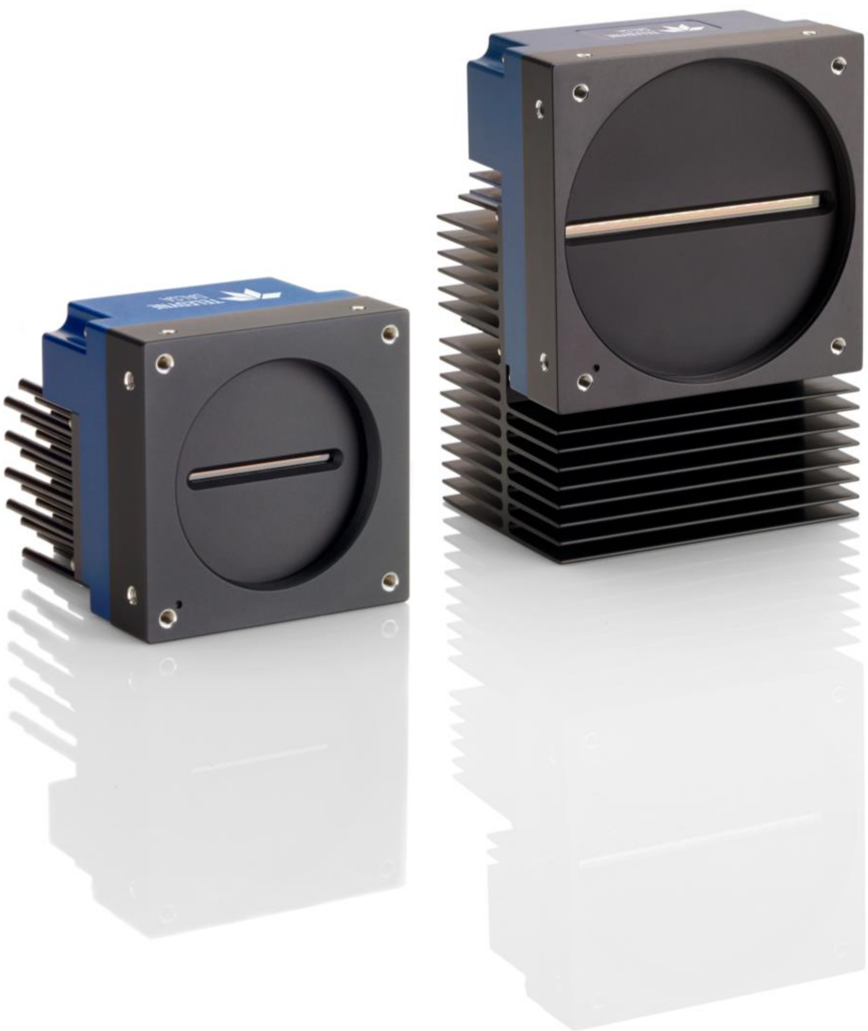
Linea™ HS Series

Camera User's Manual

Monochrome CMOS TDI Line Scan Cameras

sensors | **cameras** | frame grabbers | processors | software | vision solutions



Models

HL-FM-04K30H-00-R
HL-FM-08K30H-00-R
HL-FM-13K18H-00-R
HL-FM-16K15A-00-R
HL-HM-08K30H-00-R
HL-HM-08K40H-00-R
HL-HM-09K40H-00-B
HL-HM-13K30H-00-R
HL-HM-16K30H-00-R
HL-HM-16K40H-00-R
HL-HM-16K40H-00-B

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Notice

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About Teledyne DALSA

Teledyne DALSA, a business unit of Teledyne Digital Imaging Inc., is an international high-performance semiconductor and Electronics Company that designs, develops, manufactures, and markets digital imaging products and solutions, in addition to providing wafer foundry services.

Teledyne DALSA offers the widest range of machine vision components in the world. From industry-leading image sensors through powerful and sophisticated cameras, frame grabbers, vision processors and software to easy-to-use vision appliances and custom vision modules.

Contents

Linea HS Monochrome TDI Line Scan Cameras

Overview

Teledyne DALSA introduces a breakthrough CMOS TDI line scan camera series with unprecedented speed, responsivity and exceptionally low noise, in a variety of resolutions.

The Linea™ HS cameras have a 5 µm x 5 µm pixel size, HDR capability, and are compatible with fast, high magnification lenses.

The cameras use the Camera Link HS® (CLHS) interface—the industry standard for very high-speed camera interfaces with long transmission distances and cable flexing requirements (CX4 or LC connector).

Teledyne DALSA's Linea™ HS cameras and compatible frame grabbers combine to offer a complete solution for the next generation of automatic optical inspection systems. This camera is recommended for detecting small defects at high speeds and over a large field of view in LCD and OLED flat panel displays, DNA sequencing, printed circuit boards, film and large format web materials.

Camera Highlights

Key Features

- Highly sensitive CMOS TDI
- Monochrome 4K, 8K, 9K, 13K, 16K pixel resolution
- Up to 400 kHz line rate
- Very low noise
- Bidirectionality
- Horizontal and vertical binning and averaging
- Robust Camera Link HS interface
- CX4 or LC Camera Link HS control & data connector
- Smart lens shading correction
- High dynamic LUT mode

Programmability

- Multiple areas of interest (AOIs) for data reduction
- Region of interest for easy calibration of lens and shading correction
- Flat field and lens shading correction
- Test patterns & diagnostics

Applications

- Flat panel LCD and OLED display inspection
- Web inspection
- Printed circuit board inspection
- Pathology
- DNA sequencing
- High throughput and high-resolution applications

Part Numbers

The camera is available in the following configurations.

Table 1: Model Comparison Guide. Resolution is followed by the number of stages in each array of pixels.

Part Number	Resolution	Max Line Rates	Pixel Size	Control & Data
HL-FM-04K30H-00-R	4096 x 192 (128 + 64)	300 kHz mono / 150 kHz with HDR	5.0 x 5.0 µm	CLHS LC
HL-FM-08K30H-00-R	8192 x 192 (128 + 64)	280 kHz mono / 140 kHz with HDR 300 kHz / 150 kHz using AOI	5.0 x 5.0 µm	CLHS LC
HL-FM-13K18H-00-R	13056 x 192 (128 + 64)	180 kHz mono / 90 kHz with HDR	5.0 x 5.0 µm	CLHS LC
HL-FM-16K15A-00-R	16384 x 128	140 kHz / 150 kHz using AOI	5.0 x 5.0 µm	CLHS LC
HL-HM-08K30H-00-R	8192 x 192 (128 + 64)	300 kHz mono / 150 kHz with HDR	5.0 x 5.0 µm	CLHS CX4
HL-HM-08K40H-00-R	8192 x 192 (128 + 64)	400 kHz mono / 200 kHz with HDR	5.0 x 5.0 µm	CLHS CX4
HL-HM-09K40H-00-B	9216 x 192 (128 + 64)	400 kHz mono / 200 kHz with HDR	5.0 x 5.0 µm	CLHS CX4
HL-HM-13K30H-00-R	13056 x 192 (128 + 64)	300 kHz mono / 150 kHz with HDR	5.0 x 5.0 µm	CLHS CX4
HL-HM-16K30H-00-R	16384 x 192 (128 + 64)	300 kHz mono / 150 kHz with HDR	5.0 x 5.0 µm	CLHS CX4
HL-HM-16K40H-00-R	16,384 x 192 (128 + 64)	400 kHz mono / 200 kHz with HDR	5.0 x 5.0 µm	CLHS CX4
HL-HM-16K40H-00-B	16,384 x 192 (128 + 64)	400 kHz mono / 200 kHz with HDR	5.0 x 5.0 µm	CLHS CX4

Hardware and Software Environments

Table 2: Frame Grabber

Compatible Frame grabber	Linea HS Model
Teledyne DALSA Xtium2-CLHS FX8 (OR-A8S0-FX840)	(Models with LC connector) HL-FM-04K30H HL-FM-08K30H HL-FM-13K18H HL-FM-16K15A
Teledyne DALSA Xtium2-CLHS PX8 (OR-A8S0-PX870)	(Models with CLHS CX4 connector) HL-HM-08K30H HL-HM-08K40H HL-HM-13K30H HL-HM-16K30H HL-HM-16K40H-00-R HL-HM-16K40H-00-B
Other compatible frame grabbers may be available from third-party vendors.	

Table 3: Software

Software	Product Number / Version Number
Camera firmware	Embedded within camera
GenICam™ support (XML camera description file)	Embedded within camera
Sapera LT, including CamExpert GUI application and GenICam for Camera Link imaging driver	Latest version on the Teledyne DALSA website

Supported Industry Standards

GenICam™

The camera is GenICam compliant and implements a superset of the GenICam Standard Features Naming Convention specification V1.5.

This description takes the form of an XML device description file using the syntax defined by the GenApi module of the GenICam specification. The camera uses the GenICam Generic Control Protocol (GenCP V1.0) to communicate over the Camera Link HS command lane.

For more information see www.emva.org/standards-technology/genicam/.

Camera Link HS®

The camera is Camera Link HS (CLSH) version 1.0 compliant. Camera Link HS is the next generation of high-performance communications standards. It is used where an industrial digital camera interfaces with a single or multiple frame grabbers, and with data rates exceeding those supported by the standard Camera Link.

For more information see https://www.automate.org/vision/vision-standards/vision-standards-camera-link-hs.

Specifications

Test conditions unless otherwise specified (specifications not guaranteed when operating in area mode).

- 8-bit, 1x gain
- 100 kHz line rate
- Light source: White LED if wavelength not specified
- Front plate temperature: +45 ºC
- DN = digital number

Common Linea HS Specifications

The following specifications apply to all models.

Table 4: Common Camera Performance Specifications

Sensor		
Imager Format	High speed CMOS TDI	
Pixel Size	5.0 µm x 5.0 µm	
Pixel Fill Factor	100%	
Connectors and Mechanicals		
Control & Data Interface	Camera Link HS CX4 or LC	
Power	+12 V to +24 V DC, Hirose 12-pin circular	
Operating Temperature	+0 °C to +65 °C (front plate)	
Optical Interface		
Sensor to Camera Front Distance	12 mm	
Sensor Alignment (Relative to sides of camera)		
Flatness	50 µm	
Θ y	100 µm (Parallelism vs. front plate)	
x	± 300 µm (Cross-Scan Direction)	
y	± 300 µm (In-Scan Direction)	
z	± 300 µm (Along optical axis)	
Θ z	± 0.4° (Rotation around optical axis)	
Performance		**Notes**
Analog Gain	1x, 2x, 4x or 8x	
Digital Gain	1x to 10x	
DC Offset	0 DN	Adjustable
PRNU[3]	< ±2%	At 50% saturation[1,2]
DSNU (FPN)[4]	< ±2 DN	
Integral non-linearity	< 2%	

1 Calibration at 80% saturation, measurements at 50% saturation.
2 Light sources vary spectrally and spatially: re-calibrate cameras in actual system.
3 PRNU: Photo-Response Non-Uniformity.
4 DSNU (FPN): Dark Signal Non-Uniformity (Fixed Pattern Noise).

Environmental Specifications

Table 5: Environmental Specifications

Environmental Specifications	
Storage temperature range	-20 °C to +80 °C
Humidity (storage and operation)	15% to 85% relative, non-condensing
MTBF (mean time between failures)	> 100,000 hours, typical field operation

Flash Memory Size

Table 6: Camera Flash Memory Size

Camera	Flash memory size
All models	4 GB

Certification & Compliance

Table 7: Camera Certification & Compliance

Compliance
See the Declarations of Conformity section at the end of this manual.

Models Specifications

Below are the specifications for the various models.

SEE: Saturation Equivalent Exposure.
NEE: Noise Equivalent Exposure.

LC Fiber Optic Connector Models

The following specifications apply to models with an LC fiber optic connector (HL-FM models) used with Xtium2-CLHS FX8 frame grabbers.

Table 8: Specifications for the HL-FM models (LC connector).

Specifications	HL-FM-04K30H-00-R	HL-FM-08K30H-00-R	HL-FM-13K18H-00-R	HL-FM-16K15A-00-R
Resolution	4096 x 192	8192 x 192	13,056 x 192	16,384 x 128
Bit Depth	8-bit or 12-bit	8-bit or 12-bit	8-bit or 12-bit	8-bit or 12-bit
Line Rate Max 8-bit	300 kHz 150 kHz(HDR)	280 kHz 140 kHz (HDR)	180 kHz 90 kHz (HDR)	140 kHz
Line Rate Max 12-bit	300 kHz 150 kHz (HDR)	180 kHz 90 kHz (HDR)	TBD	90 kHz
Line Rate Min	10 kHz	10 kHz	10 kHz	10 kHz
HDR/High Full Well Modes	Yes	Yes	Yes	No
Binning	Yes	Yes	Yes	Yes
Areas of Interest	Yes	Yes	Yes	Yes
Power Dissipation (typical)	17 W	17 W	22 W	22 W
Width x Height x Depth	76 x 76 x 85 mm	76 x 76 x 85 mm	97 x 140.5 x 78.6 mm	97 x 140.5 x 78.6 mm
Mass	< 500 g	< 500 g	1.2 kg	1.2 kg
Lens Mount	M58 x 0.75 mm	M58 x 0.75 mm	M90 x 1 mm	M90 x 1 mm
Random Noise * (10 e–)	< 0.2 DN rms	< 0.2 DN rms	< 0.2 DN rms	< 0.2 DN rms
Peak Responsivity (8-bit)	500 DN/nJ/cm2	500 DN/nJ/cm2	600 DN/nJ/cm2	600 DN/nJ/cm2
Dynamic Range	68 dB	68 dB	68 dB	68 dB
Full Well	25,000 e–	25,000 e–	25,000 e–	25,000 e–
SEE @ 670 nm	0.5 nJ/cm2	0.5 nJ/cm2	0.5 nJ/cm2	0.5 nJ/cm2
NEE @ 670 nm	0.4 pJ/cm2	0.4 pJ/cm2	0.4 pJ/cm2	0.4 pJ/cm2

* Random noise below quantization limit cannot be measured accurately; use higher bit depth or higher gain for comparison purposes.

CX4 Connector Models

The following specifications tables apply to models with a CX4 connector (HL-HM models) used with an Xtium2-CLHS PX8 frame grabber.

Table 9: Specifications for the HL-HM-08K models (CX4 connector).

Specifications	HL-HM-08K30H-00-R	HL-HM-08K40H-00-R
Resolution	8192 x 192	8192 x 192
Bit Depth	8-bit or 12-bit	8-bit or 12-bit §
Line Rate Max 8-bit	300 kHz 150 kHz (HDR)	400 kHz 200 kHz (HDR)
Line Rate Max 12-bit	300 kHz 150 kHz (HDR)	400 kHz 200 kHz (HDR)
Line Rate Min	10 kHz	10 kHz
HDR/High Full Well Modes	Yes	Yes
Binning	Yes	Yes
Areas of Interest	Yes	Yes
Power Dissipation (typical)	18 W	18 W
Width x Height x Depth	76 x 76 x 85 mm	76 x 76 x 85 mm
Mass	< 500 g	< 500 g
Lens Mount	M58 x 0.75 mm	M58 x 0.75 mm
Random Noise *	< 0.2 DN rms (10 e–)	< 0.2 DN rms (14 e–)
Peak Responsivity (8-bit)	500 DN/nJ/cm2	500 DN/nJ/cm2
Dynamic Range	68 dB	65 dB
Full Well	25,000 e–	25,000 e–
SEE @ 670 nm	0.5 nJ/cm2	0.5 nJ/cm2
NEE @ 670 nm	0.4 pJ/cm2	< 0.4 pJ/cm2

§ Sensor readout is 11 bits only.
* Random noise below quantization limit cannot be measured accurately; use higher bit depth or higher gain for comparison.
† Theoretical. See Note in section Maximum Line Rate.

Table 10: Specifications for the HL-HM-13K and HL-HM-16K models (CX4 connector).

Specifications	HL-HM-13K30H-00-R	HL-HM-16K30H-00-R	HL-HM-16K40H-00-R
Resolution	13,056 x 192	16,384 x 192	16,384 x 192
Bit Depth	8-bit or 12-bit	8-bit or 12-bit	8-bit or 12-bit §
Line Rate Max 8-bit	300 kHz 150 kHz (HDR)	300 kHz 150 kHz (HDR)	400 kHz 200 kHz (HDR)
Line Rate Max 12-bit	230 kHz† 115 kHz† (HDR)	230 kHz† 115 kHz† (HDR)	275 kHz 137 kHz† (HDR)
Line Rate Min	10 kHz	10 kHz	10 kHz
HDR/High Full Well Modes	Yes	Yes	Yes
Binning	Yes	Yes	Yes
Areas of Interest	Yes	Yes	Yes
Power Dissipation (typical)	30 W	30 W	30 W
Width x Height x Depth	97 x 140.5 x 78.6 mm	97 x 140.5 x 78.6 mm	97 x 140.5 x 78.6 mm
Mass	1.2 kg	1.2 kg	1.2 kg
Lens Mount	M90 x 1 mm	M90 x 1 mm	M90 x 1 mm
Random Noise *	< 0.2 DN rms (10 e–)	< 0.2 DN rms (10 e–)	< 0.2 DN rms (14 e–)
Peak Responsivity (8-bit)	600 DN/nJ/cm2	600 DN/nJ/cm2	600 DN/nJ/cm2
Dynamic Range	68 dB	68 dB	65 dB
Full Well	25,000 e–	25,000 e–	25,000 e–
SEE @ 670 nm	0.5 nJ/cm2	0.5 nJ/cm2	0.5 nJ/cm2
NEE @ 670 nm	0.4 pJ/cm2	0.4 pJ/cm2	< 0.4 pJ/cm2

§ Sensor readout is 11 bits only.
* Random noise below quantization limit cannot be measured accurately; use higher bit depth or higher gain for comparison purposes.
† Theoretical. See Note in section <u>Maximum Line Rate.</u>

Table 11: Specifications for the HL-HM-09K and HL-HM-16K Backside Illumination models (CX4 connector).

Specifications	**HL-HM-09K40H-00-B (Backside Illumination)**	**HL-HM-16K40H-00-B (Backside Illumination)**
Resolution	9216 x 192	16,384 x 192
Bit Depth	8-bit or 12-bit §	8-bit or 12-bit §
Line Rate Max 8-bit	400 kHz 200 kHz (HDR)	400 kHz 200 kHz (HDR)
Line Rate Max 12-bit	275 kHz 137 kHz† (HDR)	275 kHz 137 kHz† (HDR)
Line Rate Min	30 kHz	30 kHz
HDR/High Full Well Modes	Yes	Yes
Binning	Yes	Yes
Areas of Interest	Yes	Yes
Power Dissipation (typical)	30 W	30 W
Width x Height x Depth	97 x 140.5 x 78.6 mm	97 x 140.5 x 78.6 mm
Mass	1.2 kg	1.2 kg
Lens Mount	M90 x 1 mm	M90 x 1 mm
Random Noise *	< 0.2 DN rms (14 e–)	< 0.2 DN rms (14 e–)
Peak Responsivity (8-bit)	680 DN/nJ/cm2	680 DN/nJ/cm2
Dynamic Range	65 dB	65 dB
Full Well	27,000 e–	27,000 e–
SEE @ 670 nm	< 0.4 nJ/cm2	< 0.4 nJ/cm2
NEE @ 670 nm	< 0.2 pJ/cm2	< 0.2 pJ/cm2

§ Sensor readout is 11 bits only.
* Random noise below quantization limit cannot be measured accurately; use higher bit depth or higher gain for comparison purposes.
† Theoretical. See Note in section <u>Maximum Line Rate.</u>

Responsivity and Quantum Efficiency Graphs

Models 4k and 8k

The following graph shows the spectral responsivity and QE from the main array (128 stages), in 8-bit. Graph applies to 4k and 8k camera models (HL-xx-04Kxx, HL-xx-08Kxx).

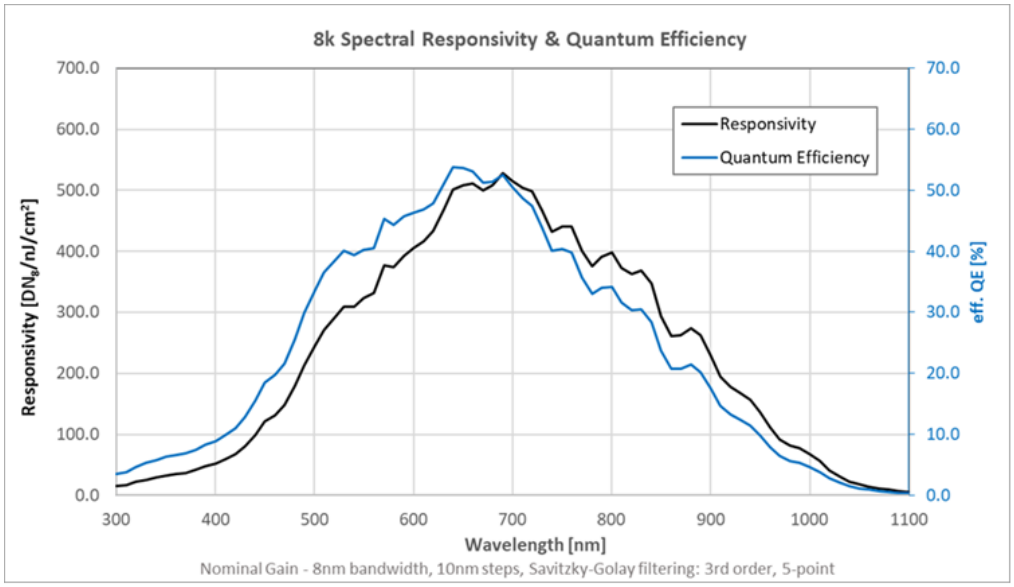


Figure 1: Spectral responsivity & QE for 4k and 8k monochrome models.

Models 13k and 16k

The following graph shows the spectral responsivity and QE from the main array (128 stages), in 8-bit. Graph applies to 13K and 16K camera models (HL-xx-13Kxx, HL-xx-16Kxx).

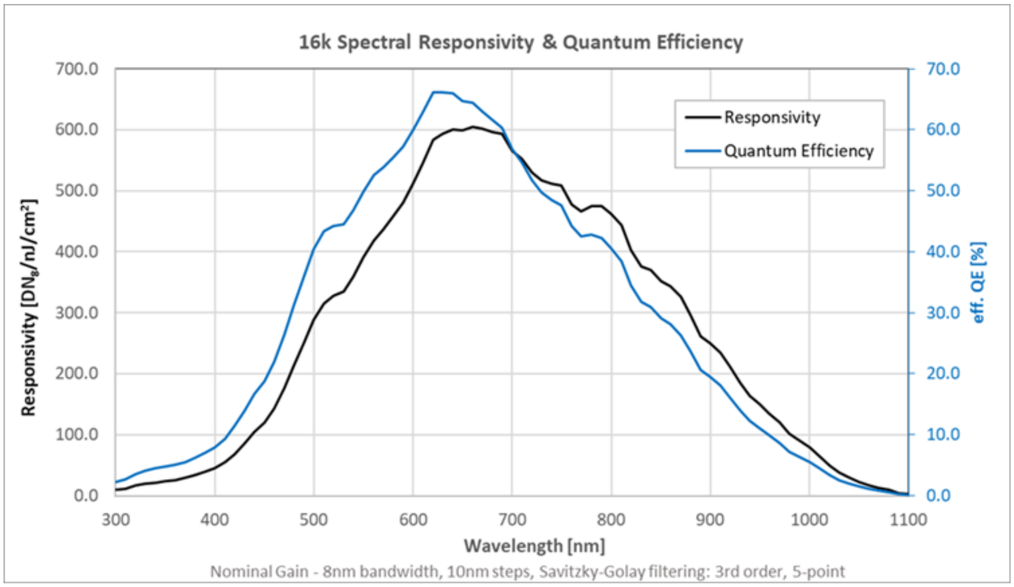


Figure 2: Spectral responsivity and QE for 13k and 16k models (except BSI model).

Models 9k and 16k Backside Illuminated

The following graphs show the spectral responsivity and QE from the main array (128 stages), in 12-bit.

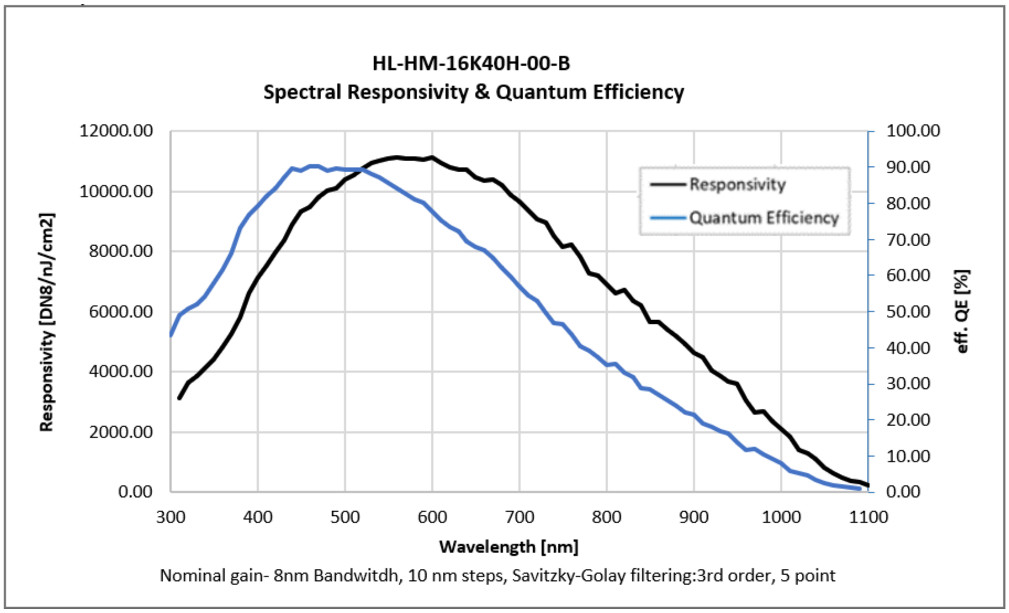


Figure 3: 16K Monochrome Models Spectral Responsivity & QE

Camera Input Power

The following graphs detail the power vs. input voltage for the indicated models.

Test conditions: Max line rate—300 kHz, TDI Mode—128, Bit Mode—8, Black Level—31, Temperature—Ambient

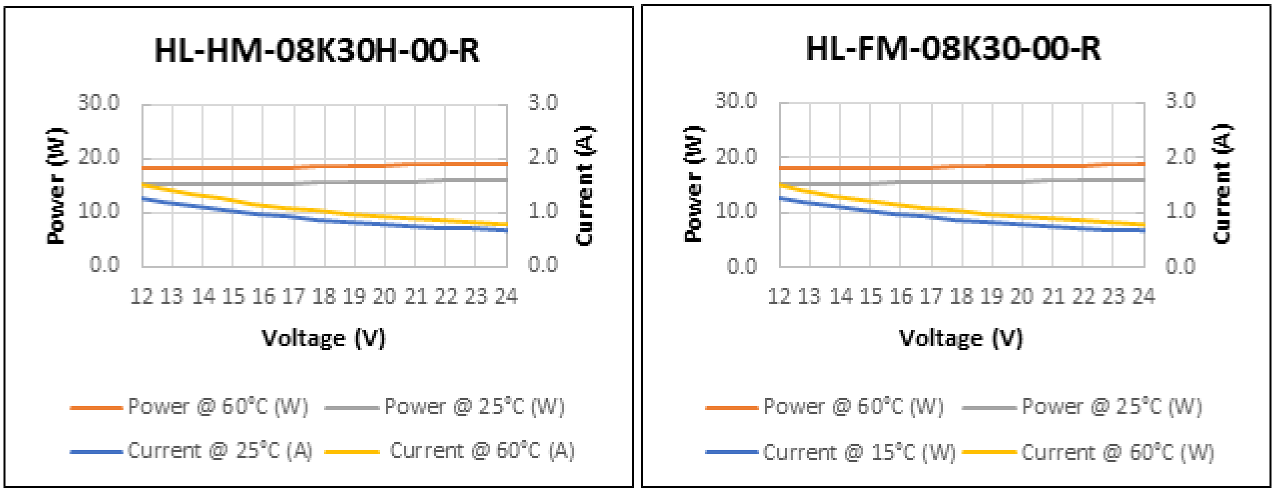


Figure 4: 8K Models Power vs. Input Voltage. Applies to 4K model also.

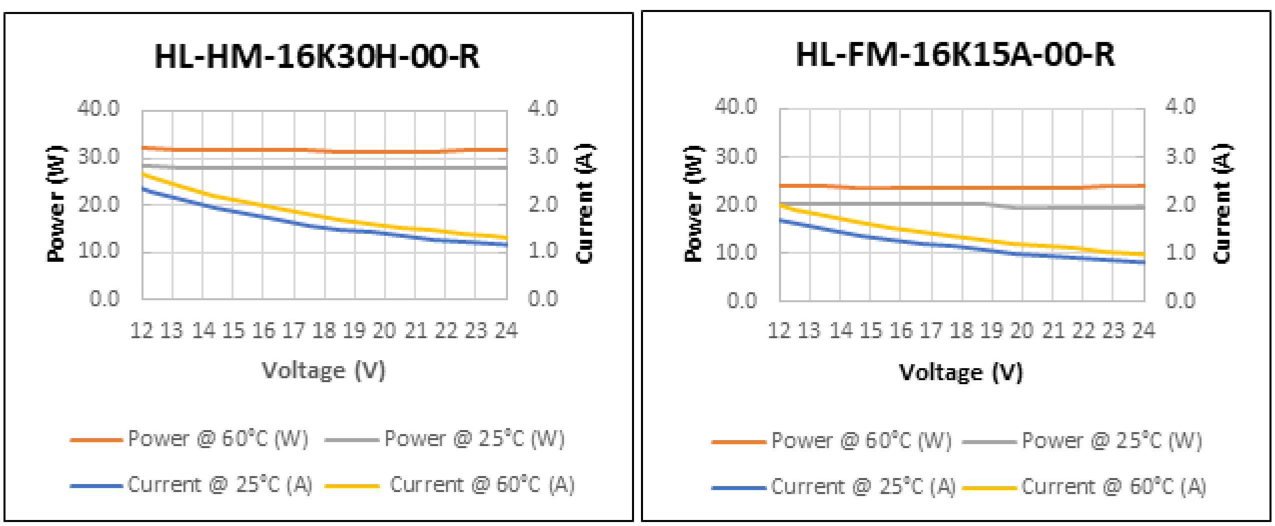


Figure 5: 16K Models Power Vs. Input Voltage. Applies to 13K models also.

The following graph details power vs. input voltage for the HL-HM-16K40H-00 models.

Test conditions: Max line rate—400 kHz, TDI Mode—128, Bit Mode—8, Black Level—31, Temperature—Ambient

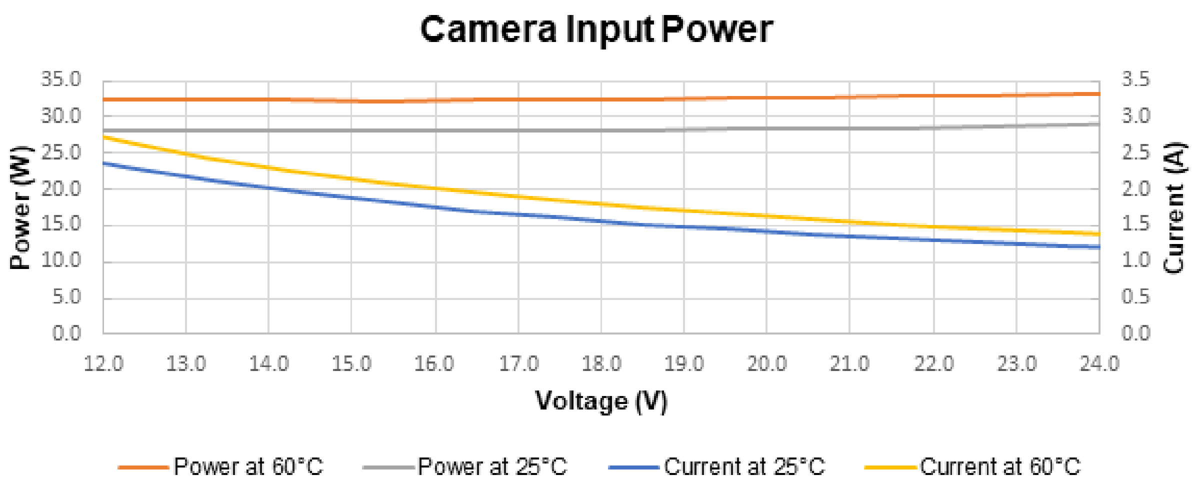


Figure 6: HL-HM-16K40H-00 Power Vs. Input Voltage.

Linea HS Dark Current

Dark current increases with both temperature and line exposure time.

- Increases linearly with the sensor exposure time:

(1 / (Line rate)) * (number of TDI Stages)

- Increases exponentially with temperature, doubling approximately every 7°C.

For best performance Teledyne DALSA recommends recalibrating the dark flat field coefficients (FPN) at a stable operating temperature; for more information of flat field correction, refer to the Flat Field section.

Note that higher dark current is expected with backside illuminated cameras compared to front side illuminated cameras. The difference in dark signal is minimized at higher line rates but can become noticeable in the image at reduced speed. If the application requires operation at line rates below 30 kHz, it is recommended to use dark current correction. See section Dark Current Correction to do calibration.

