Specim FX10 - User Manual 2.2

Contents

Specim FX10

Legal Information

Certification

Specim, Spectral Imaging Ltd has developed Quality Management System for its use covering design, development, manufacturing, sales and support of optical measurement devices. QMS follows ISO9001:2015 and enables more efficient operation and product management in a systematic way utilizing metrics. Specim QMS has been audited by Bureau Veritas Certification Holding SAS – UK Branch and found to be in accordance with the requirements of the management system standards.

Disclaimer

All information provided in this guide and provided manuals is believed to be complete, accurate and reliable at the time of delivery. No responsibility is assumed by Specim, Spectral Imaging Oy Ltd. for its use. Specim, Spectral Imaging Oy Ltd reserves the right to make changes to this information without notice. Reproduction of this manual in whole or in part, by any means, is prohibited without prior permission having been obtained from Specim, Spectral Imaging Oy Ltd.

Specim IQ ® and Specim IQ Studio ® are registered EU trademarks (Nos. 016777393 and 016777419) owned by SPECIM, Spectral Imaging Ltd.

Contacting support

Further information and technical support are available from **Specim, Spectral Imaging Oy Ltd.** in Finland. Contact information:

- WWW: *www.specim.fi*
- Email: *support@specim.fi*
- Tel: +358 (0)10 4244 400

Description

Hyperspectral Imaging

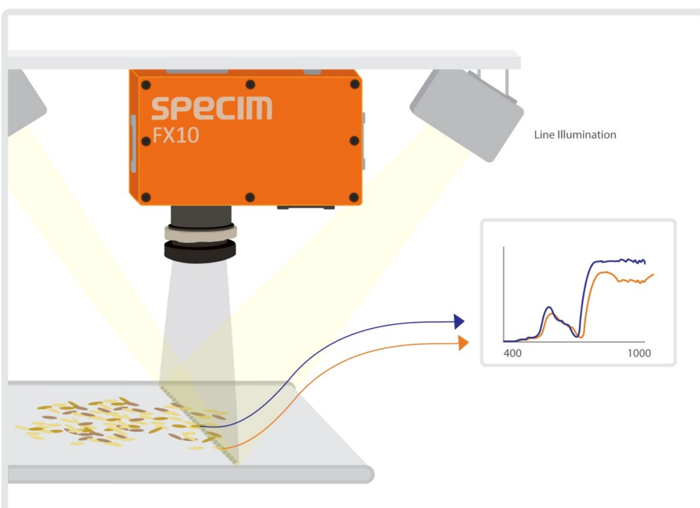
Hyperspectral imaging combines digital imaging with spectroscopy, detecting the unique spectral information in each image pixel. It can be used to identify, measure, and locate different materials and their chemical and physical properties.

Compared to the conventional visible light imaging, both monochromatic and color, hyperspectral imaging produces much more detailed information with an expanded wavelength range, also recording the data invisible to the human eye, to be computed and analyzed.

Pushbroom imaging technique

SPECIM FX cameras use pushbroom line scanning technique, which means that the target is scanned one spatial line at a time and full spectral data from that line is aqcuired simultaneously.

Using pushbroom technique always requires that either camera or the target moves and the movement builds up the image. The movement can be achieved for example by mounting the FX camera to a scanner, vehicle, or over a conveyor belt.



Illumination Overview

In spectral imaging, good illumination plays a bigger role than in conventional digital imaging. When arranging illumination, pay attention to three main parameters: intensity, spectral response and uniformity.

Intensity

Hyperspectral imaging needs more light than ordinary machine vision system as the light is divided to narrow wavelength bands and each band is measured separately. As a result, each pixel receives less light during fixed integration time than, for example, in RGB color imaging and the illumination used for hyperspectral imaging is brighter than the illumination used for standard cameras. The need for light can be partly compensated by using longer integration (exposure) times, but at the same time the measurement becomes slower.

Spectral response

Illumination for hyperspectral imaging must always have a continuous spectrum that covers the full wavelength range, over which the hyperspectral camera is operating. If the illumination does not have signal in some of the wavelengths, the measured data on those wavelengths is not valid.

The recommended options for Specim FX are halogen-based and sunlight illumination solutions.

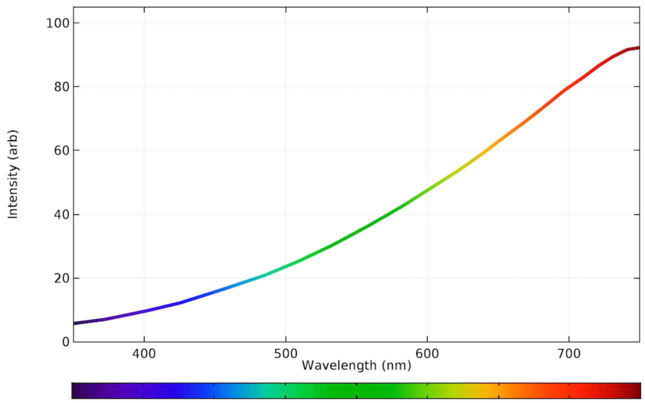


Figure 1: Halogen Spectrum

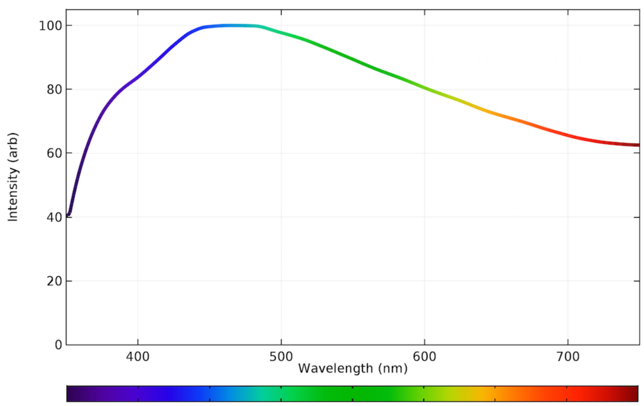


Figure 2: Sunlight Spectrum

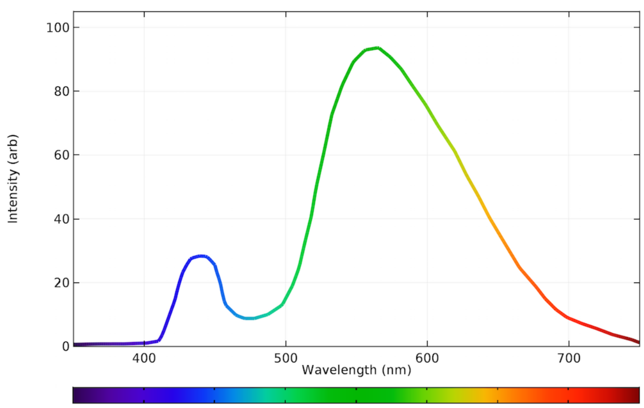


Figure 3: LED Spectrum

Uniformity

Another important illumination parameter is the uniformity of the illuminated area. The light coming for each position of the imaged area should have the same spectral response and intensity. There should be neither no shadows nor specular reflections, in the illuminated area. It is always better to use several, preferably two or four light sources instead of one, to illuminate the area.

Camera Overview

FX10 camera series is built around the monochrome CMOS image sensor that provides a resolution of 1312 x 1082 pixels at a wide range of spectral sensitivity. It is aimed at standard applications in industrial and laboratory image processing. FX10 cameras work in a push-broom mode, and collect hyperspectral data through single fore optics.

There are four versions of the FX10 camera:

- FX10, CameraLink, 400-1000 nm
- FX10e, GigE, 400-1000 nm
- FX10c, CameraLink, 400-780 nm
- FX10ce, GigE, 400-780 nm

These specifications apply to all FX10 camera versions.

Figure 4: FX10 Spectral Camera

The standard lens for FX10 is OLET15 with 38° FOV and 150 mm focusing distance. The filter thread for the standard lens is M43x0.75. The camera is always delivered with a lens cap. We recommend you use the lens cap whenever the camera is not in use.

Checking the camera version

The first digit of the camera serial number tells the version of the camera. The serial number can be found from the camera status line. For more information, see *Status Line* section of this manual and **ASCII for FX -series** document.

Serial number	Camera version
1xxxxxx	FX10
2xxxxxx	FX17
3xxxxxx	FX10e
4xxxxxx	FX17e
5xxxxxx	FX10b
6xxxxxx	FX10be
7xxxxxx	FX10c

Serial number	Camera version
8xxxxxx	FX10ce

Firmware version and updater

With the new revision of FX-series it is now possible to update the camera firmware via software updater on-site with the software package provided by Specim.

Note: It is not possible to use this feature previous revision's FX-cameras without hardware changes.

See the camera's serial number to check if your camera belongs to the new revision: the third digit of the old revision is xx0xxxx, while the new revisions' serial number is xx1xxxx.

Camera data path

A diagram of the camera data path is shown in the figure below.

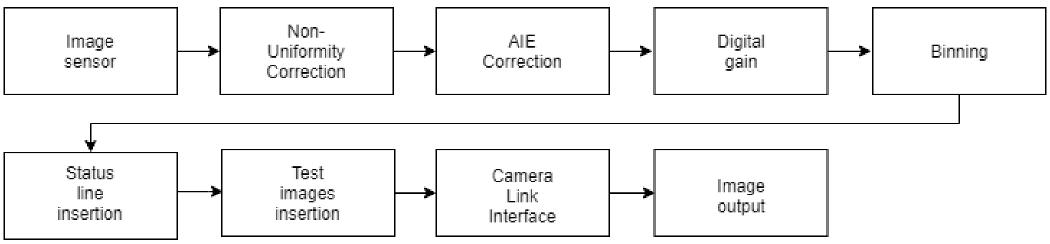


Figure 5: Camera data path

Feature Overview

Feature	Characteristics
Image sensor	CMOS
Data interface	• Camera Link in FX10 and FX10c • GigE in FX10e and FX10ce
Operating range	• 400 to 1000 nm in FX10 and FX10e • 400 to 780nm in FX10c and FX10ce
Image enhancement	• Offset and hot pixel correction • Automatic Image Enhancement (AIE)
Image size reduction	Multiple Regions of Interest (MROI)
Trigger modes	Opto isolated trigger input and opto isolated strobe output

Image Correction

The camera includes the following image corrections:

- Offset and hot pixel correction
- Automatic Image Enhancement (AIE) means that spectral calibration will be the same for every FX camera, and that smile and keystone will be corrected to practically zero for all cameras.

  A customer with several cameras can replace one camera with another and still have the same spectral calibration and smile/keystone without additional calibration.

All the corrections are enabled by default.

Regions of interest

The image sensor in FX series cameras is larger than the actual image size. Therefore the image area on the sensor is defined using the Region of Interest (ROI) feature, and the ROI values are provided in the calibration pack. ROI feature is reserved for this purpose alone, and the values must not be changed.

You can use Multiple Regions of Interest (MROI) feature to define one or several regions of interest. Using MROI feature requires 1 x 1 binning.

If you use AIE together with MROI, there must be additional 3 rows in the beginning and in the end of each MROI to prevent corruption. These extra rows must then be discarded in data processing as their data may be invalid.

External Interfaces

Power Connector

There is one Fischer Connector DBPLU1031Z012|130G in the camera back panel.

Power Connector Pin numbering

Table 1: Power Connector Pin-out

pin #	I/O Type	Name	Description
1	O	ISO_OUT0	General purpose Output 0, single-ended output
2	O	ISO_STROBE	Default Strobe out, single-ended output
3	O	RESERVED	Reserved, do not connect
4	PWR	CAMERA_GND	Camera GND, 0V
5	PWR	CAMERA_PWR	Camera Power 12V (+/- 10%), no polarity protection
6	PWR	ISO_GND	I/O GND, 0V
7	I	ISO_IN0	General purpose input 0 (5 V)
8	I	ISO_TRIGGER	Default Trigger in (5-15 V)
9	O	RESERVED	Reserved, do not connect
10	O	RESERVED	Reserved, do not connect
11	O	RESERVED	Reserved, do not connect
12	O	RESERVED	Reserved, do not connect

Camera Link Camera External Interfaces

Camera Link Connector

There is a standard MDR 26-pin camera link connector on the back panel of the camera for camera control signals and serial communication.

For more information on Camera Link connector, refer to Camera Link interface standard specifications.

LED Indications

There is one green LED in the FX camera back panel.

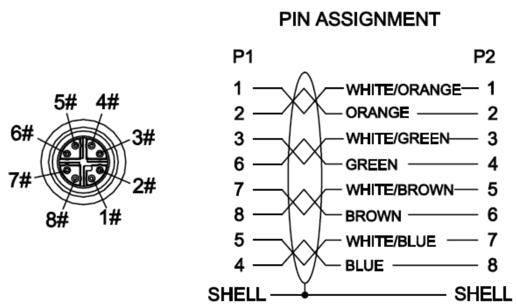
LED	Status
Not lit	Power off
Blinking green in startup	Starting up
Stable green	Power on, not recording
Blinking green	Recording, data being transferred

Note: Camera blinks briefly during startup. This period can be very short and therefore easy to miss.

GigE Camera External Interfaces

GigE Connector

There is a standard GigE M12 X-coded Ethernet connector on the back panel of the camera for camera control signals and serial communication.



LED Indications

There are three green LEDs in the FX camera back panel, one for status and two for GigE traffic indication.

Note: The LED light may appear dim.

Status LED	Status
Not lit	Power off
Stable green	Power on

GigE LED 1	Status
Not lit	No data connection
Blinking green	Data connection active

GigE LED 2	Status
Not lit	No data traffic
Blinking green	Data being transmitted

Frame Grabbers

Compatible Frame Grabbers

When you use a Camera Link camera, the system requires a frame grabber installed on the data aqcuisition PC.

The frame grabbers that have been tested to work with LUMO in WIN10 are:

- NI 1430
- Dalsa Xtium-CL_MX4
- Epix PICXi EB1

Frame Grabber Relevant Configuration

The parameters and settings, which are essential to configure the frame grabber are shown in the following table.

