 (increment: 1)

Table 5-19: High Dynamic Range registers

5.2.15.1 Multi slope HDR mode

Involved registers for the multi slope mode are:

- HDR_mode
- MultiSlopeNodeSelector
- MultiSlopeLevel
- MultiSlopeTime

In the camera, a high optical dynamic range can be realized by setting the camera to a non-linear response. For this function the multi slope feature of the sensor is used. To be more precise, the response can be piece-wise linear with up to 3 slopes (see Figure 5-11).

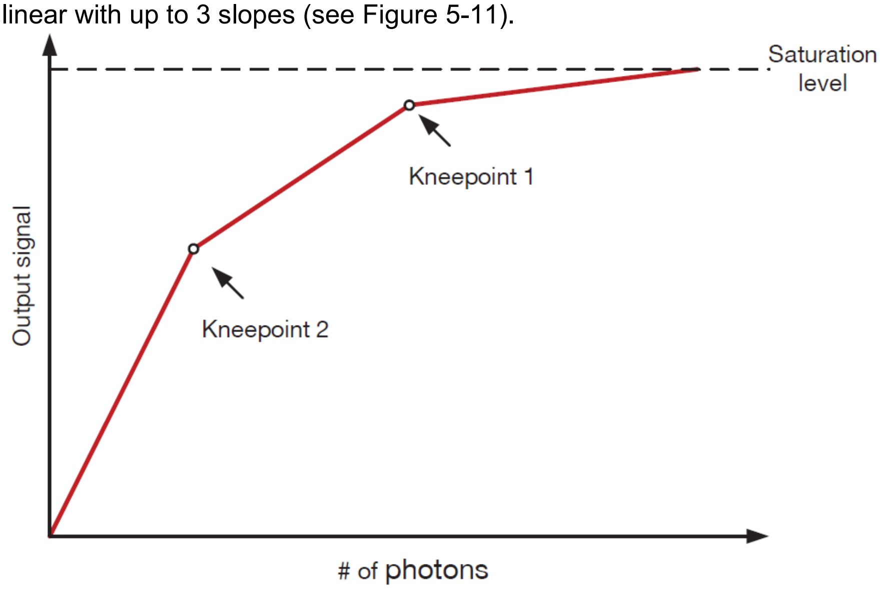

Figure 5-11: Multi slope response

Basically the multi slope response serves as a white compression, still enabling contrast in parts that else would be saturated. For high exposures, this ensures contrast in bright part of the scene that would otherwise saturate. An example of the HDR mode disabled and enabled is shown in Figure 5-12. This example shows clearly that the multi slope allows for contrast in the lamp which is with a normal linear response saturated.