NOTE

A minimum line rate of 10 kHz is recommended.

When using low line rates active cooling of the sensor is recommended to avoid offset drift due to minor temperature fluctuations.

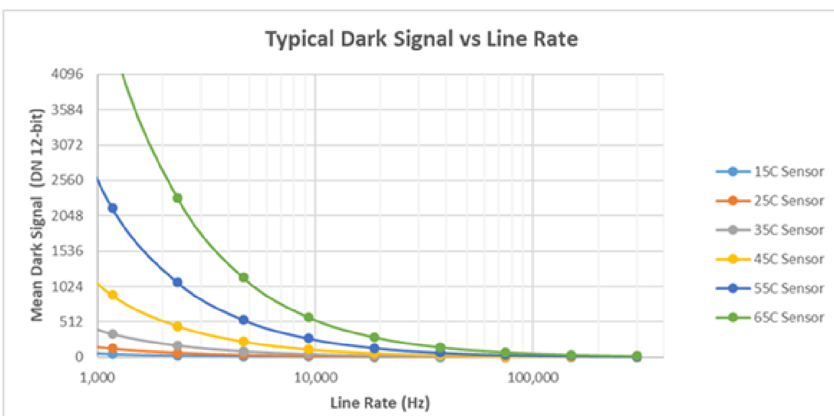


Figure 7: Typical Dark Signal vs. Line Rate

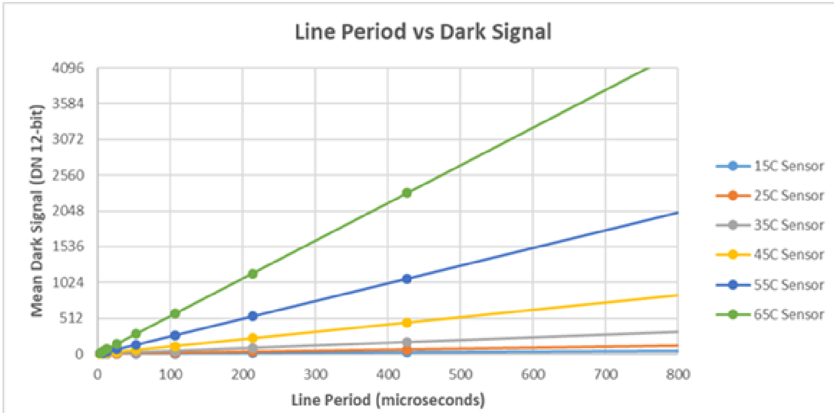


Figure 8: Dark Signal vs Line Period

Camera Pixel Arrangement

A TDI camera sensor contains multiple rows of pixels, called stages, grouped into an array; there may be up to three arrays, depending on the model. Each pixel is 5 µm x 5 µm. See section Arrays and Stages.

The monochrome models have two arrays, one of 128 stages, the other of 64 stages, except for model HL-FM-16K15A-00-R which has a single array of 128 stages. The arrays are separated by a gap of 35 rows.

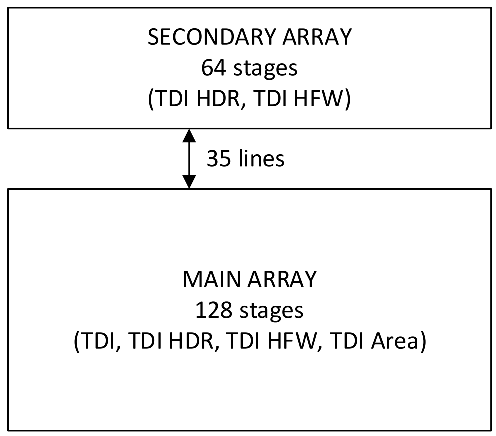


Figure 9: Dual array in monochrome models. In parentheses, the TDI imaging modes in which each array is used.

Camera Processing Chain

The diagram below details the sequence of user-adjustable, arithmetic operations performed on the camera sensor data. These adjustments are using camera features outlined in this chapter.

Video Data Processing Chain

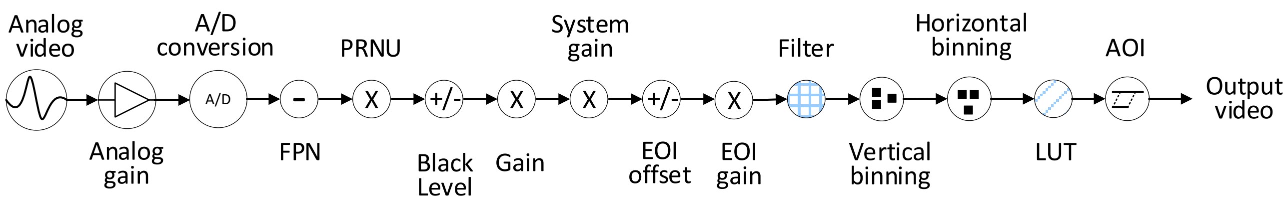


Figure 10: Video data processing chain

Installation

Please carefully read sections Handling Precautions and Preventing Operational Faults Due to ESD before installation.

If you are familiar with Camera Link HS (CLHS) cameras and Teledyne DALSA frame grabbers, follow the Quick Start Using a Teledyne DALSA Frame Grabber section to quickly install and test image acquisition with the Linea HS and the CamExpert tool provided with Sapera LT.

If using line scan cameras with frame grabbers is new to you, review the Requirements section for what you need before you start, then go to Installation Details for additional information on frame grabber and software installation, and camera connection. Refer to your frame grabber's user manual for instructions related to the board installation.

Note that you need administrator rights for installation and updates.

Handling Precautions

WARNING
Read these precautions before using the camera.

- Confirm that the camera's packaging is undamaged before opening it. If the packaging is damaged, please contact the related logistics personnel.
- Do not open the housing of the camera. The warranty is voided if the housing is opened.
- Keep the camera's front plate temperature in a range of 0 °C to +65 °C during operation. The camera can measure its internal temperature. Use this feature to record the internal temperature of the camera when it is mounted in your system and operating under the worst-case conditions. The camera will stop outputting data if its internal temperature reaches +80 °C.
- Do not operate the camera in the vicinity of strong electromagnetic fields. In addition, avoid electrostatic discharging, violent vibration, and excess moisture.
- Though this camera supports hot plugging, it is recommended that you power down and disconnect power to the camera before you add or replace system components.

Preventing Operational Faults Due to ESD

Image sensors and camera housing can be susceptible to damage from severe electrostatic discharge (ESD). Electrostatic charge introduced to the sensor window surface can induce charge buildup on the underside of the window.

WARNING
Camera installations which do not protect against ESD (electrostatic discharge) may exhibit operational faults. Problems such as random data loss, random camera resets and other non-reoccurring control issues may all be solved by proper ESD management.

Requirements

Frame Grabber

The following Teledyne DALSA frame grabbers are recommended.

Table 12: Frame grabbers

Linea HS Models	Connector Type	Compatible Frame grabber	Part Number
HL-FM	LC fiber optic	Teledyne DALSA Xtium2-CLHS FX8	OR-A8S0-FX840
HL-HM	CX4 (AOC)	Teledyne DALSA Xtium2-CLHS PX8	OR-A8S0-PX870

Camera Link HS Data Cable

The camera uses a Camera Link HS CX4 AOC (active optical cable) or LC optical fiber data cable.

The command channel is used by the frame grabber to send commands, configuration and programming data to the camera and to receive command responses, status and image data from the camera. Data and command transmission are done with CLHS X protocol (64b / 66b) at the default speed of 10 Gbps.

NOTE

Data transmits at 10 Gbps, which limits the effective distance of copper-based cables.

Cables can be bought from an OEM. OEM cables are also available for applications where flexing is present. Contact Teledyne DALSA support for recommended cable vendors, cables and part numbers.

LC Optical Fiber Data Cables

The HL-FM camera models use two LC/SFP+ connectors for data output, and require cables with LC connections on both ends. Either one or both of the camera SFP+ modules can be used, but using only one SFP+ / fiber optic will sacrifice available bandwidth.

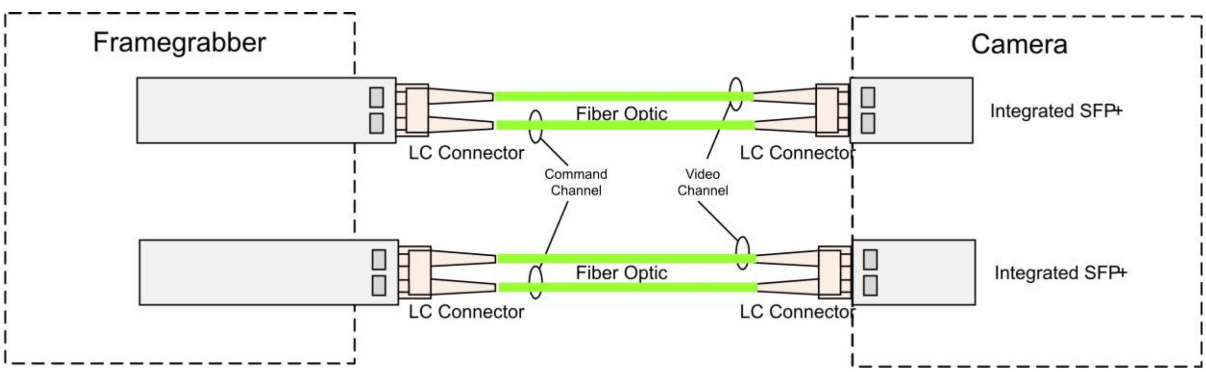


Figure 11: Linea HS Dual LC/SFP+ Connector Configuration

LC is a small-form factor optical fiber connector that uses a 1.25 mm ferrule, half the size of a standard connector. These cables are in wide use in the telecommunications industry and available in many lengths. The distance through which the data can be transmitted depends on the type of fiber used. Recommended optical fiber cables are types OM3 and OM4. The OM4 is used for distances > 300 m, but also requires SFP+ transceiver module changes.

Table 13: LC Optical Fiber Cable Details

Category	Fiber Diameter	Mode	Max Distance
OM3	50 µm	Multimode	< 280 m
OM4	50 µm	Multimode	> 300 m

CX4 AOC Data Cables

Camera Link HS CX4 AOC (Active Optical Cable) cables are made to handle very high data rates. These cables accept the same electrical inputs as traditional copper cables, but use optical fibers. AOC uses electrical-to-optical conversion on the cable ends to improve speed and distance performance of the cable without sacrificing compatibility with standard electrical interfaces.

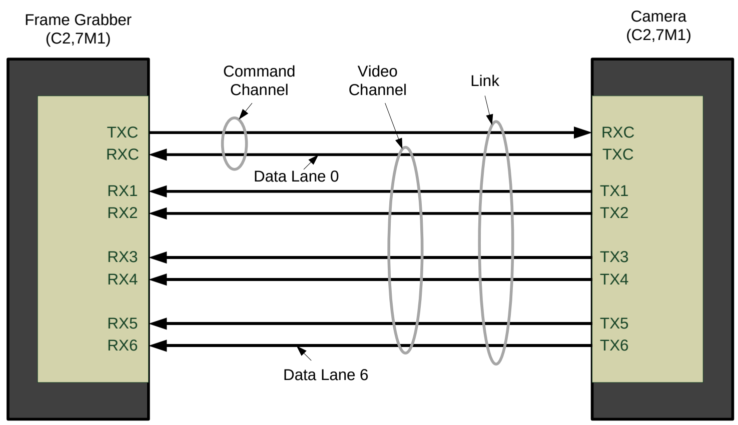


Figure 12: Single CLHS CX4 Connector Configuration

NOTE

CX4 AOC cables are unidirectional: ensure that the connector labelled **Camera** is attached to the camera, and the connector labelled **FG** is attached to the frame grabber.

Power Cable and Power Supply

All Linea HS require +12 V to +24 V DC power, supplied through a 12-pin Hirose circular male connector. The connector is used for power, trigger and strobe signals. The suggested female cable is the *Hirose model HR10A-10P-12S*.

WARNING

See Power and GPIO Connections for connector signal details.

Software and Device Driver

Sapera LT SDK

Sapera LT SDK is the image acquisition and control software development kit for Teledyne DALSA cameras. It includes the CamExpert application, which provides a graphical user interface to access camera features for configuration and setup. Sapera LT is available for download from the Teledyne DALSA website:

www.teledynedalsa.com/en/products/imaging/vision-software/sapera-lt/download/

Frame Grabber Driver

Xtium2-CLHS FX8/PX8 Board Drivers are available from the Teledyne DALSA website. Follow the installation instructions from the board's User Manual for the computer requirements, installation, and update.

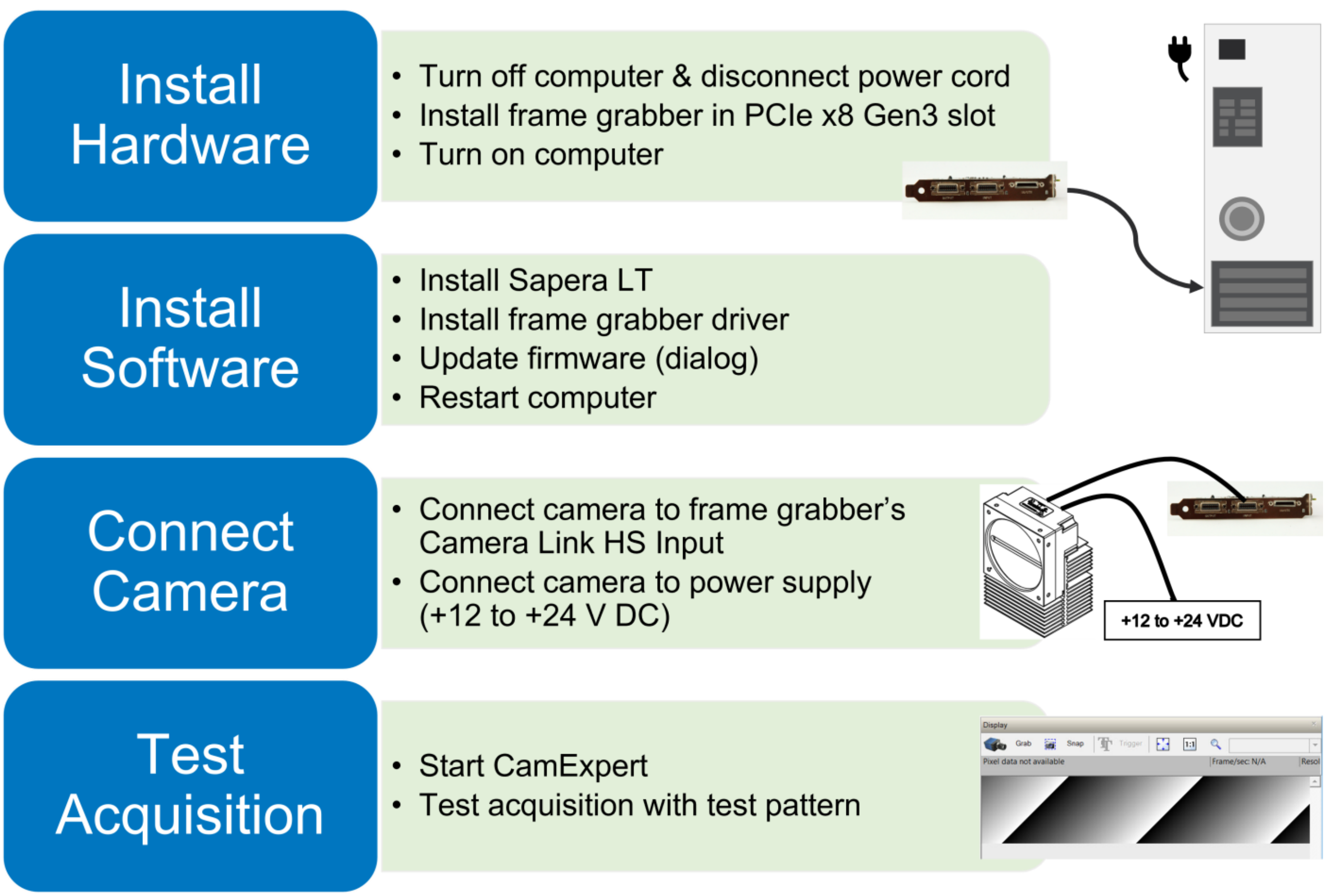
www.teledynedalsa.com/en/support/downloads-center/device-drivers/

Quick Start Using a Teledyne DALSA Frame Grabber

The following steps summarize the installation procedure. See Installation Details for further information on each step.

TDI cameras have relatively strict mounting requirements. For details, refer to application note **Application Guideline for TDI Cameras**, which can be downloaded from the Linea HS | Teledyne DALSA page.

NOTE
You need administrator rights for installation and updates.



Installation Details

Install Hardware

Follow instructions in the frame grabber's user manual.

WARNING – GROUNDING INSTRUCTIONS
Static electricity can damage electronic components. It is critical that you discharge any static electrical charge by touching a grounded surface, such as the metal computer chassis, before handling the frame grabber.

1. Turn off computer and disconnect power cord.
2. Install the Xtium2-CLHS FX8/PX8 frame grabber board into an available PCI Express x8 Gen3 slot.
3. Reconnect the power cord and turn on the computer.

Install Software

See Installing Sapera LT and Installing the Frame Grabber Driver for details.

4. Download and install the Sapera LT SDK or its runtime library. You must install Sapera LT before the frame grabber driver.
5. Download and install the Xtium2-CLHS FX8/PX8 frame grabber driver.
6. Restart the computer.

Connect Camera

See Connecting and Powering up the Camera for details.

7. Connect the Linea HS to the frame grabber with a CLHS cable. Make sure the Camera end is connected to the camera, as this cable is directional.
8. Connect and power up the camera using an appropriate power supply. The Linea HS status LED will indicate power and the Device/Host connection with a steady green color when connected. See section Camera Status LED Indicator for a description of the LED states.

Test Acquisition

See Testing Acquisition for details.

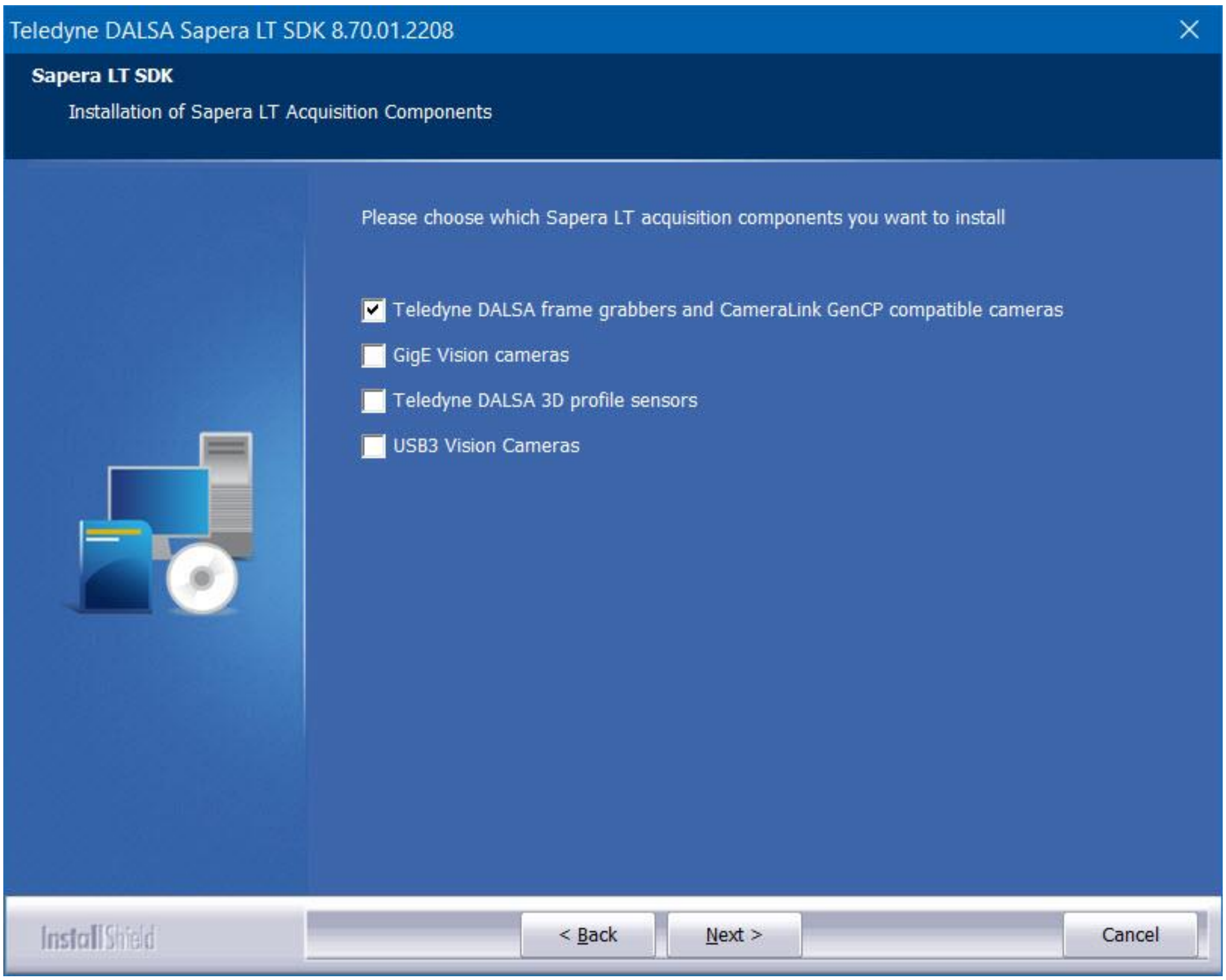
1. Start **CamExpert**. The plug-and-play feature of the frame grabber and camera will automatically configure frame buffer, data lanes, and frame rate parameters to match the Linea HS model being used. At this time, do not configure for an external trigger.
2. From the Linea HS Image Format Feature Category, select a test pattern from the *Test Image Selector* parameter.
3. Click **Grab**. You will see the pattern in the CamExpert display window.
4. If a lens is attached to the camera, turn off the test pattern and grab live again. Adjust the lens aperture and focus, and/or adjust the camera's Acquisition Line Rate as needed.

Installing Sapera LT

Download Sapera LT SDK and install Sapera LT or its runtime library.

The Sapera LT download includes several components. Install Sapera LT SDK for Developers (SaperaLTSDKSetup.exe), which includes CamExpert as well as demos and examples, if you intend to develop applications. If no Sapera development is needed, you may install the Sapera LT runtime with CamExpert (SaperaLTCamExpertSetup.exe).

Start the Sapera LT installer and follow instructions. On the **Acquisition Components** page, select the *Teledyne DALSA frame grabbers and CameraLink GenCP compatible cameras* option.



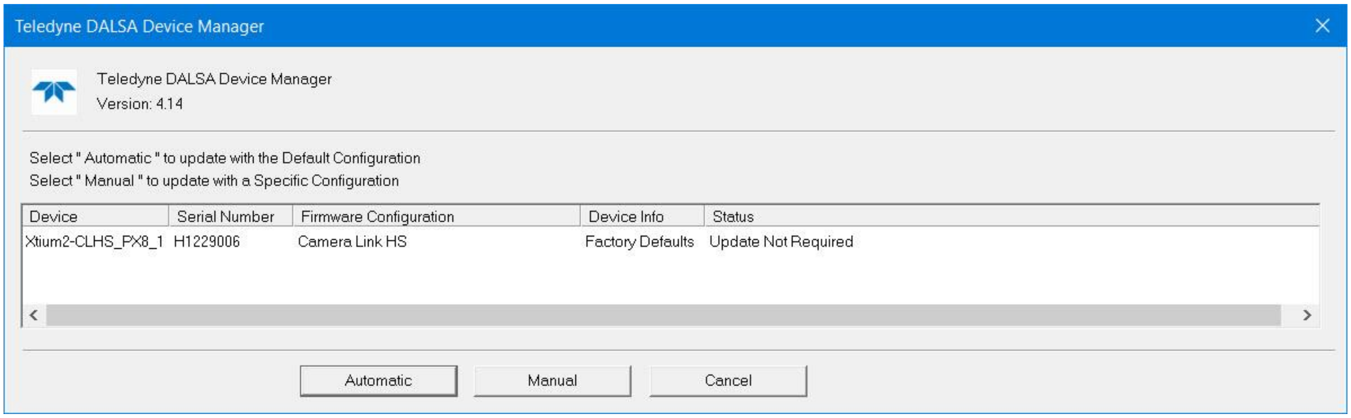
The installation program will prompt to reboot the computer. It is not necessary to reboot the computer between the installation of Sapera LT and the installation of the frame grabber driver. Reboot will be required after software and driver are installed.

Installing the Frame Grabber Driver

Download the Xtium2-CLHS frame grabber driver. Follow instructions in the frame grabber's user manual for installation of the driver.

During the last stages of the installation, the Device Manager window will open, allowing you to update the board firmware. Choose **Automatic** to update with the default configuration (Full Camera Link), or **Manual** to select another configuration option.

Reboot after installation.



Connecting and Powering up the Camera

For guidelines on connectors, power supply and connector pinout, see section Connectors.

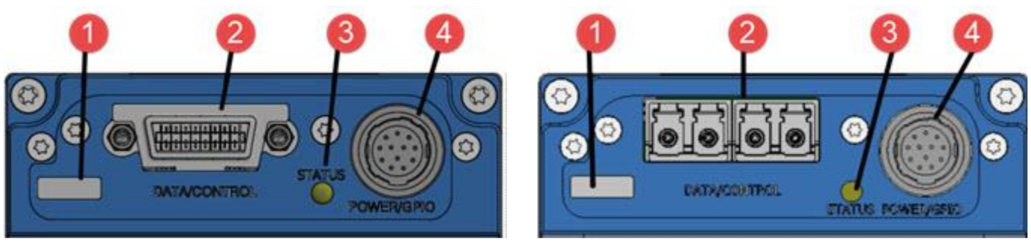


Figure 13: Camera I/O Connectors: CX4 (left) & SFP+ for LC optical fiber (right)

Camera I/O Connectors

1) Factory use only
2) Data/Control connector – CX4 or SFP+ for LC optical fiber
3) Camera Status LED Indicator
4) Power and GPIO connector: +12 V to +24 V DC, Hirose 12-pin circular

WARNING

Carefully read section Powering the Camera before applying power to the camera. Appropriate voltage ranges between +12 V and +24 V DC. Incorrect voltage may damage the camera.

For CX4 (AOC) connector models

- Connect the **Camera** end of the CX4 cable to the Data/Control connector on the camera.
- Connect the **F G** end of the CX4 cable to the J3 Camera Link HS input connector (middle) of the frame grabber.
- Connect the power cable to the power supply.

For LC optical fiber connector models

- Connect the LC cable ends to the camera and to the frame grabber.
- Connect the power cable to the power supply.

Camera Status LED Indicator

A single red/green LED is located on the back of the camera to show status.

In case of error, the Built-In Self-Test (BIST) error codes can be found in the Camera Information category under Power-on Status. See Built-In Self-Test Codes for diagnosis.

Table 14: Status LED States

LED State	Description
Off	Camera not powered up or waiting for the software to start.
Constant Red	The camera BIST status is not good.
Blinking Red	The camera has shut down due to an over temperature condition.
Blinking Orange	Powering Up. The microprocessor is loading code.
Blinking Green	Hardware is good, but the CLHS connection has not been established or has been broken.
Constant Green	The CLHS Link has been established and the camera is ready for data transfer to begin.

When the camera's LED state is steady green:

- CamExpert will search for installed Sapera devices.
- In the **Devices** list, the connected frame grabber will be shown.
- Select the frame grabber device by clicking on the name.

Testing Acquisition

Starting Sapera CamExpert

Sapera CamExpert is included as part of the Sapera LT SDK. It is Teledyne DALSA's camera and frame grabber interfacing tool that allows you to quickly validate hardware setup, change parameter settings, and test image acquisition. It is available from the Windows **Start** menu under **Teledyne DALSA Sapera LT**, or from the desktop shortcut (created at installation). See section Using CamExpert with Linea HS for details.

If there is only one Teledyne DALSA frame grabber, the **Device** list in CamExpert automatically has the frame grabber selected and the connected camera detected as shown in the image below.

If the camera is not automatically detected, verify that the camera is properly powered and that the data cable is connected correctly.

From the **Device** list, open the Teledyne DALSA frame grabber node and select the attached camera.

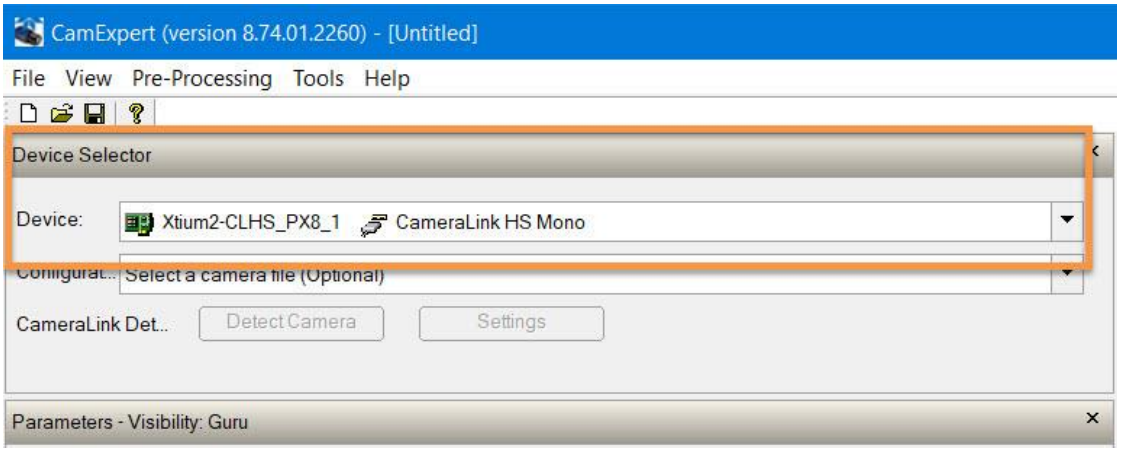
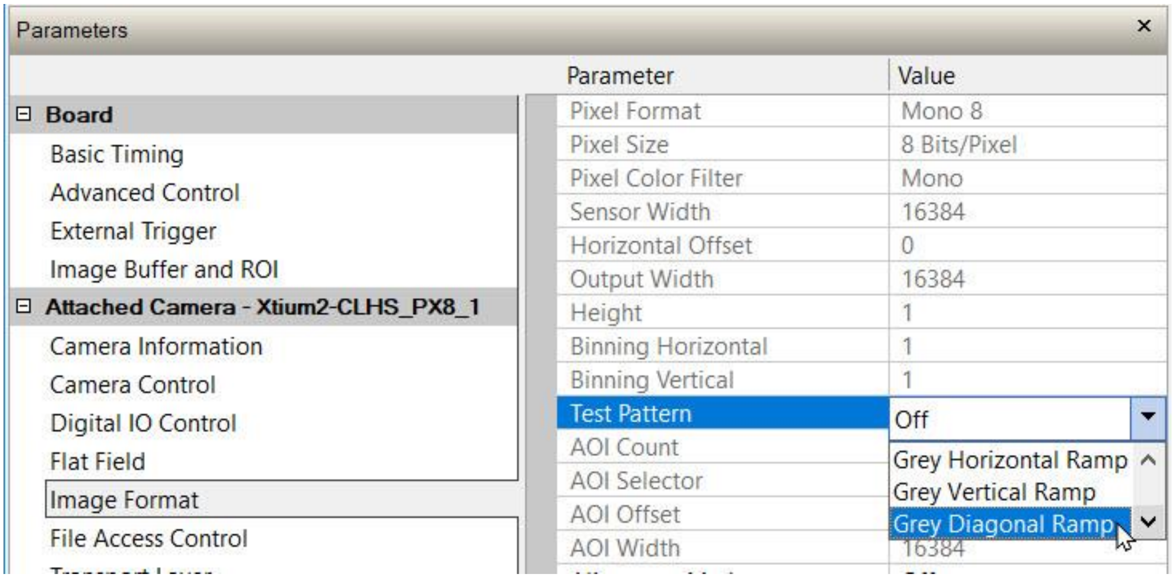


Figure 14: CamExpert and the Device Selector pane. If only one frame grabber and camera are installed, they are automatically selected.

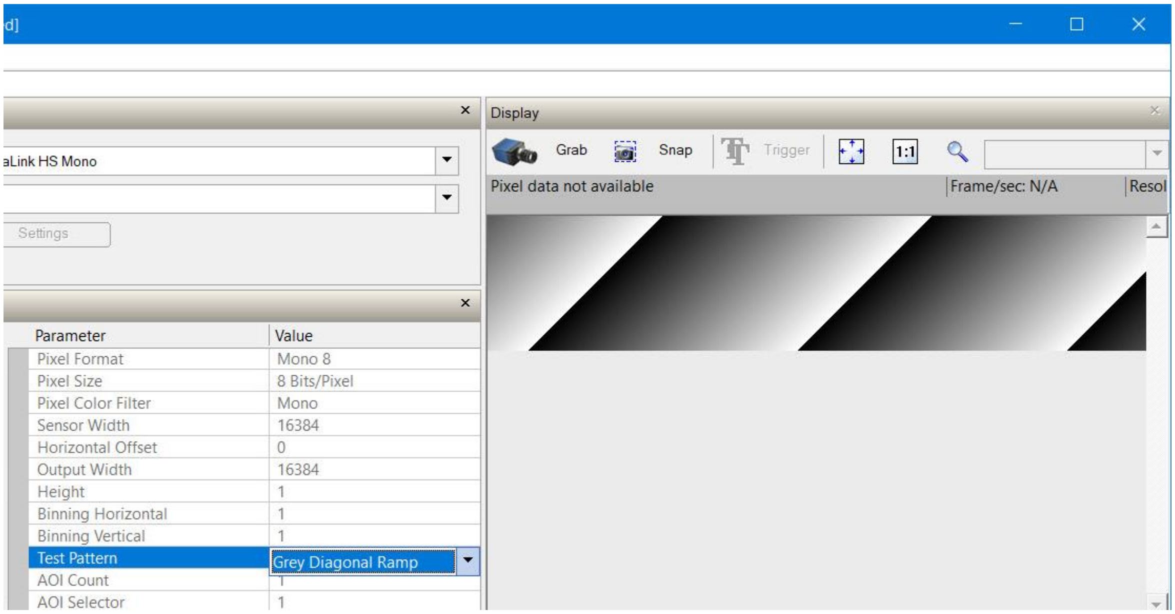
Verifying Basic Acquisition

To verify basic acquisition, the camera can output a test pattern to validate that parameter settings are correctly configured between the camera and frame grabber.