Table 2: Summary of parameters needed for frame grabber configuration

Pixel Clock per Tap	80 MHz
Number of Taps	2
Greyscale resolution	12 bit / 10 bit / 8 bit
CC1	18 clock cycles
CC2	not used
CC3	not used
CC4	not used

Camera Link port and bit assignments are compliant with the Camera Link standard

Table 3: Camera Link 2 Tap port and bit assignments

Bit	Tap 0	Tap 1	Tap 0	Tap 1	Tap 0	Tap 2
	8 Bit	8 Bit	10 Bit	10 Bit	12 Bit	12 Bit
0 (LSB)	A0	B0	A0	C0	A0	C0
1	A1	B1	A1	C1	A1	C1
2	A2	B2	A2	C2	A2	C2
3	A3	B3	A3	C3	A3	C3
4	A4	B4	A4	C4	A4	C4
5	A5	B5	A5	C5	A5	C5
6	A6	B6	A6	C6	A6	C6
7 (MSB of 8 Bit)	A7	B7	A7	C7	A7	C7

Bit	**Tap 0**	**Tap 1**	**Tap 0**	**Tap 1**	**Tap 0**	**Tap 2**
8	-	-	B0	B4	B0	B4
9 (MSB of 10 Bit)	-	-	B1	B5	B1	B5
10	-	-	-	-	B2	B6
11 (MSB of 12 Bit)	-	-	-	-	B3	B7

Installation Guide

Installation Setup Overview

The basic installation setup requires camera, data cable, power cable, data aqcuisition PC and illumination.

1. Check the delivery.
    1. Check that the package is undamaged.
    2. Check the delivery contents and make sure that all the items mentioned in the post list are included in the delivery.
2. Arrange the illumination.
3. Have the data aqcuisition PC ready.
4. Have the scanner, conveyor belt or some other method for movement ready.
5. Mount the camera.
6. Connect the cabling.
7. Install Lumo software on the data aqcuisition PC.
8. Test the signal.

Camera Mounting

The following mounting options are available:

- Standard Camera Thread (1/4-20 UNC) in the bottom for tripod mounting
- Mounting Kit + dovetail joints located on four sides of the camera

This chapter describes the mounting kit installation option.

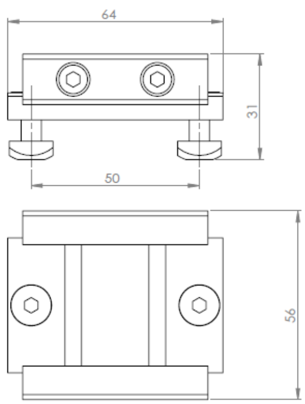


Figure 6: Mounting Kit dimensions

Note: Make sure to leave adequate space behind the camera for cabling.

Note: Pay attention to the slit orientation when mounting the camera.

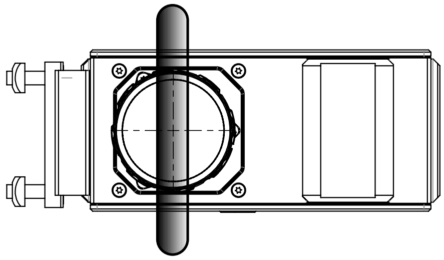


Figure 7: Slit orientation

1. Attach the mounting kit bottom plate.
2. Slide the camera holder part to the mounting kit bottom plate.

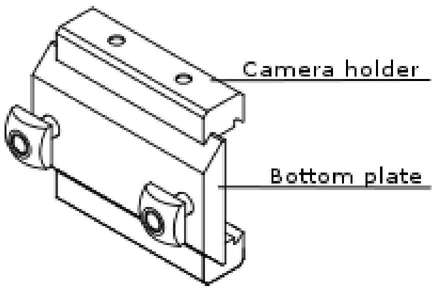


Figure 8: Mounting Kit parts

3. Slide the camera dovetails to the camera holder.

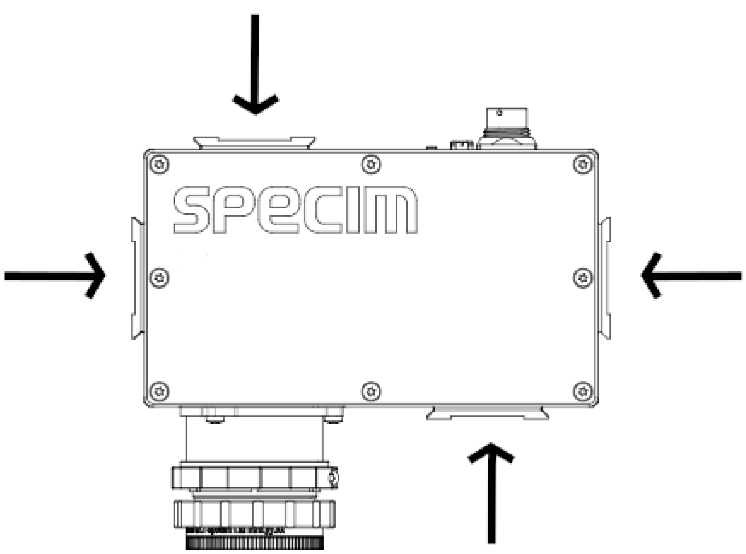


Figure 9: Dovetail joints for the Mounting Kit

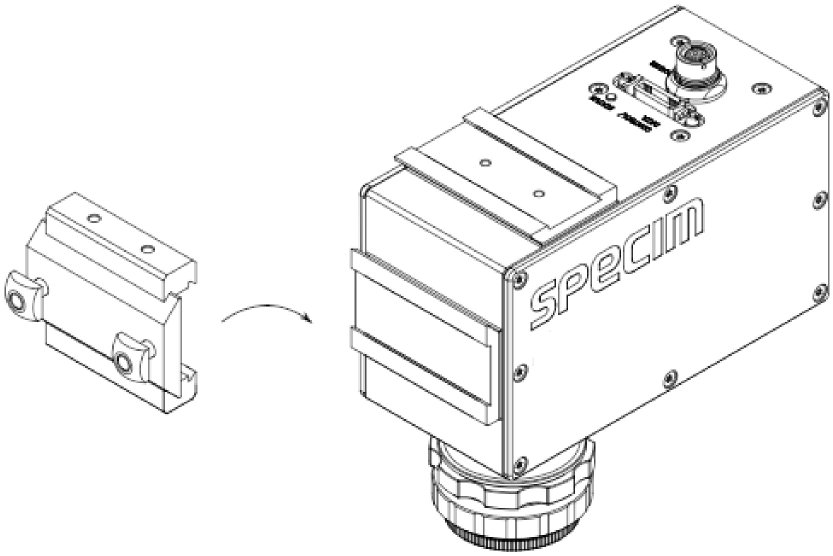


Figure 10: Mounting Kit assembly

4. Tighten the camera holder screws to secure the camera in position.

Once the camera mounting is complete, move on to cabling.

Cabling the Camera Link Camera

There are two connectors in the camera back panel (on the left picture below):

- Camera Link Connector
- Power Connector for 12V DC

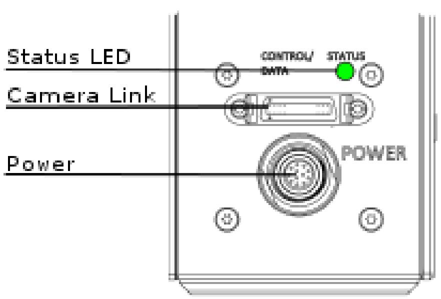


Figure 11: Back panel connectors

Note: Leave at least 150 mm space behind the camera for cabling.

Note: Make sure that the Camera Link cable is connected before powering up the camera.

Connect the cables:

1. Connect the interface connector (Camera Link) to the camera.
2. Connect the interface cable to the PC.
3. Insert the power cable to the **camera**, make sure the red dots are aligned.
4. Connect power cable to the **wall socket**.
5. Camera is on when the **Status** LED is stable green.

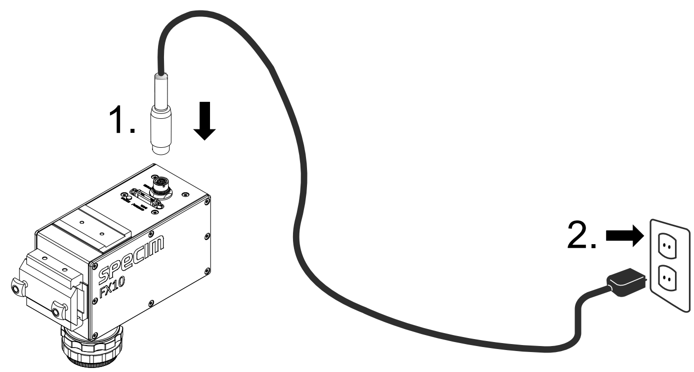


Figure 12: Powering Order

When powering off the camera, pull the power cable first from the wall socket. After removing the power cord, wait at least 30 seconds before connecting the power cord and starting camera again.

Cabling the GigE Camera

There are three LEDs and two connectors in the camera back panel (on picture below):

- GigE connector
- Power Connector for 12V DC

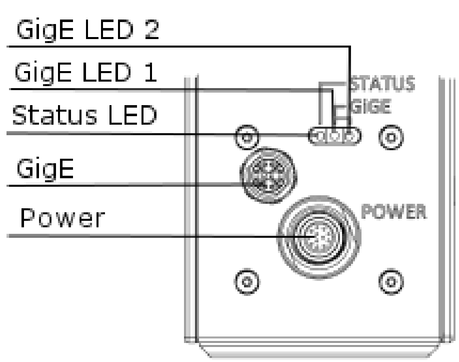


Figure 13: Back panel connectors

Note: Leave at least 60 mm space behind the camera for cabling.

Note: Make sure that the GigE data cable is connected before powering up the camera.

Connect the cables:

1. Connect the interface connector (GigE) to the camera.

2. Connect the interface cable to the PC.
3. Insert the power cable to the **camera**, make sure the red dots are aligned.
4. Connect power cable to the **wall socket**.
5. Camera is on when the **Status** LED is stable green.

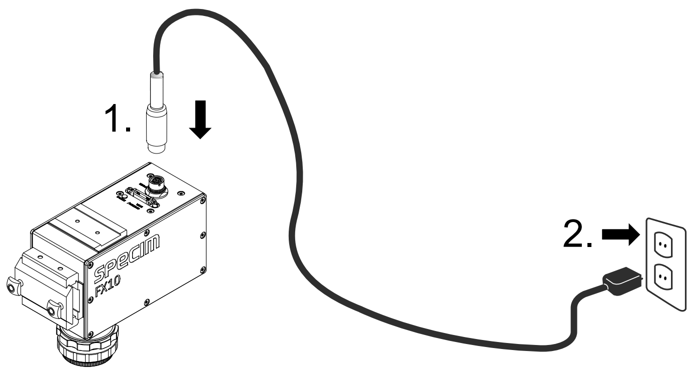


Figure 14: Powering Order

When powering off the camera, pull the power cable first from the wall socket. After removing the power cord, wait at least 30 seconds before connecting the power cord and starting camera again.

Setting the Jumbo Frame Value

When using the GigE camera version, set the jumbo frame value to maximum to ensure that the data is not corrupted when tranferred to the data acquisition PC.

1. Open Windows start menu and search for network status.

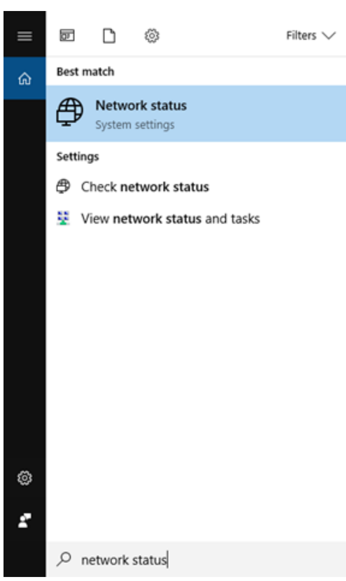
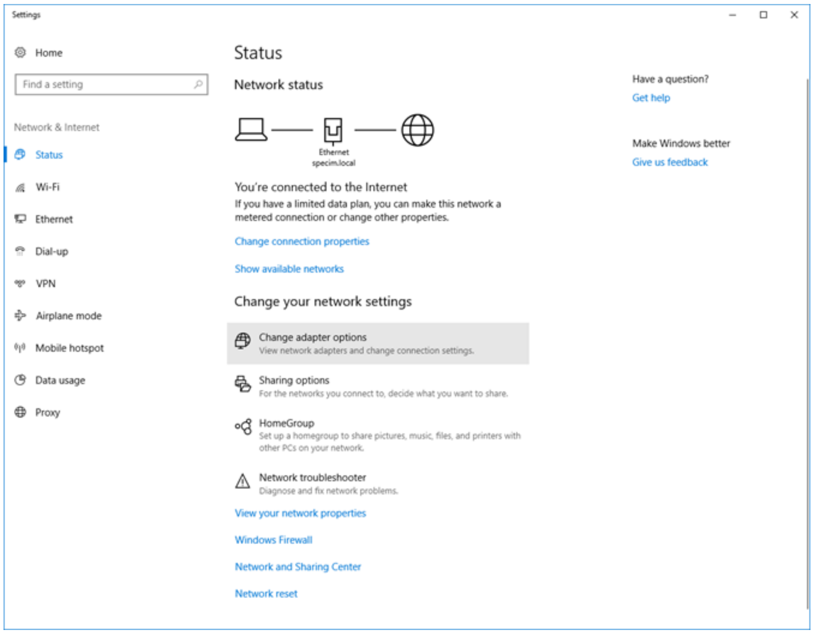
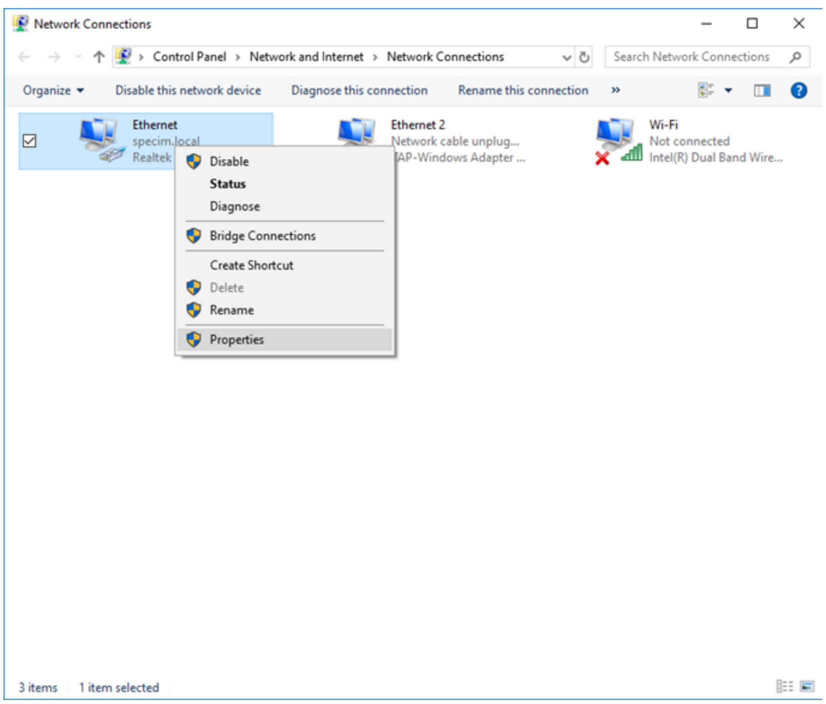


Figure 15: Network status in Windows start menu

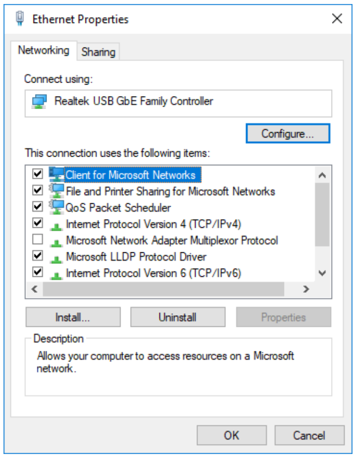
2. Open the network status window and click **Change adapter options**.