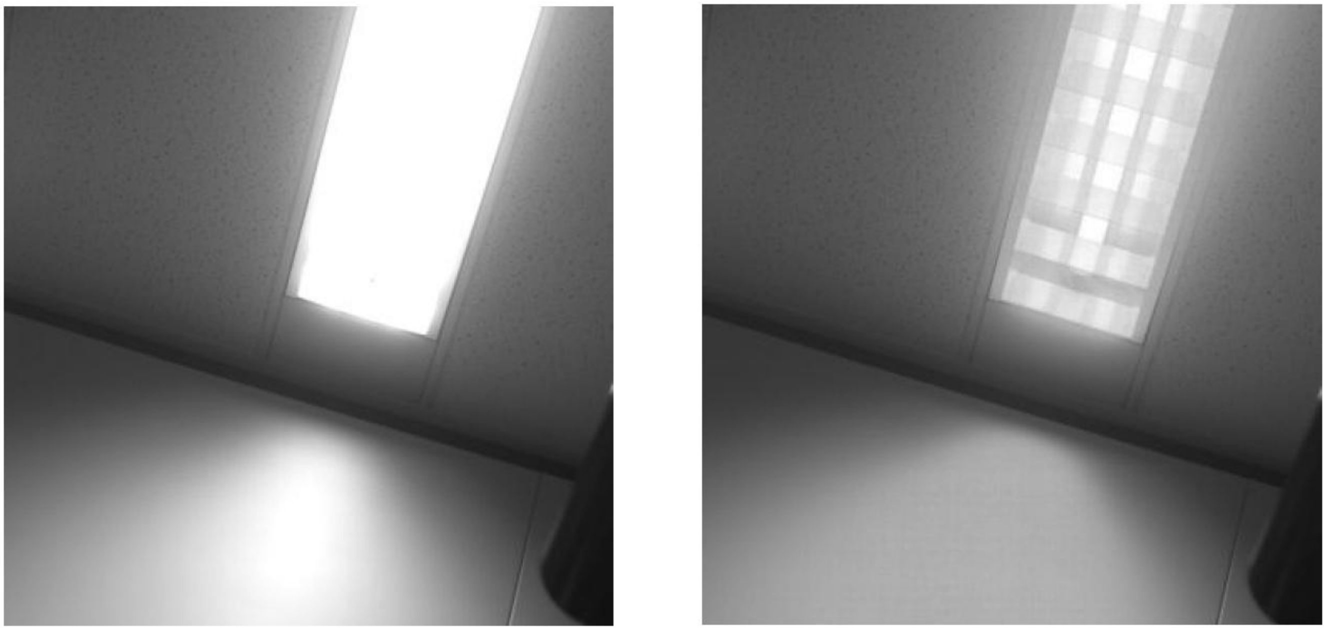

Figure 5-12: Image of fluorescent light with normal operation (left) and multislope function enabled (right).

The underlying principle of the multislope is in varying the pixel charge capacity of the sensor in steps.

This can be done up to 3 times within a single exposure time to achieve a maximum of the 3 exposure slopes. This is illustrated in the Figure 5-13.

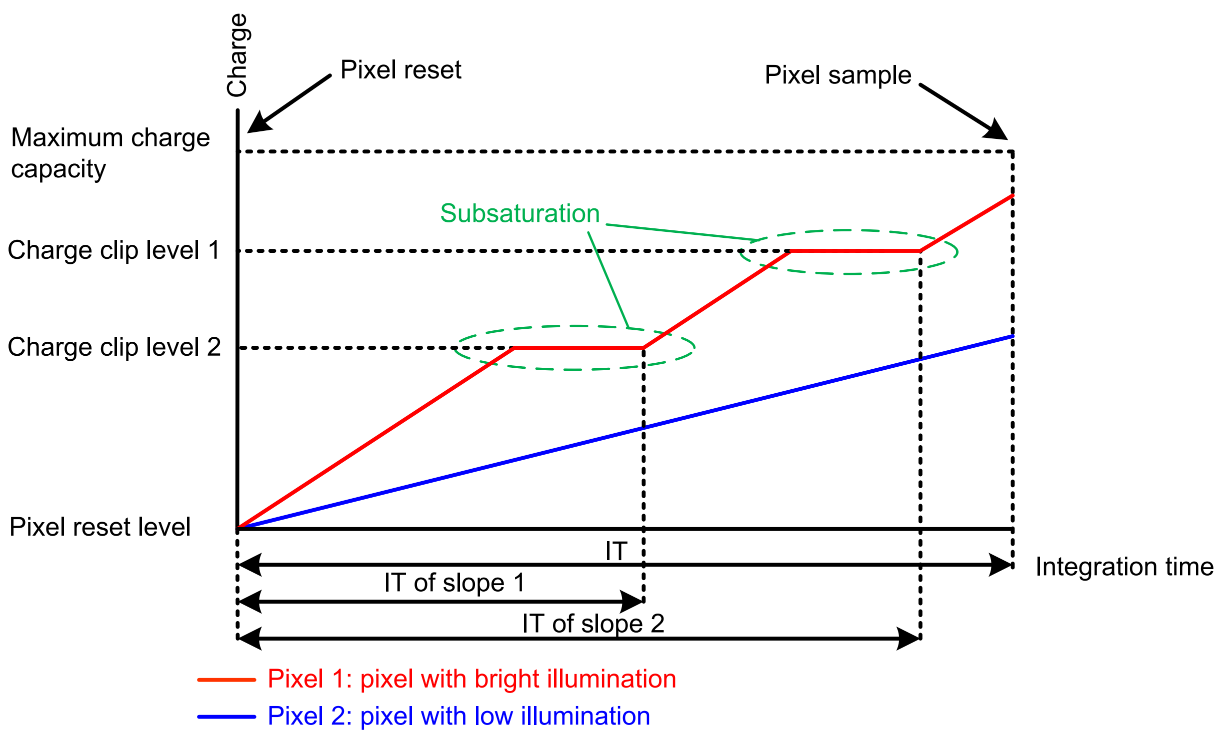

Figure 5-13: Multi slope principle

The multi slope levels “Pixel reset level” and “Maximum charge capacity” in Figure 5-13, correspond to pixel reset and normal ‘single slope’ sensor charge capacity respectively. The levels “charge clip level 1” and “charge clip level 2” 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 high 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 5-13 shows parts (horizontal lines) where the charge is constant. Basically, this is intermediate pixel saturation. The saturation comes with additional fixed pattern noise for which is not corrected for.