- Change the Pixel Format if needed. See Selecting the Data Format below.
- In the Image Format category, select Test Pattern > *Grey Diagonal Ramp*.



- Click **Snap** to view the diagonal ramp.



Selecting the Data Format

The output format for monochrome cameras are Mono8 or Mono12. To change output format, acquisition must be stopped in the Acquisition and Transfer Control category.

The frame grabber's Basic Timing > Pixel Depth and Color Type features should correspond to the camera's image format.

The camera always outputs data to the frame grabber in a ‘planar’ format—when multiple arrays are used, the corresponding lines are output separately one after the other. Please refer to the frame grabber user’s documentation for further details on selection input and output pixel formats.

Using CamExpert with Linea HS

CamExpert is the camera interfacing tool supported by the Sapera library. When used with the camera, CamExpert allows a user to test all camera operating modes. In addition, CamExpert can be used to save several user setting configurations to the camera.

An important component of CamExpert is its live acquisition display window. This window allows verification of timing or control parameters in real-time, without need for a separate acquisition program.

The central section of CamExpert provides access to the camera features and parameters.

CamExpert Panes

In the **Device** list, under the Xtium2 frame grabber node, select Camera Link HS.

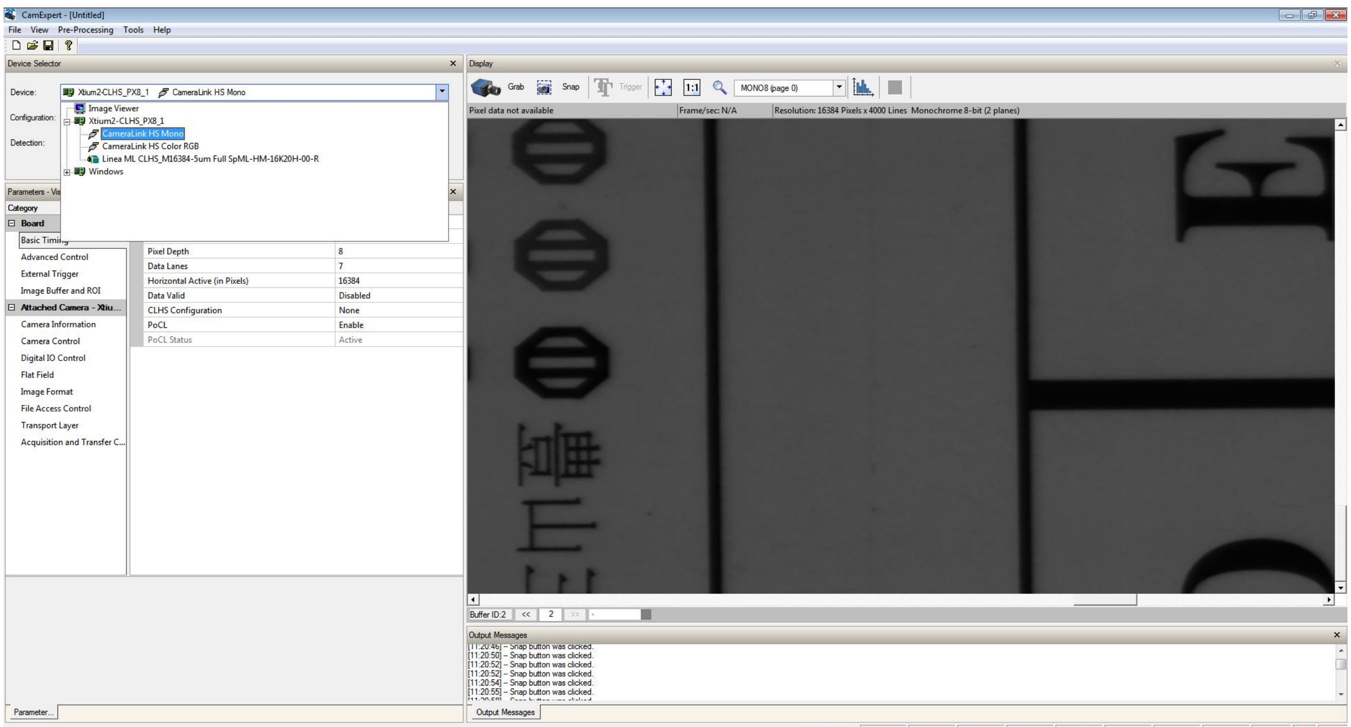


Figure 15: CamExpert Frame Grabber Control Window

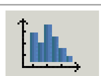
The CamExpert application uses panes to organize the selection and configuration of camera files or acquisition parameters.

Device Selector pane: View and select from any installed Sapera acquisition device. Once a device is selected, CamExpert will only show acquisition parameters for that device. Optionally, select a camera file included with the Sapera installation or saved previously.

Parameters pane: Allows the viewing or changing of all acquisition parameters supported by the acquisition device. CamExpert displays parameters only if those parameters are supported by the installed device. This avoids confusion by eliminating parameter choices when they do not apply to the hardware in use.

Display pane: Provides a live or single frame acquisition display. Frame buffer parameters are shown in an information bar above the image window.

Control Buttons: The display pane includes CamExpert control buttons. These are:

	**Live acquisition controls** Click once to start live grab, click again to stop.
	**Single frame acquisition** Click to acquire one frame from device.
	**Software trigger** With the I/O control parameters set to Trigger Enabled, click to send a single trigger command.
	**CamExpert display controls** (these do not modify the frame buffer data) Select **Fit Display to Screen**, **Reset Display to 1:1 Ratio** or **Advanced Display Options** to change image display.
	**Statistics** Select to view a histogram or line/column profile during live acquisition or in a still image.

Output Message Pane: Displays messages from CamExpert or the device driver.

At this point you are ready to start operating the camera, acquire images, set camera functions, and save settings.

CamExpert View Parameters Option

All camera features have a Visibility attribute which defines its requirement or complexity. The states vary from Beginner (features required for basic operation of the device) to Guru (optional features required only for complex operations).

CamExpert presents camera features based on their visibility attribute. CamExpert provides quick Visibility level selection via controls below each Category Parameter list [<< Less   More >>]. The user can also choose the Visibility level from the *View · Parameters Options* menu.

Overview of TDI Technology

A basic line scan sensor consists of a single row of pixels acquiring light from an object. As the object moves past the sensor, the output lines build up to create a 2D image. The image is built one line at a time, and each line of the image is the result of a single exposure from the sensor.

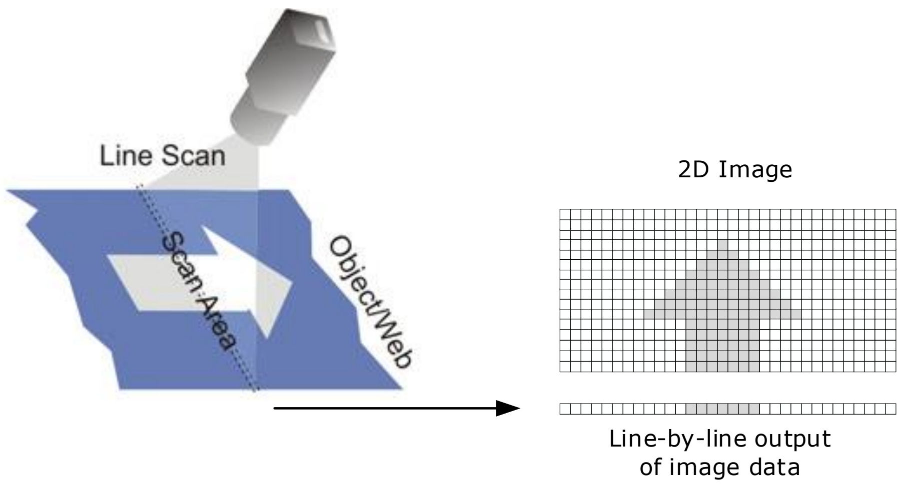


Figure 16: Line Scan Operation

Time delay integration (TDI) is based on the concept of accumulating multiple exposures of the moving object, effectively increasing the time available to collect incident light (integration time). A TDI camera sensor contains multiple rows of pixels, called stages, grouped into an array. A stage collects light, and as the object moves across the array, the following stage collects more light for the same image segment, and so on, up to the last stage. Each line of the image is thus acquired many times and corresponds to the sum of the exposures from the stages of the sensor.

The effective integration time is:

(1/Line rate) * Number of TDI Stages

To ensure a crisp image, the object's motion must be synchronized with the exposures so that each stage in the array successively captures the same image segment. See section Synchronizing to Object Motion on ways to ensure proper synchronization of acquisition and object motion.

See the TDI Primer on Teledyne DALSA's website for an illustration of how TDI works.

Arrays and Stages

A TDI sensor may comprise one, two or three arrays of pixels, where each array consists of two or more stages (rows, or lines). The following figure illustrates a single array sensor of 4096 pixels x 128 stages.

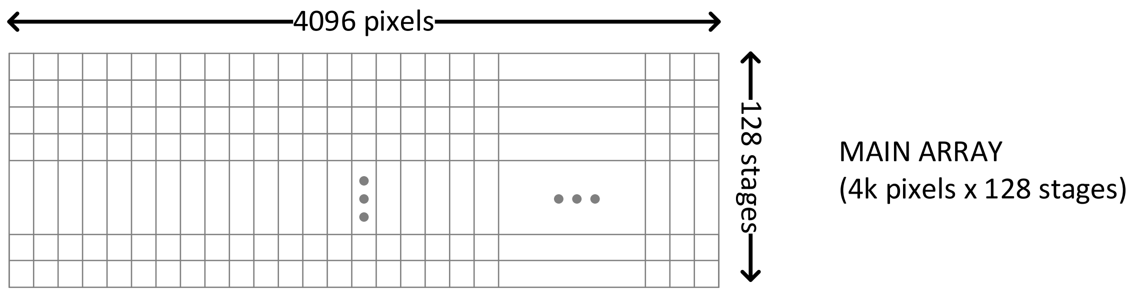


Figure 17: A 4k x 128, single array TDI sensor comprises 4k pixels across and 128 stages (rows).

In a multiple array TDI sensor, arrays are separated by a few rows. The main array typically has a larger number of stages than the secondary array(s). The number of stages used may sometimes be specified, depending on TDI Mode. The output line of the sensor combines the output line from all arrays used in acquisition.

Multiple arrays are often used for increasing the dynamic range or improving signal to noise ratio.

The following figure illustrates a dual array sensor of 4096 pixels x 192 (128 + 64) stages.

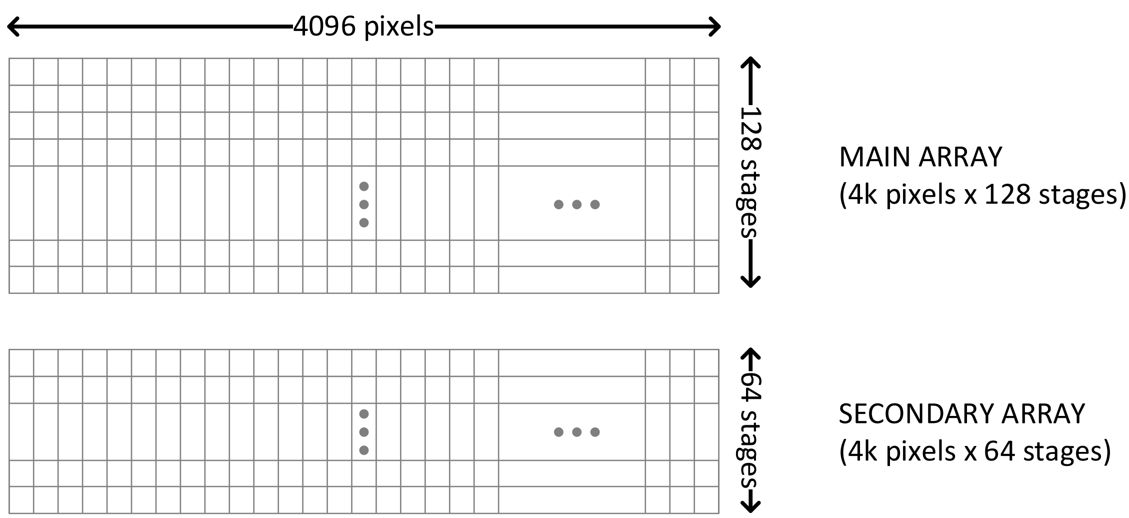


Figure 18: A 4k x 192 (128+64), dual array TDI sensor. The main array includes 128 stages, the secondary array has 64 stages. The arrays are separated; the distance between them is typically a multiple of the pixel size.

Camera Performance and Features

This section is intended to be a progressive introduction to camera features, including explanations of how to use them effectively.

Synchronizing to Object Motion

With TDI cameras, synchronization between acquisition and object motion is essential to get clear images with a correct aspect ratio. There are several features involved, described below. Basically, to properly synchronize acquisition with object motion:

- Choose a trigger source and trigger rate for acquisition. Typically, an external trigger is used, such as a signal from an encoder.
- Set scan direction. Make sure the sensor array is perpendicular to the scan direction.
- Use spatial correction when more than one array is used, e.g. TDI HDR mode.

For further details on synchronization using a rotary encoder, refer to Application Note for Multiplier & Divider (on Teledyne DALSA App Notes page).

Triggering the Camera

See Digital IO Control Category for GenICam features associated with this section and how to use them.

Related Features: TriggerMode, TriggerSource, TriggerActivation

Several different methods can be used to trigger image acquisition in the camera.

Internal Trigger

Trigger Mode = *Internal*. The acquisition trigger signals originate from the camera's internal timer. The camera trigger rate can be adjusted using the *Acquisition Line Rate* feature.

External Trigger

Trigger Mode = *External*. The acquisition trigger signals come from an external hardware source selected through the *Trigger Source* feature.

Trigger Source options are: *Line 1* (pin 5 of the GPIO connector), *CLHS In* (Camera Link HS frame grabber), or *Rotary Encoder* (pins 5 and 6 of the GPIO connector).

The Trigger Activation feature lets you choose the edge that triggers acquisition. Trigger Activation options are: *Rising Edge*, *Falling Edge* or *Any Edge*. When using *Any Edge*, be careful that the edges do not trigger acquisition at a rate that exceeds the maximum line rate of the camera. If the line rate is exceeded one of those edges will be ignored.

CamExpert can be used to configure the frame grabber for routing the encoder signal from the frame grabber input to the trigger input of the camera via the Camera Link HS data cable.

Line Rate and Synchronization

A continuous stream of encoder trigger pulses, synchronized to the object motion, establishes the line rate. The faster the object's motion is, the higher the line rate. The camera can accommodate triggers up to its specified maximum frequency. If the maximum frequency is exceeded, the camera will continue to output image data at the maximum specified. The result will be that some trigger pulses will be missed and there will be an associated distortion (compression in the scan direction) of the image data. When the line rate returns to or below the maximum specified, normal imaging will be reestablished.

Measuring Line (Trigger) Rate

See Camera Control Category for GenICam features associated with this section and how to use them.

Related Feature: measuredLineRate , refreshMeasuredLineRate

The Measured Line Rate feature returns the line rate provided to the camera by either internal or external source. Refresh Measured Line Rate command is used to read the line (trigger) rate being applied, externally or internally, to the camera.

Maximum Line Rate

The maximum achievable line rate is determined by the number of CLHS lanes and the number of cables installed, the bit depth, the TDI mode and AOI windows, as shown in the following tables.

Table 15: Maximum line rates for default and HDR modes, in 8-bit and 12-bit outputs.

Camera Model	Maximum Line Rate (kHz) (1 sensor line output)			
	8-bit	8-bit HDR mode	12-bit	12-bit HDR mode
HL-FM-04K30H-00-R	300 kHz	150 kHz x 2	300 kHz	150 kHz x 2
HL-FM-08K30H-00-R	280 kHz	140 kHz x 2	180 kHz	90 kHz x 2
HL-HM-08K30H-00-R	300 kHz	150 kHz x 2	300 kHz	150 kHz x 2
HL-HM-08K40H-00-R	400 kHz	200 kHz x 2	400 kHz	200 kHz x 2
HL-FM-13K18H-00-R	180 kHz	90 kHz x 2		
HL-HM-13K30H-00-R	300 kHz	150 kHz x 2	230 kHz*	115 kHz x 2*
HL-HM-09K40H-00-B	400 kHz	200 kHz x 2	275 kHz	137 kHz x 2*
HL-FM-16K15A-00-R	140 kHz	NA	90 kHz	NA
HL-HM-16K30H-00-R	300 kHz	150 kHz x 2	230 kHz*	115 kHz x 2*
HL-HM-16K40H-00-R	400 kHz	200 kHz x 2	275 kHz	137 kHz x 2*
HL-HM-16K40H-00-B	400 kHz	200 kHz x 2	275 kHz	137 kHz x 2*

* See Note below.

Table 16: Maximum line rates using AOIs, with 1 or 2 frame grabbers for 16K40 models.

Camera Model	Maximum Line Rate (kHz) (1 sensor line output)			
	AOI Window	Bit Depth	With 1 frame grabber	With 2 frame grabbers
HL-HM-16K40H-00-R HL-HM-16K40H-00-B	16k	12-bit	205 kHz	275 kHz
	16k	8-bit	360 kHz	400 kHz
	12k	12-bit	275 kHz	368 kHz
	12k	8-bit	400 kHz	400 kHz
	9k	12-bit	367 kHz	400 kHz
	9k	8-bit	400 kHz	400 kHz
	8k	12-bit	400 kHz	400 kHz
	8k	8-bit	400 kHz	400 kHz

NOTE

Linea HS maximum line rate values shown here are theoretical. These line rates were achieved using an Xtium2-CLHS PX8 (OR-A8S0-PX870) frame grabber in a system setup in our lab. The maximum achievable line rate depends on the frame grabber and imaging system (including CPU) used. Depending on your setup, lower line rates may be experienced.

With a system bandwidth of 6740 MB/s the following line rates were achieved:

- 12-bit: 200 kHz
- 12-bit HDR mode: 100 kHz x 2

For advice on your setup and achieving higher line rates, contact Teledyne DALSA customer support.

Minimum Line Rate

The minimum line rate is 10 kHz, except for the HL-HM-16K40H-00-B model, which is 30 kHz.

Devices can be operated under 10 kHz, but specifications will no longer be valid. Dark current correction will help optimize dark current. See Dark Current Correction.

Scan Direction

See Camera Control Category for GenICam features associated with this section and how to use them.

Related Feature: sensorScanDirectionSource, sensorScanDirection

A TDI camera requires the user to indicate to the camera the direction of travel of the object (sensorScanDirection = *Forward* or *Reverse*). It can be set manually or controlled by an external signal, depending on the value of the sensorScanDirectionSource feature:

- *Internal*: The sensorScanDirection feature sets the scan direction (manual setting).
- *Line 2* (pin 6 on the GPIO connector): The signal on Line 2 controls the scan direction.
- *Rotary Encoder* (pins 5 and 6 of the GPIO connector) : The encoder controls the scan direction. The option is only available when TriggerSource is *RotaryEncoder* and rotaryEncoderOutputMode is set to *Motion*.

It is important to perform and save a flat field calibration in the actual system with both directions used.

Direction Change Time

The direction change time between forward and reverse is < 1 ms.

Setting the Correct Scan Direction

Whether the scan direction is set correctly can easily be seen in live imaging.

- If the optical setup is correct, the image will appear normal, sharp and focused.
- If the optical setup is not properly focused, blur will occur in both horizontal (cross-scan) and vertical (in-scan) directions.
- If blur occurs only in the scan direction (see below), the scan direction is set incorrectly.

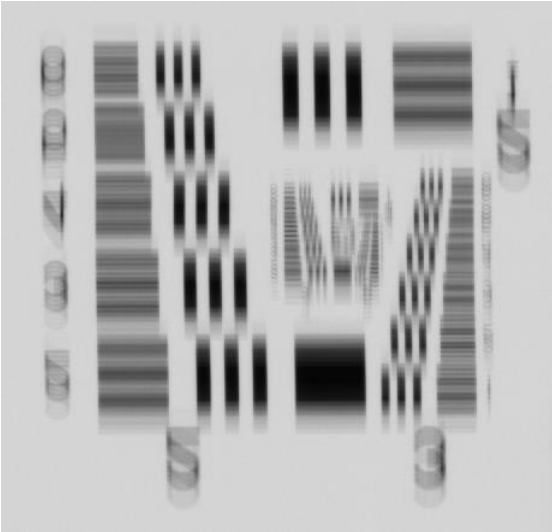


Figure 19: Image with incorrect scan direction

The diagram below shows the orientation of forward and reverse with respect to the camera body.

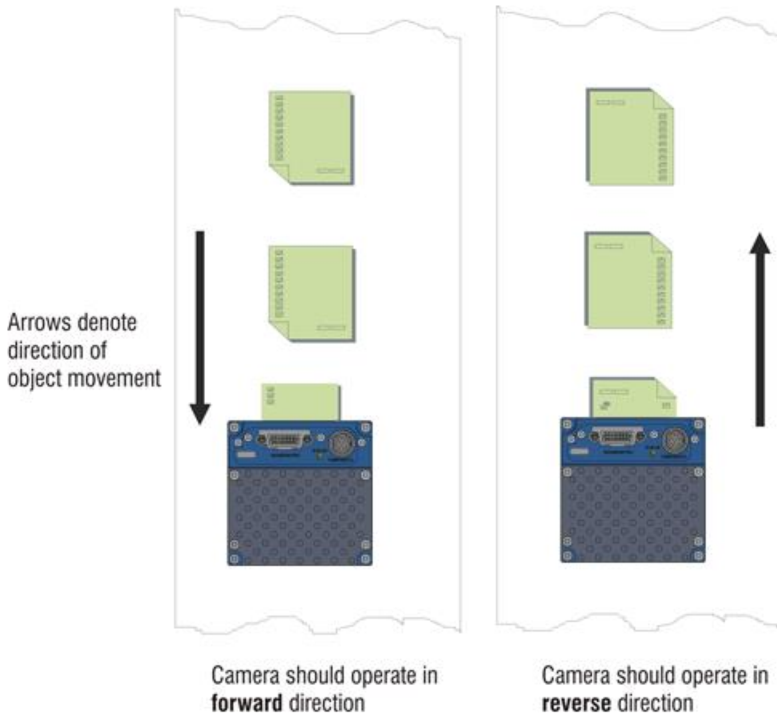


Figure 20: Example of object movement and camera direction

The diagram shows the designated camera direction. However, due to the characteristics of the lens, the direction of the object motion is opposite to the image motion direction.

NOTE

The diagram assumes the use of a lens on the camera, which inverts the image.

In model HL-HM-16K40H-00-B, the mage is flipped compared to the other models. The image can be flipped back in the frame grabber.

Some inspection systems require that the scan direction change at regular intervals. For example, scanning a panel forwards, coming to a stop and then scanning backward as the camera's field of view is progressively indexed over the entire panel. It is necessary for the system to over-scan the area being imaged by at least the 128 stages of the TDI sensor before the direction is changed. This ensures that valid data will be generated on the return path as the camera's field of view reaches the area to be inspected.

Spatial Correction

Spatial correction is necessary when using multiple array output, such as when using HDR or high full well modes. To achieve a sharp image in the scan direction, it is important that the lines being used are aligned correctly. Line spatial correction is used to that end.

Spatial correction is not necessary when using the camera with one array only. For single array TDI operation, this functionality is disabled.

FYI

Teledyne DALSA Xtium and Xtium2 CLHS frame grabbers automatically perform spatial correction for Linea HS cameras.

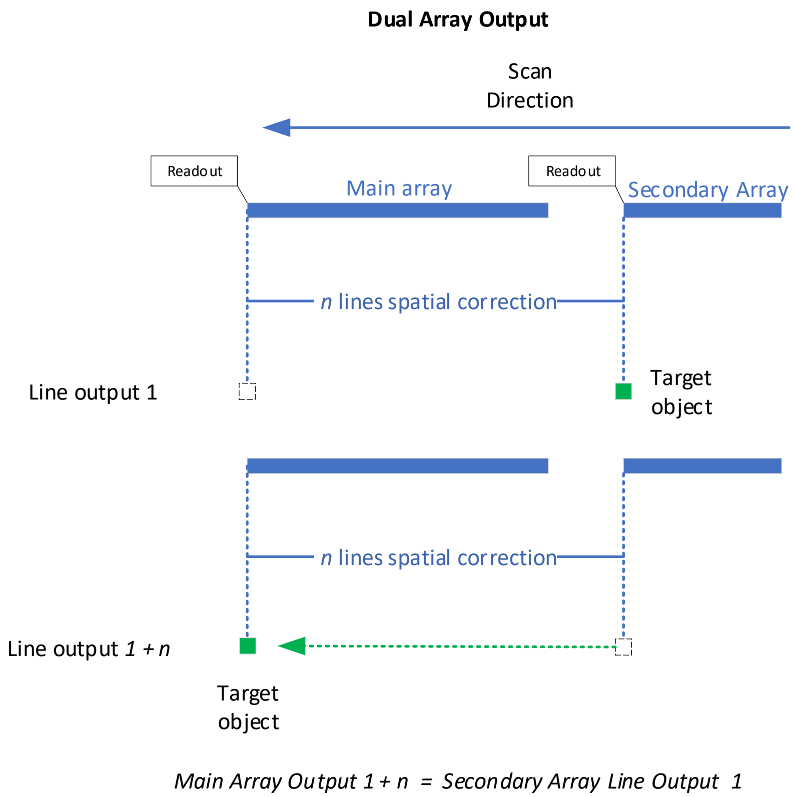


Figure 21: Spatial Correction

At a high level, spatial correction is a two step process; 1) camera assigns row spacing data to each row; 2) the frame grabber uses this row spacing data to align the image data. All data buffering is performed by the frame grabber as the camera does not have adequate memory resources for this function.

Spatial correction compensates for the direction of travel and changes to the scan direction. For example, in dual array output, the main array row output that aligns to the second array output either to 163 or 99 rows apart depending on the scan direction.

NOTE

The frame grabber must be set to two planes to align the data for dual array output; for 3 array output 3 planes are required.

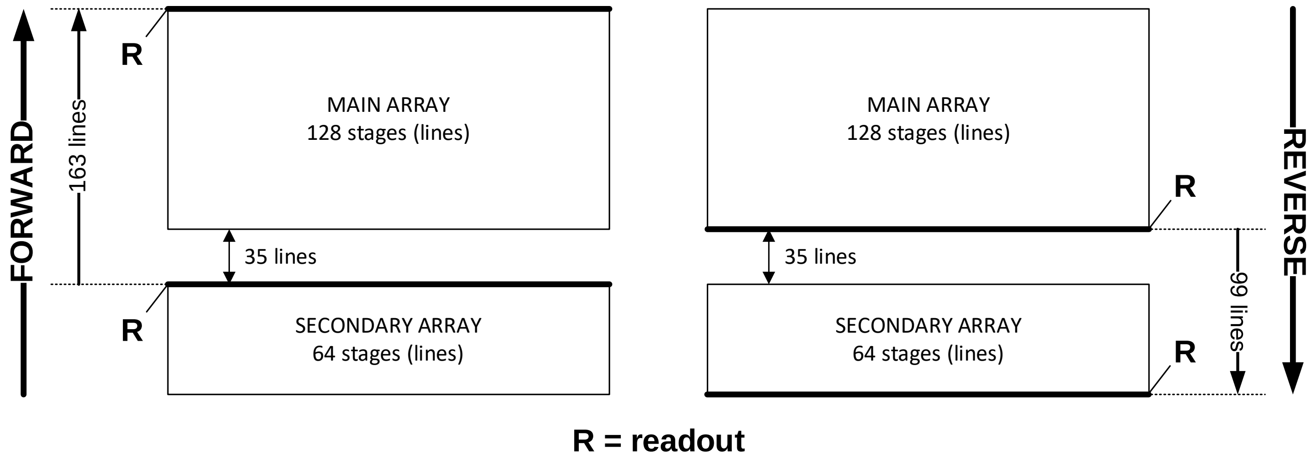


Figure 22: Camera line spacing. (Left) Forward direction. (Right) Reverse direction.

Alignment Markers

See Camera Control Category for GenICam features associated with this section and how to use them.

Related Features: alignmentMarkerEnable, alignmentMarkerVerticalSpacing, alignmentMarkerVerticalOffset, alignmentMarkerHorizontalSpacing, alignmentMarkerHorizontalOffset and alignmentMarkerBlack

Use alignment markers to assist in aligning the camera to ensure that all sensor columns (the vertical axis of the sensor) align with the direction of travel. Proper sensor alignment ensures that a pixel in the first stage captures the same part of the object as the pixel below it in the last stage; misalignment can result in blurred or smeared images.

When enabled, alignment markers are displayed as graphic overlays in the image output. Spacing, offset and color of markers may be adjusted to facilitate alignment.

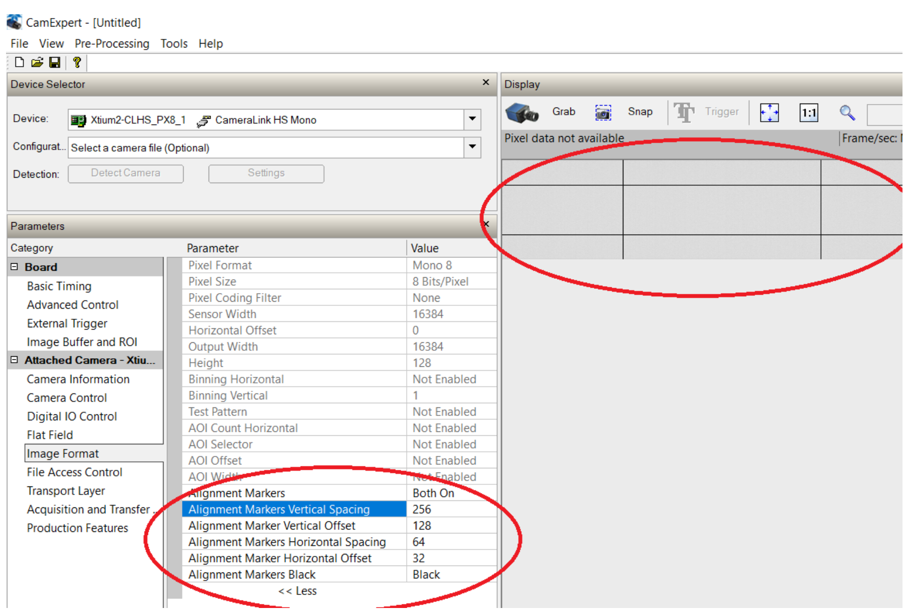


Figure 23: Alignment Markers

Imaging Modes

See the section Camera Control Category for GenICam features associated with this section and how to use them.

Related Features: sensorTDIModeSelection

The Linea HS models may be used in four different modes: TDI, TDI HDR (High Dynamic Range), TDI HFW (High Full Well) and TDI Area.

TDI

TDI mode is the default operating mode for the camera. The camera combines multiple exposures of an object as it passes each row in the array into one high sensitivity image. In this mode the main 128 stage array is used, and the max line rate can be achieved.

TDI Stages

When operating in different TDI modes the number of stages in the array is adjusted, resulting in different responsivities. In TDI mode, the main array is configurable to 128 or 64 stages; secondary arrays are not used.

Table 17: TDI Mode Stages

Array	Number of Stages Used
Main Array	128, 64

It is important to execute flat field correction based on the number of stages in the final application, since pixel behavior changes with stage selection.

TDI HDR

HDR (high dynamic range) enables imaging of (exceedingly) bright and dark areas in a single scan, replacing dual-scan setups with dedicated cycles. In TDI HDR mode, image data is collected from 2 TDI arrays; the camera outputs two rows that are combined to create an HDR image. This limits the maximum line rate to half the max line rate.

To adapt to the imaged scene dynamic range, the HDR ratio can be selected, as shown in the table below. This ratio controls the number of stages used in each TDI pixel array.

Table 18: HDR Mode Stages

HDR Ratio	Main Array Stages	Secondary Array Stages
2:1	128	64
4:1	64	16
8:1	128	16

TDI HFW

TDI HFW (High Full Well) mode sets both arrays at equal stage count, providing an additional bit of output data. Processing the upper bits [N..1] provides a 2x full well increase at lower responsivity. Processing the lower bits [N-1…0] maintains responsivity with √2 improved NEE.