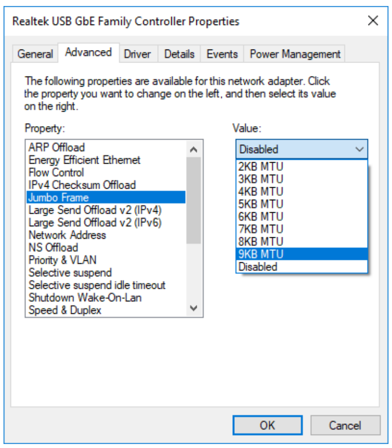
3. In the Network Connections window, click the right mouse button on the network adapter used by the camera. Select **Properties**.



4. Click **Configure**.



5. Open the **Advanced** tab and select **Property: Jumbo frame**.



6. Set the property to the maximum value (typically 9KB MTU).

Software Options

Lumo Software

Lumo is a family of software products for hyperspectral sensor data acquisition.

- Lumo Recorder, for when there is no Specim scanner used in the setup
- Lumo Scanner, for when there is a Specim scanner in use

With Lumo Software you can select camera and scanner, adjust acquisition parameters, and save raw data of the camera. It can also control other external devices, required for certain sensors, such as thermal calibrator, triggering electronics, motors, and so on.

Lumo Software has a built-in scripting and sequential workflow engine controlling all the steps and automation to be performed for each measurement.

For instructions on how to use your Lumo software, refer to the relevant Lumo Software User Manual.

SpecSensor SDK

SpecSensor SDK is a unified SDK for all our cameras, and it is typically used by OEM and integrators. C style API can be used from different programming languages.

SpecSensor SDK sends commands to cameras and gets the frames from the cameras, however it does not have a GUI or record data to the disk.

For instructions on how to use your Specim SDK, refer to the SpecSensor SDK User Manual.

ASCII Commands

the Camera Link version of the FX camera can be controlled with ASCII commands, for example in cases where hyperspectral imaging is integrated in an existing ASCII based system or when required features are not supported by LUMO or LUMO SDK Software.

ASCII commands are available in separate ASCII documentation. Note, that Specim does not provide support packages for ASCII use cases.

GigE Vision

GigE version of the FX camera is complient with GigE Vision interface standard, which is a global standard for video transfer and device control over Ethernet networks. For more information, refer to GigE Vision Standard Specification.

Functionality

Image Aqcuisition

Readout Modes

The FX cameras provide two different readout modes:

- **Sequential readout:** Frame time is the sum of exposure time and readout time. Exposure time of the next image can only start if the readout time of the current image is finished.
- **Simultaneous readout (interleave):** The frame time is determined by the maximum of the exposure time or of the readout time, which ever of both is the longer one. Exposure time of the next image can start during the readout time of the current image.

The camera chooses the interlace mode of IWR or ITR automatically depending on integration time and frame rate settings. With the new revision of the camera, it is possible to change the readout mode by sending a command to the camera. For more information, see the *ASCII for FX -series* document or the GigE software user interface.

Note: It is not possible to use this feature with the previous revision's FX17 cameras without hardware changes.

The following figure illustrates the effect on the frame rate when using either the sequential readout mode or the simultaneous readout mode (interleave exposure).

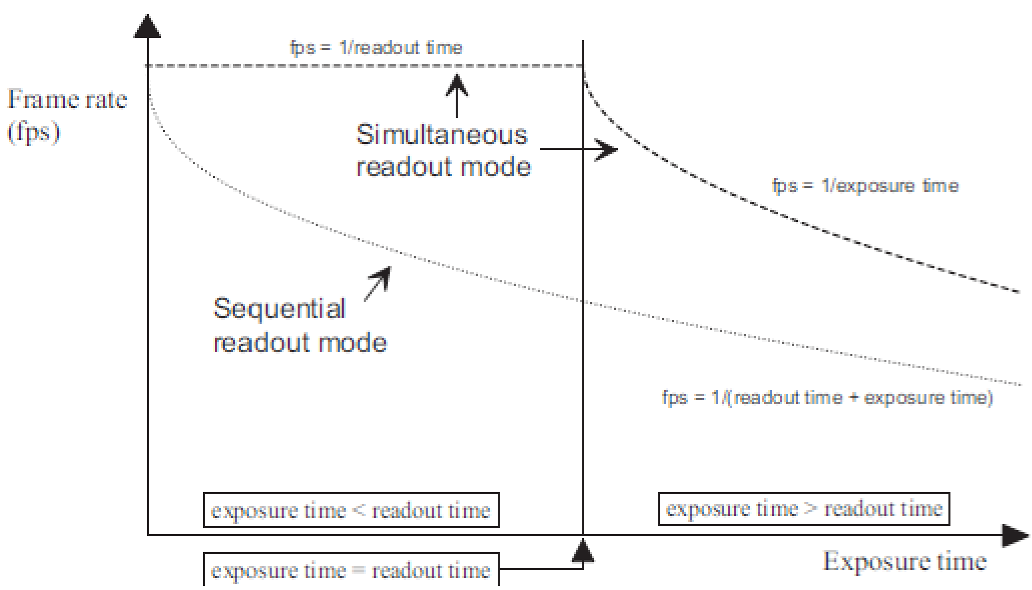


Figure 16: Frame rate in sequential readout mode and simultaneous readout mode

Sequential readout mode For the calculation of the frame rate only a single formula applies: frames per second equal to the inverse of the sum of exposure time and readout time.

Simultaneous readout mode (exposure time is less than readout time) The frame rate is given by the readout time. Frames per second equal to the inverse of the readout time.

Simultaneous readout mode (exposure time is greater than readout time) The frame rate is given by the exposure time. Frames per second equal to the inverse of the exposure time.

The simultaneous readout mode allows higher frame rate. However, if the exposure time greatly exceeds the readout time, then the effect on the frame rate is neglectable.

Note: In simultaneous readout mode image output faces minor limitations. The overall linear sensor reponse is partially restricted in the lower grey scale region.

Note: When changing readout mode from sequential to simultaneous readout mode or vice versa, new settings of the BlackLevelOffset and of the image correction are required.

Sequential readout

By default the camera continuously delivers images as fast as possible ("Free-running mode") in the sequential readout mode. Exposure time of the next image can only start if the readout time of the current image is finished.

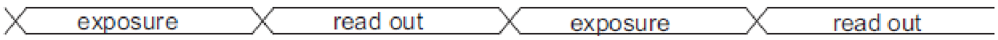


Figure 17: Timing in free-running sequential readout mode

When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used. In this mode, the camera is idle until it gets a signal to capture an image.

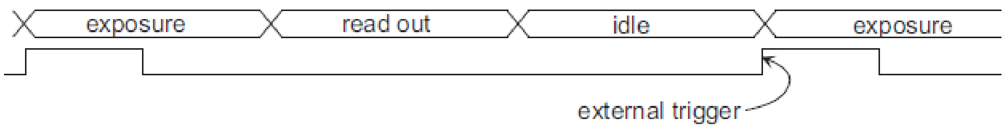


Figure 18: Timing in triggered sequential readout mode

Simultaneous readout (interleave exposure)

To achieve highest possible frame rates, the camera must be set to "Free-running mode" with simultaneous readout. The camera continuously delivers images as fast as possible. Exposure time of the next image can start during the readout time of the current image.

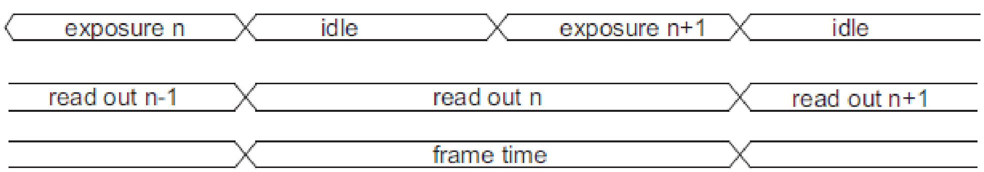


Figure 19: Timing in free-running simultaneous readout mode (exposure time is greater than readout time)

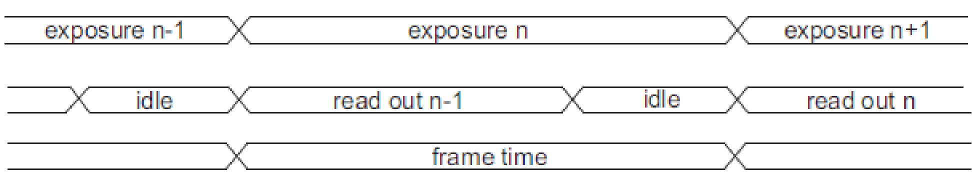


Figure 20: Timing in free-running simultaneous readout mode (exposure time is greater than than readout time)

When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used. In this mode, the camera is idle until it gets a signal to capture an image.

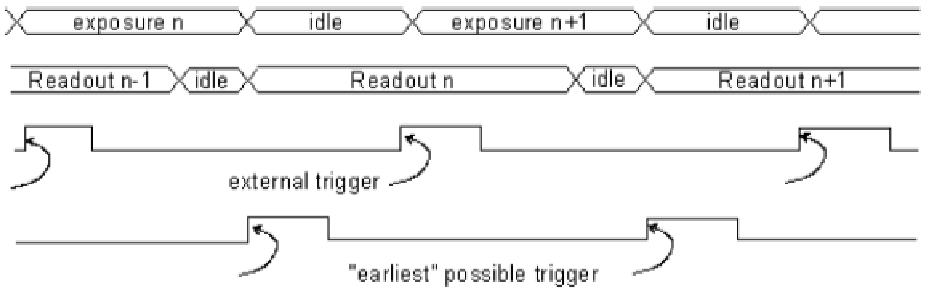


Figure 21: Timing in triggered simultaneous readout mode

Readout Timing

Sequential readout timing

By default, the camera is in free running mode and delivers images without any external control signals. The sensor is operated in sequential readout mode, which means that the sensor is read out after the exposure time. Then the sensor is reset, a new exposure starts and the readout of the image information begins again. The data is output on the rising edge of the pixel clock. The signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER indicates the active exposure period of the sensor and is shown for clarity only.

Simultaneous readout timing

To achieve highest possible frame rates, the camera must be set to "Free-running mode" with simultaneous readout. The camera continuously delivers images as fast as possible. Exposure time of the next image can start during the readout time of the current image. The data is output on the rising edge of the pixel clock. The signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER indicates the active integration phase of the sensor and is shown for clarity only.