The levels and exposure times are programmable via a command set from Table 5-19. This feature results in the multi slope (piece wise linear) response curve as in Figure 5-11. The placement of the knee points depends on the specific Voltage and Timing programming.

The multi slope can currently only be used in *Timed* and in *TimedTriggerControl* mode.

The intermediate 2 multi slope levels and 2 multi slope times are expressed as a percentage from the normal saturation level and exposure time. The node points are configurable by sequentially selecting them with the MultiSlopeNodeSelector. MultiSlopeLevel and MultiSlopeTime are read and written for the selected node.

5.2.16 Analog control

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
GainSelector	35072	4	E	RW	B	Selects which Gain is controlled by the various Gain features.	0	Chapter 5.2.16.1
Gain	-	4	F	-	B	Controls the selected gain as an absolute physical value.	-	Chapter 5.2.16.2
GainRaw	35080	4	I	RW	B	Controls the selected gain as an absolute physical value.	100	Chapter 5.2.16.2
BlackLevel	-	4	F	-	B	Controls the analog black level as an absolute physical value.	-	Chapter 5.2.16.3
BlackLevelRaw	35116	4	I	RW	B	Controls the analog black level as an absolute physical value.	0	Chapter 5.2.16.3
WhiteBalanceWidth	35124	4	I	RW	E	Width of the white balance region of interest (in pixels).	4096	Chapter 5.2.16.4
WhiteBalanceHeight	35128	4	I	RW	E	Height of the white balance region of interest (in pixels).	3072	Chapter 5.2.16.4
WhiteBalanceOffsetX	35132	4	I	RW	E	Horizontal offset from the output image region of interest to the white balance region of interest (in pixels).	0	Chapter 5.2.16.4
WhiteBalanceOffsetY	35136	4	I	RW	E	Vertical offset from the origin to the region of interest (in pixels).	0	Chapter 5.2.16.4
WhiteBalanceCalibrate	35140	4	C	WO	E	Starts the white balance calibration in the white balance region of interest.	0	-
WhiteBalanceStatus	35144	4	E	RO	E	Returns the white balance status of the camera.	0	Chapter 5.2.16.5

Table 5-20: Analog control registers

5.2.16.1 Gain selector

Depending on the camera model (monochrome or color) the control of the gain can be applied on all pixels or only on the selected color plane which can be selected via the gain selector.

Gain selector value	*Description*	*Register value*
All	In case of the monochrome sensor only this value can be selected. When selected with a color sensor the set gain value will be applied for all color planes.	0x0(0)
Red	Gain selector for the red pixels (selection only available for color sensor)	0x1(1)
Green	Gain selector for the green pixels (selection only available for color sensor)	0x2(2)
Blue	Gain selector for the blue pixels (selection only available for color sensor)	0x3(3)

Table 5-21: Gain selector

5.2.16.2 Gain raw

The digital fine gain can be set in steps of 0.001x, the gain range depends on the gain selector and camera model, the range can be found in Table 5-22.

Camera model	*Gain selector value*	*Gain raw range*
Monochrome	All	1000 – 32000 (where 1000 represents 1x gain)
Color	All	1000 – 8000
	Red	1000 – 4000
	Green	1000 – 4000
	Blue	1000 – 4000

Table 5-22: Gain

5.2.16.3 Black Level raw

The average black level can be set with the *BlackLevelRaw* register with a range from 0 to 511 in units of 1 digital number at 10 bit data resolution. When the *PixelFormat* is set to 8 bit per pixel the average black level will be divided by 4. Example: In case the *BlackLevelRaw* is set to 20 and the *PixelFormat* to *Mono8* the average video level of a black image will be 5 digital numbers.

5.2.16.4 White balance window

The calculation of the white balance is performed on the defined white balance window. This white balance window is clipped to fall within the set video region of interest. The corresponding origins with respect to the white balance window parameters are defined in Table 5-23.

White balance window parameter	*Origin register*	*Unit steps in pixels*
WhiteBalanceWidth	Width	1, with minimum width of 32 columns
WhiteBalanceHeight	Height	1, with minimum height of 2 rows
WhiteBalanceOffsetX	OffsetX	1
WhiteBalanceOffsetY	OffsetY	1

Table 5-23: White balance window

5.2.16.5 One push white balance

The one push white balance calibration is executed with the WhiteBalanceCalibrate register. If the acquisistion is active, an image from the stream is used for the calculation. If the acquisition is inactive, the camera automatically starts an acquisition of one image.