Table 19: High Full Well Mode Stages

Ratio	Main Array Stages	Secondary Array Stages
1:1	64	64

TDI Area

In Area Mode, the camera operates as an area scan camera using the main array of pixels (16 384 x 128 pixels). Area Mode is useful during setup, both for aligning and focusing the camera. In sufficiently slow applications, area mode can provide a high-aspect 2D image.

When selecting TDI Area mode, the Device Scan Type feature changes to *Areascan* and the Height feature changes to 128, automatically.

TDI Mode and Line Rate

See the section Camera Control Category for GenICam features associated with this section and how to use them.

Related Feature: AcquisitionFrameRate, AcquisitionLineRate

When the Trigger Mode feature is set to *Internal*, the line rate is controlled with the AcquisitionLineRate or AcquisitionFrameRate feature. The chosen TDI mode, area of interest (AOI) window size, bit depth (8-bit vs. 12-bit) and number of frame grabbers affect the maximum achievable rate as indicated in section Maximum Line Rate.

- **TDI** (default): The maximum line rate is as indicated in the specifications.
- **TDI HDR**: The line rate is ½ of the TDI mode maximum line rate as this mode combines the output from two arrays.
- **TDI HFW**: The line rate is ½ of the TDI mode maximum line rate as this mode combines the output from two arrays.
- **TDI Area**: The frame rate is as indicated in the AcquisitionFrameRate feature. This value is read only.

Configuring the Frame Grabber for Different TDI Modes

When selecting a device from the **Device** list in CamExpert, the frame grabber selects the default working feature settings in the Image Buffer Format category. You may want to retrieve different channels, in which case the frame grabber should be made aware.

The table below indicates, for the available TDI modes, the possible frame grabber's image buffer formats that can be used depending on the information to retrieve.

Table 20: Configuring the frame grabber.

TDI Mode	Image Buffer Format	Note
TDI	Monochrome 8-bits	
TDI HDR	Monochrome 8-bits or Monochrome 8-bits (2 planes)	HDR generates 2 images. If you need the merged result, select Monochrome 8-bits, otherwise select Monochrome 8-bits (2 planes).
TDI HFW	Monochrome 8-bits	
TDI Area	Monochrome 8-bits	

Adjusting Responsivity and Contrast Enhancement with Black Level and Gain

See the section Camera Control Category for GenICam features associated with this section and how to use them.

Related Features: GainSelector, Gain, BlackLevel

It is best for camera performance to always use the maximum exposure time possible based on the maximum line rate of the inspection system and any margin that may be needed to accommodate illumination degradation. However, it will be necessary to adjust the responsivity to achieve the desired output from the camera. The camera has black level (offset) and gain features that can be used to adjust the camera's responsivity.

Gain and black level settings are applied as follows:

$$DN_{out} = ((DN_{in} + \text{Black Level}) * \text{Gain}) * \text{System Gain}$$

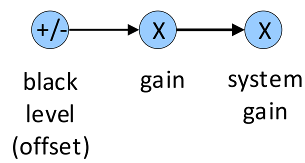


Figure 24: Black Level, Gain and System Gain Processing Chain

Refer to the Camera Processing Chain section for an overview of the entire processing chain.

Black Level

The black level feature allows a specified offset to be added to or subtracted from the image data. It may be used to remove data below a given threshold; the gain feature can then be used to return the peak image data to near output saturation with the result being increased image contrast.

1. With the current gain setting, use the histogram tool to determine the offset value to subtract from the image.
2. Set the Black Level parameter as a negative offset value.
3. Apply additional gain to achieve the desired peak image data values.

NOTE

A positive offset value is not useful for contrast enhancement. However, it can be used while measuring the dark noise level of the camera to ensure that no clipping is present.

Gain

Gain is used to increase the brightness of image data. It consists of a multiplication factor, as indicated in Figure 24. For monochrome cameras, gain adjustment is applied to all sensor array output rows; for the multifield/color cameras, gain can be applied to each color array output row individually or to all rows. Row Gain can be adjusted from 1 to ~4x. System Gain can be adjusted from 1 to 10x.

Establishing the Optimal Response

An important camera performance characteristic is its responsivity and associated noise level at the system's maximum line rate and with the required illumination and lens configuration.

Responsivity and noise performance can be assessed using a stationary, plain white target under bright field illumination. However, to accurately evaluate the camera's real-life performance, it is important that the setup is representative of the final system configuration.

The ideal test setup meets the following conditions:

- The lens is in focus, at the desired magnification and with the desired aperture.
- The illumination intensity is equal to that of the inspection system and aligned with the camera's field of view.
- The camera is operated with an exposure time that will allow the maximum line rate of the system to be achieved. The camera's internal line rate generator and exposure control can be used for a stationary target.

Exposure Control by Light Source Strobe

Related Features: outputLineSource, outputLinePulseDelay, outputLinePulseDuration, LineInverter

NOTE
TDI sensors do not have exposure control built in. Pixels continuously convert photons to electrons. After receiving a line trigger, the camera instructs the sensor to execute the analog read operation. During this time incoming photons are still detected and may associate with the current or subsequent line. This effect is negligible when constant lighting is used. When using strobed lighting, assure a minimum delay of 1.4 µs between the rising edge of EXSYNC and powering-on of the light source.

Using the GPIO controls the camera can be set up to strobe a light source, effectively giving exposure control. Figure 25 shows an example of an output signal used as a strobe signal.

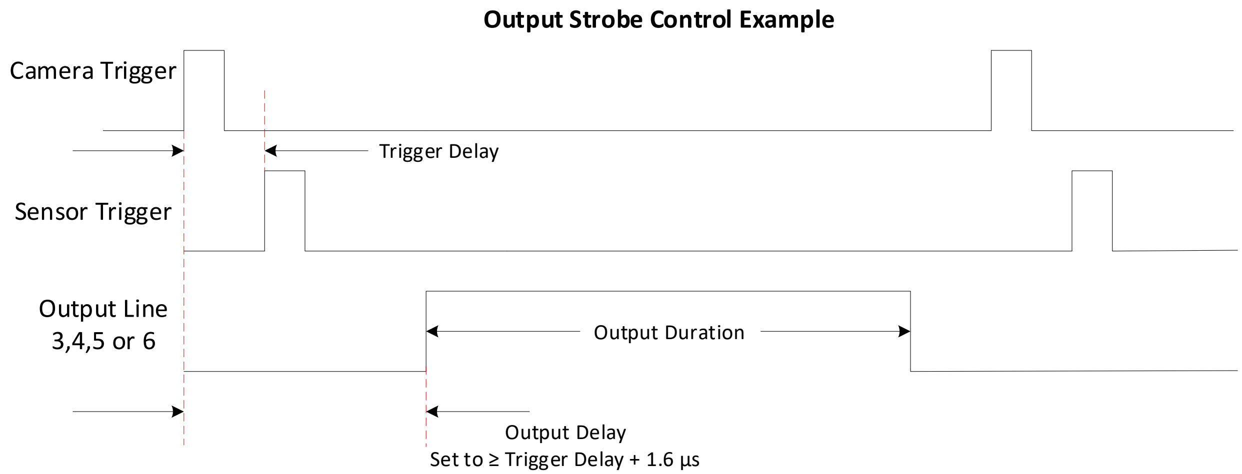


Figure 25: Strobe Timing

The camera logic enables simplified control of external, pulsed light sources to assure reliable timing association.

For this purpose, the trigger signal received from the system is managed by the camera to trigger sensor response and data processing. In addition, an Exposure Active signal is generated and can be supplied to any of the GPIO outputs. This allows triggering or timing external light sources.

The following diagram illustrates the logical control signal flow in the Linea HS series camera family.

The *outputLineSource*, *outputLinePulseDelay*, *outputLinePulseDuration* and *LineInverter* allow the user to control a strobe light source in order to coordinate with the sensor exposure.

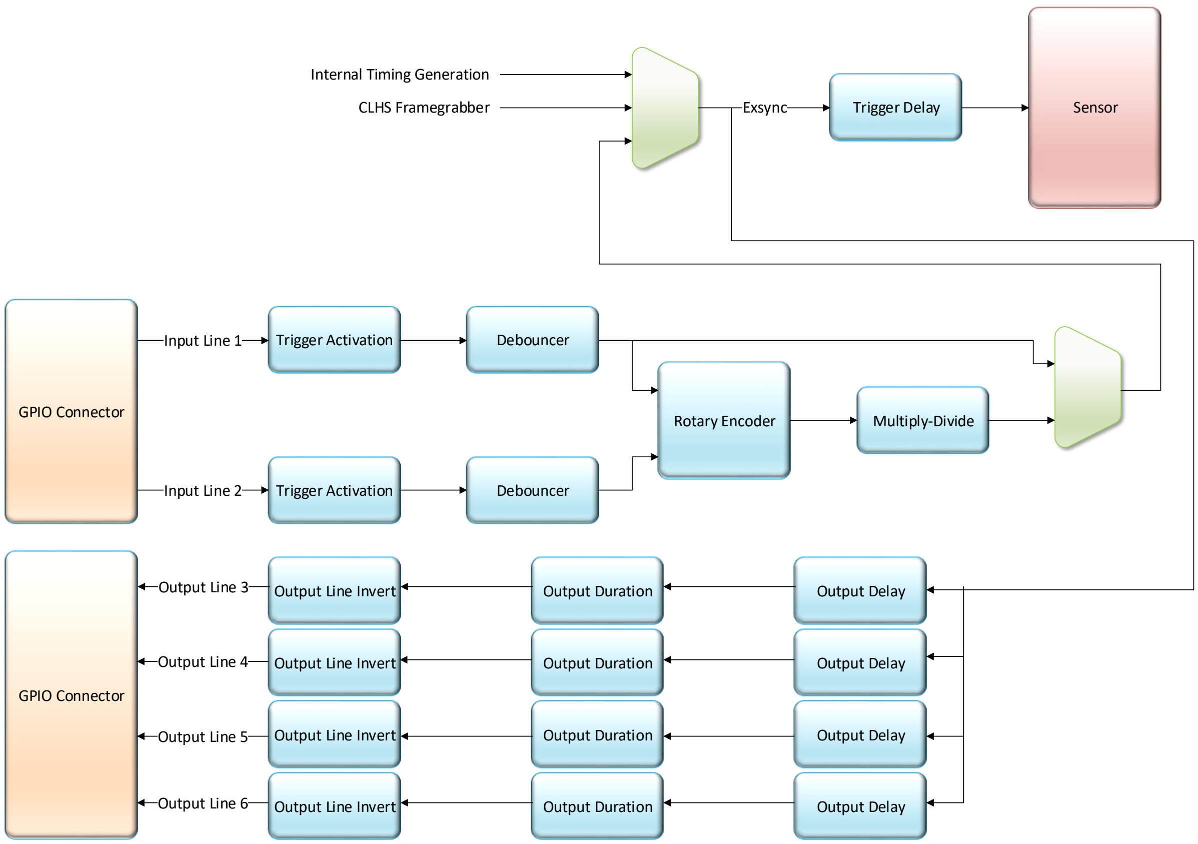


Figure 26: GPIO functionality block diagram

Flat Field Calibration

See the section Flat Field Category for GenICam features associated with this section and how to use them. See also Performing a Flat Field Calibration Using CamExpert for detailed procedure.

Related Features: flatfieldCalibrationFPN, flatfieldCalibrationPRNU, flatfieldCorrectionAlgorithm, flatfieldCalibrationTarget

Sensor pixels do not output the exact same value under uniform illumination due to small differences in the responsivity of individual pixels. This results in a non uniform but static pattern. Flat Field Correction (FFC) is used to adjust the gain and offset of each pixel individually so that all pixels of a sensor produce a uniform response under uniform lighting conditions.

FFC uses two coefficients per pixel to correct the pixel's gain and offset. FFC applies the following formula:

newPixelValue[x] = (sensorPixelValue[x] – FFCOffset[x]) * FFCGain[x]

where:

- [**x**] is the pixel coordinate (see *flatfieldCorrectionPixelXCoordinate*).
- **newPixelValue** is the pixel value after Flat Field Correction is applied.
- **sensorPixelValue** is the pixel value before Flat Field Correction is applied.
- **FFCOffset** is the offset coefficient value to subtract from the sensorPixelValue.
- **FFCGain** is the gain coefficient value that is multiplied with the sensorPixelValue.

FFC is achieved by performing FPN (fixed pattern noise) calibration and PRNU (photo-response non-uniformity) calibration (see Performing a Flat Field Calibration Using CamExpert).

IMPORTANT

It is imperative to perform FPN and PRNU calibration under the same imaging conditions as the camera is to be used in. Line rate and internal camera temperature need to be similar to the expected operating conditions.

Flat Field Calibration Algorithm

Typically, FFC will adjust all pixels to have the same value as the peak pixel value or as a given target level. The Calibration Algorithm parameter (flatfieldCorrectionAlgorithm feature) proposes four options:

- **Peak**. Each pixel is gained up to the peak pixel. Preferred option.
- **Set Target**. Each pixel is gained up to the value set in Flat Field Calibration Target. Preferred option.
- **Peak, Image Filtered**. A low pass filter is applied to the average line values before calculating the coefficients using the Peak algorithm. Use if the calibration target is not uniformly white or if it is not possible to defocus the image. Because of the low pass filter, this algorithm is not able to correct pixel-to-pixel variations.
- **Set Target, Image Filtered**. A low pass filter is applied to the average line values before calculating the coefficients using the Set Target algorithm. Use if the calibration target is not uniformly white or if it is not possible to defocus the image. Because of the low pass filter, this algorithm is not able to correct pixel-to-pixel variations.

NOTE

This filter is only capable of compensating for small, occasional contaminants. It will not overcome large features in a target's texture.

The cameras have multiple FFC user memory spaces to hold calibration data, allowing users to store FFC data for different optimized exposure setups.

NOTE

The Linea camera has many different modes of operation. It is strongly recommended that the camera be flat fielded for the intended mode of operation.

The FFC procedure is detailed in section Performing a Flat Field Calibration Using CamExpert.

Dark Current Correction

Related Features: flatfieldCalibrationFPN, flatfieldCorrectionAlgorithmFPN

Sweeping line rates at the lower line rates of camera operation may cause unwanted noise to be introduced. This is due to the dark current in the sensor, which at low line rates and high temperatures will be more pronounced.

Dark noise (FPN) calibration is done at a certain line rate. However, if the camera is operated using sweeps or changes in line rates, then the calibration will not be perfect across the line rate range. For example, when sweeping the line rate between 4 kHz and 60 kHz, if one calibrates at either end (4 or 60 kHz), the output won't be perfectly corrected at the other end because the correction coefficients were created for a different line rate.

The FPN Calibration Algorithm feature (flatfieldCorrectionAlgorithmFPN) includes a *Dark Current* option whose goal is to correct for the sensor's dark current at lower line rates (i.e., 4-60 kHz) by applying a calculated scale factor internally.

Note that:

- Factory standard FPN calibration is done at 100 kHz.
- Dark current calibration will subtract a scaled FPN value for line rates between 4 and 60 kHz; above or below this line rate, the coefficients at closest limit will be applied.
  - For instance, at 1.9 kHz, the coefficients applied will be the same as the ones at 4 kHz.
  - At line rates above 60 kHz, it is OK to use standard FPN correction, as dark current is not as pronounced at higher line rates.

To perform flat field calibration at low frame rate

1. Wait until the camera is at a steady state operating temperature (e.g., 55°C).
2. Block light from entering the sensor (i.e., close shutter or cover lens).
3. In the FlatField category, set the FPN Calibration Algorithm feature value to Dark Current.
4. Next to Calibrate FPN, click Press.
5. Proceed with PRNU calibration (as described in Performing Flat Field Calibration using CamExpert), if needed.
6. Save the coefficients in a user set.

Caution

Since the correction coefficients are generated at a particular temperature (e.g., 55°C), if the camera is cooled down, the coefficients will overcorrect the output, which may cause the output to go below 0 DN in a dark environment.

- You can see this by changing the "Black Level" feature to the maximum value and observing some pixel values are less than the Black Level.
- The output will become normal again as the camera heats up to the temperature at which it was calibrated.

Example

- Calibrate dark current correction at 55°C. Output looks good, everything works as expected.
- Camera is then powered off and allowed to cool down.
- Camera is powered on and allowed to reach 30°C, with dark current correction enabled and using the coefficients created previously at 55°C.

- Camera output is now at 0 DN in dark; this is due to the coefficients over correcting the pixels.
- The user can either:
  - Wait until the camera reaches its steady state (55°C), at which point the output will be back to normal.
  - Recalibrate at the current temperature so the output will be the proper DN. However, it is recommended to calibrate at the steady state temperature for best performance.

Saving & Loading a PRNU Set Only

See the Flat Field Category for GenICam features associated with this section and how to use them.

Related Features: flatfieldCorrectionCurrentActiveSet, flatfieldCalibrationSave, flatfieldCalibrationLoad

A user set includes all the configuration settings (such as gain, line rate), FPN (Fixed Pattern Noise) and PRNU (Photo Response Non-Uniformity) coefficients, and LUT. Loading a complete user set takes approximately 1 second, but loading only the PRNU coefficients takes less than 200 milliseconds.

Use the PRNU Current Active Set parameter to select the set you want to save or load. There are 17 sets available—16 user and 1 factory. The *Factory Set* is read-only and contains all "1"s. Loading the *Factory Set* is a good way to clear the user PRNU.

Custom Flat Field Coefficients

Flat Field (PRNU) coefficients can be downloaded from the camera, customized and uploaded back to the camera.

NOTE
Customization requires a parameter viewer file. Contact Teledyne DALSA Technical Support.

To upload or download coefficients

1. Open the File Access Control dialog.
2. In the **Type** list select *Miscellaneous.*
3. In the **File Selector** list select *Current PRNU*.
4. Select Upload (to Camera) or Download (from Camera).

The PRNU coefficients are used by the camera as soon as they are uploaded. To avoid loss at power up or while changing row settings, the uploaded coefficients should be saved to one of the available user sets.

Flat Field Calibration Regions of Interest

See the section Flat Field Category for GenICam features associated with this section and how to use them.

Related Features: flatfieldCalibrationROIOffsetX, flatfieldCalibrationROIWidth

There are occasions when the camera’s field of view includes areas that are beyond the material to be inspected.

This may occur when cameras image off the edge of a panel or web or when an inspection system is imaging multiple lanes of material. The edge of the material or area between lanes may not be illuminated in the same way as the areas of inspection and, therefore, will cause problems with a flat field calibration.

The camera can accommodate these “no inspection zones” by defining a Region of Interest (ROI) where flat field calibration is performed. Image data outside the ROI is ignored by the flat field calibration algorithm. The ROI is selected by the user and with the pixel boundaries defined by the pixel start address and pixel width and then followed by initiating flat field calibration for that region. Once set, another ROI can be defined and flat field calibrated.

Operating Backside Illumination Cameras at Low Line Rates

Related Features: flatfieldCalibrationFPN, flatfieldCorrectionAlgorithmFPN

Higher FPN is expected in backside illuminated cameras, such as models HL-HM-09K40H-00-B and HL-HM-16K40H-00B, compared to frontside illuminated cameras. The difference in FPN is minimized at higher line rates but can become noticeable in the image at reduced speed. If the application requires operation at line rates below 30 kHz, it is recommended for the user to recalibrate the FFC coefficients.

Similarly, higher dark current is expected in model HL-HM-16K40H-00B compared to front side illuminated cameras. The difference in dark signal is minimized at higher line rates but can become noticeable in the image at reduced speed. If the application requires operation at line rates below 30 kHz, dark current correction is recommended. See Dark Current Correction.

Image Filters

See the section Flat Field Category for GenICam features associated with this section and how to use them.

Related Features: imageFilterMode, imageFilterType, imageFilterKernalSize, imageFilterContrastRatio

The camera has a selection of image filters that can be used to reduce image noise.

Use the *imageFilterMode* feature to turn the filtering on or off. Use the *imageFilterType* feature to read the type of filter that is being used.

Kernels

Use the *ImageFilterKernalSize* feature to select the number of pixels involved in the filter or the kernel size. The options are: 1 x 3 and 1 x 5 filter kernels.

The 1 x 3 and 1 x 5 filter kernels are “weighted average” filters.

The 1 x 3 filter kernel uses 75% of the original pixel and 12.5% of the adjacent pixels.

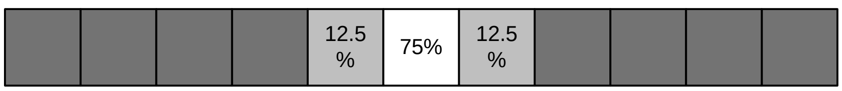


Figure 27: 1 x 3 kernel

The 1 x 5 filter kernel uses 50% of the original pixel and 12.5% of the adjacent two pixels on both sides of the original pixel.

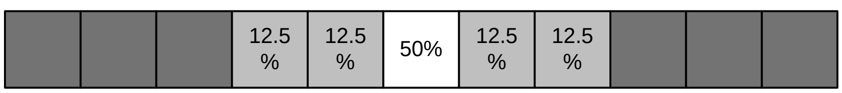


Figure 28: 1 x 5 kernel

Image Filter Contrast Ratio

The *imageFilterContrastRatio* feature is used to determine when to apply the filter to the image data. The control looks at the ratio between two adjacent pixels (prior to filter processing) on the sides of the relevant pixel and determines the difference or contrast between those pixels.

If the contrast ratio is greater than the value set by the user, then the filter automatically turns off for those two pixels. If the contrast is below the set value, then the pixel filter is applied.

A value of 0 will turn off the filters for all pixels and a value of 1 will keep the filter on for all pixels.

Binning

See the section Image Format Control Category for GenICam features associated with this section and how to use them.

Related Features: BinningHorizontal, BinningVertical, BinningHorizontalAvgEN, BinningVerticalAvgEN

In certain applications, lower image resolution may be acceptable if the desired defect detection can still be achieved. This accommodation can result in higher scan speeds, as the effective distance travelled per encoder pulse is increased due to the larger object pixel size. The camera has a binning feature that produces rapid adjustment to a lower object pixel resolution without having to change the optics, illumination intensity, or encoder pulse resolution.

Binning is a process whereby the charges of adjacent pixels are combined. The camera supports 1x, 2x, and 4x horizontal and vertical binning. Vertical binning is only available in TDI single plane mode.

Horizontal binning is achieved by summing adjacent pixels in the same row of the TDI array, vertical binning by summing adjacent pixels in the same column.

Because pixels are summed, the image gets brighter: 1x2 and 2x1 are twice as bright, 2x2 is four times as bright, and so forth. Binning 2x also halves the amount of image data out of the camera. This can be used to save processing bandwidth in the host and storage space by creating smaller image file sizes.

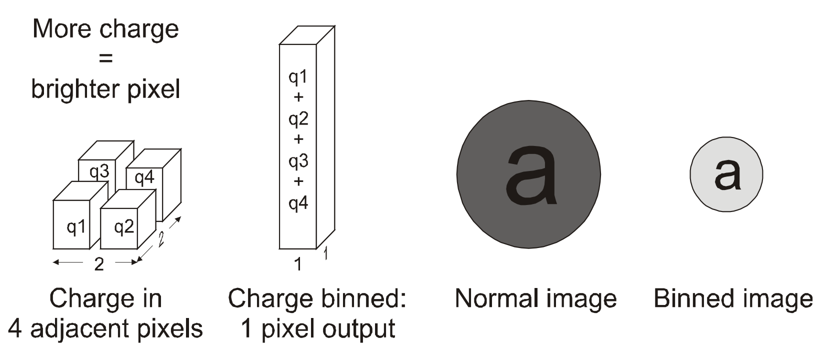


Figure 29: 2x2 Binning

Binning behaviour can be modified to average the pixels instead. The image will not be brighter, but the signal to noise ratio and effective full well will improve. Note that summing and averaging may be mixed, e.g., 2x2 binning may be set and vertical averaging enabled, resulting in summing horizontally and averaging vertically.

For the camera, the default binning value is 1 x 1, with averaging disabled.

NOTE

Binning parameters can only be changed when image transfer to the frame grabber is stopped. Refer to the Acquisition and Transfer Control Category for details on stopping and starting the acquisition.

Areas of Interest (AOIs)

See the section Image Format Control Category and Acquisition and Transfer Control Category for GenICam features associated with this section and how to use them

Related Features: multipleROICount, multipleROISelector, multipleROIOffsetX, multipleROIWidth, AcquisitionStart, AcquisitionStop and AcquisitionStatus

If the camera's field of view includes areas that are not needed for inspection (also refer to the description in the Flat Field Calibration Regions of Interest section), then the user may want to ignore this superfluous image data.

Eliminating unwanted image data reduces the amount of information the host computer needs to process. This may result in an increase of the allowable line rate when using 12-bit output data.

The camera can accommodate up to four AOIs. Image data outside the AOIs is discarded. Each AOI is user selected and its pixel boundaries defined. The camera assembles the individual AOI's into one contiguous image line with a width equal to the sum of the individual AOIs.

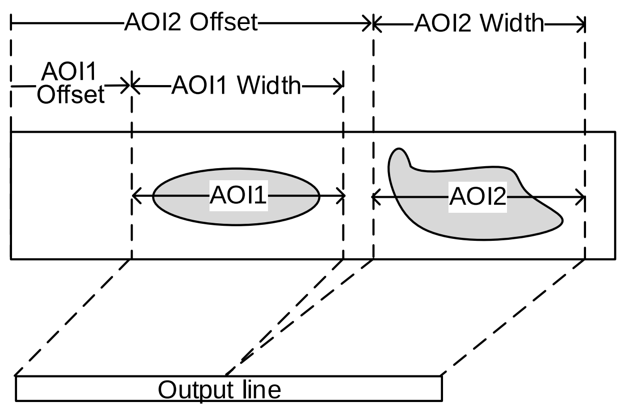


Figure 30: In this figure, objects to scan can be found within 2 regions of interest. The width of the output line is the sum of the width of the defined AOIs.

NOTE

The frame grabber will need to be adjusted to accommodate the smaller overall image width. As the host computer defined the size of each individual AOI, it will be able to extract and process each individual AOI from the single larger image.

Rules for Setting Areas of Interest

The rules are dictated by how image data is organized for transmission over the available CLHS data lanes. The camera/XML will enforce these rules, truncating entered values where necessary.

NOTE

AOI parameters can only be changed when image transfer to the frame grabber is stopped. Refer to the Acquisition and Transfer Control Category for details on stopping and starting the acquisition.

Rules below illustrate a 16k model; they may be adapted similarly to other size models.

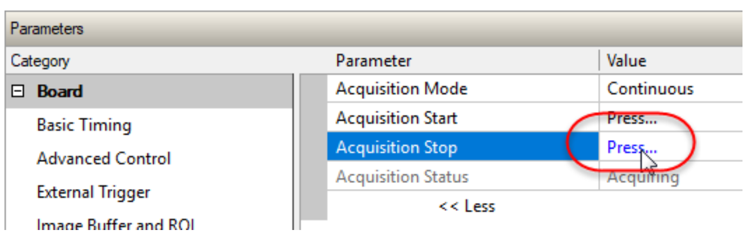
- Acquisition must be stopped to change the AOI configuration.
- 1-4 AOIs can be selected.
- Minimum width is 96 pixels per AOI.
  - The total width of all AOIs must be at least 1,024.
  - The total width of all AOIs must be no more than 16,384.
  - Maximum 8k bytes per CLHS lane.
- AOI width step size is 32 pixels.
- The offset of each AOI may range from 0 to 16,288 (16,384 – 96).
- Overlapping AOIs are allowed.
- Offset and width for individual AOI's will adjust one another.
  - For example, if an AOI has offset 0 and width 16,384, and the offset is changed to 4096, then the width will be adjusted to 12,288.
  - AOI's only affect one another by limiting the maximum width.
- AOIs are concatenated together in numerical order and sent to the frame grabber starting at column zero. If the AOI count is reduced to less than the current AOI count, the AOI selector will be changed to the largest of the new AOI count available.

Setting up Areas of Interest

Plan your AOIs using the rules above beforehand.

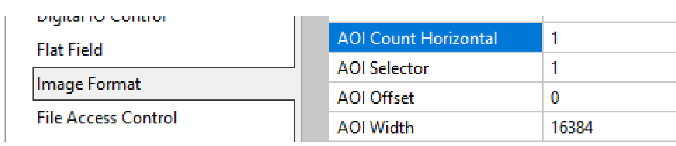
To setup an area of interest

1. In CamExpert, click Acquisition and Transfer Control > Acquisition Stop > *Press*.



   The Acquisition Status feature should now indicate *Not Acquiring*.

2. Set the number of AOIs using the AOI Count Horizontal (*multipleROICount*) feature. In CamExpert, AOI related features are available in the Image Format category.



3. Select the first AOI and set its offset and width. If the other AOIs are large you may need to select them first and reduce their widths.
4. Repeat for each AOI in turn.
5. Start acquisition, using Acquisition and Transfer Control > Acquisition Start > *Press*.

Enhancement of Interest (EOIs)

See the section Flat Field Category for GenICam features associated with this section and how to use them.

Related Features: enhancedImage, enhancedImageCount, enhancedImageSelector, enhancedImageWidth, enhancedImageOffset, enhancedImageGain

Enhancement of Interest (EOI) allow rapid gain and black level offset settings to be applied to up to 4 regions in the image. EOIs are supported in all imaging modes.

The EOI feature has been optimized to load in minimum time (~ 50 ms) by only applying a gain and offset on a region rather than per-pixel. EOIs are designed for applications where maximum line rate is a priority and pixel flatness for the region is tolerable, as compared to HDR mode or regional flat field correction (FFC), which provide per pixel adjustments.

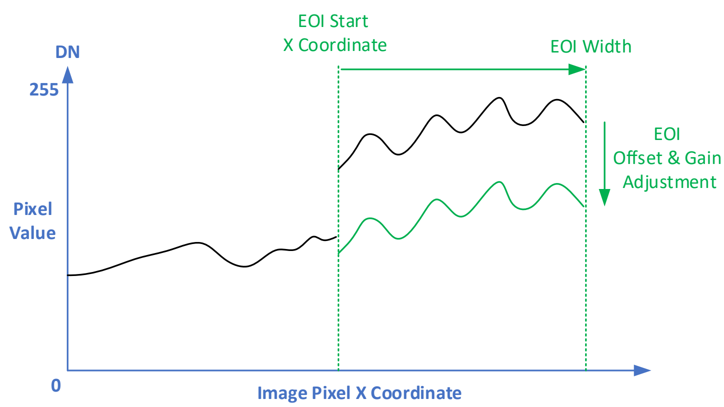


Figure 31: Enhancement of Interest

For example, if an image has regions that are highly reflective and other regions that are dark, the response in a region can be adjusted to flatten the output: HDR mode or regional FFC can compensate for this by applying a per-pixel based correction, providing the best result for a flat image. However, HDR limits the maximum line rate due to dual line acquisition, and FFC requires greater than 2 seconds to load user set coefficients and cannot be used to adjust to changes in image regions in real-time. Alternatively, EOIs provide the maximum line rate but with a flattened image region.

To set up EOIs

1. Set EOI > Off.
2. Set EOI Count.
3. For each EOI, set:
   a. EOI Start
   b. EOI Width
   c. EOI Offset
   d. EOI Gain
4. Set EOI > On.

NOTE
EOI parameter settings are not stored in the camera and are erased at camera reset.

Customized Linearity Response (LUT)

See the section Flat Field Category for GenICam features associated with this section and how to use them.

Related Features: lutMode and gammaCorrection

The camera allows the user to access a LUT (Look Up Table) to customize the linearity of how the camera responds. This can be done by uploading a LUT to the camera using the file transfer features, or by using the Gamma Correction feature.

NOTE

These features may only be useful in applications that use the frame grabber's Mono Image Buffer Format. (See section Changing Output Pixel Format.)

Gamma correction value can be adjusted by the user at any time.

When the LUT is enabled, there is no change in maximum line rate or amount of data output from the camera. The LUT can be used with any mode of the camera. Further, when the LUT is enabled, it is recommended that the fixed Offset available in the Camera Control category be set to zero.

To upload a LUT, use *File Access Control Category* > *Upload / Download File* > *Settings* and select *Look Up Table* to upload a file.

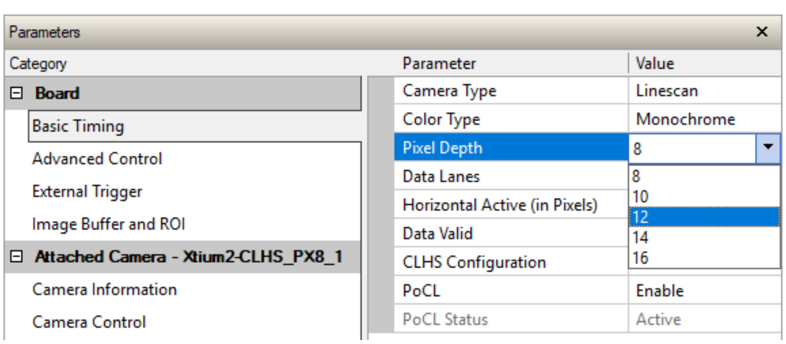
The file format is described in 03-084-20133 Linea Binary File Format which can be obtained from Teledyne DALSA Technical Support. This document also includes Excel spreadsheet examples.