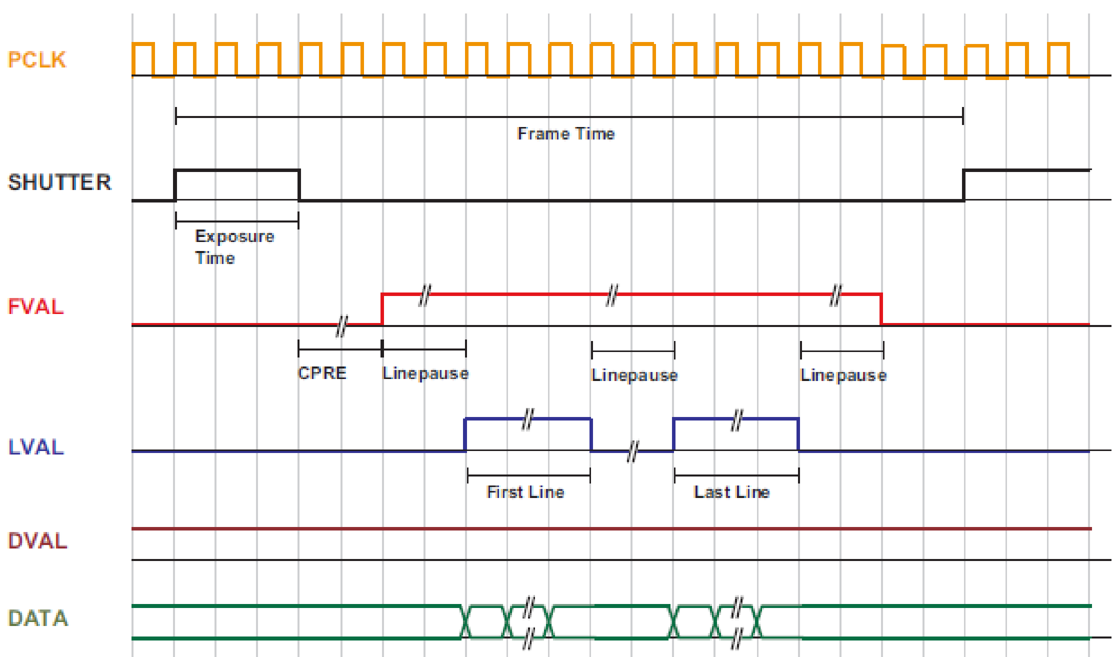


Figure 22: Timing diagram of sequential readout mode

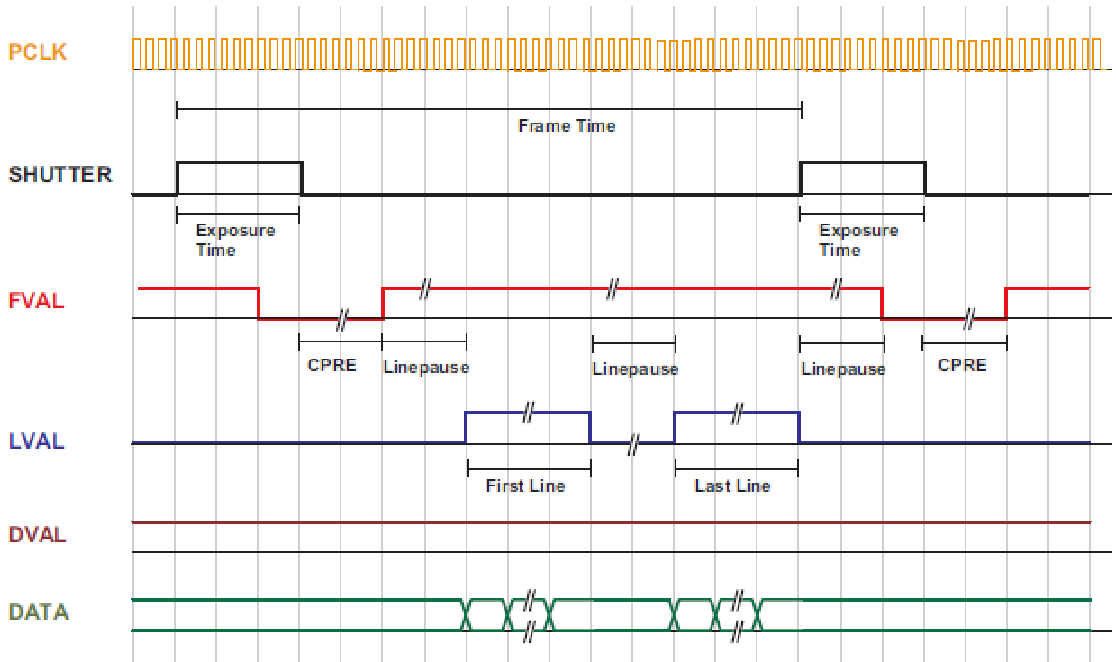


Figure 23: Timing diagram of simultaneous readout mode (readout time is greater than exposure time)

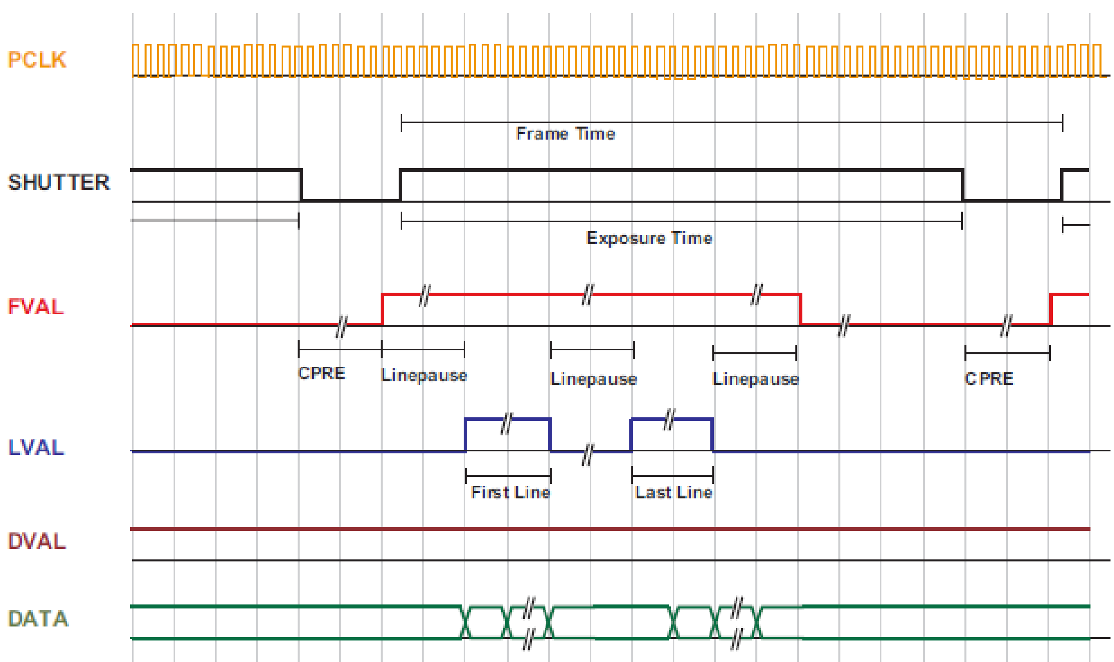


Figure 24: Timing diagram simultaneous readout mode (readout time is less than exposure time)

Table 4: Explanation of control and data signals used in the timing diagram

Frame time	Frame time is the inverse of the frame rate.

Exposure time	Period during which the pixels are integrating the incoming light.
PCLK	Pixel clock on CameraLink® interface.
SHUTTER	Internal signal, shown only for clarity. Is ’high’ during the exposure time.
FVAL (Frame Valid)	Is ’high’ while the data of one complete frame are transferred.
LVAL (Line Valid)	Is ’high’ while the data of one line are transferred. Example: To transfer an image with 640x480 pixels, there are 480 LVAL within one FVAL active high period. One LVAL lasts 640 pixel clock cycles.
DVAL (Data Valid)	Is ’high’ while data are valid.
DATA	Transferred pixel values. Example: For a 100x100 pixel image, there are 100 values transferred within one LVAL active high period, or 100*100 values within one FVAL period.
Line pause	Delay before the first line and after every following line when reading out the image data.

Reduction of Image Size

Region of Interest (ROI)

The image sensor in FX series cameras is larger than the actual image size. Therefore the image area on the sensor is defined using the Region of Interest (ROI) feature, and the ROI values are provided in the calibration pack. ROI feature is reserved for this purpose alone. Do not change these values.

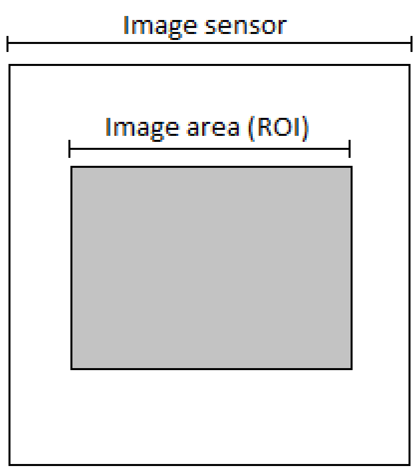


Figure 25: FX camera image size (ROI) on sensor

When you want to define a region of interest, it is done using the Multiple Regions of Interest (MROI) feature. See *Multiple Regions of Interest* for more information.

Multiple Regions of Interest

FX-series cameras have the multiple MROI feature to reduce the number of pixels to be read from the detector. As a result the maximum achievable frame rate can be increased. The multiple ROIs are joined together and form a single image, which is transferred to the frame grabber.

Since the ROI feature is used for the image area on the sensor, the MROI feature is also used for setting a single ROI in FX series.

MROI feature works differently in FX10/FX10e and FX17/FX17e:

- User sets wanted rows to be read and camera electronics “goes” straight to those rows in focal plane array and reads them out.
- In FX17/FX17e MROI works differently. First MROI’s are configured. During reading out the image the camera goes through all the rows from the first in the first MROI to last in last MROI and reads out only those that are included in MROI configuration. Reading out only rows in MROI’s increases maximum frame rate but “checking” other rows takes some time. Resulting maximum frame rate depends then
  - On the total number of rows included in MROI’s but
  - also the total number of rows within MROI outlining rectangle that are NOT included in MROI’s.

The number of MROI’s can be between 1 and 512. Binning must be disabled.

MROI in Lumo

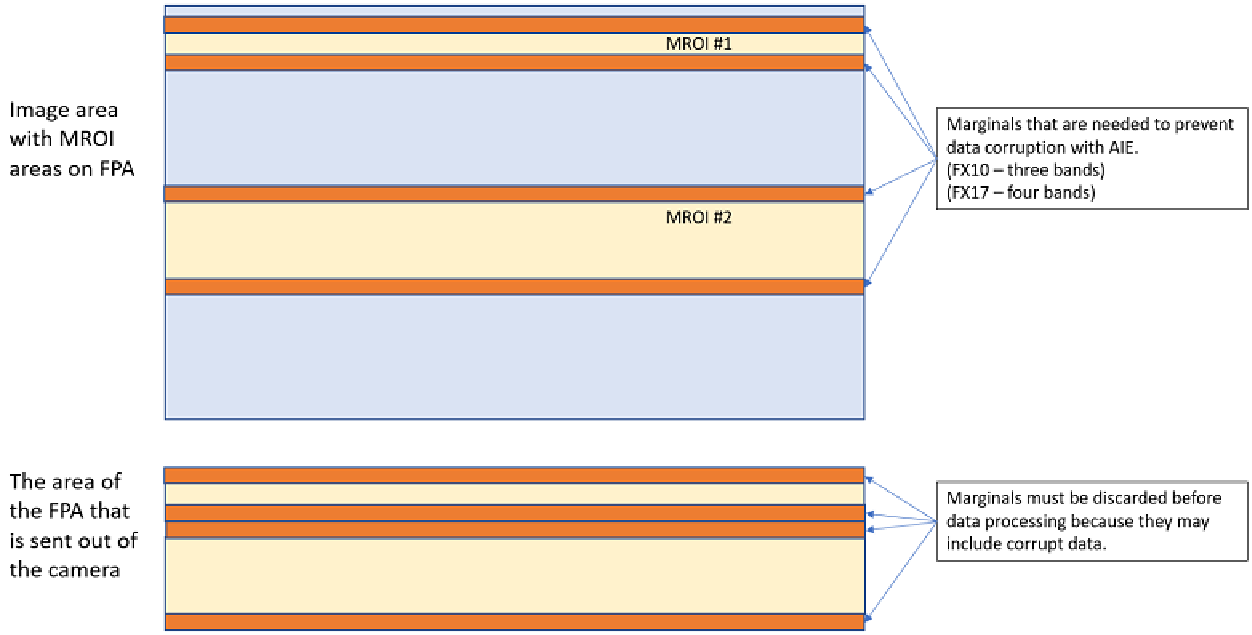
In Lumo (SpecSensor SDK, Recorder or Scanner), start row index is relative row index inside of full image area (Full frame is bigger). In FX10, start row and height of MROI can be any number between 0 and 447 (MROI total height must be not bigger than 448). In FX17, Start row must be an even number between 0 and 222 and height of MROI must be an even number between 2 and 224 (MROI total height must be not bigger than 224).

MROI in ASCII or GigEVision

In ASCII, GigEVision and FX configurator, the start row refers straight to “native” row indexes. In FX10 it can be any number between Window.Y and Window.Y + 447. Height of MROI can be any number between 1 and 448 (MROI total height must be not bigger than 448). In FX17, the start row can be an even number between Window.Y and Window.Y + 222 and the height of and MROI can be an even number between 2 and 224 (MROI total height must be not bigger than 224).

MROI and AIE

There must be additional rows in the beginning and in the end of each MROI to prevent corruption of the intended MROI rows. There needs to be three rows in FX10/FX10e and four rows in FX17/FX17e. These extra rows must then be discarded in data processing as their data may be invalid.



Trigger and Strobe

Introduction

The start of the exposure of the camera's image sensor is controlled by the trigger. The trigger can either be generated internally by the camera (free running trigger mode) or by an external device (external trigger mode).

Notice: Camera's regular power cable does not support external triggering. Use the power cable version designed for external trigger use.

This section refers to the external trigger mode if not otherwise specified. In external trigger mode, the trigger can be applied through the Camera Link interface (interface trigger) or directly by the power supply connector of the camera (I/O Trigger). The trigger signal can be configured to be active high or active low. When the frequency of the incoming triggers is higher than the maximal frame rate of the current camera settings, then some trigger pulses will be missed. A missed trigger counter counts these events. This counter can be read out by the user.

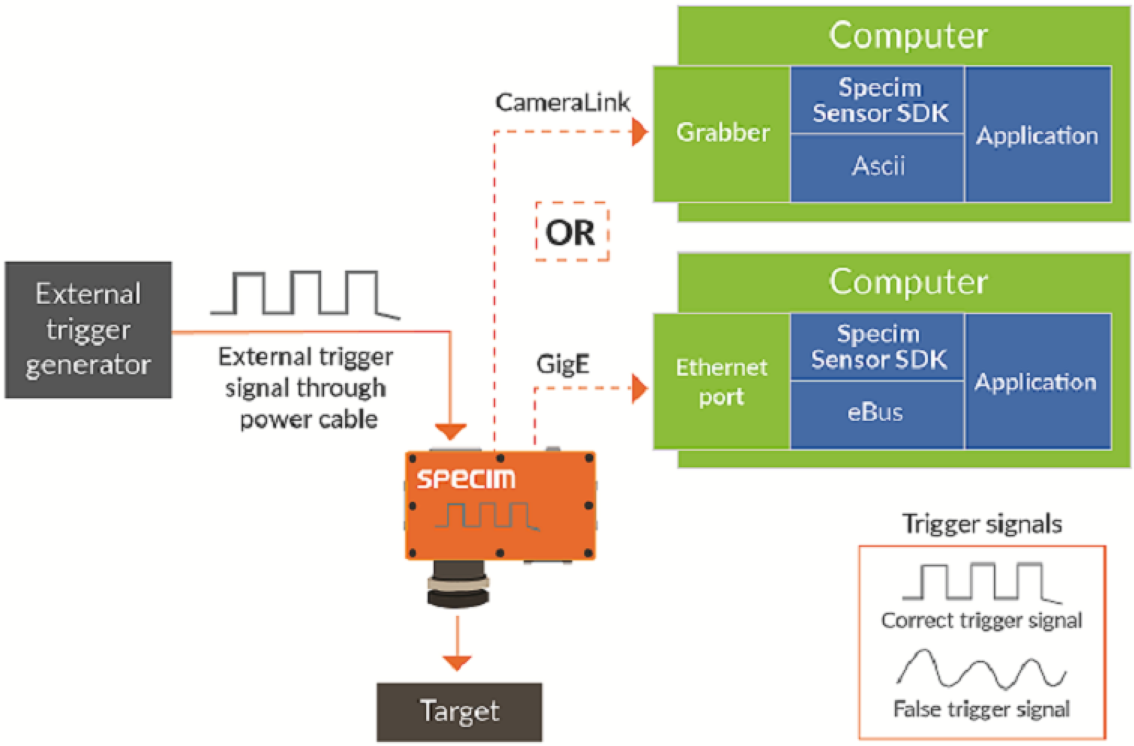


Figure 26: I/O Trigger setup

The exposure time in external trigger mode can be defined by the setting of the exposure time register (camera controlled exposure mode) or by the width of the incoming trigger pulse (trigger controlled exposure mode).