After calculation of the white balance settings the values for the red, blue and green channel are automatically set.

The WhiteBalanceStatus register returns the status of the one push white balance calibration.

White balance status value	*Description*
WhiteBalanceIdle	White balance calibration in idle situation
WhiteBalanceStarted	Pending one push white balance calibration
WhiteBalanceCalibrateOK	One push white balance calibration succeeded
WhiteBalance_SensorTooDark	One push white balance calibration not executed because the scene is too dark
WhiteBalance_ColorClipped	The red, green or blue channel is clipped to 4x gain as a result of the one push white balance calibration

Table 5-24: One push white balance modes

5.2.17 Sensor

Settings in the sensor chapter directly control sensor related settings.

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
SensorBitDepth	41880	4	E	RW	E	Controls the resolution of the Sensor ADC	1	Resolution_8_Bit = 0x0(0) Resolution_10_Bit = 0x1(1) Chapter 5.2.17.1
ProgrammableGainAmplifier	35120	4	I	RW	G	Controls the PGA register of the sensor. The configured value reflects the gain of the PGA.	0	Chapter 5.2.17.2

Table 5-25: Sensor registers

5.2.17.1 SensorBitDepth

This function controls the sensor ADC bit depth which is selectable between 8 and 10 bits per pixel. It is recommended to only select 8 bit per pixel if a frame rate higher than 150 fps is required at full resolution. In the 8 bit resolution the maximum achievable frame rate is 187 fps. When 10 bit per pixel is selected the image quality is slightly better as compared to 8 bit ADC mode.

5.2.17.2 ProgrammableGainAmplifier

The programmable gain amplifier controls the analog gain in the sensor. Changing the sensors analog gain amplifier will affect the maximum full well capacity and read noise of the image sensor. Typical measured values with different analog gain settings are shown in Table 5-26.

ProgrammableGainAmplifier range	*Definition*	*Maximum full well capacity (e-)*	*Read noise (e-)*	*Dynamic range (dB)*
1	Unity gain	10000	15,9	56,0
2	2 x analog gain	5000	11,8	52,6
3	3 x analog gain	3400	10,8	49,9
4	4 x analog gain	2500	10,1	47,9

Table 5-26: Programmable gain amplifier

5.2.18 Factory

The factory settings are not user accessible, this mode is only required to adjust factory settings.

5.2.19 LUT Control

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
LUTEnable	35332	4	B	RW	E	Activates the (selected) LUT.	FALSE	-
LUTIndex	35336	4	I	RW	E	Control the index (offset) of the coefficient to access in the (selected) LUT. LUTStart and LUTEnd do NOT work with this Index.	0	0 to 1023 (increment: 1)
LUTValue	35340	4	I	RW	E	Returns the Value at entry LUTIndex of the LUT. Read returns the LUT value at Index. Write does NOT work with the Index, but with LUTStart and LUTEnd.	0	0 to 1023 (increment: 1)
LUTStart	35348	4	C	WO	E	Starts the adding of LUT values at the begining of the LUT. LUTStart does NOT work with an Index.	-	-
LUTEnd	35352	4	C	WO	E	Ends the adding of LUT values. LUTEnd does NOT work with an Index.	-	-
LUTStatus	35356	4	E	RO	E	Returns the LUT status of the camera.	0	Chapter 5.2.19

Table 5-27: LUT control registers

In the camera an output look-up table (LUT) can be applied.
When the table is programmed in the camera, it can be enabled with the *LUTEnable* register.
The LUT can be programmed by the following sequence of registers:

- LUTStart
- $\text{LUTValue}_{\text{value\_index0}}$
- $\text{LUTValue}_{\text{value\_index1}}$
- ....
- $\text{LUTValue}_{\text{value\_index1022}}$
- $\text{LUTValue}_{\text{value\_index1023}}$
- LUTEnd

The exact amount of 1024 entries should be written, this can be verified with the *LUTStatus* register. Refer to Table 5-28 for the description of this status register.