How to Generate a LUT with CamExpert

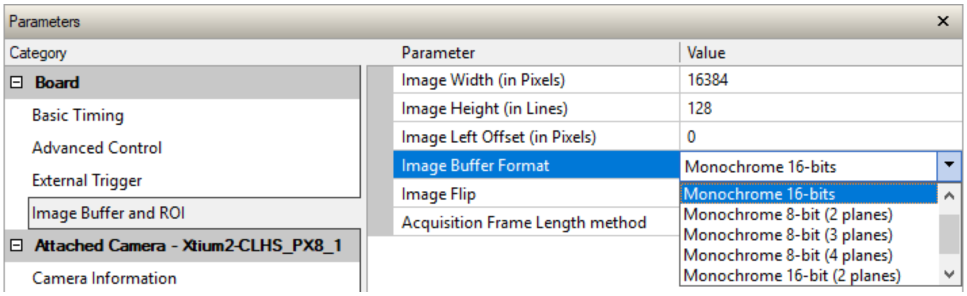
CamExpert can be used to create a LUT file. The camera uses a 12-bit in/12-bit out LUT (even if the camera is outputting an 8-bit image). CamExpert can be configured to create a 12-bit in/16-bit out LUT - the camera will convert it to the required format.

To generate a LUT

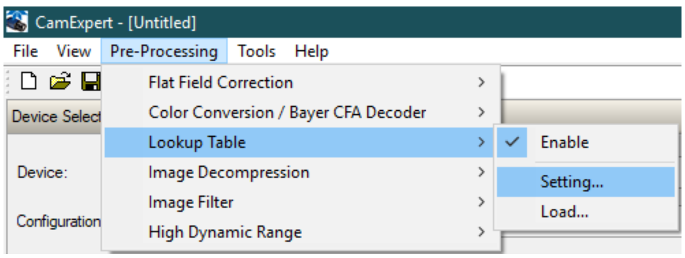
1. Open CamExpert (version 8.40 or higher).
2. Under Board, set Basic Timing > Pixel Depth to *12*.



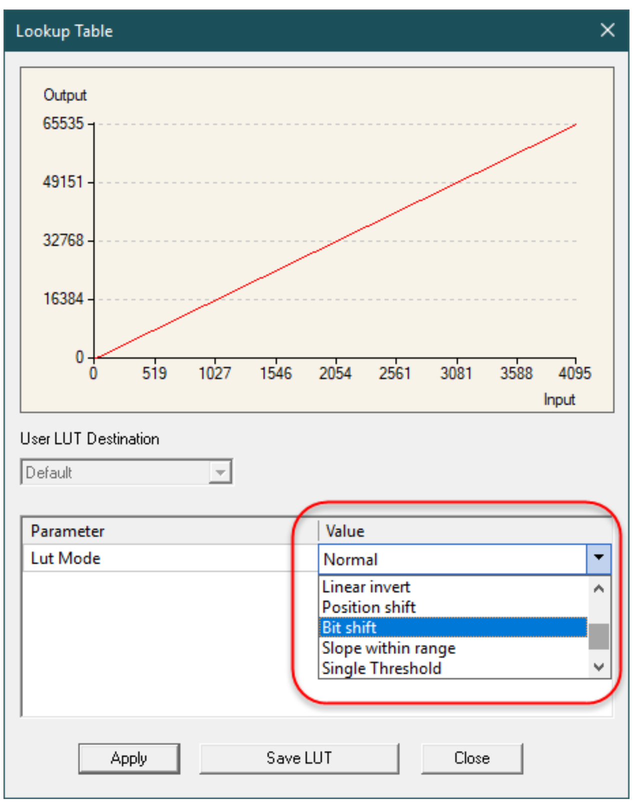
3. Under Board, set Image Buffer and ROI > Image Buffer Format to *Monochrome 16-bits*.



4. In CamExpert's menu bar, select Pre-Processing > Lookup Table, then
   - select **Enable**
   - select **Setting**.



5. In the Lookup Table dialog, under the **Value** column, select the output LUT by scrolling through the different options. Configure any required parameters (for example, Gamma correction requires a Correction factor).



6. Click **Save LUT** to create a LUT file.

7. This file can be loaded into the camera using the File Access features. It is saved with the current Load/Save Configuration user set; ensure that a user set and not the factory set is selected, otherwise the upload will fail.
8. Deselect the Lookup Table > Enable.
9. Return the Board parameters to original settings :
    - Basic Timing > Pixel Depth = *8*
    - Image Buffer and ROI > Image Buffer = *8-bits*.

IMPORTANT

- The frame grabber must be configured mono 12-bits in, 16-bits out.
- In the Parameters pane, a frame grabber feature must be selected, not a camera feature.
- The Lookup table must be enabled to be created but should be disabled to use the camera LUT.

Changing Output Pixel Format

See the section Image Format Control Category for GenICam features associated with this section and how to use them

Related Feature: PixelFormat, AcquisitionStart and AcquisitionStop

The camera can output video data as 8-bit or 12-bit.

Use the Mono8 Pixel Format to process image data as one or more separate image planes.

The frame grabber's Basic Timing > Pixel Depth and Color Type features should correspond to the camera's image format.

NOTE

Pixel Format and associated features can only be changed when the image transfer to the frame grabber is stopped. Use the commands in the Acquisition and Transfer Control Category.

To change pixel format from 8-bit to 12-bit

1. In Acquisition and Transfer Control category, click **Press** next to Acquisition Stop.
2. In Image Format category, set Pixel Format to Mono 12 (or BGR 12 if supported).
3. In Basic Timing category of the frame grabber, set Pixel Depth to 12.
4. In Acquisition and Transfer Control category, click **Press** next to Acquisition Start.

Saving & Restoring Camera Setup Configurations

See the section Camera Information Category for GenICam features associated with this section and how to use them

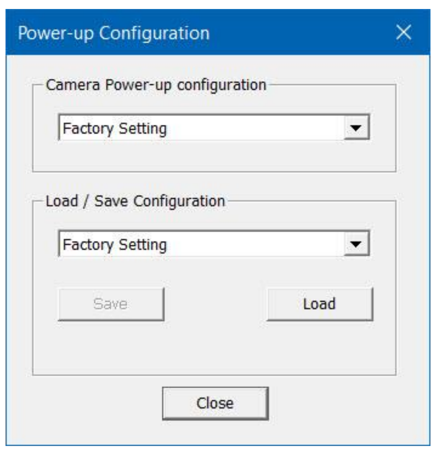
Related Features: UserSetSelector, UserSet1 thru UserSet16, UserSetDefaultSelector, UserSetLoad, UserSetSave

An inspection system may use multiple illumination, resolution and responsivity configurations in order to cover the different types of inspection it performs. The camera includes 16 user sets where camera setup information can be saved to and restored from—either at power up or dynamically during inspection.

User sets and factory settings are saved in non-volatile memory on the camera. CamExpert provides a dialog that combines the features to select the camera settings at power-up, to save the current camera settings in a user set, or to load a saved set and make it active.

To open the Power-up Configuration dialog

- In the Camera Information Category, next to Power-up Configuration click **Setting**.



Camera Power-up Configuration

The **Camera Power-up Configuration** list allows the user to select the camera configuration to load when the camera is powered-up or reset (see UserSetDefaultSelector). The user chooses from the factory set or one of the user sets.

Load / Save Configuration

The **Load / Save Configuration** list allows the user to change the camera configuration any time after a power-up (see UserSetSelector).

To reset the camera to factory configuration

- Select *Factory Setting* and click **Load**.

To save the current camera configuration

- Select one of the user sets and click **Save**.

To restore a previously saved configuration

- Select a user set and click **Load**.

NOTE
Changes made after a configuration is loaded will be lost if the camera resets, is powered down or loses power, unless the current configuration is saved again.

TIP
By default, the user sets contain the factory settings.

Operational Reference

Camera Feature Categories

This chapter lists the available GenICam camera features. The user may access these features using the CamExpert interface or equivalent GUI.

Many of the features shown in CamExpert may be changed directly in CamExpert or programmatically via an imaging application. Their availability may depend on other feature settings, and while some features are read-only (RO), others may be changed even during acquisition. Note that features shown by CamExpert may change with different device models implementing different sensors, image resolutions, and color versions; that is, a specific camera model may not support the full feature set defined in a category and described here.

CamExpert presents camera features based on their visibility (view) attribute. Quick Visibility level selection can be made via controls below each Category Parameter list [<< Less   More >>]. The user can also choose the Visibility level from the *View · Parameters Options* menu.

The following description tables list and describe the device features along with their view level attribute. The View column also indicates whether the parameter is a member of the DALSA Features Naming Convention (using the tag **DFNC**), versus the GenICam Standard Features Naming Convention (SFNC tag not shown).

Features listed in the description table but tagged as *Invisible* are typically reserved for Teledyne DALSA support or third-party software usage, and not typically required by end user applications.

NOTE

The CamExpert screen captures are shown for illustrative purposes and may not entirely reflect the features and parameters available from the camera model used in your application.

The features described below may not all be available in your camera model.

Camera Information Category

Camera information can be retrieved via a controlling application. Parameters such as camera model, firmware version, etc., uniquely identify the connected camera and are typically read-only.

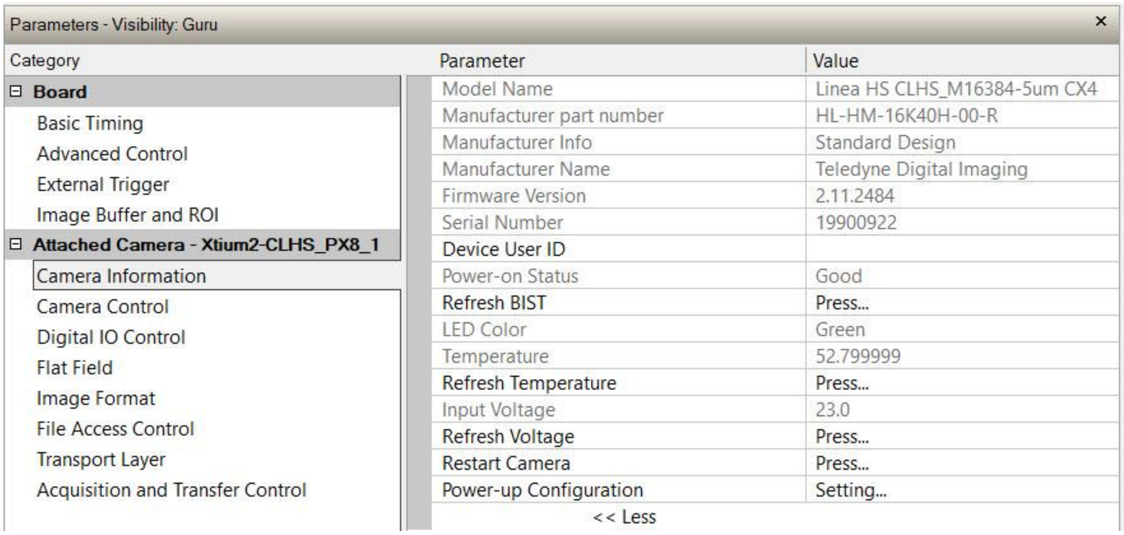


Figure 32: Example CamExpert Camera Information Panel

Camera Information Feature Descriptions

Display Name	Feature	Description	View
Model Name	DeviceModelName	Displays the device model name. (RO)	Beginner
Manufacturer part number	deviceManufacturersPartNumber	Displays the manufacturer part number. (RO)	Beginner DFNC
Manufacturer Info	DeviceManufacturerInfo	Displays extended manufacturer information about the device. Indicates if it is a standard product or a custom camera. (RO)	Beginner
Manufacturer Name	DeviceVendorName	Displays the device vendor name. (RO)	Beginner
Firmware Version	DeviceFirmwareVersion	Displays the currently loaded firmware version. (RO)	Beginner
Serial Number	DeviceSerialNumber	Displays the factory set serial number of the device. (RO)	Beginner
Device User ID	DeviceUserID	Stores a user-programmable identifier. The maximum character limit is device-specific. The default factory setting is the camera serial number. (RW)	Beginner
Power-on Status	deviceBISTStatus	Reports the status of the device's Built-In Self Test (BIST). Possible return values are device-specific. (RO) See Built-In Self-Test Codes for status code details.	Beginner DFNC
Refresh BIST	deviceBIST	Performs an internal test to determine the status of the device. (W)	Beginner DFNC

Display Name	Feature	Description	View
LED Color	deviceLEDColorControl	Reports the LED color.	Beginner DFNC
Off	*Off*	*Off*	
Red	*Red*	*BIST error.*	
Green	*Green*	*Operational.*	
Waiting for EXSYNC	*Fast_Green*	*4 Hz Green.*	
Thermal Shutdown	*Medium_Red*	*2 Hz Red.*	
Looking for link	*Slow_Green*	*1 Hz Green.*	
Busy	*Medium_Orange*	*2 Hz Orange.*	
Temperature	DeviceTemperature	Reports the internal temperature of the device in degrees Celsius. (RO)	Beginner DFNC
Refresh Temperature	refreshTemperature	Updates the temperature readout.	Beginner DFNC
Input Voltage	deviceInputVoltage	Reports the current input voltage of the device. (RO)	Beginner DFNC
Refresh Voltage	refreshVoltage	Updates the input voltage.	Beginner DFNC
Restart Camera	DeviceReset	Resets the device to its power up state.	Beginner
Power-up Configuration			
Power-on User Set	UserSetDefaultSelector	Selects the camera configuration set to load on camera power up or reset. The camera configuration sets are located on the camera in non-volatile memory. (RW) See Camera Power-Up Configuration Selection Dialog.	Beginner
Factory Set	*Factory*	*Load factory default feature settings on power up or reset.*	
UserSet1, …, UserSet16	*UserSet1, …, UserSet16*	*Load the selected UserSet on power up or reset.*	
Current User Set	UserSetSelector	Selects the camera configuration set to load feature settings from or save current feature settings to. The Factory set contains default camera feature settings. User camera configuration sets contain feature settings previously saved by the user. (RW)	Beginner
Factory Set	*Factory*	*Default camera feature settings.*	
UserSet 1, …, UserSet 16	*UserSet1, …, UserSet16*	*Current feature settings are loaded from/saved to the selected UserSet.*	
Load User Set	UserSetLoad	Loads the camera configuration set specified by the User Set Selector parameter to the camera and makes it active. (W)	Beginner
Save User Set	UserSetSave	Saves the current camera configuration to the user set specified by the User Set Selector parameter. The user sets are located on the camera in non-volatile memory. (W)	Beginner

Built-In Self-Test Codes (BIST)

In the Camera Information screen shot example above, the Power-On Status is showing *Good*, indicating that the camera powered up without any problems.

Details of the BIST codes can be found in section Built-In Self-Test Codes of Troubleshooting Guide.

Camera Power-Up Configuration Selection Dialog

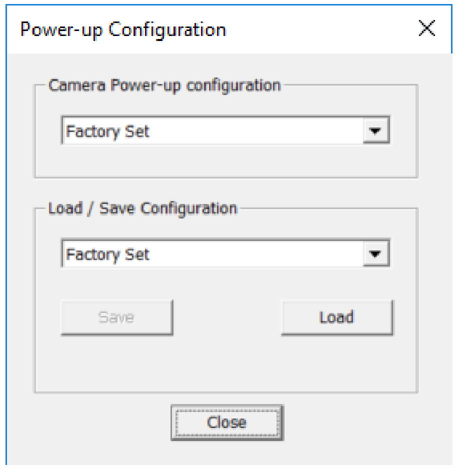


Figure 33: CamExpert Power-Up Configuration Dialog

CamExpert provides a dialog that combines the GenICam features used to select the camera's power-up state and for the user to save or load a camera state as a specific user set that is kept in the camera's non-volatile memory.

See section Saving & Restoring Camera Setup Configurations for details.

Camera Control Category

The camera control category, as shown by CamExpert, groups control parameters such as line rate, exposure time, scan direction, and gain.

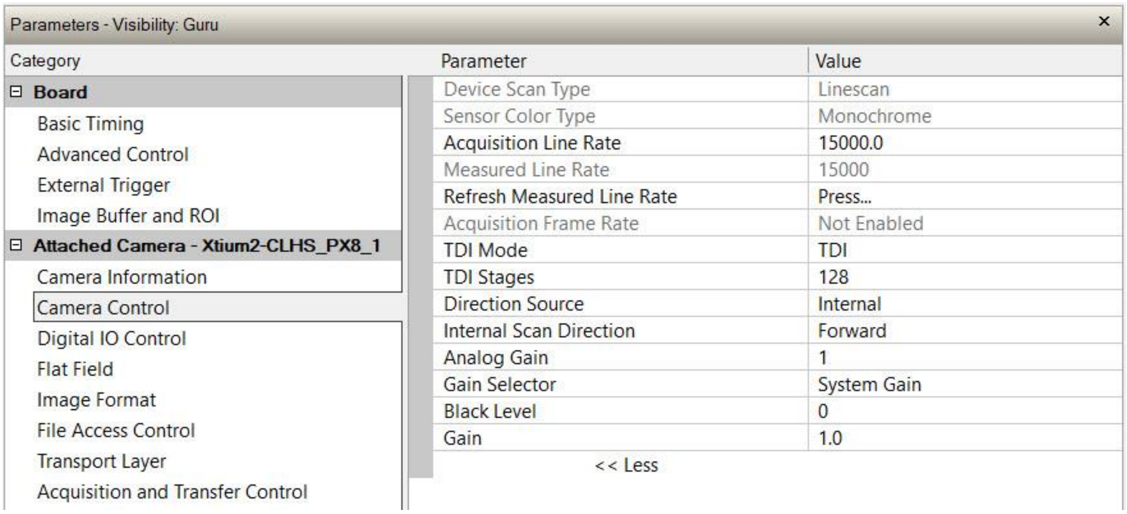


Figure 34: Camera Control Panel

Camera Control Feature Descriptions

Display Name	Feature	Description	View
Device Scan Type *Linescan*	DeviceScanType *Linescan*	Scan type of the sensor. *Linescan sensor.*	Beginner
Sensor Color Type *Monochrome*	sensorColorType *Monochrome*	Sensor color type. *Monochrome sensor.*	Beginner DFNC
Acquisition Line Rate	AcquisitionLineRate	Specifies the camera line rate, in Hz, when Trigger Mode is set to *Internal*. Note that any user entered value is automatically adjusted to a valid camera value.	Beginner
Measured Line Rate	measuredLineRate	Returns the line rate, in Hz, provided to the camera by either internal or external source. (RO)	Beginner DFNC
Refresh Measured Line Rate	refreshMeasuredLineRate	Updates the line rate provided to the camera by either internal or external sources.	Beginner DFNC
Acquisition Frame Rate	AcquisitionFrameRate	Returns the camera frame rate, in Hz. (Available in TDI Area mode).	Beginner

Display Name	Feature	Description	View
TDI Mode	sensorTDIModeSelection	Selects the TDI mode for the sensor, which specifies how to combine the rows for processing.	Beginner DFNC
TDI	*Tdi*	*Output one row from the main TDI array.*	
TDI HDR	*Tdi2Array*	*High Dynamic Range mode. Output two rows, one from each of the main and secondary array with the responsivity ratio selectable.*	
TDI HFW	*TdiHfw*	*High Full Well mode. Output two rows, one from each of the main and secondary array, both set to 64 stages.*	
TDI Area	*TdiArea*	*Output the entire 128 row main array with an FVAL.*	
TDI Stages	sensorTDIStagesSelection	Selects the number of rows to integrate in the TDI main array. Ratios control the number of rows used in main and secondary arrays in modes such as TDI HDR and TDI HFW.	Beginner DFNC
1:1	*Ratio1*	*One line from each array. (TDI HFW mode.)*	
2:1	*Ratio05*	*Two rows from main array for each row in secondary array. (TDI HDR mode.)*	
4:1	*Ratio025*	*Four rows from main array for each row in secondary array. (TDI HDR mode.)*	
8:1	*Ratio0125*	*Eight rows from main array for each row in secondary array. (TDI HDR mode.)*	
64	*Lines64*	*64 rows. (TDI mode.)*	
128	*Lines128*	*128 rows. (TDI mode.)*	
Direction Source	sensorScanDirectionSource	Selects the source that controls a change in the scan direction.	Beginner DFNC
Internal	*Internal*	*Scan direction is controlled by the SensorScanDirection feature.*	
Line 2	*GPIO2*	*Scan direction is controlled by Pin 6 (Low: forward, high: reverse). Available when TriggerSource is not Encoder.*	
RotaryEncoder	*Encoder*	*Scan direction is controlled by a rotary encoder. Available when TriggerSource is Encoder and rotaryEncoderOutputMode is Motion (see Digital IO Control category).*	
Internal Scan Direction	sensorScanDirection	Controls the scan direction when *ScanDirectionSource* is set to Internal.	Beginner DFNC
Forward	*Forward*	*Forward scan direction (from sensor top to bottom).*	
Reverse	*Reverse*	*Reverse scan direction (from sensor bottom to top).*	
Analog Gain	AnalogGain	Analog gain.	Beginner
1	*One*	*No gain applied.*	
2	*Two*	*2x analog gain applied.*	
4	*Four*	*4x analog gain applied.*	
8	*Eight*	*8x analog gain applied.*	
Gain Selector	GainSelector	Selects the channel to which gain and black level offset are applied.	Beginner
All Rows	*All*	*Gain and offset applied to all channels.*	
System Gain	*System*	*System gain will apply the gain value while maintaining the existing gain ratios.*	
Black Level	BlackLevell	A signed offset added to the output. DN_out = (DN_in + Black_Level) * Gain.	
Gain	Gain	Video signal multiplier.	Beginner

Digital IO Control Category

The camera's Digital IO Control category is used to configure camera acquisition using triggers and input/output signals.

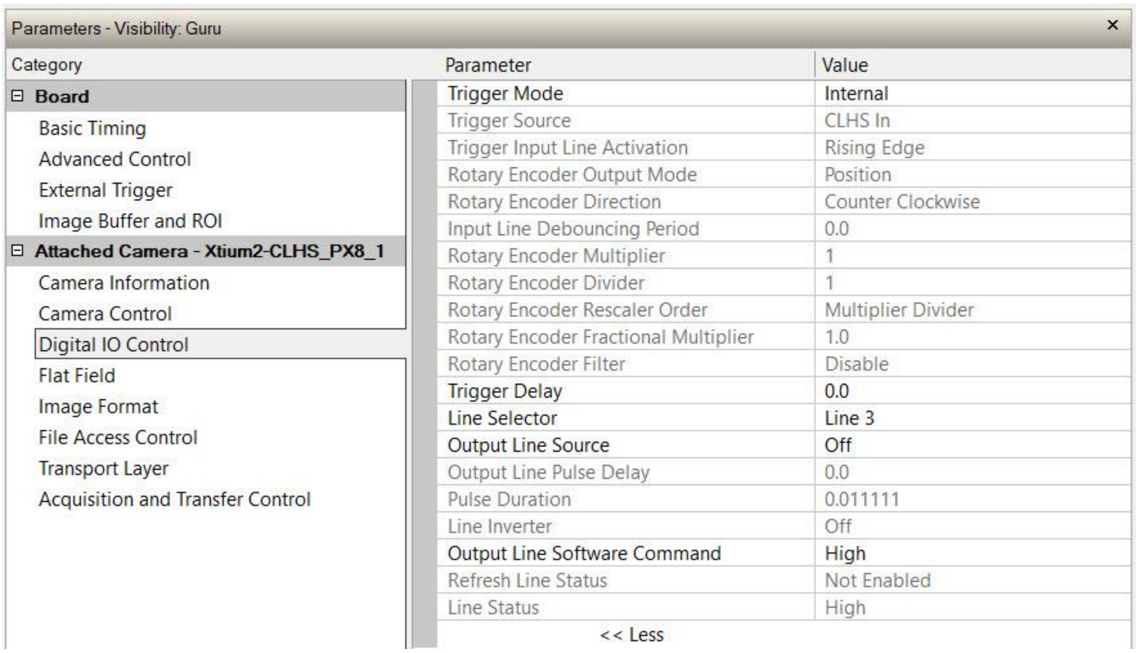


Figure 35: Digital I/O Control Panel

Digital IO Control Feature Descriptions

Display Name	Feature	Description	View
Trigger Mode	TriggerMode	Controls whether the external trigger is active.	Beginner
Internal	*Internal*	*Line rate is controlled with the AcquisitionLineRate feature.*	
External	*External*	*Trigger comes from CLHS (frame grabber), GPIO or rotary encoder.*	
Trigger Source	TriggerSource	Determines the source of the external trigger. Trigger Mode must be set to *External*.	Beginner
CLHS In	*CLHS*	*Source of trigger is from the frame grabber over CLHS.*	
Rotary Encoder	*Encoder*	*Trigger source is from the two shaft encoder inputs.*	
Line 1	*GPIO1*	*Trigger source is from Line 1 of the GPIO connector.*	
Trigger Input Line Activation	TriggerActivation	Edge of the input signal that will trigger the camera.	Beginner
Rising Edge	*RisingEdge*	*The trigger is considered valid on the rising edge of the line source signal (after any processing by the line inverter module).*	
Falling Edge	*FallingEdge*	*The trigger is considered valid on the falling edge.*	
Any Edge	*AnyEdge*	*The trigger is considered valid on any edge.*	

Display Name	Feature	Description	View
Rotary Encoder Output Mode	rotaryEncoderOutputMode	Specifies the conditions for the rotary encoder interface to generate a valid encoder output signal.	Beginner DFNC
Position	*Position*	*Triggers are generated at all new position increments in the selected direction. If the encoder reverses, no trigger events are generated until it has again passed the position where the reversal started.*	
Motion	*Motion*	*Triggers are generated for all motion increments in either direction.*	
Rotary Encoder Direction	rotaryEncoderDirection	Specifies the phase which defines the encoder forward direction.	Beginner DFNC
Counter Clockwise	*CounterClockwise*	*Inspection goes forward when the rotary encoder direction is counterclockwise (phase A is ahead of phase B).*	
Clockwise	*Clockwise*	*Inspection goes forward when the rotary encoder direction is clockwise (phase B is ahead of phase A).*	
Input Line Debouncing Period	lineDebouncingPeriod	Specifies the minimum delay (µs) before an input line voltage transition is recognized as a signal transition.	Beginner DFNC
Rotary Encoder Multiplier	rotaryEncoderMultiplier	Specifies a multiplication factor for the rotary encoder output pulse generator.	Beginner
Rotary Encoder Divisor	rotaryEncoderDivider	Specifies a division factor for the rotary encoder output pulse generator.	Beginner DFNC
Rotary Encoder Rescaler Order	rotaryEncoderRescalerOrder	Specifies the order in which the multiplier and divider are applied. For details, see <u>Application Note for Multiplier and Divider</u>.	Guru DFNC
Multiplier Divider	*multiplierDivider*	*The signal is multiplied before being divided.*	
Divider Multiplier	*dividerMultiplier*	*The signal is divided before being multiplied*	
Fractional Multiplier Divider	*fractionalMultiplierDivider*	*The signal is multiplied by the fractional number before being divided.*	
Rotary Encoder Fractional Multiplier	rotaryEncoderFractionalMultiplier	Specifies a fractional multiplication for the rotary encoder output pulse generator.	Beginner DFNC
Rotary Encoder Filter	rotaryEncoderFilter	Rotary Encoder Trigger Filter value.	Beginner DFNC
Trigger Delay	TriggerDelay	Specifies the delay in microseconds (µs) to apply after the trigger reception before activating it.	Beginner
Line Selector	LineSelector	Selects the physical line (or pin) of the external device connector to configure.	Beginner
Line 1	*GPIO1*	*GPIO 1 (input 1).*	
Line 2	*GPIO2*	*GPIO 2 (input 2).*	
Line 3	*GPIO3*	*GPIO 3 (output 1).*	
Line 4	*GPIO4*	*GPIO 4 (output 2).*	
Line 5	*GPIO5*	*GPIO 5 (output 3).*	
Line 6	*GPIO6*	*GPIO 6 (output 4).*	
Output Line Source	outputLineSource	Selects which features control the output on the selected line.	Beginner DFNC
Off	*Off*	*Line output level is controlled by the outputLineSoftwareCmd feature.*	
On	*On*	*Line output level is controlled by the outputLinePulseDelay, outputLinePulseDuration, and LineInverter features.*	
Output Line Pulse Delay	outputLinePulseDelay	Sets the delay (µs) before the output line pulse signal.	Beginner DFNC
Pulse Duration	outputLinePulseDuration	Sets the width (duration) of the output line pulse in microseconds (µs).	Beginner DFNC

Display Name	Feature	Description	View
Line Inverter	LineInverter	Controls whether to invert the polarity of the selected input or output line signal.	Beginner
Off	*Off*	*Leave signal unchanged.*	
On	*On*	*Invert line signal.*	
Output Line Software Command	outputLineSoftwareCmd	Sets the GPIO out value when outputLineSource is off.	Expert DFNC
Low	*Low*	*Output line is low.*	
High	*High*	*Output line is high.*	
Refresh Line Status	refreshLineStatus	Updates the LineStatus feature.	Beginner DFNC
Line Status	LineStatus	Returns the current state of the GPIO line selected with the LineSelector feature. (RO)	Expert

Flat Field Category

The Flat Field controls, group parameters used to control the FPN (fixed pattern noise) and PRNU (photo-response non-uniformity) calibration process.