An external trigger pulse starts the exposure of one image. In Burst Trigger Mode however, a trigger pulse starts the exposure of a user defined number of images. The start of the exposure is shortly after the active edge of the incoming trigger. An additional trigger delay can be applied that delays the start of the exposure by a user defined time. This is often used to start the exposure after the trigger to a flash lighting source.

Trigger source

The trigger signal can be configured to be active high or active low. One of the following trigger sources can be used:

- **Free running:** The trigger is generated internally by the camera. Exposure starts immediately after the camera is ready and the maximal possible frame rate is attained, if Constant Frame Rate mode is disabled. In Constant Frame Rate mode, exposure starts after a user-specified time (Frame Time) has elapsed from the previous exposure start and therefore the frame rate is set to a user defined value.
- **Interface Trigger:** In the interface trigger mode, the trigger signal is applied to the camera by the CameraLink® interface. The trigger is generated by the frame grabber board and sent on the CC1 signal through the CameraLink® interface. Some frame grabbers allow the connection external trigger devices through an I/O card.
- **I/O Trigger:** In the I/O trigger mode, the trigger signal is applied directly to the camera by the power supply connector (via an optocoupler).

Exposure time control

Depending on the trigger mode, the exposure time can be determined either by the camera or by the trigger signal itself.

In **camera-controlled exposure time** the exposure time is defined by the camera. For an active high trigger signal, the camera starts the exposure with a positive trigger edge and stops it when the preprogrammed exposure time has elapsed. The exposure time is defined by the software.

In **trigger-controlled exposure time** the exposure time is defined by the pulse width of the trigger pulse. For an active high trigger signal, the camera starts the exposure with the positive edge of the trigger signal and stops it with the negative edge.

External Trigger with Camera controlled Exposure Time

In the external trigger mode with camera controlled exposure time the rising edge of the trigger pulse starts the camera states machine, which controls the sensor and optional external strobe output. The following figure shows the detailed timing diagram for the external trigger mode with camera controlled exposure time.

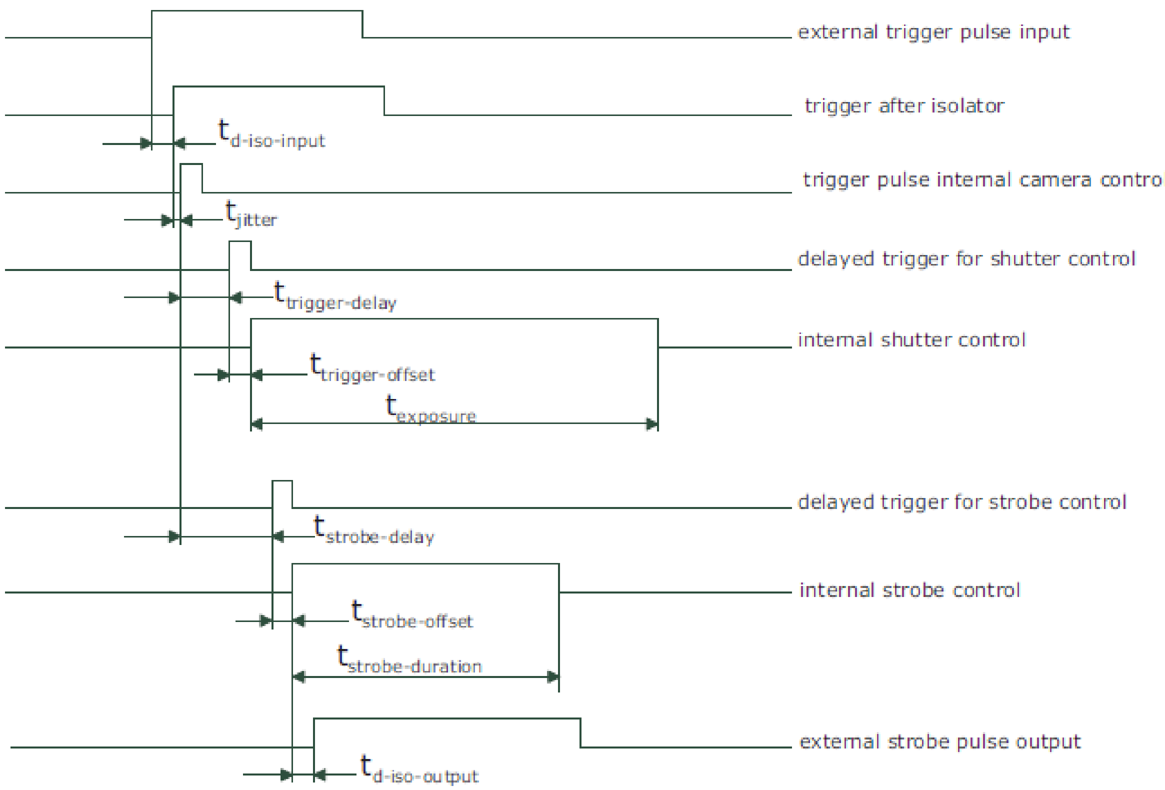


Figure 27: Timing diagram for the camera controlled exposure time

The rising edge of the trigger signal is detected in the camera control electronic which is implemented in an FPGA. Before the trigger signal reaches the FPGA it is isolated from the camera environment to allow robust integration of the camera into the vision system. In the signal isolator the trigger signal is delayed by time $t_{d-iso-input}$. This signal is clocked into the FPGA which leads to a jitter of t_{jitter}. The pulse can be delayed by the time $t_{trigger-delay}$ which can be configured by a user defined value via camera software. The trigger offset delay $t_{trigger-offset}$ results then from the synchronous design of the FPGA state machines. The exposure time $t_{exposure}$ is controlled with an internal exposure time controller.

The trigger pulse from the internal camera control starts also the strobe control state machines. The strobe can be delayed by $t_{strobe-delay}$ with an internal counter which can be controlled by the customer via software settings. The strobe offset delay $t_{strobe-delay}$ results then from the synchronous design of the FPGA state machines. A second counter determines the strobe duration $t_{strobe-duration}$(strobe-duration). For a robust system design the strobe output is also isolated from the camera electronic which leads to an additional delay of $t_{d-iso-output}$. The following tables give an overview over the minimum and maximum values of the parameters.

External Trigger with Pulse width controlled Exposure Time

In the external trigger mode with Pulsewidth controlled exposure time the rising edge of the trigger pulse starts the camera states machine, which controls the sensor. The falling edge of the trigger pulse stops the image acquisition. Additionally the optional external strobe output is controlled by the rising edge of the trigger pulse. The timing diagram below shows the detailed timing for the external trigger mode with pulse width controlled exposure time.

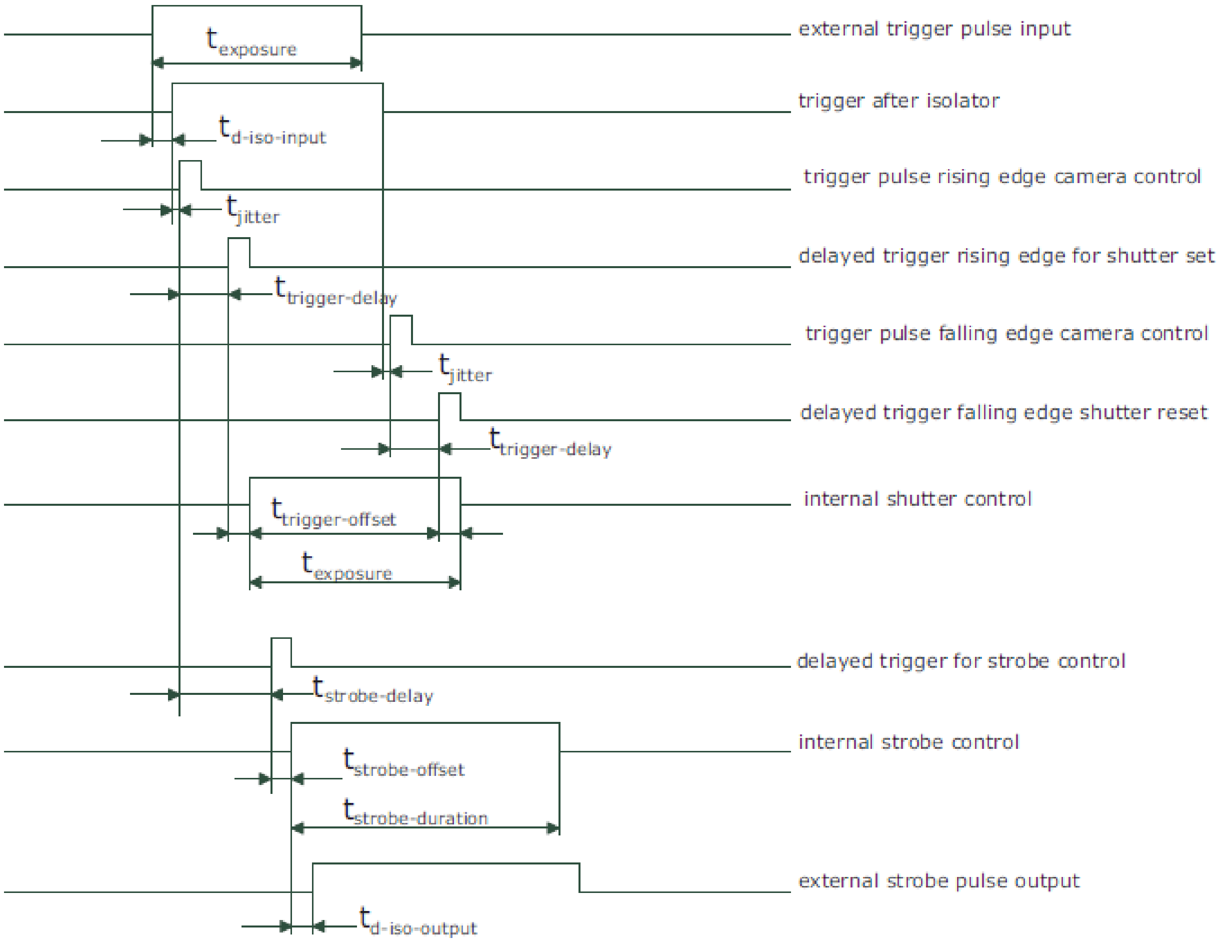


Figure 28: Timing diagram for the pulse width controlled exposure time

The timing of the rising edge of the trigger pulse until to the start of exposure and strobe is equal to the timing of the camera controlled exposure time. In this mode, however, the end of the exposure is controlled by the falling edge of the trigger pulse width: The falling edge of the trigger pulse is delayed by the time $t_{d-iso-input}$ which is results from the signal isolator. This signal is clocked into the FPGA which leads to a jitter of t_{jitter}. The pulse is then delayed by $t_{trigger-delay}$ by the user defined value which can be configured via camera software. After the trigger offset time $t_{trigger-offset}$ the exposure is stopped.

Trigger delay

The trigger delay is a programmable delay in milliseconds between the incoming trigger edge and the start of the exposure. This feature may be required to synchronize to external strobe with the exposure of the camera.

Burst trigger

The camera includes a burst trigger engine. When enabled, it starts a predefined number of acquisitions after one single trigger pulse. The time between two acquisitions and the number of acquisitions can be configured by a user defined value via the camera software. The burst trigger feature works only in the mode "Camera controlled Exposure Time".