LUTStatus value	*Description*	*Register value*
LUT_Idle	LUT programming sequence in idle situation	0x0(0)
LUT_Started	LUT programming sequence started	0x1(1)
LUT_Restarted	LUT programming sequence restarted	0x2(2)
LUT_TooMuchEntries	Too much LUT entries (LUTValue) written before LUTEnd command is written	0x3(3)
LUT_NotEnoughEntries	Not enough LUT entries (LUTValue) written before LUTEnd command is written	0x4(4)
LUT_Stored	LUT programming sequence finished and stored in memory	0x5(5)
LUT_NotStarted	LUT programming sequence started	0x6(6)

Table 5-28: LUT status register

5.2.20 Transport layer control

The *PayLoadSize* register is an indicator for the bytes transferred for each image on the stream channel.

Register name	Address	Size (bytes)	Interface	Access	Visibility	Description	Default	Range
PayloadSize	43008	4	I	RO	E	Provides the number of bytes transferred for each image or chunk on the stream channel.	0	0 to 4294967295 (increment: 1)

Table 5-29: Transport layer control register

5.2.21 Defect pixel

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
DefectPixelCorrectionEnable	41268	4	B	RW	G	Controls the defect correction of the video processing.	TRUE	-
DefectPixelTestMode	41280	4	E	RW	E	Display defect pixels in an output image.	0	Off = 0x0(0) MarkDefectsWhiteOnVideo = 0x1(1) MarkDefectsBlackOnVideo = 0x2(2) ShowDefectsAsWhite OnBlackBackground = 0x3(3)
DefectPixelTotal	41216	4	I	RO	E	Returns the total amount of pixels to be corrected.	0	Chapter 5.2.21
DefectPixelSelect	41220	4	I	RW	E	Selects the pixel to be read back.	1	0 to 999 (increment: 1) Chapter 5.2.21
DefectPixelReadX	41224	4	I	RO	E	Returns the horizontal coordinate of the pixel selected by DefectPixelSelect. The origin of the coordinates is 0.	0	Chapter 5.2.21
DefectPixelReadY	41228	4	I	RO	E	Returns the vertical coordinate of the pixel selected by DefectPixelSelect. The origin of the coordinates is 0.	0	Chapter 5.2.21
DefectPixelWriteX	41248	4	I	RW	E	Select the horizontal coordinate of the defect pixel being corrected. The origin of the coordinates is 0.	1	0 to 4096 (increment: 1) Chapter 5.2.21
DefectPixelWriteY	41252	4	I	RW	E	Select the vertical coordinate of the defect pixel being corrected. The origin of the coordinates is 0.	1	0 to 3072 (increment: 1) Chapter 5.2.21
DefectPixelAdd	41256	4	C	WO	E	Add the defect pixel determined by DefectPixelWriteX and DefectPixelWriteY to non volatile memory.	-	Chapter 5.2.21
DefectPixelRemove	41260	4	C	WO	E	Remove the defect pixel determined by DefectPixelWriteX and DefectPixelWriteY from non volatile memory.	-	Chapter 5.2.21
DefectPixelClearAll	41264	4	C	WO	E	Clear all defect pixels from non volatile memory.	-	Chapter 5.2.21
DefectPixelSave	41272	4	C	WO	E	Save the defect pixel list as a user list to the non-volatile memory of the device.	-	Chapter 5.2.21
DefectPixelRestore	41276	4	C	WO	E	Restores the defect pixel user list to the device and makes it active.	-	Chapter 5.2.21
DefectPixelRestoreFactory	41284	4	C	WO	E	Restore the factory default defect pixel table. All existing defect pixel coordinates will be lost.	-	-
DefectPixelSave AsFactoryDefault	41288	4	C	WO	G	Save the current defect pixel table as factory default. Factory only.	-	-

Table 5-30: Defect pixel registers

A defect pixel correction is available that replaces a defect pixel by a horizontally interpolated value or a vertically interpolated value or a horizontal nearest neighbor value depending on the local defect distribution.

Adimec does not release cameras with more than 1 adjacent defect pixel upon delivery. However, additional defect pixels to be corrected can be user-programmed.

Up to 1000 unique defect pixel coordinates can be stored in non volatile memory.

The correction method is illustrated in Figure 5-14.

Pixels are corrected according to the diagram below. Per tile, the center pixel correction method is indicated. In Mask, pixels marked by 1 are defect, pixels marked by 0 are not defect and irrelevant pixels are indicated by x. In the correction tile the weight factor per pixel is indicated.

For a color camera the same method applies but with the difference that in this situation only pixels of the same color plane are regarded.