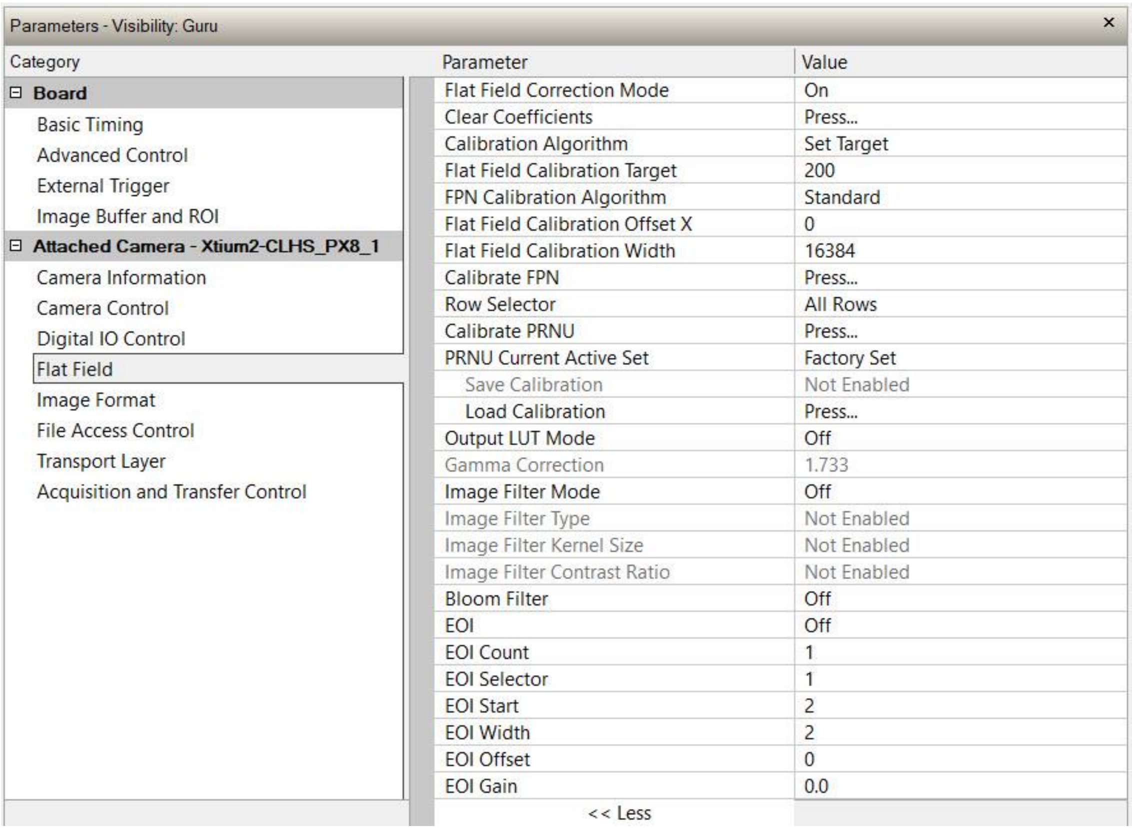


Figure 36: Flat Field Panel

Flat Field Control Feature Description

Display Name	Feature	Description	View
Flat Field Correction Mode	flatfieldCorrectionMode	Enables or disables flat field correction.	Beginner DFNC
Off	*Off*	Flat field correction is disabled.	
On	*On*	Flat field correction is enabled.	
Clear Coefficients	flatfieldCalibrationClearCoefficient	Sets all FPN coefficients to 0 and all PRNU coefficients to 1.	Beginner DFNC

Display Name	Feature	Description	View
Calibration Algorithm	flatfieldCorrectionAlgorithm	Specifies the PRNU calibration algorithm to use. See Flat Field Calibration.	Beginner DFNC
Peak	*Peak*	*PRNU coefficients bring all pixels to the peak pixel value (brightest).*	
Peak, Image Filtered	*PeakFilter*	*A low pass filter is applied to the average line values before calculating the coefficients. Use this algorithm if the calibration target is not uniformly white or if it is not possible to defocus the image. Because of the low pass filter, this algorithm is not able to correct pixel-to-pixel variations and so it is preferable to use the "Peak" algorithm.*	
Set Target	*Target*	*PRNU coefficients bring all pixels to the value specified in Flat Field Calibration Target.*	
Set Target, Image Filtered	*TargetFilter*	*A low pass filter is applied to the average line values before calculating the coefficients. Use this algorithm if the calibration target is not uniformly white or if it is not possible to defocus the image. Because of the low pass filter this algorithm is not able to correct pixel-to-pixel variations and so it is preferable to use the "Target" algorithm.*	
Flat Field Calibration Target	flatfieldCalibrationTarget	Sets the target value for the PRNU calibration.	Beginner DFNC
FPN Calibration Algorithm	flatfieldCorrectionAlgorithmFPN	Specifies the FPN flat-field calibration algorithm to use.	Beginner DFNC
Standard	*Standard*	*Calculates Fixed Pattern Noise (FPN) for each pixel.*	
Dark Current	*DarkCurrent*	*Corrects for dark current when imaging at lower line rates (4-60 kHz). See Dark Current Correction.*	
Flat Field Calibration Offset X	flatfieldCalibrationROIOffsetX	Sets the starting point of a region of interest where a flat field calibration will be performed.	Beginner DFNC
Flat Field Calibration Width	flatfieldCalibrationROIWidth	Sets the width of the region of interest where a flat field calibration will be performed.	Beginner DFNC
Calibrate FPN	flatfieldCalibrationFPN	Initiates the FPN calibration process so that the responsivity of all pixels in a dark environment is the same.	Beginner DFNC
Row Selector	flatfieldCalibrationColorSelector	Specify the sensor rows on which to perform PRNU calibration, all or individual colors.	Beginner DFNC
Calibrate PRNU	flatfieldCalibrationPRNU	Initiates the PRNU calibration process so that the responsivity of all pixels in a bright unsaturated environment is the same.	Beginner DFNC
PRNU Current Active Set	flatfieldCorrectionCurrentActiveSet	Selects the PRNU set to be saved or loaded.	Guru DFNC
Factory Set	*Factory Set*	*Factory set (can be loaded only).*	
User Set 1 (1 thru 16)	*UserSet1 (1 thru 16)*	*Only the PRNU values are saved or loaded which is much faster than saving or loading the full Factory or User set.*	
Save Calibration	flatfieldCalibrationSave	Saves the current PRNU coefficients to the selected *flatfieldCorrectionCurrentActiveSet* user set. This command remains unavailable if *flatfieldCorrectionCurrentActiveSet* is the Factory Set.	Guru DFNC
Load Calibration	flatfieldCalibrationLoad	Loads the PRNU coefficients from the selected *flatfieldCorrectionCurrentActiveSet* user set and makes it active.	Guru DFNC
Output LUT Mode	lutMode	Allows the output LUT to be selected. When enabled, the same LUT is used for all colors.	Beginner DFNC
Off	*Off*	*The output LUT is disabled and linear data is output.*	
Gamma Correction	*Gamma*	*LUT populated using the Gamma correction equation.*	
User Defined	*UserDefined*	*LUT uploaded by the user.*	

Display Name	Feature	Description	View
Gamma Correction	gammaCorrection	Sets the output LUT gamma correction factor. LUT is populated using the following gamma correction equation: $$DN_{out} = 255 \times \left(\frac{DN_{in}}{255}\right)^{\frac{1}{\gamma}}$$	Beginner DFNC
Image Filter Mode	imageFilterMode	Enables image filter correction.	Guru DFNC
Off	*Off*	*Image filter is disabled.*	
Active	*Active*	*Image filter is enabled.*	
Image Filter Type	imageFilterType	Selects the type of image filter to use.	Guru DFNC
Weighted Average	*Weighted_Average*	*Weighted average algorithm.*	
Image Filter Kernel Size	imageFilterKernelSize	Sets the image filter kernel size.	Guru DFNC
Kernel 1x3	*KERNEL_1x3*	1x3 kernel.	
Kernel 1x5	*KERNEL_1x5*	1x5 kernel.	
Image Filter Contrast Ratio	imageFilterContrastRatio	Sets the image filter contrast ratio threshold.	Guru DFNC
Bloom Filter	bloomFilter	Enables the anti-blooming filter.	Guru DFNC
Off	*Off*	*Anti-blooming filter is disabled.*	
Active	*Active*	*Anti-blooming filter is enabled.*	
EOI	enhancedImage	Enables enhanced regions of interest (EOI). EOIs allow for rapid adjustment of gain and offset values for specific regions of the image.	Beginner DFNC
Off	*Off*	*EOIs are disabled.*	
On	*On*	*EOIs are enabled.*	
EOI Count	enhancedImageCount	Sets the number of EOIs. Up to 4 EOIs can be defined.	Beginner DFNC
EOI Selector	enhancedImageSelector	Selects the EOI to define.	Beginner DFNC
EOI Start	enhancedImageStart	Sets the starting X position of the selected EOI.	Beginner DFNC
EOI Width	enhancedImageWidth	Sets the width of the selected EOI.	Beginner DFNC
EOI Offset	enhancedImageOffset	Sets the black level offset to apply to the selected EOI. Possible values range from -127 to 127.	Beginner DFNC
EOI Gain	enhancedImageGain	Sets the gain to apply to the selected EOI.	Beginner

Image Format Category

The Image Format are parameters used to configure camera pixel format, image cropping, binning and test pattern generation features.

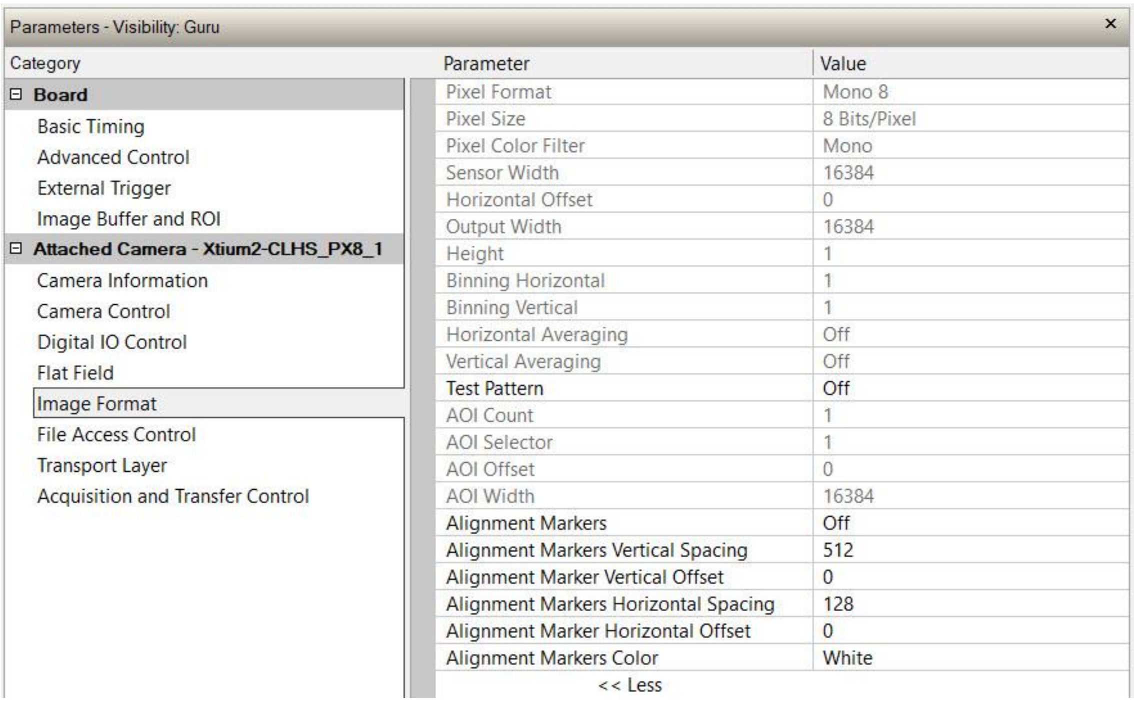


Figure 37: Image Format Panel

Image Format Control Feature Description

Display Name	Feature	Description	View
Pixel Format	PixelFormat	Output image pixel coding format of the sensor.	Beginner
Mono 8	*Mono8*	*Monochrome 8-bit monochrome.*	
Mono 12	*Mono12*	*Monochrome 12-bit.*	
Pixel Size	PixelSize	Total size in bits of an image pixel. (RO)	Guru
8 Bits/Pixel	*Bpp8*	*8 bits per pixel.*	
10 Bits/Pixel	*Bpp10*	*10 bits per pixel.*	
12 Bits/Pixel	*Bpp12*	*12 bits per pixel.*	
16 Bits/Pixel	*Bpp16*	*16 bits per pixel.*	
Pixel Color Filter	PixelColorFilter	Indicates the type of color filter used in the camera. (RO)	Guru DFNC
Mono	*None*	*Monochrome.*	
Color BGR	*CFA1B3_BGR*	*Color BGR.*	
Color BGR-NIR	*CFA1B4_BGRN*	*Color BGR-NIR.*	
Sensor Width	WidthMax	Sensor width in pixels. (RO)	Beginner
Horizontal Offset	OffsetX	Horizontal offset from the origin (always zero). (RO)	Beginner
Output Width	Width	Horizontal width in output pixels. Equals to sum of AOI widths divided by horizontal binning factor. (RO)	Beginner
Height	Height	Height of the image provided by the device (in pixels). (RO)	Beginner

Display Name	Feature	Description	View
Binning Horizontal	BinningHorizontal	Number of horizontally adjacent pixels to sum together. This increases the intensity of the pixels and reduces the horizontal resolution of the image.	Beginner
Binning Vertical	BinningVertical	Number of vertically adjacent pixels to sum together. This increases the intensity of the pixels and reduces the vertical resolution of the image.	Beginner
Horizontal Averaging	BinningHorizontalAvgEN	Averages the pixels that have been selected with BinningHorizontal. This will improve the Signal to Noise Ratio.	Beginner
Off	*Off*	*Horizontal averaging is disabled.*	
On	*On*	*Horizontal averaging is enabled.*	
Vertical Averaging	BinningVerticalAvgEN	Averages the pixels that have been selected with BinningVertical. This will improve the Signal to Noise Ratio.	Beginner
Off	*Off*	*Vertical averaging is disabled.*	
On	*On*	*Vertical averaging is enabled.*	
Test Pattern	TestImageSelector	Selects the type of test image that is sent by the camera. Note. Grey images are displayed so that any bit error will immediately be apparent as a color.	Beginner
Off	*Off*	*Image is coming from the camera sensor.*	
Each Tap Fixed	*EachTapFixed*	*Selects a grey scale value that is increased every 512 pixels.*	
Grey Horizontal Ramp	*GreyHorizontalRamp*	*Image is filled horizontally with an image that goes from the darkest possible value to the brightest.*	
Grey Vertical Ramp	*GreyVerticalRamp*	*Image is filled vertically with an image that goes from the darkest possible value to the brightest.*	
Grey Diagonal Ramp	*GreyDiagonalRamp*	*Image is filled diagonally with an image that goes from the darkest possible value to the brightest.*	
User Pattern	*UserTp*	*User can define a test pattern by uploading to the camera a PRNU file using the FileAccess > Miscellaneous > User PRNU feature. The PRNU coefficients will be applied to a midscale (128 DN) test image.* *Contact Teledyne DALSA support for an Excel file that can help with this.*	
AOI Count	multipleROICount	Specifies the number of AOIs (Area of Interest) available in an acquired image.	Beginner DFNC
AOI Selector	multipleROISelector	Selects which AOI (Area of Interest) to configure.	Beginner DFNC
AOI Offset	multipleROIOffsetX	Horizontal offset in pixels from the origin to the selected AOI (Area of Interest).	Beginner DFNC
AOI Width	multipleROIWidth	Horizontal width in pixels of the selected AOI (Area of Interest). The sum of all AOI widths cannot exceed the sensor width. For example, for a 16k sensor, if there are two AOIs with the first 12k wide, then the second can be no wider than 4k.	Beginner DFNC

Display Name	Feature	Description	View
Alignment Markers	alignmentMarkerEnable	To assist with camera alignment, alignment markers can be enabled in the output.	Beginner DFNC
Off	*Off*	*Disable alignment markers.*	
Vertical On	*Vertical*	*Enable vertical alignment markers only.*	
Horizontal On	*Horizontal*	*Enable horizontal alignment markers only.*	
Both On	*Both*	*Enable vertical and horizontal alignment markers.*	
Alignment Marker Vertical Spacing	alignmentMarkerVerticalSpacing	Vertical spacing between alignment markers, in pixels.	Beginner DFNC
64	*Ver64*	*64 pixels between vertical alignment markers.*	
128	*Ver128*	*128 pixels between vertical alignment markers.*	
256	*Ver256*	*256 pixels between vertical alignment markers.*	
512	*Ver512*	*512 pixels between vertical alignment markers.*	
Alignment Marker Vertical Offset	alignmentMarkerVerticalOffset	Pixel count before first vertical alignment marker.	Beginner DFNC
Alignment Marker Horizontal Spacing	alignmentMarkerHorizontalSpacing	Horizontal spacing between alignment markers, in pixels.	Beginner DFNC
16	*Hor16*	*16 pixels between horizontal alignment markers.*	
32	*Hor32*	*32 pixels between horizontal alignment markers.*	
64	*Hor64*	*64 pixels between horizontal alignment markers.*	
128	*Hor128*	*128 pixels between horizontal alignment markers.*	
Alignment Marker Horizontal Offset	alignmentMarkerHorizontalOffset	Pixel count before first horizontal alignment marker.	Beginner DFNC
Alignment Markers Color	alignmentMarkerBlack	Alignment markers color.	Beginner DFNC
White	*White*	*White alignment markers.*	
Black	*Black*	*Black alignment markers.*	

File Access Control Category

The File Access control in CamExpert allows the user to quickly upload and download of various data files to/from the connected the camera. The supported data files for the camera include Flat Field coefficients.

NOTE

The communication performance when reading and writing large files can be improved by stopping image acquisition during the transfer.

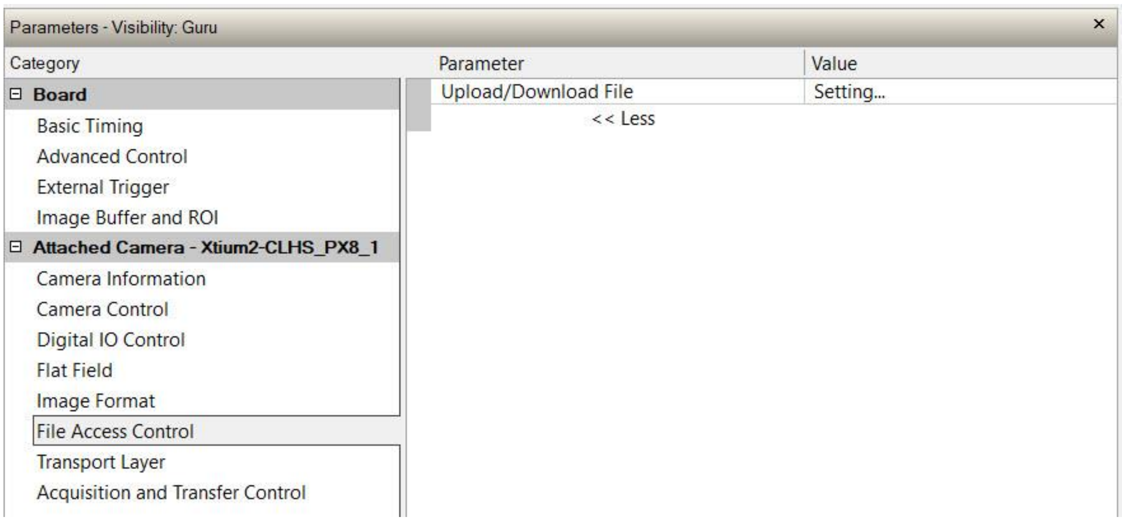


Figure 38: File Access Control Panel

File Access Control Feature Descriptions

Display Name	Feature	Description	View
File Selector	FileSelector	Selects the file to access. The files that are accessible are device-dependent.	Guru
All Firmware	*Firmware1*	*Upload new firmware to the camera, which will execute on the next camera reboot cycle. Reset the device after the upload.*	
User Set	*User_Set*	*Use UserSetSelector to specify which user set to access.*	
Output LUT	*Output_LUT*	*Use UserSetSelector to specify which LUT to access.*	
User PRNU	*User_PRNU*	*Use UserSetSelector to specify which user PRNU to access.*	
User FPN	*User_FPN*	*Use UserSetSelector to specify which user FPN to access.*	
Current PRNU	*Cur_PRNU*	*PRNU coefficients that are currently being used by the camera (not necessarily saved).*	
Camera Data	*CameraData*	*Camera information for customer support. This is a text file, please ensure that it has a .txt file name extension.*	

Display Name	Feature	Description	View
File Operation Selector	FileOperationSelector	Selects the target operation for the selected file in the device. This operation is executed when the FileOperationExecute feature is called.	Guru
Open	*Open*	*Open operation.*	
Close	*Close*	*Close operation.*	
Read	*Read*	*Read operation.*	
Write	*Write*	*Write operation.*	
File Operation Execute	FileOperationExecute	Executes the operation selected by File Operation Selector on the selected file.	Guru
File Open Mode	FileOpenMode	Access mode used to open a file on the device.	Guru
Read	*Read*	*Select READ only open mode*	
Write	*Write*	*Select WRITE only open mode*	
File Access Buffer	FileAccessBuffer	Intermediate access buffer that allows the exchange of data between the device file storage and the application.	Guru
File Access Offset	FileAccessOffset	Controls the mapping offset between the device file storage and the file access buffer.	Guru
File Access Length	FileAccessLength	Number of bytes to transfer between the device file storage and the file access buffer.	Guru
File Operation Status	FileOperationStatus	Returns the status of the last file operation. (RO).	Guru
Success	*Success*	*The last file operation has completed successfully.*	
Invalid Parameter	*InvalidParameter*	*The last file operation has completed unsuccessfully because of an invalid parameter.*	
Write Protect	*WriteProtect*	*The last file operation has completed unsuccessfully because the file is read-only.*	
File Not Open	*FileNotOpen*	*The last file operation has completed unsuccessfully because the selected file has not been opened.*	
File Too Big	*FileTooBig*	*The last file operation has completed unsuccessfully because the file is larger than expected.*	
File Invalid	*FileInvalid*	*The last file operation has completed unsuccessfully because the selected file is not present in this camera.*	
File Operation Result	FileOperationResult	Displays the number of successfully read/written bytes during the last operation. (RO)	Guru
File Size	FileSize	Represents the size of the selected file in bytes.	Guru

File Access Control Dialog

Click **Setting** to open the File Access Control dialog box.

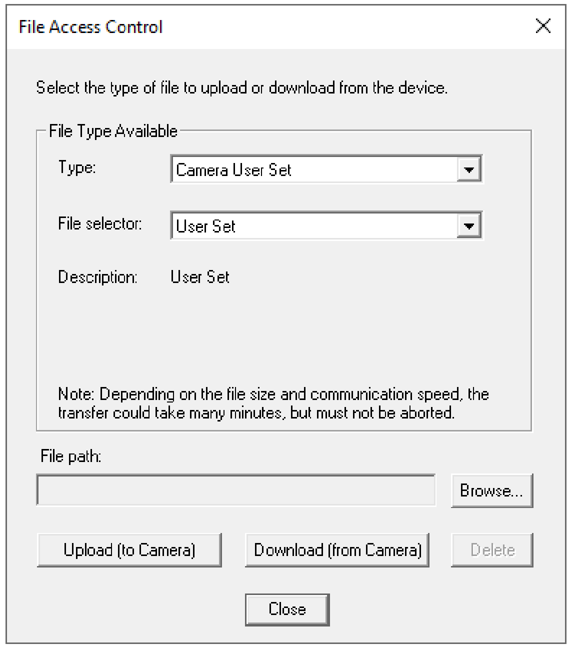


Figure 39: File Access Control Tool

- From the **Type** list, select the file type that will be uploaded to the camera or downloaded from the camera.
- From the **File Selector** list, select the file to be uploaded or downloaded.

To upload a file

1. Click **Browse** to open a typical Windows Explorer window.
2. Select the specific file from the system drive or from a network location.
3. Click **Upload (to Camera)** to execute the file transfer to the camera.

Alternatively, click **Download (from Camera)** and then specify the location where the file should be stored.

ABOUT FIRMWARE UPDATES
Firmware updates require a firmware file to be provided. Ask technical customer support for a firmware update file and proper procedure.

CLHS File Transfer Protocol

If you are not using CamExpert to perform file transfers, pseudo-code for the CLHS File Transfer Protocol is as follows.

To download a file from camera

- Select the file by setting the FileSelector feature.
- Set the FileOpenMode to *Read*.
- Set the FileOperationSelector to *Open*.

- Open the file by setting FileOperationExecute to *1*.
  This is a read-write feature - poll it every 100 ms until it returns 0 to indicate it has completed.
- Read FileOperationStatus to confirm that the file opened correctly. A return value of 0 is success. Error codes are listed in the XML.
- Read FileSize to get the number of bytes in the file.
- From FileAccessBuffer.Length you will know that maximum number of bytes that can be read through FileAccessBuffer is 988.
- For Offset = 0 While ((Offset < FileSize) and (Status = 0)) Do
  - Set FileAccessOffset to Offset
  - Set FileAccessLength to min(FileSize - Offset, FileAccessBuffer.Length), the number of bytes to read
  - Set the FileOperationSelector to Read
  - Read the file by setting FileOperationExecute to 1 and poll until 0 and complete
  - Read FileOperationStatus to confirm the read worked
  - Read FileOperationResult to confirm the number of bytes read
  - Read the bytes from FileAccessBuffer
  - Write bytes read to host file.
- Next Offset = Offset + number of bytes read.
- Set the FileOperationSelector to Close.
- Close the file by setting FileOperationExecute to 1 and poll until 0 and complete.
- Read FileOperationStatus to confirm the close worked.

To upload a file to camera

- Select the file by setting the FileSelector feature.
- Set the FileOpenMode to Write.
- Set the FileOperationSelector to Open.
- Open the file by setting FileOperationExecute to 1. This is a read-write feature - poll it every 100 ms until it returns 0 to indicate it has completed
- Read FileOperationStatus to confirm that the file opened correctly. A return value of 0 is success. Error codes are listed in the XML.
- Read FileSize to get the maximum number of bytes allowed in the file.
  - Abort and jump to Close if this is less the file size on the host
- From FileAccessBuffer.Length you will know that maximum number of bytes that can be written through FileAccessBuffer is 988.
- For Offset = 0 While ((Offset < Host File Size) and (Status = 0)) Do
  - Set FileAccessOffset to Offset
  - Set FileAccessLength to min(Host File Size - Offset, FileAccessBuffer.Length), the number of bytes to write
  - Read next FileAccessLength bytes from host file.
  - Write the bytes to FileAccessBuffer
  - Set the FileOperationSelector to Write
  - Write to the file by setting FileOperationExecute to 1 and poll until 0 and complete
  - Read FileOperationStatus to confirm the write worked
  - Read FileOperationResult to confirm the number of bytes written.

- Next Offset = Offset + number of bytes written.
- Set the FileOperationSelector to *Close*.
- Close the file by setting FileOperationExecute to 1 and poll until 0 and complete.
- Read FileOperationStatus to confirm the close worked.

Download a List of Camera Parameters

For diagnostic purposes you may want to download a list of all the parameters and values associated with the camera.

- In the File Access Control tab click **Settings**.
- In the **Type** list select *Miscellaneous*.
- In the **File Selector** list select *CameraData*.
- Click **Download (from Camera)**.
- Save the text file and send the file to Teledyne DALSA customer support.

Transport Layer Control Category

The Transport Layer Control category is used to configure features related to CLHS connection.

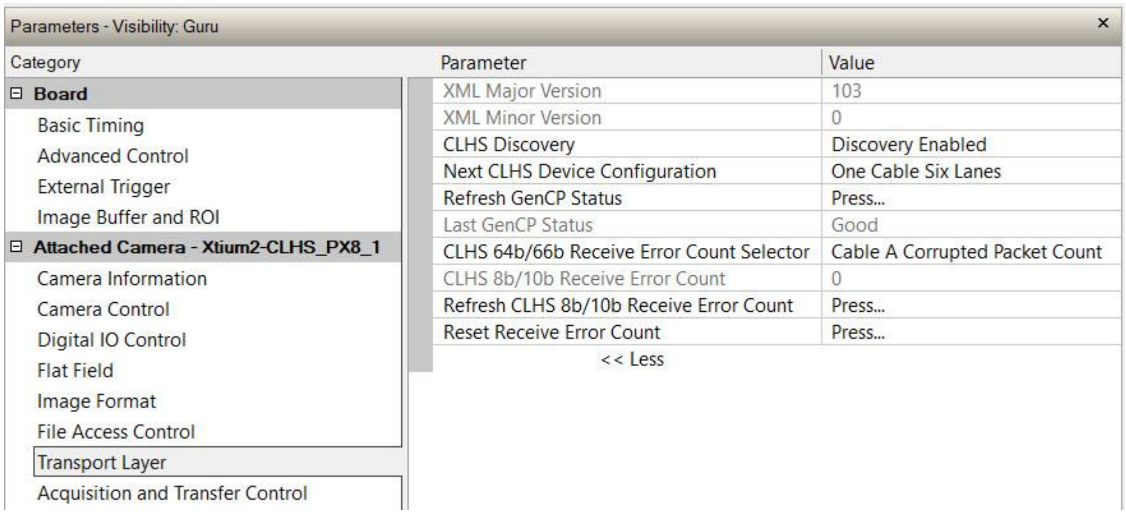


Figure 40: Transport Layer Panel

Transport Layer Feature Descriptions

Display Name	Feature	Description	View
XML Major Version	DeviceManifestXMLMajorVersion	Together with DeviceManifestXMLMinorVersion, specifies the GenICam feature description XML file version. (RO)	Beginner
XML Minor Version	DeviceManifestXMLMinorVersion	Together with DeviceManifestXMLMajorVersion, specifies the GenICam feature description XML file version. (RO)	Beginner
CLHS Discovery	clhsDiscovery	Disable CLHS Discovery if not implemented in the frame grabber. If disabled, the camera will enable image transmitters as soon as the cable is connected.	Beginner DFNC
Discovery Disabled	*DiscoveryDisable*	*CLHS transmitters are enabled immediately on power up.*	
Discovery Enabled	*DiscoveryEnable*	*CLHS transmitters are enabled after sending an Acquisition Start.*	
Next CLHS Device Configuration	clhsNextDeviceConfig	Selects a CLHS device configuration to use. Reboot or reconnect cable to activate. (Available options depend on connector type and camera model.)	Beginner DFNC
One Cable One Lane	*OneCableOneLane*	*One cable one lane (SFP+).*	
Two Cables One Lane	*TwoCablesOneLane*	*Two cables one lane (SFP+).*	
One Cable Three Lanes	*OneCableThreeLanes*	*One cable three lanes (CX4).*	
One Cable Four Lanes	*OneCableFourLanes*	*One cable four lanes (CX4).*	
One Cable Five Lanes	*OneCableFiveLanes*	*One cable five lanes (CX4).*	
One Cable Six Lanes	*OneCableSixLanes*	*One cable six lanes (CX4).*	
One Cable Seven Lanes	*OneCableSevenLanes*	*One cable seven lanes (CX4).*	
Refresh GenCP Status	refreshGenCPStatus	Updates the GenCP Status.	Beginner DFNC
Last GenCP Status	genCPStatus	Returns the last bad GenCP status. Reading this feature clears it. Sapera only.	Beginner DFNC

Display Name	Feature	Description	View
CLHS 64b/66b Receive Error Count Selector	clhsErrorCountSelector	Selects the error count that is reported by the clhsErrorCount feature.	Guru DFNC
Cable A Corrupted Packet Count	*CorruptedPacketCntA*	*Number of corrupted packets on cable A.*	
Cable A Corrected Packet Count	*CorrectedPacketCntA*	*Number of corrected packets on cable A.*	
Cable B Corrupted Packet Count	*CorruptedPacketCntB*	*Number of corrupted packets on cable B.*	
Cable B Corrected Packet Count	*CorrectedPacketCntB*	*Number of corrected packets on cable B.*	
CLHS 8b/10b Receive Error Count	clhsErrorCount	CLHS 8b/10b Receive Error count.	Guru DFNC
Refresh CLHS 8b/10b Receive Error Count	clhsErrorCountRefresh	Updates the selected receive error count value.	Guru DFNC
Reset Receive Error Count	clhsErrorCountReset	Resets the selected receive error count value to 0.	Guru DFNC

Acquisition and Transfer Control Category

The Acquisition and Transfer Control category is used to start and stop acquisition to allow some features to be changed.

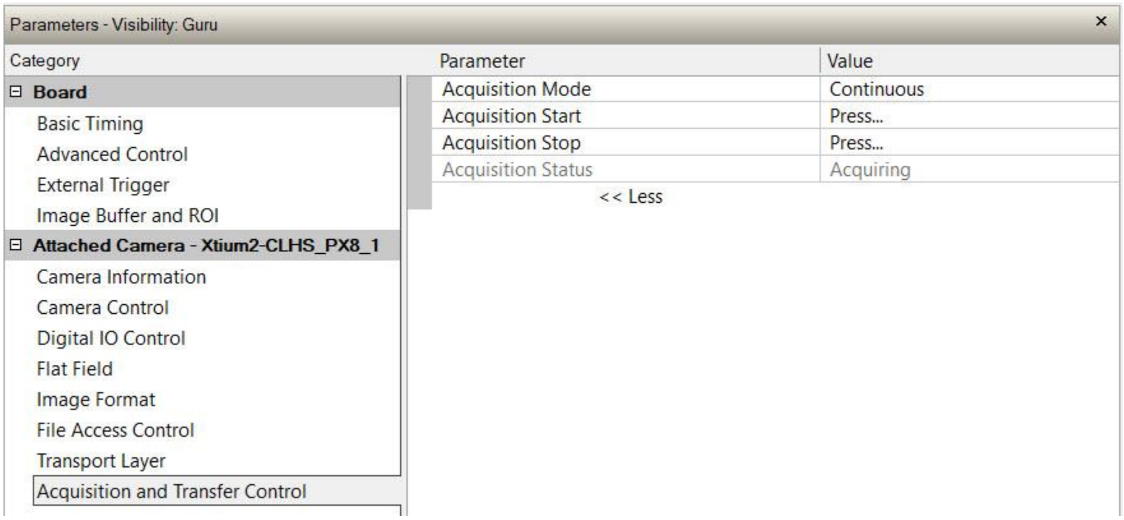


Figure 41: Acquisition & Transfer Control Panel

Acquisition and Transfer Control Feature Descriptions

Display Name	Feature	Description	View
Acquisition Mode *Continuous*	AcquisitionMode *Continuous*	Defines the way that frames are acquired. *Frames are captures continuously until stopped with the Acquisition Stop command.*	Beginner
Acquisition Start	AcquisitionStart	Commands the camera to start sending image data. (WO)	Beginner
Acquisition Stop	AcquisitionStop	Commands the camera to stop sending image data at the end of the current line. (WO)	Beginner
Acquisition Status *Acquiring* *Not Acquiring*	AcquisitionStatus *Acquiring* *NotAcquiring*	Reads the acquisition state. *Currently acquiring and sending image data.* *Currently not acquiring or sending image data.*	Beginner

Technical Specifications

Labeling

Linea HS cameras have an identification label applied to the case, with the following information:

Model Part Number
Serial number
2D barcode
Made in Canada

Temperature Management

Linea HS cameras are designed to optimally transfer internal component heat to the outer metallic body. If the camera is free standing (that is, not mounted) it will be hot to the touch.

Basic heat management is achieved by mounting the camera onto a metal structure via its mounting screw holes. Heat dissipation is improved by using thermal paste between the camera body (not the front plate) and the metal structure plus the addition of a heatsink structure.