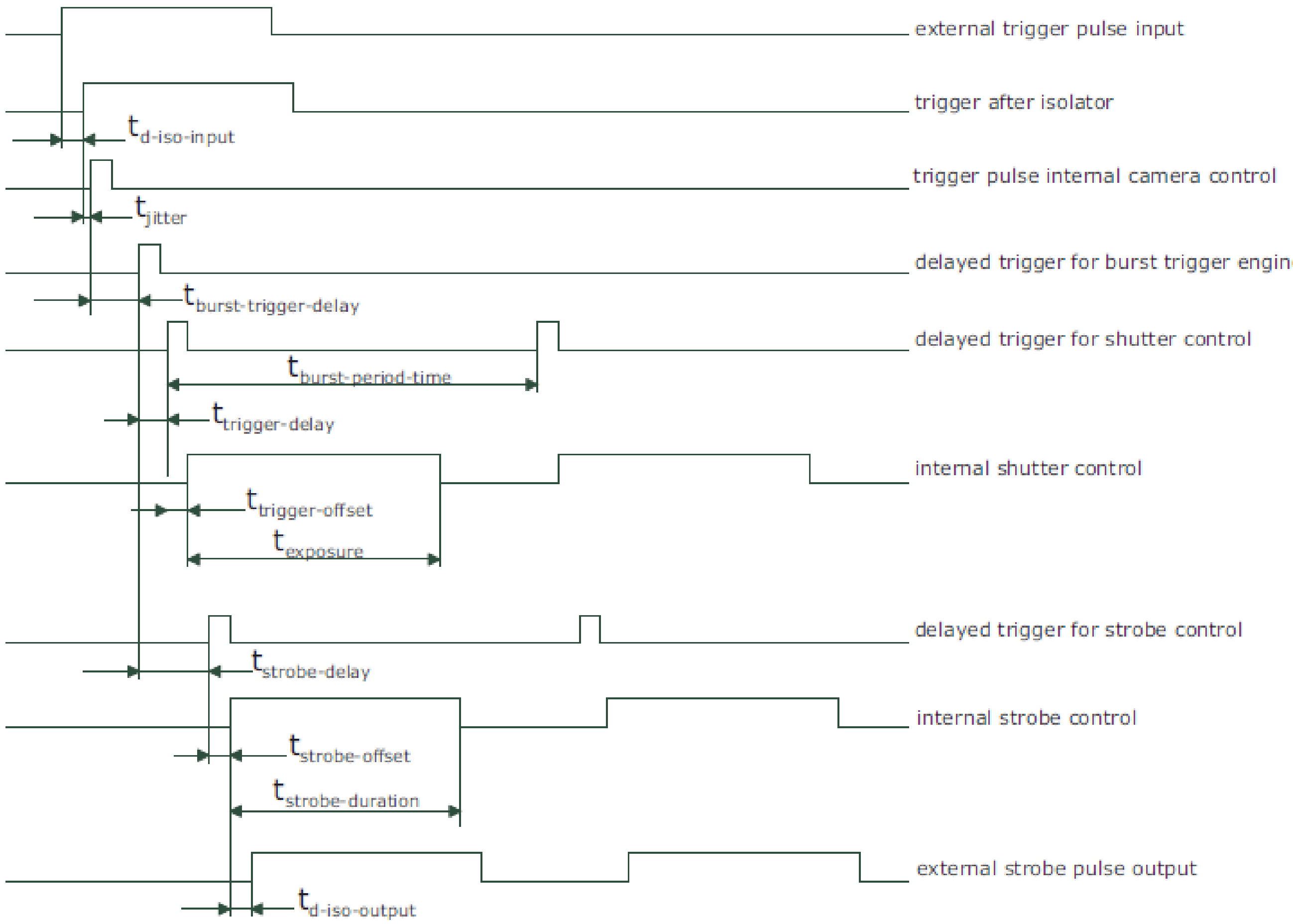


Figure 29: Timing diagram for the burst trigger mode

The burst trigger signal can be configured to be active high or active low. When the frequency of the incoming burst triggers is higher than the duration of the programmed burst sequence, then some trigger pulses will be missed. A missed burst trigger counter counts these events. This counter can be read out by the user.

The timing diagram of the burst trigger mode is shown in the *Timing diagram for the burst trigger mode* figure. The timing from the "external trigger pulse input" to the "trigger pulse internal camera control" is equal to the timing in the figure *Timing diagram for the pulse width controlled exposure time* above. This trigger pulse then starts after a user configurable burst trigger delay time $t_{burst-trigger-delay}$ the internal burst engine, which generates an internal triggers for the shutter and strobe control. A user configurable value defines the time $t_{burst-period-time}$ between two acquisitions.

Software trigger

The software trigger enables to emulate an external trigger pulse by the camera software through the serial data interface. It works with both burst mode enabled and disabled. As soon as it is performed via the camera software, it will start the image acquisition(s), depending on the usage of the burst mode and the burst configuration. The trigger mode must be set to Interface Trigger or I/O Trigger.

Strobe output

The strobe output is an opto-isolated output located on the power supply connector that can be used to trigger a strobe. The strobe output can be used both in free-running and in trigger mode. There is a programmable delay available to adjust the strobe pulse to your application.

Timing parameters

The following table gives an overview of the minimum and maximum values of the trigger and strobe parameters.

Table 5: Timing parameters

Timing parameter	Min	Max
$t_{d-iso-input}$	5 µs (typical)	18 µs
t_{jitter}	0	50 ns
$t_{input\text{-}jitter}$	FX10: 75 ns FX17: 83.3 ns	FX10: 100 ns FX17: 111.1 ns
$t_{pulse\text{-}delay}$	0 s	0.466 s
$t_{trigger-delay}$	0 s	419 ns
$t_{trigger-offset}$ (trigger not during readout)	600 ns	600 ns
$t_{exposure\text{-}offset}$	FX10: 225 ns FX17: 250 ns	FX10: 250 ns FX17: 280 ns [1)] / (time of 1 image row 6.4 µs) [2)]
$t_{exposure}$	333 ns	0.466 s
$t_{timer\text{-}delay}$	0 s	119 s
$t_{timer\text{-}duration}$	0 s	119 s
$t_{lineout\text{-}offset}$	111 ns	111 ns
$t_{d\text{-}iso\text{-}output}$	5 µs (typical)	18 µs
$t_{strobe\text{-}delay}$	0	419 ms

[1)]New exposure starts after readout of previous image;

[2)]New exposure starts during readout of previous image

Image Correction

Overview

The camera includes the following image corrections:

- Automatic Image Enhancement (AIE)
- Offset and hot pixel correction

All the corrections are enabled by default.

Automatic Image Enhancement (AIE)

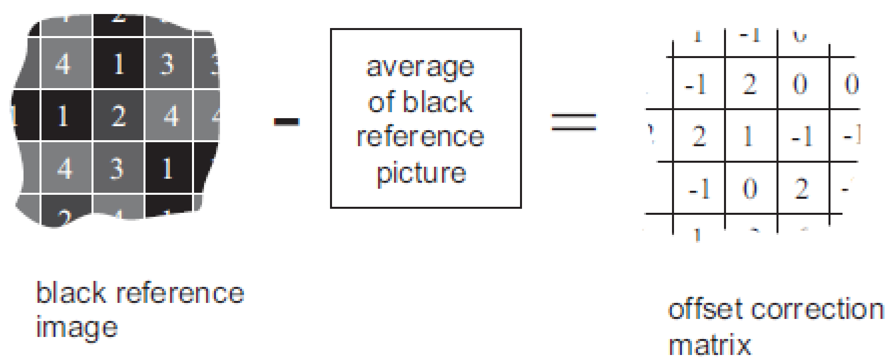
Automatic Image Enhancement unifies spectral bands (wavelength calibration) and minimizes keystone and smile. It functions in camera electronics real time after read-out and non-uniformity correction (fixed pattern removal) steps. The correction is based on two correction value tables that are generated in final calibration. The correction value tables are then uploaded to camera's internal memory. Correction values are relative addresses where the camera output data is interpolated for each pixel. The correction is performed separately in a spectral and a spatial direction.

For example if the correction values for pixel (row,col)=(12;33) are (-1.1; 0.8): Final output data for the pixel is found from (row,col)=(10.9; 33.8) by interpolating adjacent pixel data values.

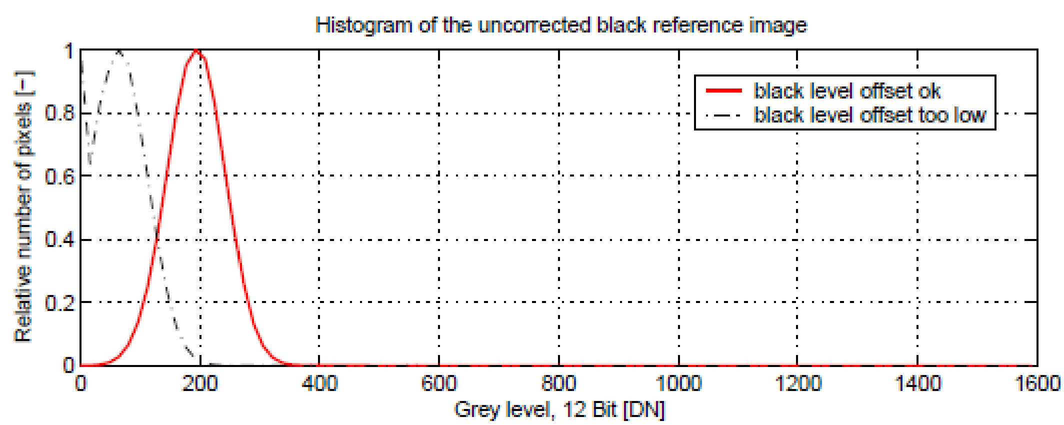
Wavelength calibration, smile and keystone corrections are turned on and off with the same activation command at the same time.

Offset correction

The offset correction subtracts a configurable positive or negative value from the live image and thus reduces the fixed pattern noise of the CMOS sensor. In addition, hot pixels can be removed by interpolation. The gain correction can be used to flatten uneven illumination or to compensate shading effects of a lens. Both offset and gain correction work on a pixel-per-pixel basis, i.e. every pixel is corrected separately. For the correction, a black reference and a grey reference image are required. Then, the correction values are determined automatically in the camera.



The offset correction is based on a black reference image, which is taken at no illumination (e.g. lens aperture completely closed). The black reference image contains the fixed-pattern noise of the sensor, which can be subtracted from the live images in order to minimise the static noise.



Offset correction algorithm

After configuring the camera with a black reference image, the camera is ready to apply the offset correction:

1. Determine the average value of the black reference image.
2. Subtract the black reference image from the average value.
3. Mark pixels that have a grey level higher than 1008 DN (@ 12 bit) as hot pixels.
4. Store the result in the camera as the offset correction matrix.

5. During image acquisition, subtract the correction matrix from the acquired image and interpolate the hot pixels.

How to Obtain a Black Reference Image

In order to improve the image quality, the black reference image must meet certain demands.

- The black reference image must be obtained at no illumination, e.g. with lens aperture closed or closed lens opening.
- It may be necessary to adjust the black level offset of the camera. In the histogram of the black reference image, ideally there are no grey levels at value 0 DN after adjustment of the black level offset. All pixels that are saturated black (0 DN) will not be properly corrected. The peak in the histogram should be well below the hot pixel threshold of 1008 DN @ 12 bit.
- Camera settings may influence the grey level. Therefore, for best results the camera settings of the black reference image must be identical with the camera settings of the image to be corrected.

Hot pixel correction

Every pixel that exceeds certain threshold in the black reference image is marked as a hot pixel. If the hot pixel correction is switched on, the camera replaces the value of a hot pixel by an average of the surrounding pixels.

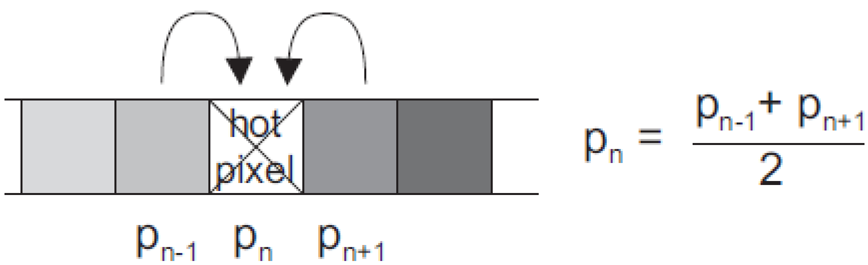


Figure 30: Hot pixel replacement options in FX10

It is possible to turn these feature on and off. However, if AIE is used it performs the hot pixel correction automatically, whether the feature is on or not.

Digital Gain and Offset

Gain x1, x2, x4 and x8 are digital amplifications, which means that the digital image data are multiplied in the camera module by a factor 1, 2, 4 or 8, respectively. It is implemented as a binary shift of the image data, which means that there will be missing codes in the output image as the LSB’s of the gray values are set to ’0’. E.g. for gain x2, the output value is shifted by 1 and bit 0 is set to ’0’.

A user-defined value can be subtracted from the gray value in the digital offset block. This feature is not available in Gain x1 mode. If digital gain is applied and if the brightness of the image is too big then the output image might be saturated. By subtracting an offset from the input of the gain block it is possible to avoid the saturation.

Status Line

If enabled, the status line replaces the last row of the image with camera status information. Every parameter is coded into fields of 4 pixels (LSB first) and uses the lower 8 bits of the pixel value, so that the total size of a parameter field is 32 bit. The assignment of the parameters to the fields is listed in the table below.

Table 6: Parameter field

Start pixel index	Parameter width [bit]	Parameter Description
0	32	Preamble: 0x66BB00FF

Start pixel index	Parameter width [bit]	Parameter Description
4	32	Counter 0 Value
8	32	Counter 1 Value
12	32	Counter 2 Value
16	32	Counter 3 Value
20	32	Timer 0 Value in units of clock cycles
24	32	Timer 1 Value in units of clock cycles
28	32	Timer 2 Value in units of clock cycles
32	32	Timer 3 Value in units of clock cycles
36	24	Integration Time in units of clock cycles
40	24	Reserved
44	32	Reserved
48	12	Image Average Value("raw" data without considering gain settings)
52	12	Horizontal start position of ROI (OffsetX)
56	12	Image Width
60	12	Vertical start position of ROI (OffsetY). In MROI-mode this parameter is the start position of the first ROI.
64	12	Image Height
68	2	Digital Gain
72	12	Digital Offset
76	16	FineGain. This is a fixed-point value in the format: 4 digits integer value, 12 digits fractional value.
80	1	Line Input Level
84	16	Electronics Type Code
88	32	Electronics Serial Number
92	32	Spectral camera serial number
96	32	Custom value 1: value of register StatusLineCustomValue1 that can be set by the user

Test Images

Test images are generated in the camera FPGA, independent of the image sensor. They can be used to check the transmission path from the camera to the frame grabber. Independent from the configured grey level resolution, every possible grey level appears the same number of times in a test image. Therefore, the histogram of the received image must be flat.

Note: A test image is a useful tool to find data transmission errors that are caused most often by a defective cable between camera and frame grabber.

Note: The analysis of the test images with a histogram tool gives the correct result at a resolution of 1024 x 1024 pixels only.

Ramp

Depending on the configured grey level resolution, the ramp test image outputs a constant pattern with increasing grey level from the left to the right side.

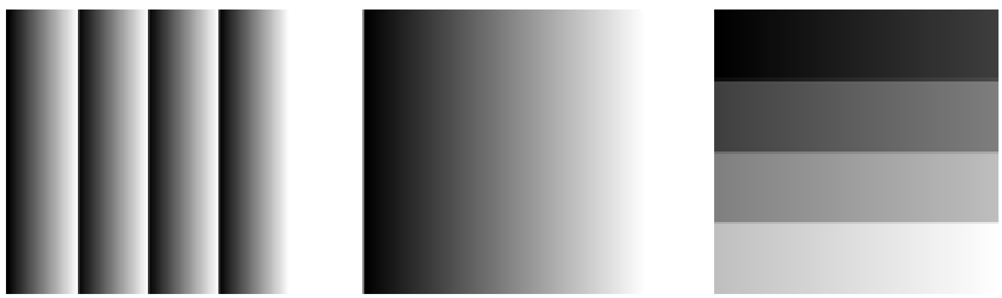


Figure 31: Ramp test images: 8 bit output (left), 10 bit output (middle),12 (right)

LFSR

The LFSR (linear feedback shift register) test image outputs a constant pattern with a pseudo-random grey level sequence containing every possible grey level that is repeated for every row. The LFSR test pattern was chosen because it leads to a very high data toggling rate, which stresses the interface electronic and the cable connection.