MASK	$\begin{bmatrix} X & X & X \\ 0 & 1 & 0 \\ X & X & X \end{bmatrix}$	$\begin{bmatrix} X & 0 & X \\ 1 & 1 & X \\ X & 0 & X \end{bmatrix}$	$\begin{bmatrix} X & 0 & X \\ X & 1 & 1 \\ X & 0 & X \end{bmatrix}$	$\begin{bmatrix} X & 1 & X \\ 0 & 1 & 1 \\ X & X & X \end{bmatrix}$	$\begin{bmatrix} X & X & X \\ 0 & 1 & 1 \\ X & 1 & X \end{bmatrix}$
Correction	$\begin{bmatrix} 0 & 0 & 0 \\ 1/2 & 0 & 1/2 \\ 0 & 0 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 1/2 & 0 \\ 0 & 0 & 0 \\ 0 & 1/2 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 1/2 & 0 \\ 0 & 0 & 0 \\ 0 & 1/2 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$
MASK	$\begin{bmatrix} X & 1 & X \\ 1 & 1 & 0 \\ X & X & X \end{bmatrix}$	$\begin{bmatrix} X & X & X \\ 1 & 1 & 0 \\ X & 1 & X \end{bmatrix}$	$\begin{bmatrix} X & 0 & X \\ 1 & 1 & 1 \\ X & 1 & X \end{bmatrix}$	$\begin{bmatrix} X & 1 & X \\ 1 & 1 & 1 \\ X & 0 & X \end{bmatrix}$	$\begin{bmatrix} X & 1 & X \\ 1 & 1 & 1 \\ X & 1 & X \end{bmatrix}$
Correction	$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

Figure 5-14: Defect pixel correction method

Operation	Description
Add defect	The following steps are required to add a defect pixel to the defect pixel list: - Write the defect pixel location (origin of the most left top pixel has coordinate 0;0): *DefectPixelWriteX* and *DefectPixelWriteY*. - Execute *DefectPixelAdd* to add the defect pixel. If the marked defect is not existing and the defect list does contain less than 1000 defects, the defect is added to the non volatile defect list. Defects can be added in any order.
Remove defect	The following steps are required to remove a defect pixel from the defect pixel list: - Write the location of the defect pixel that should be removed: *DefectPixelWriteX* and *DefectPixelWriteY*. - Execute *DefectPixelRemove* for the removal of defect pixel. If existing, the defect is removed from the list in volatile memory. The defect pixel correction uses the updated list showing the removed defect location unmodified. Defects can be removed from the list in any order
Obtain defect list	User can read the total number of defects from *DefectPixelTotal*. A defect location is obtained by writing the index to *DefectPixelSelect* and then read the coordinates from *DefectPixelReadX* and *DefectPixelReadY*. The index of the first defect in the table is 1.
Store user defect list	Execute *DefectPixelSave* to store the current defect list in non-volatile memory.
Restore user defect list	Execute *DefectPixelRestore* to restore the defect list to the stored user defect list. Defects that were added by the user and have not been saved are lost.
Restore factory default list	Execute *DefectPixelRestoreFactoryDefault* to restore the defect list to the original factory default defects. Defects that were added by the user and have not been saved are lost.
Clear defect list	Execute *DefectPixelClearAll* to clear the defect pixel list.

Table 5-31: Defect pixel functions

It's not possible for the user to execute the *DefectPixelSaveFactoryDefault,* this function is only accessible in the factory mode.

5.2.22 Dark field

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
DF_BlackClamp	41984	4	B	RW	E	Enables or disables the dark field black clamp.	TRUE	-
DF_ColumnOffsetCorrection	41988	4	B	RW	E	Enables or disables the dark field column offset correction.	TRUE	-
DF_Calibrate	41992	4	C	WO	E	Starts the dark field calibration of the camera. DarkFieldStatus will return the status after this calibration.	0	Chapter 5.2.22.2
DF_Status	41996	4	E	RO	E	Returns the dark field calibration status of the camera.	0	DF_CalibrateOK = 0x0(0) DF_CalibrateError = 0x1(1) DF_SensorNotDark = 0x2(2) Chapter 5.2.22.2
DF_RestoreFactory	42000	4	C	WO	E	Restore the camera to the factory calibration status.	0	Chapter 5.2.22.2
DF_SaveAsFactoryDefault	42004	4	C	WO	G	Save the dark field calibration to memory.	-	-
DF_IsUserCalibration	42008	4	B	RO	B	Indicates if the current correction is factory (false) or user (true) calibrated.	FALSE	-

Table 5-32: Dark field registers

Two independent dark field correction mechanisms are present in the camera, i.e. *DF_BlackClamp* and *DF_ColumnOffsetCorrection*.