Mechanical Drawings

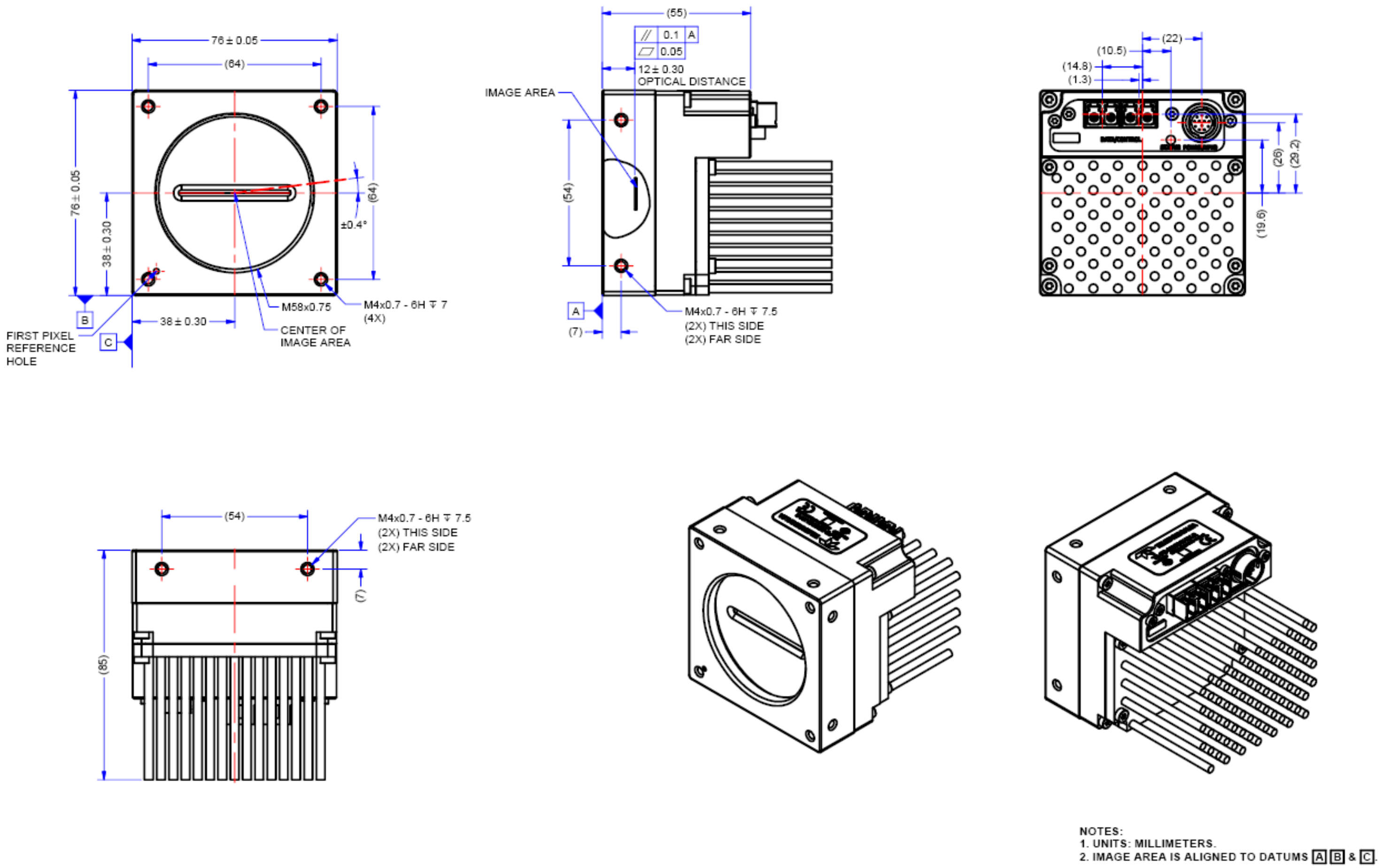


Figure 42: HL-FM-04K30H-00-R and HL-FM-08K30H-00-R Mechanical Drawing

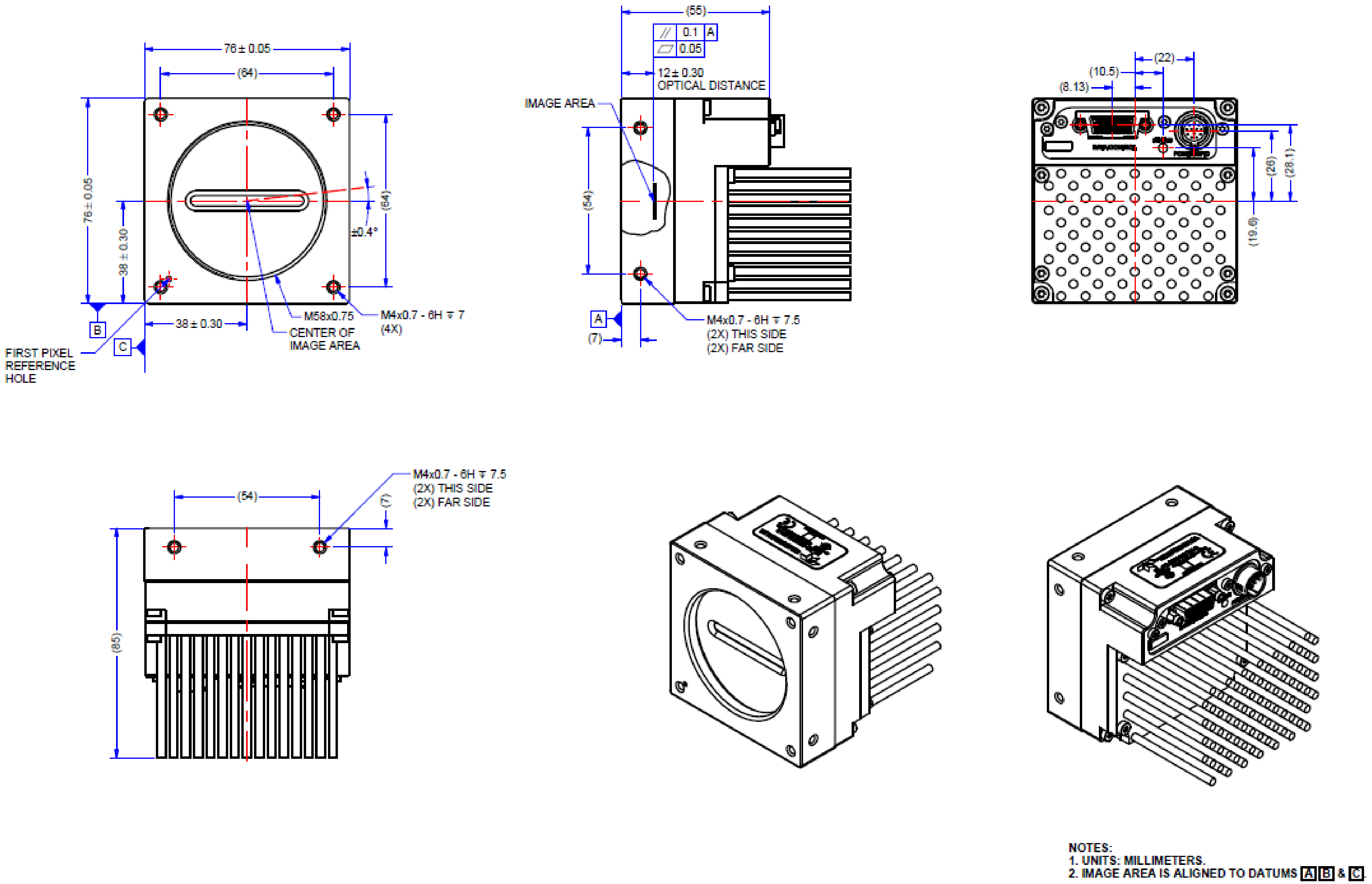


Figure 43: HL-HM-08K30H-00-R and HL-HM-08K40H-00-R Mechanical Drawing

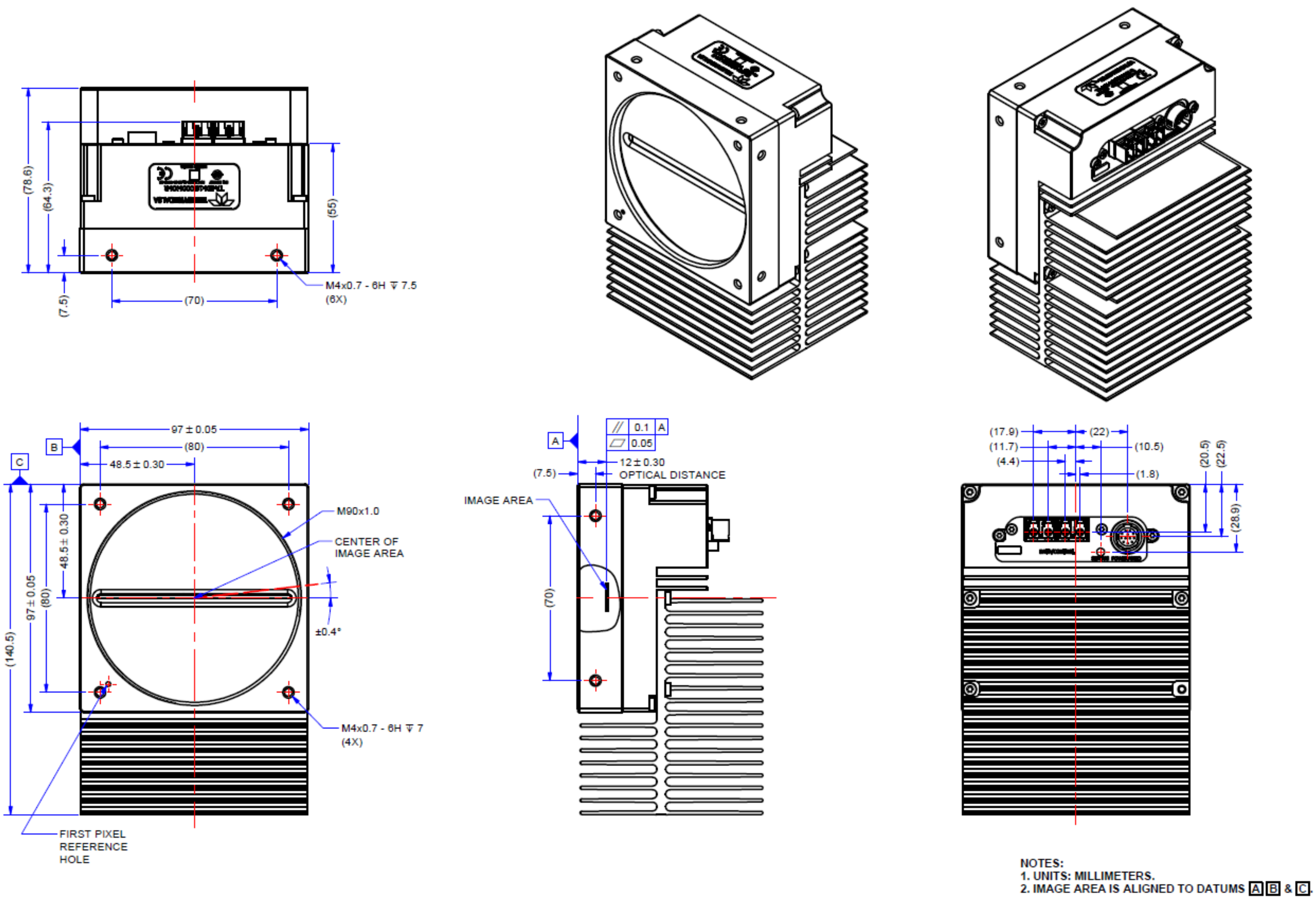


Figure 44: HL-FM-13K18H-00-R and HL-FM-16K15A-00-R Mechanical Drawing

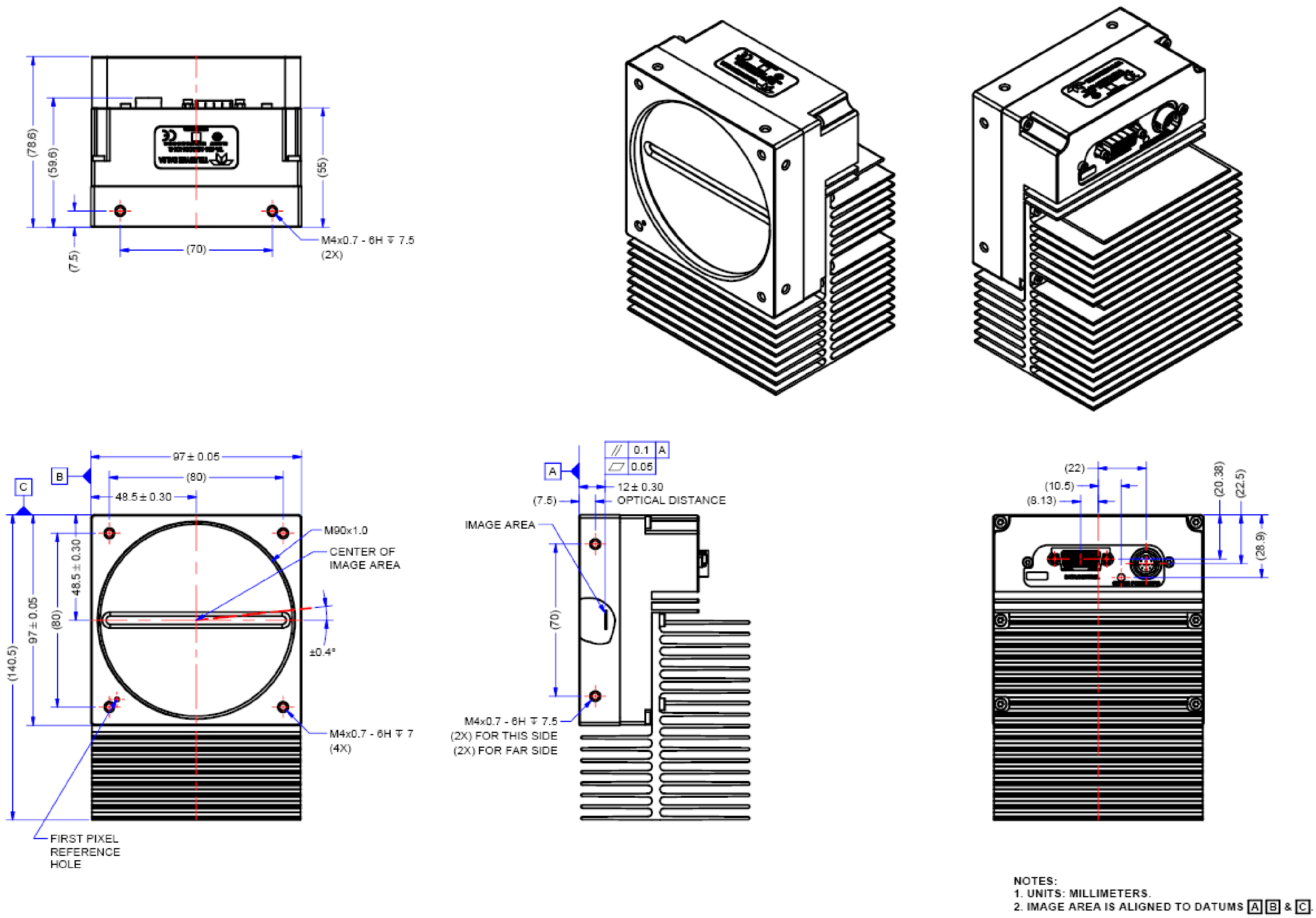


Figure 45: HL-HM-13K30H-00-R, HL-HM-16K30H-00-R, HL-HM-16K40H-00-R, HL-HM-16K40H-00-B Mechanical Drawing

Connectors

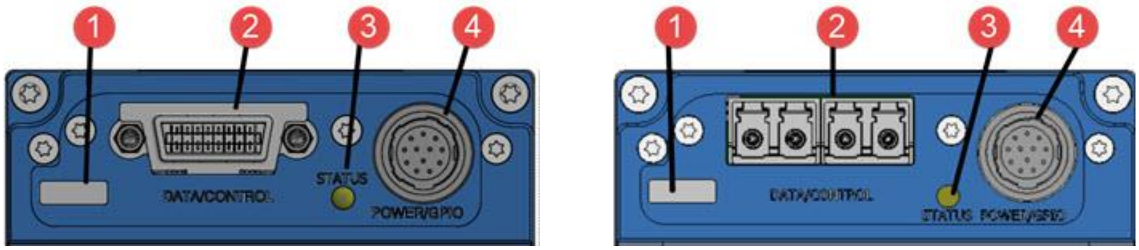


Figure 46: Camera I/O Connectors: CX4 (left) & SFP+ LC optical fiber (right)

Camera I/O Connectors

1) Factory use only
2) Data and control connectors - CX4 or SFP+ for LC optical fiber
3) LED status indicator
4) Power and GPIO connector: +12 V to +24 V DC, Hirose 12-pin circular

Powering the Camera

WARNING

When setting up the camera's power supply, follow these guidelines:

- Apply proper voltage between +12 V to +24 V. Incorrect voltage may damage the camera.
- The power supply ground (supply negative) must only be connected to the camera power ground pins 1 and 9.
- Do not connect the power supply ground (supply negative) to the camera chassis or the signal ground (pins 11 and 12). Doing so will not damage the camera, however, it will bypass the internal reverse voltage protection circuits.
- Before connecting power to the camera, test all power supplies.
- Protect the camera with a 3 amp slow-blow fuse between the power supply and the camera.
- The ground shield on the Power/GPIO cable must not be connected to the power supply ground (supply negative) or to the camera power pins 1 and 9. It can be connected to the camera chassis or earth ground at the power supply if the power supply ground (supply negative) is isolated from earth ground.
- Keep leads as short as possible to reduce voltage drop.
- Use high quality supplies to minimize noise.
- When using a 12 V supply, voltage loss in the power cables will be greater due to the higher current. Use the Camera Information category to refresh and read the camera's input voltage measurement. Adjust the supply to ensure that it reads above or equal to 12 V.

NOTE

If your power supply does not meet these requirements, then the camera performance specifications are not guaranteed.

Power and GPIO Connections

The camera uses a single 12-pin Hirose male connector for power, trigger and strobe signals. The suggested female cable mating connector is the *Hirose model HR10A-10P-12S*.

12-Pin Hirose Connector Signal Details

The following figure shows the pinout identification when looking at the camera's 12-pin male Hirose connector. The table below lists the I/O signal connections.

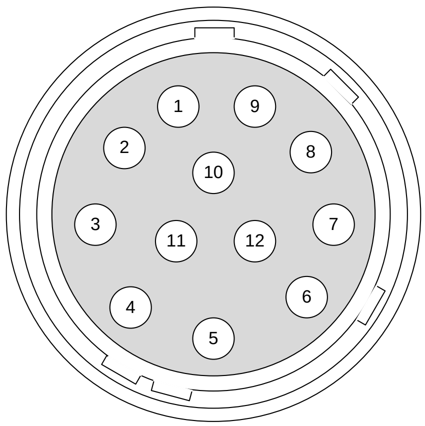


Figure 47: 12-pin Hirose Pin Numbering

Table 21: 12-pin Hirose Pin Assignment

Pin	Input / Output	Signal Details	Notes
1		Power Ground*	Do not connect to pins 11 or 12 or to the camera chassis.
2		+12 V to +24 V power*	
3	Output	Line 3 Out	0 to 3.3 V TTL
4	Output	Line 4 Out	0 to 3.3 V TTL
5	Input	Line 1 / Trigger / Phase A	0 to 3.3 V TTL
6	Input	Line 2 / Scan Direction / Phase B	0 to 3.3 V TTL
7	Output	Line 5 Out	0 to 3.3 V TTL
8	Output	Line 6 Out	0 to 3.3 V TTL
9		Power Ground*	Do not connect to pins 11 or 12 or to the camera chassis.
10		+12 V to +24 V power*	
11		Signal Ground	Intended as a return path for GPIO signal. Not intended as a power ground. Do not connect to pins 1 or 9 or to the camera chassis.
12		Signal Ground	Intended as a return path for GPIO signal. Not intended as a power ground. Do not connect to pins 1 or 9 or to the camera chassis.

* Connect all power pins. Each pin is rated 2A.

The wire gauge of the power cable should be sufficient to accommodate a surge during power-up of at least 3 amps with a minimum voltage drop between the power supply and camera. The camera can accept any voltage between +12 and +24 Volts. If there is a voltage drop between the power supply and camera, ensure that the power supply voltage is at least 12 Volts plus this voltage drop. The camera input supply voltage can be read using CamExpert. Refer to the section on Voltage & Temperature Measurement for more details.

External Input Electrical Characteristics

Table 22: External Input Electrical Characteristics

	Switching Voltage		
Input Level Standard	**Low to high**	**High to low**	**Input Impedance**
3.3 V TTL	2.1 V	1 V	10 kΩ

External Input Timing Reference

Table 23: External Input Timing Reference

Input Level Standard	Max Input Frequency	Min Pulse Width	Max Signal Propagation Delay @ 60°C	
3.3 V TTL	20 MHz	25 ns	0 to 3.3 V	< 100 ns
			3.3 V to 0	< 100 ns

External Output Electrical Characteristics

Table 24: External Output Electrical Characteristics

Output Level Standard	V_{OL}	V_{OH}
3.3 V TTL	< 0.8 V @ 10 mA*	> 3.1 V @ 10 mA*

*See Linear Technology data sheet LTC2864.

External Output Timing Reference

Table 25: External Output Timing Reference

Output Level Standard	Max Output Frequency	Min Pulse Width	Output Current	Max Signal Propagation Delay @ 60°C	
3.3 V TTL	Line rate dependent	25 ns	< 180 mA	0 to 3.3 V	< 100 ns
				3.3 V to 0	< 100 ns

NOTE

To reduce the chance of stress and vibration on the cables, we recommend that you use cable clamps, placed close to the camera, when setting up your imaging system. Stress or vibration of the heavy CLHS AOC cables may damage the camera’s connectors.

Mating GPIO Cable Assembly

An optional GPIO breakout cable (12-pin Female Hirose to 13-Pos Euro Block) is available for purchase from Teledyne DALSA under accessory number #CR-GENC-IOP00 to order.

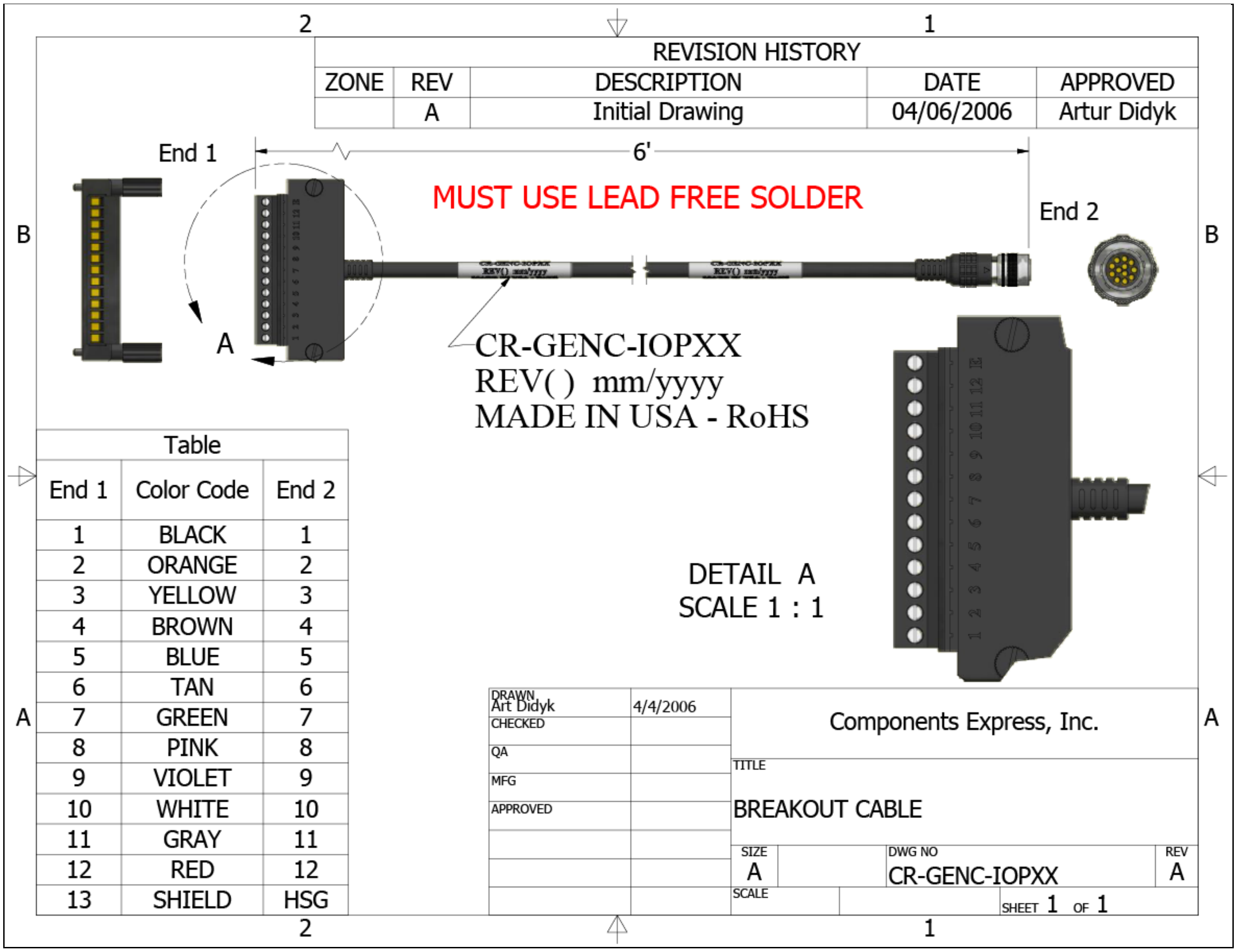


Table		
End 1	Color Code	End 2
1	BLACK	1
2	ORANGE	2
3	YELLOW	3
4	BROWN	4
5	BLUE	5
6	TAN	6
7	GREEN	7
8	PINK	8
9	VIOLET	9
10	WHITE	10
11	GRAY	11
12	RED	12
13	SHIELD	HSG

Figure 48: GPIO cable accessory #CR-GENC-IOP00

Declarations of Conformity

Copies of the Declarations of Conformity documents are available on the product page on the Teledyne DALSA website or by request.

FCC Statement of Conformance

This equipment complies with Part 15 of the FCC rules. Operation is subject to the following conditions:

1. The product may not cause harmful interference; and
2. The product must accept any interference received, including interference that may cause undesired operation.

FCC Class A Product

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

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This equipment is intended to be a component of a larger industrial system.

CE Declaration of Conformity

Teledyne DALSA declares that this product complies with applicable standards and regulations.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This product is intended to be a component of a larger system and must be installed as per instructions to ensure compliance.

Additional Reference Information

Optical Considerations

This section provides an overview to illumination, light sources, filters, lens modeling, and lens magnification. Each of these components contribute to the successful design of an imaging solution.

Illumination

The wavelengths and intensity of light required to capture useful images vary per application. The image will be affected by speed, spectral characteristics, exposure time, light source characteristics, environmental and acquisition system specifics, etc. Look at Teledyne DALSA's Knowledge Center for articles on this potentially complicated issue.

Exposure settings have more effect than illumination. The total amount of energy (which is related to the total number of photons reaching the sensor) is more important than the rate at which it arrives.

Example: 5 $\mu J/cm^2$ can be achieved by exposing 5 mW/cm^2 for 1 ms or exposing 5 W/cm^2 for 1 μs.

Light Sources

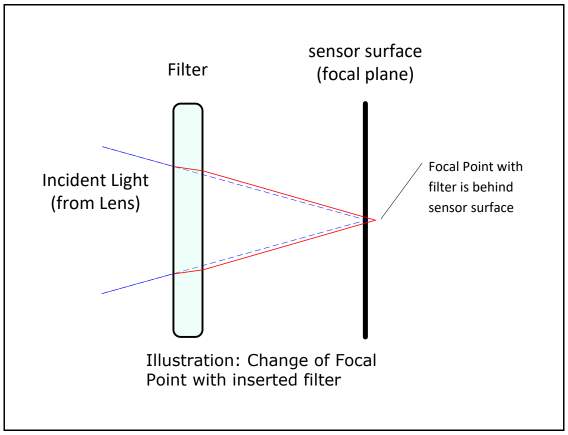
Keep these guidelines in mind when selecting and setting up a light source:

- LED light sources are inexpensive and provide a uniform field with a longer life span compared to other light sources.
- Halogen and fiber-optic light sources provide very little blue relative to IR.
- Some light sources age and produce less illumination in some areas of the spectrum.

Back Focal Variance when using any Filter

Inserting a filter between a lens and sensor changes the back focal point of the lens used. A variable focus lens simply needs to be adjusted, but in the case of a fixed focus lens, the changed focal point needs correction.

The following simplified illustration describes this but omits any discussion of the optics, physics, and math behind the refraction of light through glass filter media.



In this example when a glass filter is inserted between the lens and the camera sensor, the focal point is now about 1/3 of the filter thickness behind the sensor plane.

Lens Modeling

Any lens surrounded by air can be modeled for camera purposes using three primary points: the first and second principal points and the second focal point. The primary points for a lens should be available from the lens data sheet or from the lens manufacturer. Primed quantities denote characteristics of the image side of the lens. That is, h is the object height and h′ is the image height.

The focal point is the point at which the image of an infinitely distant object is brought to focus. The effective focal length (f′) is the distance from the second principal point to the second focal point. The back focal length (BFL) is the distance from the image side of the lens surface to the second focal point. The object distance (OD) is the distance from the first principal point to the object.

Primary Points in a Lens System

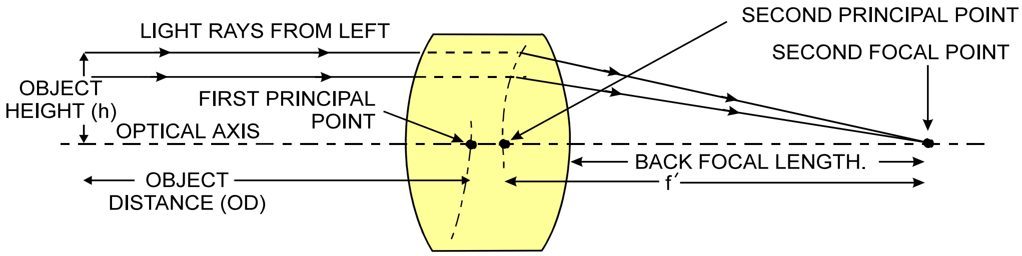


Figure 49: Primary Points in a Lens System

Magnification and Resolution

The magnification of a lens is the ratio of the image size to the object size:

$m = h'/h$	Where m is the magnification, h' is the image height (pixel size) and h is the object height (desired object resolution size).

By similar triangles, the magnification is alternatively given by:

$m = f'/OD$	Where f' is the focal length and OD is the target object distance.

These equations can be combined to give their most useful form:

$h'/h = f'/OD$	This is the governing equation for many object and image plane parameters.

Example: An acquisition system has a 512 x 512-element 10 µm pixel pitch, a lens with an effective focal length of 45 mm. For each pixel in the image sensor to correspond to 100 µm in the object space, using the preceding equation, the object distance must be 450 mm (0.450 m).

$(10\ \mu m)/(100\ \mu m) = (45\ mm)/OD$	$OD = 450\ mm\ (0.450\ m)$

Sensor Handling Instructions

This section reviews procedures for handling, cleaning or storing the camera. The sensor must be kept clean and away from static discharge to maintain design performance.

Electrostatic Discharge and the Sensor

Camera sensors containing integrated electronics are susceptible to damage from electrostatic discharge (ESD). See section Preventing Operational Faults Due to ESD for precautions.

Protecting Against Dust, Oil and Scratches

The sensor window is part of the optical path and must be handled with extreme care.

Dust can obscure pixels producing dark patches on the sensor image. Dust is most visible when the illumination is collimated. The dark patches shift position as the angle of illumination changes. Dust is normally not visible when the sensor is positioned at the exit port of an integrating sphere where illumination is diffused.

Blowing compressed air on the window will remove dust particles unless they are held by an electrostatic charge. In this case, either an ionized air blower or a wet cleaning is necessary.

Touching the surface of the window will leave oily residues. Using rubber finger cots and rubber gloves can prevent oil contamination. Avoid friction between the rubber and window or electrostatic charge build up may damage the sensor.

When handling or storing the camera without a lens always install the protective cap.

NOTE
When exposed to uniform illumination, a scratched window will normally display brighter pixels adjacent to darker pixels. The location of these pixels will change with the angle of illumination.

Cleaning the Sensor Window

Even with careful handling, the sensor window may need cleaning. The following steps describe techniques to clean minor dust particles or accidental finger touches.

- Use compressed air to blow off loose particles. This step alone is usually sufficient to clean the sensor window. Avoid moving or shaking the compressed air container and use short bursts of air while moving the camera in the air stream. Agitating the container will cause condensation to form in the air stream. Long bursts will chill the sensor window causing more condensation. Condensation, even when left to dry naturally, will deposit more particles on the sensor.
- When compressed air cannot clean the sensor, Teledyne DALSA recommends using lint-free ESD-safe cloth wipers or swabs that do not contain particles that can scratch the window. Do not use regular cotton swabs since these can introduce static charge to the window surface. Wipe the window carefully and slowly when using these products.

Cleaning the Camera Housing Surface

To clean the surface of the camera housing, use a soft, dry cloth. Avoid electrostatic charging by using a dry, clean absorbent cotton cloth dampened with a small quantity of pure alcohol. Do not use methylated alcohol. To remove severe stains, use a soft cloth dampened with a small quantity of neutral detergent and then wipe dry. Do not use volatile solvents such as benzene and thinners, as they can damage the surface finish.

Troubleshooting Guide

Diagnostic Tools

Camera Data File

The camera data file includes the operational configuration and status of the camera.

This text file can be downloaded from the camera and forwarded to Teledyne DALSA Technical Customer support team to aid in diagnosis of any reported issues. See Saving & Restoring Camera Setup Configurations for details on downloading the Camera Data file.

Voltage & Temperature Measurement

The camera can measure the input supply voltage at the power connector and the internal temperature. Both features are accessed using the CamExpert > Camera Information tab. Press the associated refresh button for a real-time measurement.

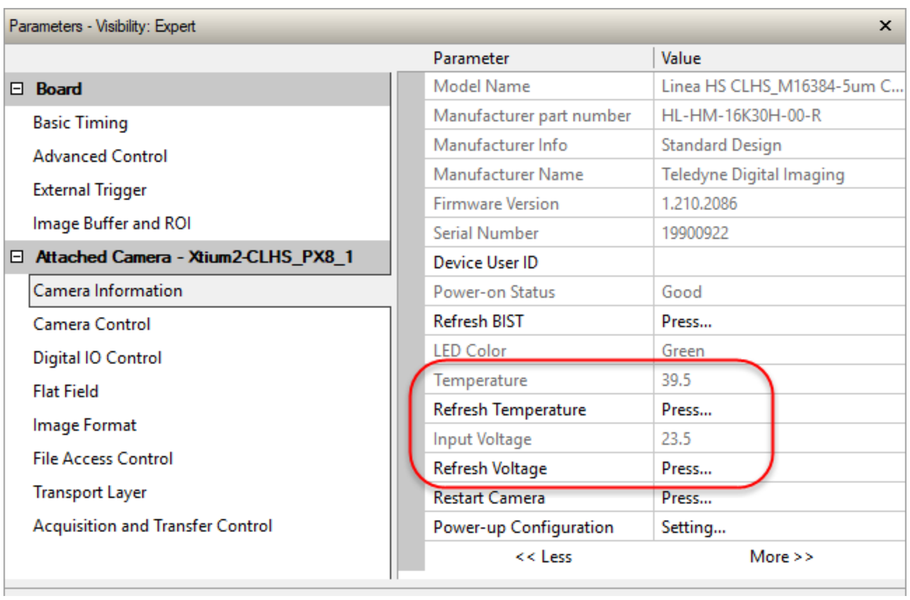


Figure 50: CamExpert Voltage & Temperature Features

Test Patterns – What Can They Indicate?