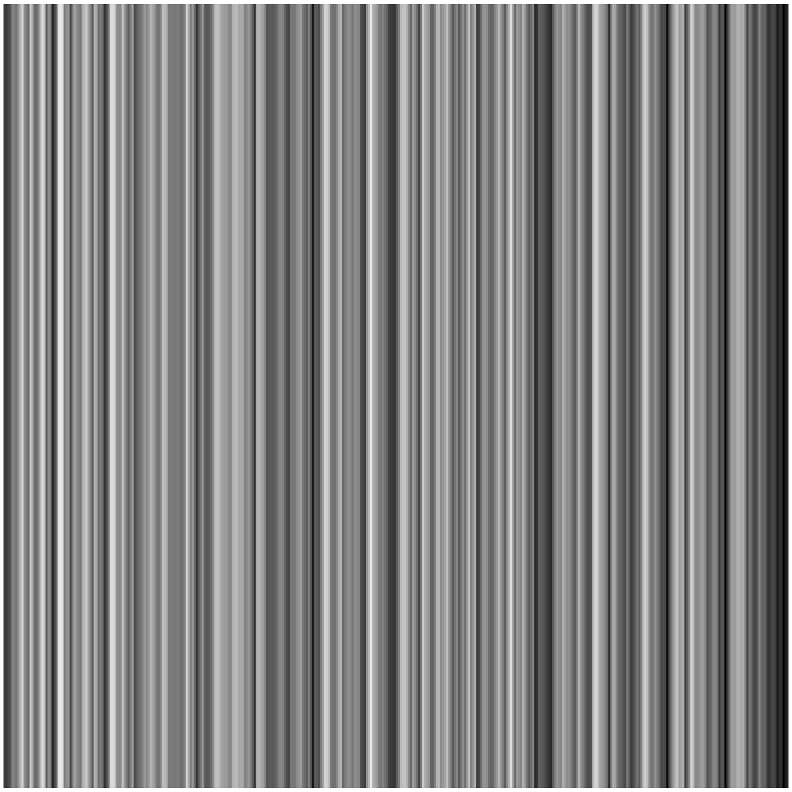


Figure 32: LFSR (linear feedback shift register) test image

Troubleshooting using the LFSR

To control the quality of your complete imaging system enable the LFSR mode, set the camera window to 1024 x 1024 pixels (x=0 and y=0) and check the histogram. If your frame grabber application does not provide a real-time histogram, store the image and use a graphic software tool to display the histogram.

In the LFSR (linear feedback shift register) mode the camera generates a constant pseudo-random test pattern containing all grey levels. If the data transmission is error free, the histogram of the received LFSR test pattern will be flat. On the other hand, a non-flat histogram indicates problems, that may be caused either by the cable, by the connectors or by the frame grabber.

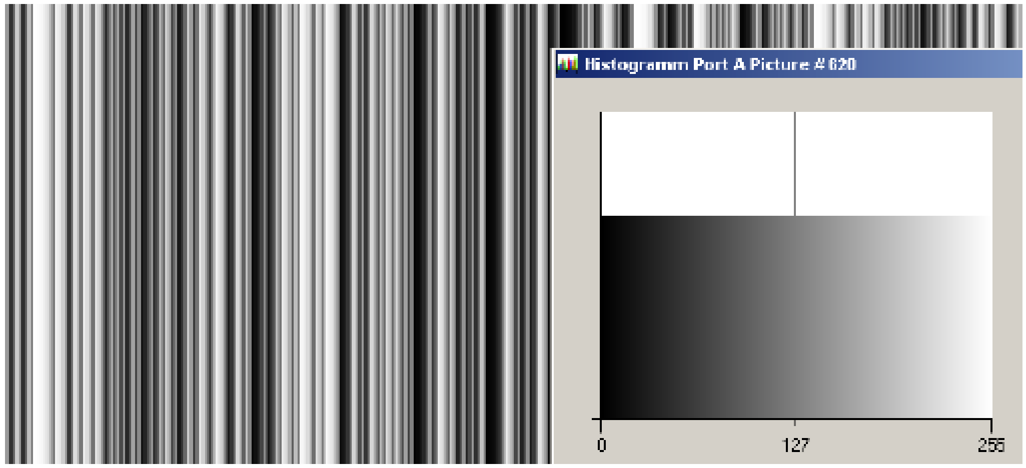


Figure 33: LFSR test pattern received at the frame grabber and typical histogram for error-free data transmission

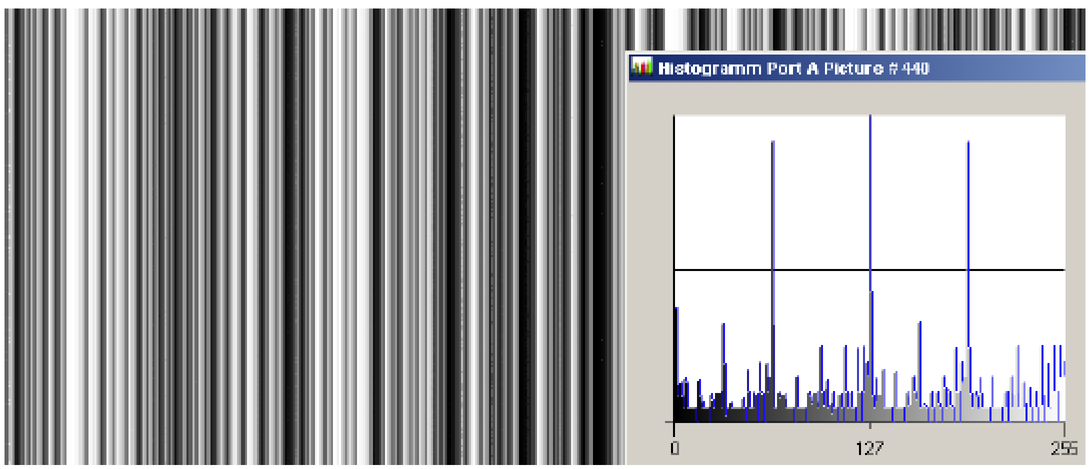


Figure 34: LFSR test pattern received at the frame grabber and histogram containing transmission errors

Note: A possible origin of failure message can be caused by the Camera Link cable which exceeds the maximum length. Also, Camera Link cables may suffer either from stress due to wrong installation or from severe electromagnetic interference.

Note: Some thinner Camera Link cables have a predefined direction. In these cables not all twisted pairs are separately shielded to meet the RS644 standard. These pairs are used for the transmission of the RX/TX and for the CC1 to CC4 low frequency control signals

Note: Camera Link cables contain wire pairs, which are twisted in such a way that the cable impedance matches with the LVDS driver and receiver impedance. Excess stress on the cable results in transmission errors which causes distorted images. Therefore, please do not stretch and bend a Camera Link cable.

In robots applications, the stress that is applied to the Camera Link cable is especially high due to the fast movement of the robot arm. For such applications, special drag chain capable cables are available. Contact Specim for more information.

Configuration Options

MROI Configuration in Lumo

An individual MROI region is defined by its starting value in Y-direction (MROI.Y) and its height (MROI.H).

Note: Using MROI feature demands using 1 x 1 binning in Lumo

Note: MROI works as a multi-band feature

1. Open Lumo Recorder or Lumo Scanner.
2. Go to Setup tab and select Show log window. Log window opens.
3. Click Console in the Log window to open the console.
4. First, disable the MROI. Type the following command in the console:

```
host.run("sensor1", "setbool", "Camera.MROI.Enable", false)
```

5. Set MROI's starting at rows y1, y2, etc and corresponding heights h1, h2 and so on.

```
host.run("sensor1", "setstring", "Camera.MROI.MultibandString", "y1 h1;y2 h2;y3 h3")
```

6. Enable MROI.

```
host.run("sensor1", "setbool", "Camera.MROI.Enable", true)
```

Changing AIE Settings

In order to set the AIE in Lumo Scanner or Recorder software, please do the following:

1. Open Lumo Scanner/Recorder.
2. Enable the **Console window** in the Setup view.
3. Type the following commands (lines starting with "host.run")

```
### Enable AIE ###
host.run("sensor1", "setbool", "Camera.Image.AberrationCorrection.Enabled",true)
### Disable AIE ###
host.run("sensor1", "setbool", "Camera.Image.AberrationCorrection.Enabled",false)
```

For more detailed information on AIE, please refer to the *Image Correction* chapter.

Triggering and Strobe through Power Connector

The Power Connector on FX Series cameras is not only for powering the camera but has also pins for Trigger input and Strobe signal output. This chapter offers a brief introduction to external triggering. For more detailed description, refer to technical note TN_58 - Trigger and Strobe with FX10 and FX17.

Notice: Camera's regular power cable does not support external triggering. Use the power cable version designed for external trigger use.

Pinout

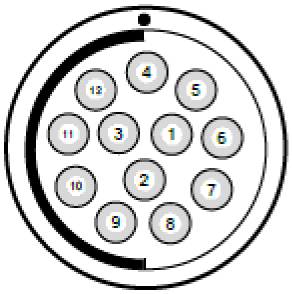


Table 7: Power Connector Pin-out

pin #	I/O Type	Name	Description
1	O	ISO_OUT0	General purpose Output 0, single-ended output
2	O	ISO_STROBE	Default Strobe out, single-ended output
3	O	RESERVED	Reserved, do not connect
4	PWR	CAMERA_GND	Camera GND, 0V
5	PWR	CAMERA_PWR	Camera Power 12V (+/- 10%)
6	PWR	ISO_GND	I/O GND, 0V
7	I	ISO_IN0	General purpose input 0 (5 V)
8	I	ISO_TRIGGER	Default Trigger in (5-15 V)
9	O	RESERVED	Reserved, do not connect
10	O	RESERVED	Reserved, do not connect
11	O	RESERVED	Reserved, do not connect
12	O	RESERVED	Reserved, do not connect

Trigger input

The Trigger Input on FX Series cameras is opto-isolated. Trigger Input is pin #8 ISO_TRIGGER. Use pin #6 ISO_GND as a ground signal. Trigger signal input range is with 5 to 15 VDC. Acceptable minimum Trigger Input pulse width is 0.2 us. Maximum pulse width is half of frame period. For example, with 100 fps the half would be 5 ms.

Note: The trigger input is equipped with a constant current diode which limits the current of the optocoupler over a wide range of voltage. Trigger signals can thus directly get connected with the input pin and there is no need for a current limiting resistor, that depends with its value on the input voltage.

Caution: The input voltage to the ISO_TRIGGER pin must not exceed +15V DC, to avoid damage to the internal ESD protection and the optocoupler!

Strobe Output

The Strobe Output is pin #2 ISO_STROBE. Use pin #6 ISO_GND as a ground signal. To use the Strobe Output, the internal optocoupler must be powered with 5 to 15 VDC (STROBE_VDD). The ISO_STROBE signal is an open collector output; therefore, the user must connect a pull-up resistor of e.g. 1 kΩ to STROBE_VDD. STROBE_VDD must be supplied by the user. This resistor should be located directly at the signal receiver. Acceptable minimum Strobe Output pulse width is 0.2 us. Maximum pulse width is half of frame period. For example, with 100 fps the half would be 5 ms.

Caution: Do not use CAMERA_PWR as STROBE_VDD as this disables the output protection circuit.

External Trigger Configuration

External triggering can be configured through power connector.

These instructions are for trigger configuration in Lumo Recorder or Lumo Scanner. If you are using Specim SDK or ASCII, refer to the relevant documentation.

1. Configure the external trigger source and connect the cables.
2. Set external trigger on in Lumo.
3. Set trigger source on low frame rate (for example 10 Hz)
4. Check that the frame rate matches in Lumo live image.
5. Change the frame rate in trigger source and make sure the change is shown in Lumo as well.

Maintenance Guide

Important Maintenance Information

Caution: Do not open the camera enclosure.

There are no parts inside the spectrograph or spectral camera that need annual adjustments or maintenance. Therefore, do not ever open the camera enclosure.

Cleaning the Fore Optics

The first surface of the spectrograph fore optics gets dirty during active use. To reduce dust and dirt, insert protective caps on both the spectrograph front and the objective ends when removing the fore optics from the spectrograph.

In normal measurements, any dirt in the surface will be cancelled out when making referencing to the white sample, and will not affect the final results. However, extreme dust can cause scattering which could deteriorate the performance.

Important: Only clean the optics when absolutely necessary.

1. Clean the dust with a rubber dust blower or canned air.
2. Use fine optics brush on dust that cannot be removed with air.
3. Clean fingerprints or smudges from the lens with cotton swabs moistened in isopropanol.

   Start from the middle and work your way towards the edges in circular motion.

   Caution: Remove fingerprints immediately to avoid damage to the lens.

Troubleshooting

Troubleshooting FX

This section provides troubleshooting instructions for FX series.

Symptom	Possible Cause	Solution
Camera does not start, LED is blinking.	Boot loop	Remove camera power cord from the wall socket, wait a few minutes, then reconnect the power.
No signal to data acquisition PC.	Lens is covered.	Remove the lens cap.
	Non-standard lens aperture is too small	Check if the camera lens is standard. If not • Check if the lens aperture can be changed • Check that the aperture is not too small
Image quality is poor.	Insufficient illumination.	• Add lighting. • Lengthen the integration time.
Camera shuts down unexpectedly.	Operating temperature is too high.	Disconnect the power cord and let the camera cool down before trying to power it up again. Add cooling if the temperature rises repeatedly.
Data is not stored to PC.	Save folder is not set.	Define the save folder in LUMO.

Technical Information

Default Settings and Calibrations

This section describes the default settings and calibrations of the camera as it leaves from the factory.