5.2.22.1 Black clamp

If *DF_BlackClamp* is enabled there will be 8 pixels on each side of the image over the full sensor height that will appear dark. They are set to an electrical dark reference. These pixels are used for a row wise correction; they basically define for each row the black level. It will reduce row wise noise.

5.2.22.2 Dark field calibration

If *DF_ColumnOffsetCorrection* is enabled a column wise noise correction will be applied. This correction compensates for dark signal non-uniformities (DSNU) in between columns. This correction is factory calibrated but can be re-calibrated in the field as well with *DF_Calibrate*.

A column offset correction calibration has to be performed in dark. During calibration the camera uses the internal timing generator to acquire images with an exposure time of 1 µs, the flash strobe output is inactive during calibration. A user calibration is automatically saved to non-volatile memory. It is always possible to restore to the factory calibrated correction.

Eight separate correction sets have to be stored for each *ProgrammableGainAmplifier* step (4 in total) in both *SensorBitDepth* modes. The calibration is only performed for the active configuration. Refer to Table 5-33 for a description of the dark field calibration functions.

It is not possible for the user to execute the *DF_SaveAsFactoryDefault,* this function is only accessible in the factory mode.

Register function	Description
DF_Calibrate	Starts the dark field calibration of the camera. The status of the calibration can be read back with the *DarkFieldStatus* register.
DF_Status	Returns the status of the dark field calibration: - DF_CalibrateOK: calibration performed successfully - DF_CalibrateError: calibration failed, recalibration is required - DF_SensorNotDark: calibration not executed because the sensor is not dark, make sure the scene is complete dark and perform recalibration.
DF_RestoreFactory	Restore dark field calibration set to the factory calibration set. Only the factory set in the selected operating condition will be loaded. (*SensorBitDepth* in combination with the selected *ProgrammableGainAmplifier*)

Table 5-33: Dark field calibration

5.2.23 Bright field

Register name	Address	Size	Interface	Access	Visibility	Description	Default	Range
BF_ColumnGainCorrection	42240	4	B	RW	E	Enables or disables the bright field column gain correction.	TRUE	-
BF_AutoLevelAdjust	42284	4	B	RW	E	If enabled the camera tries to adjust the video level before calibrating.	TRUE	-
BF_CalibrationVideoLevel	42264	4	I	RW	E	Sets the target videolevel in percent at which the brightfield calibration will take place.	60	10 to 90 (increment: 1) % Chapter 5.2.23.1
BF_OutputImagesDuring Calibration	42288	4	B	RW	E	If enabled the camera will output the images acquired during calibration.	TRUE	-
BF_Calibrate	42244	4	C	WO	E	Starts the bright field calibration of the camera. BrightFieldStatus will return the status after this calibration.	0	Chapter 5.2.23.1
BF_Status	42248	4	E	RO	E	Returns the bright field calibration status of the camera.	0	BF_CalibrateOK = 0x0(0) BF_UnderExposed = 0x1(1) BF_OverExposed = 0x2(2) BF_UnstableExposure = 0x3(3) BF_CalibrateError = 0x4(4) BF_WrongExposureMode = 0x5(5) Chapter 5.2.23.1
BF_RestoreFactory	42252	4	C	WO	E	Restore the camera to the factory calibration status.	0	Chapter 5.2.23.1
BF_SaveAsFactoryDefault	42256	4	C	WO	G	Save the bright field calibration to memory.	-	-
BF_IsUserCalibration	42260	4	B	RO	B	Indicates if the current correction is factory (false) or user (true) calibrated.	FALSE	-

Table 5-34: Bright field registers

The bright field calibration measures and compensates for the pixel response non-uniformities (PRNU) between columns. This correction is factory calibrated but can be re-calibrated in the field.

5.2.23.1 Bright field calibration

The bright field calibration can be calibrated in the field. It is important that the full image sensor resolution (4096x3072 pixels) is illuminated with a uniform scene because the calibration is always performed on the full resolution.

If the *ExposureMode* is configured to *Timed* the camera uses the internal timing generator to acquire images. The exposure time is adjusted to accomplish the configured video level in the *BF_CalibrationVideoLevel* register. If the *BF_AutoLevelAdjust* is disabled the user should adjust the *ExposureTime* or illumination to achieve a usable calibration scene.

It is recommended to adjust the video level to 50-70% of the full scale in case of a bright field calibration. In case of a color camera, the color plane with the highest videolevel is adjusted to the configured set point. During calibration the scene should be continuously illuminated or the light source should be synchronized with the flash strobe output.