The camera can generate fixed test patterns that may be used to determine the integrity of the CLHS communications beyond the Lock status. The test patterns give the user the ability to detect bit errors using an appropriate host application. This error detection would be difficult, if not impossible, using normal image data.

NOTE

Gray images are displayed so that any bit error will immediately be apparent as colored pixels in the image.

There are several test patterns that can be selected via the Image Format > Test Pattern parameter in CamExpert.

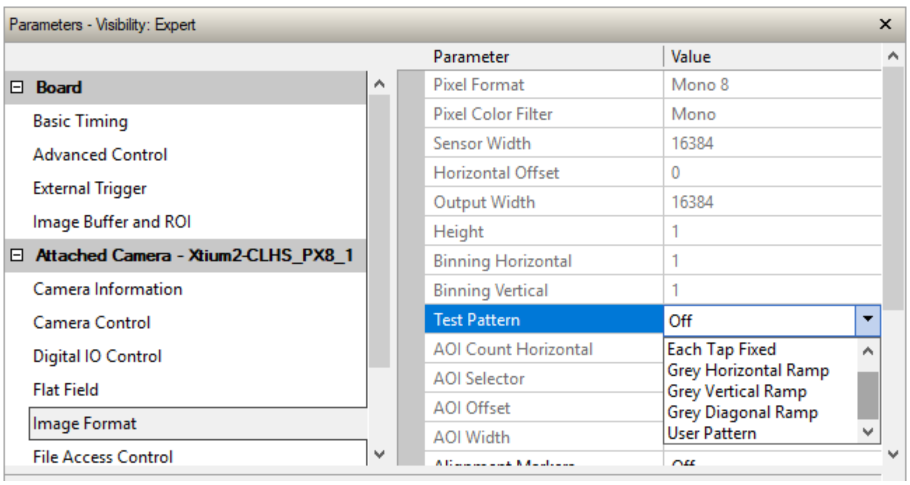


Figure 51: CamExpert Test Pattern Feature

They have the following format when using 8-bit data:

- **Each Tap Fixed**. Starting at 64 increases in by 4 steps every 512 pixels ending in 188.
- **Grey Horizontal Ramp**. Two horizontal ramps starting at 00H increasing by 01H every 32 pixels.
- **Grey Vertical Ramp**. Vertical ramp starting with 1st row 5, next row 12, and incrementing by 3 every line.
- **Grey Diagonal Ramp**. Add horizontal and vertical ramps.
- **User Pattern**. When selected, the camera will first output all pixel values to be half full scale. The user can then generate a custom test pattern by uploading PRNU coefficients that appropriately manipulate the half scale data to achieve the desired pattern. See section Custom Flat Field Coefficients for details.

Built-In Self-Test Codes

The Built-In Self-test (BIST) codes are in the Camera Information category under Power-on Status. None of these should occur in a properly functioning camera except OVER_TEMPERATURE. The OVER_TEMPERATURE code occurs if the ambient temperature is too high where there is insufficient air circulation or heat sinking.

Table 26: Built-In Self-Test (BIST) Codes

Bit Number	Name	Hex Position	Binary Translation
1	I2C	0x00000001	0000 0000 0000 0000 0000 0000 0000 0001
2	FPGA_NO_INIT	0x00000002	0000 0000 0000 0000 0000 0000 0000 0010
3	FPGA_NO_DONE	0x00000004	0000 0000 0000 0000 0000 0000 0000 0100
4	SENSOR_SPI	0x00000008	0000 0000 0000 0000 0000 0000 0000 1000
5	ECHO_BACK	0x00000010	0000 0000 0000 0000 0000 0000 0001 0000
6	FLASH_TIMEOUT	0x00000020	0000 0000 0000 0000 0000 0000 0010 0000
7	FLASH_ERROR	0x00000040	0000 0000 0000 0000 0000 0000 0100 0000
8	NO_FPGA_CODE	0x00000080	0000 0000 0000 0000 0000 0000 1000 0000
9	NO_COMMON_SETTINGS	0x00000100	0000 0000 0000 0000 0000 0001 0000 0000
10	NO_FACTORY_SETTINGS	0x00000200	0000 0000 0000 0000 0000 0010 0000 0000
11	OVER_TEMPERATURE	0x00000400	0000 0000 0000 0000 0000 0100 0000 0000
12	SENSOR_PATTERN	0x00000800	0000 0000 0000 0000 0000 1000 0000 0000
13	NO_USER_FPN	0x00001000	0000 0000 0000 0000 0001 0000 0000 0000
14	NO_USER_PRNU	0x00002000	0000 0000 0000 0000 0010 0000 0000 0000
15	CLHS_TXRDY_RETRY	0x00004000	0000 0000 0000 0000 0100 0000 0000 0000
16	(Reserved)	0x00008000	0000 0000 0000 0000 1000 0000 0000 0000
17	NO_USER_SETTINGS	0x00010000	0000 0000 0000 0001 0000 0000 0000 0000
18	NO_ADC_COEFFICIENTS	0x00020000	0000 0000 0000 0010 0000 0000 0000 0000
19	NO_SCRIPT	0x00040000	0000 0000 0000 0100 0000 0000 0000 0000
20	(Reserved)	0x00080000	0000 0000 0000 1000 0000 0000 0000 0000
21	(Reserved)	0x00100000	0000 0000 0001 0000 0000 0000 0000 0000
22	(Reserved)	0x00200000	0000 0000 0010 0000 0000 0000 0000 0000
23	NO_FACT_PRNU	0x00400000	0000 0000 0100 0000 0000 0000 0000 0000
24	NO_FATFS	0x00800000	0000 0000 1000 0000 0000 0000 0000 0000

Resolving Camera Issues

Communications

No Camera Features when Starting CamExpert

If the camera's CamExpert is opened and no features are listed, then the camera may be experiencing lane lock issues.

While using the frame grabber in CamExpert you should be able to see a row of status indicators below the image display area that indicates the status of the CLHS communications. These indicators include several lane lock status and a line valid (LVAL) status.

If the status for one or more lane locks is red, then there is likely an issue with the CLHS connectors at the camera and / or frame grabber. Ensure that the connectors are fully engaged and that the jack screws are tightened. Ensure that you are also using the recommended cables.

No Line Valid Status

If the LVAL (Line Valid) status is red and all lane locks are green, then there may be an issue with the camera receiving the encoder pulses.

- Set Digital I / O Control > Trigger Mode to *Internal*, and
- Set Camera Control > Acquisition Line Rate to the maximum that will be used.

The trigger signal from the frame grabber will not be used and the LVAL status should now be green. This will confirm the integrity of the image data portion of the CLHS cabling and connectors.

- Set Digital I / O Control > Trigger Mode to *External*.
- From the Frame Grabber > Advanced Control:
  - set Line Sync Source to *Internal Line Trigger*
  - set Internal Line Trigger to the maximum frequency that will be used.

The trigger source is now being generated by the frame grabber and the LVAL status should be green. This will confirm the integrity of the General Purpose I / O portion of the CLHS cabling and connectors.

- From the Frame Grabber > Advanced Control:
  - set Line Sync Source to *External Line Trigger* and
  - set Line Trigger Method to *Method 2*.
- From the Frame Grabber > External Trigger, set External Trigger to *Enable*.

If LVAL status turns red, check the following:

- Is the transport system moving such that encoder pulses are being generated?
- Has the encoder signal been connected to the correct pins of the I/O connector of the frame grabber? See the Xtium2-CLHS frame grabber user manual for details.
- Do the encoder signal levels conform to the requirements outlined in the Xtium2-CLHS frame grabber user manual?

Image Quality Issues

Vertical Lines Appear in Image After Calibration

The purpose of flat field calibration is to compensate for the lens edge roll-off and imperfections in the illumination profiles by creating a uniform response. When performing a flat field calibration, the camera must be imaging a flat white target that is illuminated by the actual lighting used in the application. Though the camera compensates for illumination imperfection, it will also compensate for imperfections such as dust, scratches, paper grain, etc. in the white reference. Once the white reference is removed and the camera images the material to be inspected, any white reference imperfections will appear as vertical stripes in the image. If the white reference had imperfections that caused dark features, there will be a bright vertical line during normal imaging. Similarly, bright features will cause dark lines. It can be very difficult to achieve a perfectly uniform, defect-free white reference. The following two approaches can help in minimizing the effects of white reference defects:

- Move the white reference closer to or further away from the object plane such that it is out of focus. This can be effective if the illumination profile changes minimally when relocating the white reference.
- If the white reference must be located at the object plane, then move the white reference in the scan direction or sideways when flat field calibration is being performed. The camera averages several thousand lines when capturing calibration reference images so any small imperfections are averaged out.

Use the cameras flat field calibration filter feature, as detailed in the Flat Field Calibration section. This algorithm implements a low pass moving average that covers several adjacent pixels. This filter can help minimize the effects of minor imperfections in the white reference. Note: this filter is NOT USED in normal imaging.

Over Time, Pixels Develop Low Response

When flat field calibration is performed using a white reference, as per the guidelines in the user manual, all pixels should achieve the same response. However, over time dust in the lens extension tube may migrate to the sensor surface and reduce the response of some pixels.

If the dust particles are small, they may have only a minor effect on responsivity, but still create vertical dark lines that interfere with defect detection and that need to be corrected.

Because repeating the flat field calibration with a white reference may not be practical while the camera installed in the system, the camera has a feature where the flat field coefficients can be downloaded to the host PC and adjusted using a suitable application, such as Microsoft Excel. (See section Custom Flat Field Coefficients for details.)

If the location of the pixel returning a low response can be identified from the image, then the correction coefficient of that pixel can be adjusted, saved as a new file, and then uploaded to the camera; thereby correcting the image without performing a flat field calibration.

See File Access Control Dialog for details on downloading and uploading camera files using CamExpert.

NOTE

Dust accumulation on the lens will not cause vertical lines. However, a heavy accumulation of dust on the lens will eventually degrade the camera's responsivity and focus quality.

Smeared or Distorted Images

To achieve a well-defined image, the multiple lines are summed together and delayed in a manner that matches the motion of the image across the sensor.

This synchronization is achieved by sending an external synchronization (EXSYNC) signal to the camera, where one pulse is generated when the object moves by the size of one object pixel. See External Triggers.

Any transport motion that is not correctly reflected in the EXSYNC pulses will cause image distortion in the scan direction. For standard line scan cameras, this type of image distortion may not greatly affect edge sharpness and small defect contrast; thereby having minimal impact on defect detection. However, TDI image quality is more sensitive to object motion synchronization errors.

The following subsections discuss causes of poor image quality resulting from the EXSYNC signal not accurately reflecting the object motion.

Continuously Smeared, Compressed or Stretched Images

When accurate synchronization is not achieved, the image appears smeared in the scan direction.

If the EXSYNC pulses are coming too fast, then the image will appear smeared and stretched in the machine direction. If the pulses are too slow, then the image will appear smeared and compressed.

Check the resolution of the encoder used to generate the EXSYNC pulses, along with the size of the rollers, pulleys, gearing, etc. to ensure that one pulse is generated for one pixel size of travel of the object.

It is also important that the direction of image travel across the sensor is matched to the camera's scan direction, as set by the user. See 'Scan Direction' in the user manual for more information.

If the scan direction is incorrect, then the image will have a significant smear and color artifacts in the scan direction. Changing the scan direction to the opposite direction should resolve this problem.

Refer to section Setting the Correct Scan Direction for more information on how to determine the correct direction orientation for the camera.

NOTE
The lens has a reversing effect on motion. That is, if an object passes the lens-outfitted camera from left to right, the image on the sensor will pass from right to left. The diagrams in the user manual take the lens effect into account.

Randomly Compressed Images

It is possible that when the scan speed nears the maximum allowed, based on the exposure time used, the image will be randomly compressed and possibly smeared for short periods in the scan direction.

This is indicative of the inspection systems transport mechanism dynamics causing momentary over-speed conditions. The camera can tolerate very short durations of over-speed, but if it lasts too long, then the camera can only maintain its maximum line rate, and some EXSYNC pulses will be ignored, resulting in the occasional compressed image.

The loss EXSYNC due to over-speed may also cause horizontal color artifacts.

Over-speeding may be due to inertia and / or backlash in the mechanical drive mechanism, causing variations around the target speed.

The greater the speed variation, the lower the target speed needs to be to avoid over-speed conditions. If the speed variation can be reduced by eliminating the backlash in the transport mechanism and / or optimizing the motor controller characteristics, then a higher target speed will be achievable.

Distorted Image when Slowing Down Changing Direction

The camera must align the rows in a fashion that accurately follows the object motion.

When the scan direction changes, then the process must reverse to match the reversed image motion across the sensor.

Only when all rows being accumulated have received the same image will the output be correct. Prior to this some lines have been exposed to one direction and other lines exposed to the opposite direction in the accumulated output.

Power Supply Issues

For safe and reliable operation, the camera input supply must be +12 V to +24 V DC.

The power supply to the camera should be suitably current limited, as per the applied input voltage.

Assume a worst-case power consumption of +24 W and a 150% current rating for the breaker or fuse.

NOTE
The camera will not start to draw current until the input supply is above approximately 10.5 V and 200 ms has elapsed. If the power supply stabilizes in less than 200 ms, then inrush current will not exceed normal operating current.

It is important to consider how much voltage loss occurs in the power supply cabling to the camera, particularly if the power cable is long and the supply is operating at +12 V where the current draw is highest.

Reading the input supply voltage as measured by the camera will give an indication of the supply drop being experienced.

The camera tolerates “hot” unplugging and plugging.

The camera has been designed to protect against accidental application of an incorrect input supply, up to reasonable limits. With the following input power issues, the status LED will be OFF:

- The camera will protect against the application of voltages above approximately +28 V. If the overvoltage protection threshold is exceeded, then power is turned off to the camera’s internal circuitry. The power supply must be recycled to recover camera operation. The input protection circuitry is rated up to an absolute maximum of +30 V. Beyond this voltage, the camera may be damaged.
- The camera will also protect against the accidental application of a reverse input supply of –30 V. Beyond this voltage, the camera may be damaged.

Causes for Overheating & Power Shut Down

For reliable operation, the camera’s face plate temperature should be kept below +65 °C and the internal temperature kept below +70 °C.

Many applications, such as in clean rooms, cannot tolerate the use of forced air cooling (fans) and therefore must rely on convection.

The camera’s body has been designed with integrated heat fins to assist with convection cooling. The fins are sufficient to keep the camera at an acceptable temperature if convection flow is unimpeded.

The camera also benefits from conducting heat away from the body via the face plate into the lens extension tubes and camera mount. It is therefore important not to restrict convection airflow around the camera body, especially the fins and the lens assembly and camera mount. Lowering the ambient temperature will equally lower the camera's temperature.

If the camera's internal temperature exceeds +80 °C, then the camera will partially shut down to protect itself against damage.

Commands can still be sent to the camera to read the temperature, but the image sensor will not be operational and LVAL in response to line triggers will not be generated.

Additionally, the camera's power will reduce to approximately 70% of normal operation. If the camera's temperature continues to rise, at +90 °C the camera will further reduce it power to approximately 30% of normal operation and any communication with the camera will not be possible.

The only means to recover from a thermal shutdown is to turn the camera's power off. Once the camera has cooled down, the camera data can be restored by reapplying power to the camera.

Appendix

Performing Flat Field Calibration Using CamExpert

The goal of camera flat field calibration is to produce a uniform image at a desired gray level while imaging a uniform white target in the application setup environment. CamExpert tool provides a GUI that facilitates flat field calibration. The process requires the user to plan acquisitions in dark and bright conditions, followed by the FFC procedure itself. These steps are detailed below.

Before performing a FFC follow these guidelines:

- Ensure the camera is at normal operating temperature. Apply power for at least 30 minutes.
- All parameters should meet your application's specifications. If parameters change after FFC completion, the results may no longer be accurate. Perform another FFC.

Flat Field Calibration White Target

Flat field calibration requires a white target that consists of a controlled diffused light source aimed directly at the lens or a non-glossy paper (or evenly lit wall) with the lens slightly out of focus. Ideally, use a professional target. If a sheet of material is being used, it must be completely free of blemishes and texture; the presence of dirt or texture will generate a variation in the image that will be incorporated into the calibration coefficients of the camera, creating vertical stripes in scanned images.

One way to minimize this effect is to have the white target in motion or to defocus the lens during calibration. This has the result of averaging out any dirt or texture present. If this is not possible, the camera provides options where a flat field calibration filter can be applied while generating the flat field correction coefficients—which can minimize the effects of dirt. See Flat Field Calibration.

Set up Dark and Bright Image Acquisitions with the Histogram Tool

To prepare for calibration, follow the guidelines:

- Verify the camera's dark and bright acquisition with a live grab.
  - Dark image acquisition requires a lens cap.
  - Bright acquisition requires a flat, light image. See Flat Field Calibration White Target.
- Use CamExpert **Statistics** command while grabbing to display the image characteristics. In the Statistics dialog, use the **Selected view** list to select *Histogram* or *Line Profile*.

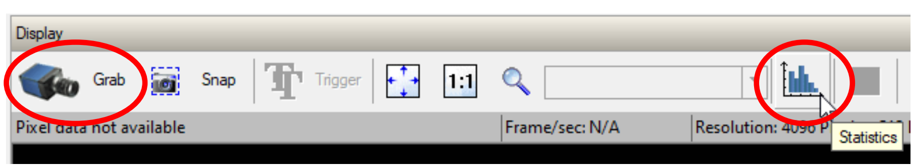


Figure 52: CamExpert – Grab & Statistics Buttons

Figure 53: CamExpert Statistics Dialog – Selected View

Set up Dark Image

Dark acquisition requires that the lens be covered with the lens cap. During acquisition, the **average** pixel value for the frame should be close to zero. Sensors might show a much higher maximum pixel value due to one or more hot pixels. If some of the pixel output is zero, adjust the Black Level feature offset value to ensure that all pixel output is above zero.

The following figure shows a typical histogram for a camera grabbing a dark image.

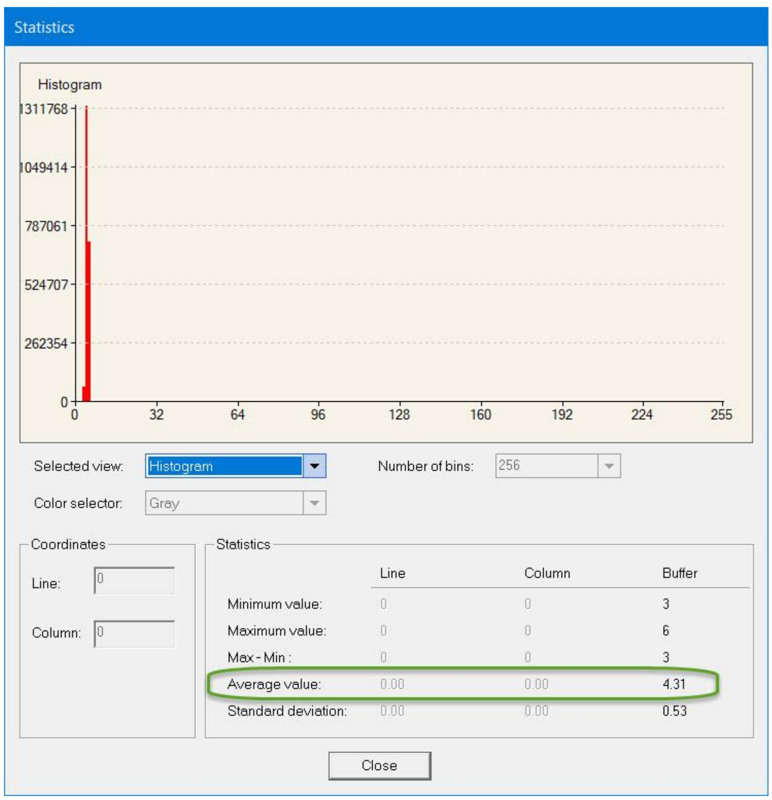


Figure 54: CamExpert Statistics Dialog – Average Dark Pixel Value

Set up Bright Image

For a bright image, use a white target (see Flat Field Calibration White Target). During acquisition, use the lens iris to adjust for a bright but unsaturated gray level, around 200 (for 8-bit).

During calibration, you may choose to adjust all pixels to a target value, e.g., 200, or to the peak pixel value, depending on the chosen flatfieldCalibrationAlgorithm option. See Flat Field Calibration Algorithm.

Note that sensors may show a much higher maximum or lower minimum pixel value due to one or more hot or dead pixel. The sensor specification accounts for a small number of hot, stuck, or dead pixels (pixels that do not react to light over the full dynamic range specified for that sensor).

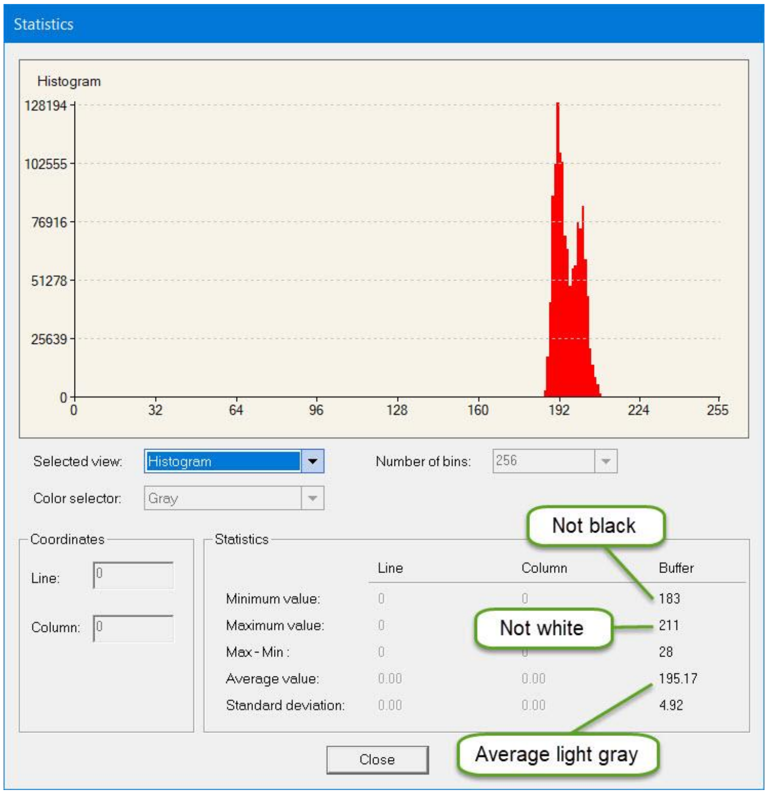


Figure 55: CamExpert Statistics Dialog – Verifying Bright Acquisition

When the bright image acquisition setup is complete, note the camera and lens iris position for repeatability in the future.

Flat Field Correction Calibration

Flat Field Correction Calibration (FFC) involves:

- Evaluating a bare image.
- Performing FPN (Fixed Pattern Noise).
- Performing PRNU (Photon Response non-uniformity) corrections.

NOTE
During calibration, no other feature settings should be accessed or modified.

Bare Image Evaluation

Before you perform the FFC, Teledyne DALSA recommends that you to try to improve the bare image quality first: a good bare image will improve the quality of the FFC. A bare image is obtained using your bright target with no gain applied.

To obtain a bare image

1. Set the Flat Field Correction Mode feature to *Off*.
2. Use the Gain Selector to set the Gain value of all options to *1.0.*

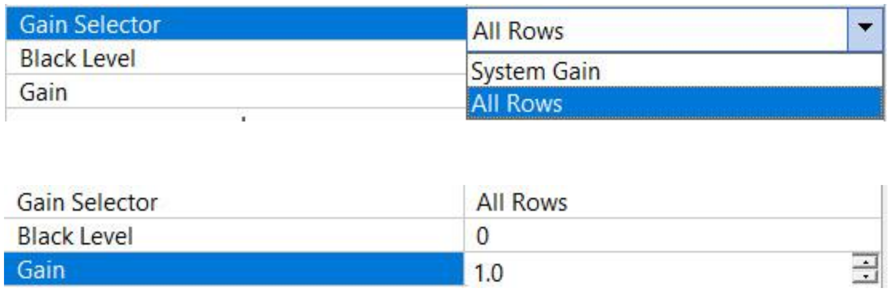


Figure 56: CamExpert – Gain

3. Click **Grab** and open the **Statistics** tool with the *Line Profile* view option to evaluate a bare image.

A line profile is mainly characterized by two factors: flatness and height.

- **Flatness.** Line profile should be as flat as possible. Note that due to lens-shading effect, light falls off near the edges, which results in lower output. This produces higher noise levels near the edges. A smaller aperture opening and longer focal length can reduce lens–shading effect. In some demanding applications, optimized low–shading lenses should be considered.
- **Height.** An average value near your calibration target is ideal. Level can be higher, but a much lower level is not desirable. An extremely low output height compared to the target will increase noise level significantly after the PRNU is corrected. To avoid SNR and/or DNR not meeting your application requirements, the profile should reach a level near the calibration target.

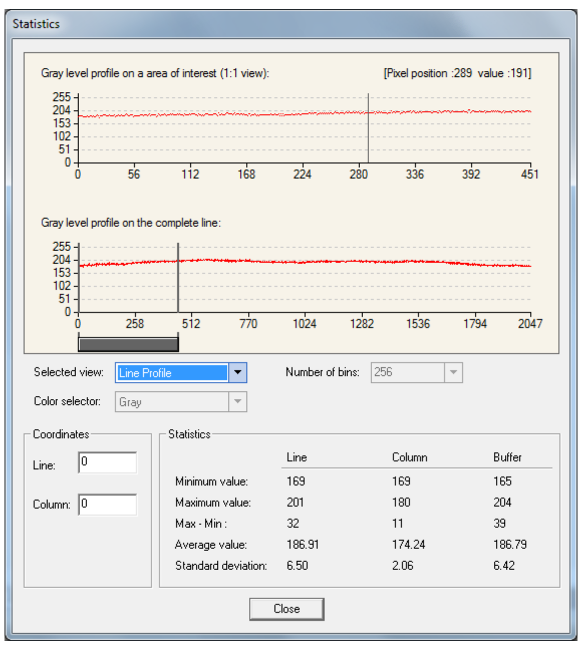


Figure 57: CamExpert Statistics Dialog – Line Profile of a bare image of a white uniform target.

To improve a bare image profile, increasing the output level by enhancing illumination (light source, lens, line rate, etc.) is the preferred method. If, despite the above effort, you still do not meet your goals, you may try adjusting gain features in the SNR allowable range. Keep in mind that changes to gain do not improve the image quality from an SNR perspective. All gains are digital multipliers and, as such, the gain scales up signal and noise proportionally. Use this method only as long as the SNR meets your application requirements.

Keep the following in mind:

- Ensure that the camera's temperature is in a stable condition.

- All parameters should meet your application's specifications. If you change parameters after the FFC is done, then the FFC results many no longer be relevant. When parameters change, you should consider running the FFC procedure again.

Once a good bare image is achieved, you can proceed with the FPN calibration.

FPN Calibration

To perform FPN Calibration

1. Set the Flat Field Correction Mode to *On*.
2. Click **Press** next to Clear Coefficients.

Parameter	Value
Flat Field Correction Mode	On
Clear Coefficients	Press...

3. Cover the lens (place the sensor in dark).
4. Click **Grab** and check the line profile/histogram. If some, or all, of the pixels outputs are zero, adjust the Black Level offset (Camera Control category) value to ensure that all pixel output is above zero.

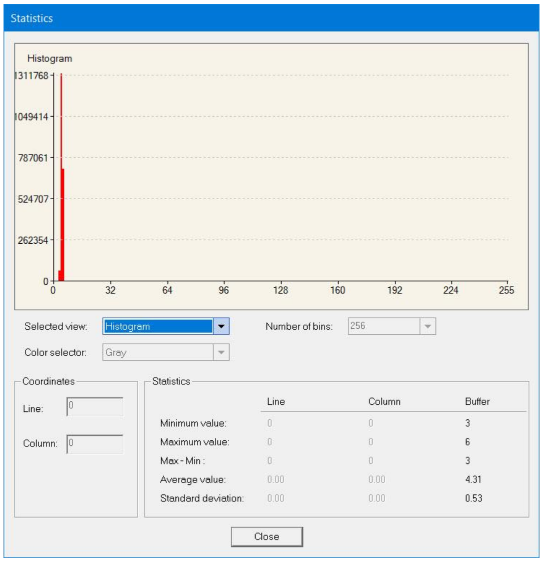


Figure 58: CamExpert Statistics Dialog – FPN Pixel Output

5. Click **Press** next to Calibrate FPN.

You may proceed with PRNU calibration.

PRNU Calibration

To perform PRNU Calibration

1. Uncover the lens and point the camera at a diffused light source or at your chosen white target, using the setup and iris position tested before.
2. If using the *Set Target* option in the Calibration Algorithm parameter, adjust the Flat Field Calibration Target. A value of 200 DN is commonly used target in 8-bit output format.

Parameter	Value
Flat Field Correction Mode	On
Clear Coefficients	Press...
Calibration Algorithm	Set Target
Flat Field Calibration Target	200

3. Click **Grab**.
4. Click **Press** next to Calibrate PRNU.

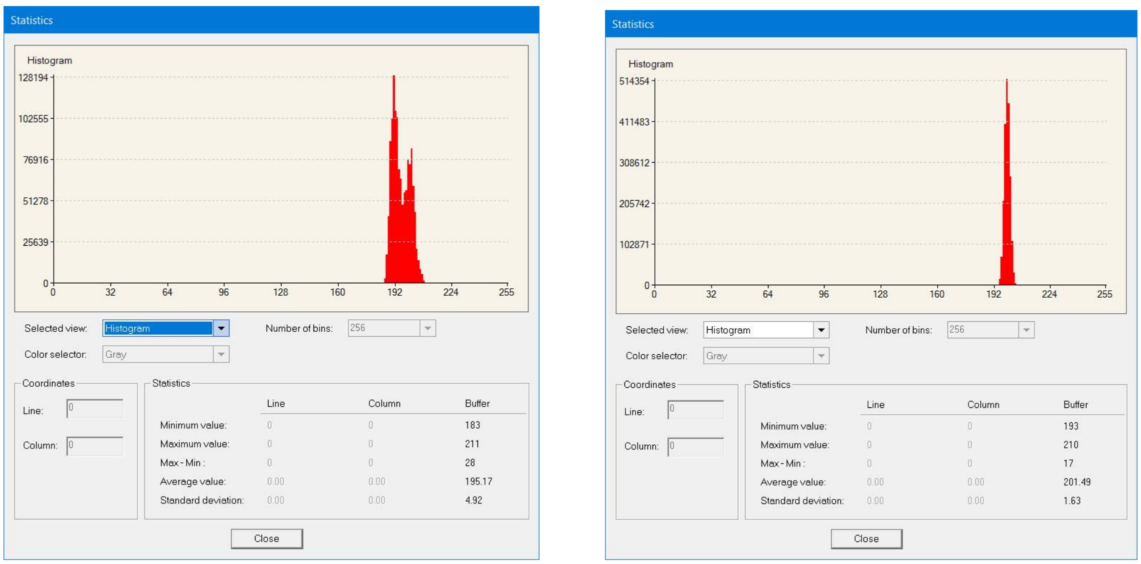


Figure 59. Histogram before and after PRNU calibration using a 200 DN target.

5. Select a user set from the PRNU Correction Current Active Set list, then click **Press** next to Save Calibration. The FFC results will be stored in the selected user set.

PRNU Current Active Set	User Set 5
Save Calibration	Press...
Load Calibration	Press...

NOTE

Saving a calibration in this way only saves the PRNU coefficients. To save FPN coefficients as well, you need to use the Power-up Configuration (see below).

6. To save this calibration and all current settings for future use, save it to a camera configuration user set through the Power-up Configuration dialog (see Saving & Restoring Camera Setup Configurations). The dialog allows you to save or load a configuration user set dynamically, or to load automatically a selected user set when resetting or powering the camera.

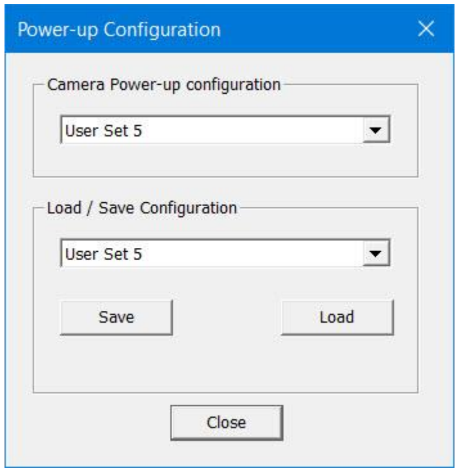


Figure 60: CamExpert – Power-up Configuration Dialog.

Revision History

Revision	Description	Date
00	Initial release.	August 1, 2024

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Technical Support

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