Table 8: Default Settings

Characteristics	Value
Integration time	5 ms
Frame rate	50
Spectral binning	2
Spatial binning	1
Focusing distance	~1 m
Dark signal level	~200 DN (with 5 ms tint)
Data format	Mono12
Digital gain	0 (low gain)
Fine gain	1 (digital multiplier)
MROI	Disabled
AIE	Enabled
Shutter	Opens in power-up
Acquisition mode	Continuous
Triggering and exposure control	Camera internal mode (Frame rate and exposure time set explicitly in camera settings)
Interleave mode	Enabled (Camera uses IWR mode when frame rate – exposure time allows)
Image correction mode (NUC)	Offset and hotpixel correction
Temperature limits to cancel operation	FPGA: 90°C Processing board: 80°C

Offset and black level calibrations and bad pixel mapping have been performed with default camera settings.

The calibration information is stored in the calibration pack which is delivered with the camera. Copy the calibration pack to your PC before using the camera.

There are two calibration pack versions included in the delivery: one with "FX" in the file name is to be used with AIE image corrections, and the other without it.

Note: We recommend to always use the FX calibration pack.

Optical Characteristics

This section describes the nominal optical performance characteristics of the camera with the standard OLET15 lens.

Table 9: Optical Characteristics

Optical Characteristics	FX10/FX10e	FX10c
Spectral range	400-1000 nm	400-780 nm
F number	1.7	1.7
FOV	38 degrees	38 degrees
Minimum focusing distance	150 mm	150 mm

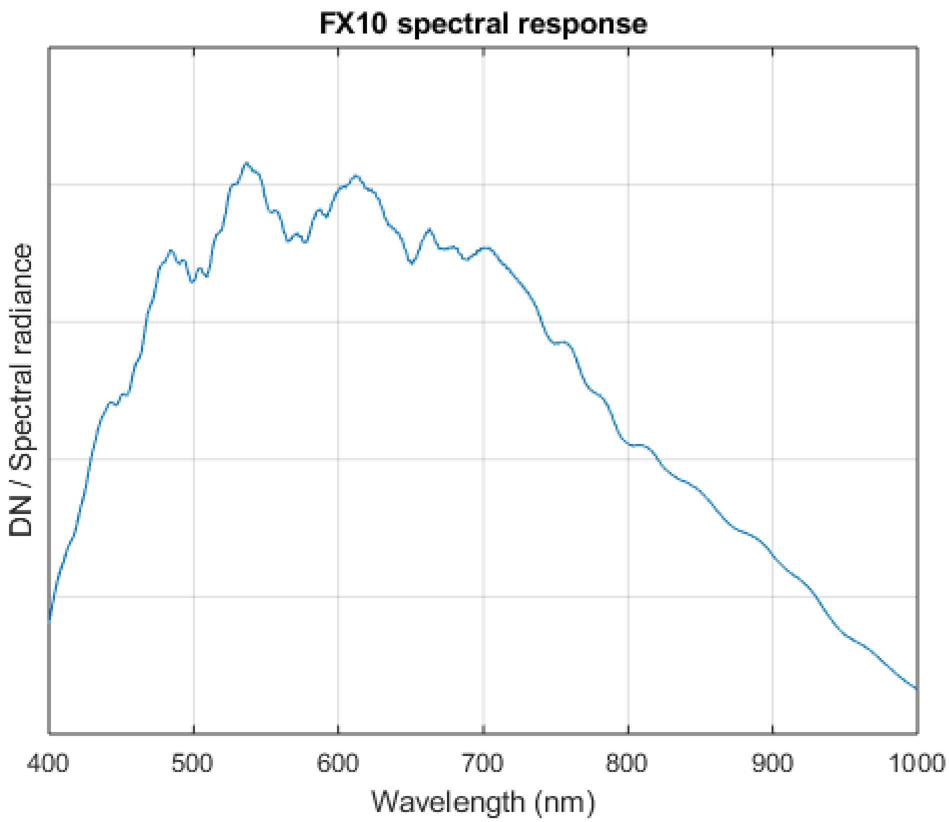


Figure 35: FX10 Spectral Response Graph

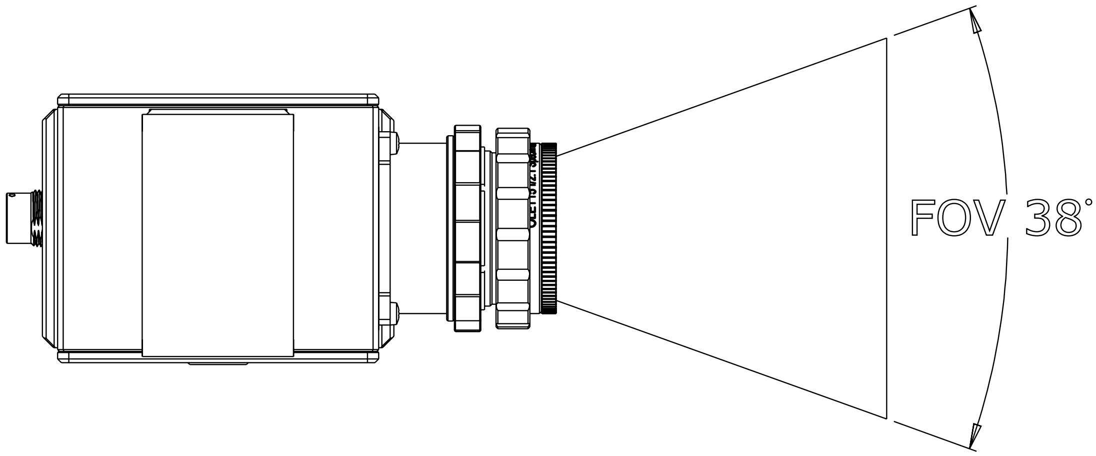


Figure 36: Field of View

Performance Characteristics

This section describes the performance characteristics of the camera.

The camera is operated in a default binning mode of 2(spectral) x 1(spatial) pixels, which gives the effective pixel size on array of 16x8 um given in the table.

Table 10: Camera Performance Characteristics FX10/FX10e

Characteristics	Value		
Detector type	CMOS		
Slit width	Physical width 42 µm. Projection on sensor 32 µm (M~1/1.3)		
Pixel size	16x8 µm		
# Spatial pixels	1024		
Binning (spectral x spatial)	2 x 1		
Spectral binning options	2x	4x	8x
# Spectral bands covering the specified range	224	112	56
Spectral sampling/pixel	2.7 nm	5.4 nm	10.8 nm
Spectral resolution FWHM	5.5 nm (mean)		
SNR @ max. signal	420:1		
Frame rate (fps), full range (224 bands) max.	327 FPS		
Frame rate (fps), MROI examples	20 bands = 2800 FPS 5 bands = 6500 FPS		
Integration time	Adjustable, within frame time		
Sensor cooling	Passive		

Characteristics	Value
Shutter	Electromechanical shutter for dark background registration
Order blocking filter	yes

Table 11: Camera Performance Characteristics FX10c

Characteristics	Value		
Detector type	CMOS		
Slit width	Physical width 42 µm. Projection on sensor 32 µm (M~1/1.3)		
Pixel size	16x8 µm		
# Spatial pixels	1024		
Binning (spectral x spatial)	2 x 1		
Spectral binning options	2x	4x	8x
# Spectral bands covering the specified range	70	35	17.5
Spectral sampling/pixel	2.7	5.5	10.8
Spectral resolution FWHM	5.5 nm (mean)		
SNR @ max. signal	420:1		
Frame rate (fps), full range (140 bands) max.	514 FPS		
Frame rate (fps) examples	70 bands = 985 FPS 35 bands = 1813 FPS 1 band = 9900 FPS		
Integration time	Adjustable, within frame time		
Sensor cooling	Passive		
Shutter	Electromechanical shutter for dark background registration		
Order blocking filter	yes		

For more information on maximum frame rates, refer to *Technical Note: Maximum frame rates in FX10/FX10e and FX17/FX17e*.

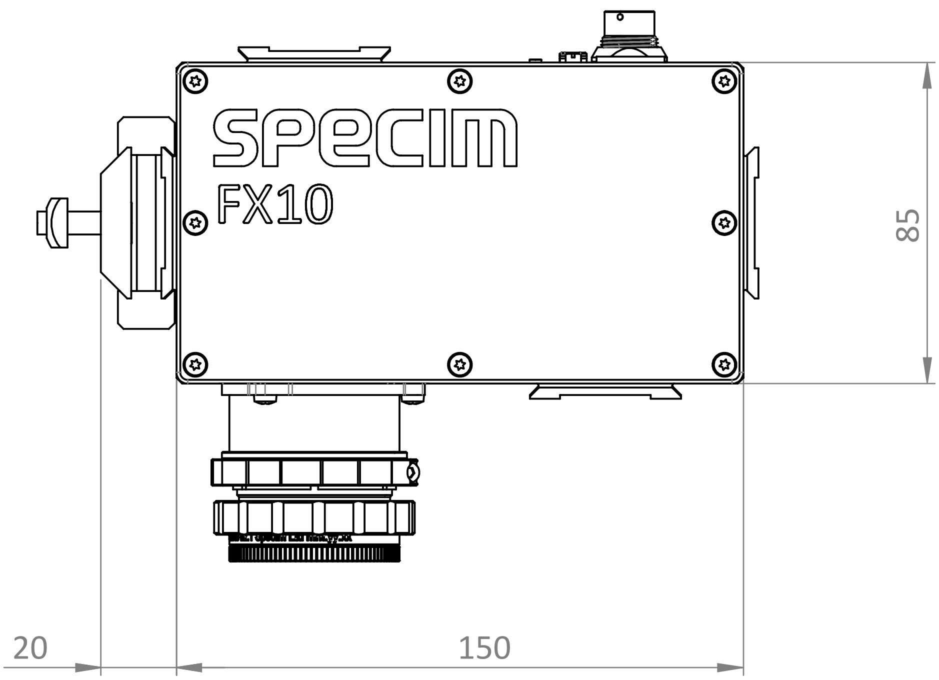
Mechanical Specifications

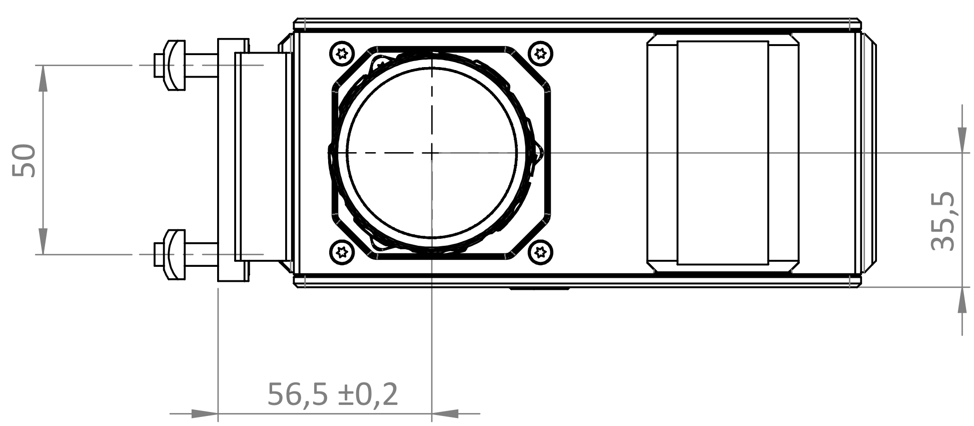
This section describes the mechanical specifications of the camera.

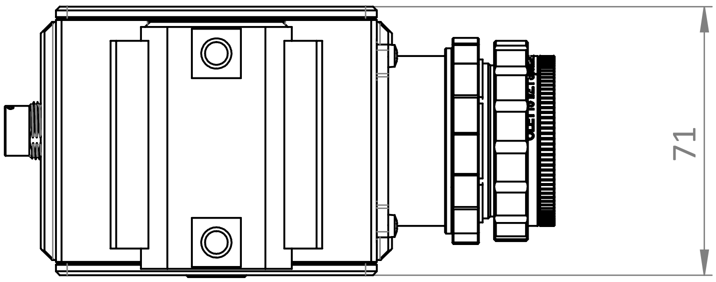
Table 12: Mechanical Specification

Characteristics	Value
Housing	Painted aluminium case

Characteristics	**Value**
Size (L x W x H)	150 x 85 x 71 mm
Weight	1.3 kg







Electrical Specifications

This section describes the electrical specifications of the system.

Table 13: Electrical Specification

Characteristics	Value
Input supply voltage	12 DC (+- 10%), no polarity protection
Trigger voltage	5-15 V
Power consumptions	
Camera	Max. 4 W

Environmental Specifications

This section describes the environmental requirements of the system use and storage.

Table 14: Environmental Specification

Characteristics	Value
IP classification code	IP52
Storage temperature	-20 ... +50°C, non-condensing
Operating temperature	+5 … +40°C, non-condensing
Cooling	Passive

Random vibration

The camera has been tested for and tolerates random vibration, MIL-STD 810 F method 514.5 : 4.01 grms, 1 hour / axis (3 axis):

- 15Hz - 105.94Hz: 0.01 g^2/Hz
- 105.94Hz - 150Hz: +6 dB/Oct.
- 150Hz - 500Hz: 0.02 g^2/Hz
- 500Hz - 2000Hz: -6 dB/Oct

Shock

The camera has been tested for and tolerates shock:

- ½ sine 40 g, 11 ms, with 3 shocks per axis per direction.

Temperature test

The temperature test has been performed in temperature cycle, run for 2 weeks. The test cycle was as follows:

- Ramp to 5°C (30 min)
- Steady 5°C for 240 min
- Ramp to 40°C (30 min)
- Steady 40°C for 240 min
- Ramp to 22°C (30 min)

Change History

Date	Version	Description
2020	2.2	• Document name changed from Reference Manual to User Manual. This change does not affect the version numbering; User Manual 2.2 follows the Reference Manual 2.1. • Added default lens information • Corrected trigger and strobe timing table information • Updated Default Settings and Calibrations section • Removed Line Pause from Frame Grabber Relevant Configuration • Restructured AIE information
12 November 2019	2.1	• Added hyperspectral imaging and illumination overviews • Added the spectral response graph • Added default settings and calibrations information • Additional information about triggering via power connector • Minor typo corrections
27 March 2019	2.0	• Added the possibility for firmware update • Added possibility to change the readout mode • Updated the GigE LED information • Added the results of vibration, shock and operation temperature tests
20 December 2018	1.1	Corrected grabber information
18 July 2018	1.0	First version