If the *ExposureMode* is configured to *TriggerWidth*, *SyncControlMode* or *TimedTriggerControl* the video level could not be automatically adjusted, the user is in this case responsible for the adjustment of the illumination or exposure time.

After execution of the bright field calibration the calibration set is stored automatically in non-volatile memory. Eight separate correction sets have to be stored for each *ProgrammableGainAmplifier* step (4 in total) in both *SensorBitDepth* modes. The calibration is only performed for the active configuration. Refer to Table 5-35 for a description of the bright field calibration functions.

It is not possible for the user to execute the *BF_SaveAsFactoryDefault,* this function is only accessible in the factory mode.

Register function	Description
BF_CalibrationVideoLevel	This setting configures the target videolevel in percent at which the bright field calibration will take place.
BF_Calibrate	Starts the bright field calibration of the camera. The status of the calibration can be read back with the *BrightFieldStatus* register.
BF_Status	Returns the status of the bright field calibration: - BF_CalibrateOK: calibration performed successfully - BF_UnderExposed: Calibration failed, configured video level cannot be reached with adjusted exposure time. Increase exposure level and recalibrate. - BF_OverExposed: Calibration failed, configured video level cannot be reached with adjusted exposure time. Decrease exposure level and recalibrate. - BF_UnstableExposure: Calibration failed, - BF_CalibrateError: calibration failed, recalibration is required - BF_WrongExposureMode: calibration not executed because wrong exposure mode is selected.
DF_RestoreFactory	Restore bright field calibration set to factory calibration set. Only the factory set in the selected operating condition will be loaded. (*SensorBitDepth* in combination with the selected *ProgrammableGainAmplifier*)

Table 5-35: Bright field calibration

5.2.24 User set control

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. Therefore a copy of the factory default settings is stored in the camera.

The user can change the default configuration settings of the camera with the individual register settings. When the settings performed are satisfactory, they may be used as the settings to be used by the camera after power-up.

The user set functions are described in Table 5-36.

Register function	Description
UserSetSelector	Function to select the feature user set to load, save or configure: - Default: Select the factory settings set (register value 0x0(0)) - UserSet1: Select the default set after power-up with the user settings set. (register value 0x1(1))
UserSetLoad	Loads the User Set specified by *UserSetSelector* to the device and makes it active. It's required to stop acquisition during the load of the settings.
UserSetSave	Save the User Set to the non-volatile memory of the device. This is only possible for the user if *UserSet1* of the *UserSetSelector* register is selected.

Table 5-36: User set control

Table 5-37 gives an overview of the registers which can be stored or loaded with the user set and the corresponding default values.

Group	*Register name*	*Default value*
DeviceControl	DeviceIndicatorMode	Active
ImageFormatControl	Width	4096
	Height	3072
	OffsetX	0
	OffsetY	0
	ReverseX	0
	ReverseY	0
	PixelFormat	Mono10 / BayerGB10
	TestImageSelector	0
	TestImageVideoLevel	0
	CrossHairOverlay	0
AcquisitionControl	AcquisitionFramePeriodRaw	100000
	TriggerSource	Trigger
	TriggerActivation	RisingEdge
	ExposureMode	Timed
	ExposureTimeRaw	5000
	InterfaceUtilization	100
CounterAndTimerControl	FlashStrobeMode	Disabled
	FlashStrobeDurationRaw	250
	FlashStrobeDelayRaw	0
	FlashStrobeActiveState	Conducting
HDR	HDR_Mode	Off
	MultiSlopeLevel	33
	MultiSlopeTime	33
AnalogControl	All, Red, Green, Blue	1000
	BlackLevelRaw	20
	WhiteBalanceWidth	4096
	WhiteBalanceHeight	3072
	WhiteBalanceOffsetX	0
	WhiteBalanceOffsetY	0
Sensor	SensorBitDepth	Resolution_10_Bit
	ProgrammableGainAmplifier	1
LUTControl	LUTEnable	0
DefectPixel	DefectPixelCorrectionEnable	1
	DefectPixelTestMode	Off
DarkField	DF_BlackClamp	1
	DF_ColumnOffsetCorrection	1
BrightField	BF_ColumnGainCorrection	1
	BF_AutoLevelAdjust	0
	BF_CalibrationVideoLevel	65
	BF_OutputImagesDuring Calibration	0

Table 5-37: User savable registers and default values