Falcon4 86M

Camera User's Manual

FA-S0-86M16-01-R and FA-S1-86M16-00-R

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

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Notice

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About Teledyne DALSA

Teledyne DALSA 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 Digital Imaging 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.

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The Falcon4 86M Camera

Description

Teledyne DALSA's new generation of color and monochrome area scan cameras—the Falcon4™ 86M—incorporate very large resolutions and fast frame rates, enabling high-speed image capture with superb spatial resolution and excellent image quality. Global shuttering and correlated double sampling ensure smear free and low noise images. These features make the Falcon4 cameras the best choices for applications where throughput, resolution and high pixel capacity matter most.

Inside the Falcon4 camera is our leading-edge, global shutter CMOS sensor, which enables high speed imaging at very large resolutions. Global shutter technology removes the need for mechanical shutters which are limited in the number of open / shut operations.

The Falcon4 camera is compliant with GenICam™ and CameraLink HS™ (CLHS) specifications—delivering 12 and 16 bits of data. In addition, the M95 thread opening allows for your choice of lens.

Key Features

- Global shutter and exposure control
- Cross-track of 10,720 pixels
- Faster frame rates through windowing
- Good NIR response
- Built-in FPN and PRNU correction
- CLHS interface and GenICam compliant

Programmability

- Adjustable digital gain and offset
- 12 and 16 bit output
- Adjustable integration time and frame rate
- Test patterns and camera diagnostics

Applications

- Aerial imaging
- Aerial reconnaissance
- Surveillance
- Machine vision

Model Numbers and Software Requirements

This manual covers the Falcon4 camera models summarized below. New models are added to this manual as they are released by Teledyne DALSA.

Table 1: Camera Models Overview

Model Number	Description
FA-S0-86M16-01-R	86M pixel monochrome, Camera Link HS.
FA-S1-86M16-00-R	86M pixel color, Camera Link HS.

Table 2: Camera Accessories

Part Number	Description
AC-MS-00117-00-R	Fan mounting accessory. Allows a fan to be mounted on the camera case to direct air flow over the heat sink.

Table 3: Software

Software	Product Number / Version Number
Camera firmware	Embedded within camera
GenICam™ support (XML camera description file)	Embedded within camera
Recommended: Sapera LT, including CamExpert GUI application and GenICam for Camera Link imaging driver.	Version 7.50 or later

Camera Performance Specifications

Table 4: Camera Performance Specifications

Specifications	Performance
Resolution	10720 (H) x 8064 (V)
Pixel Rate	1.38 Gpixel / s
Frame Rate	16 fps, maximum
Pixel Size	6 µm x 6 µm
Bit Depth	12 and 16 bits, selectable Camera Link HS
Exposure Time	100 µs minimum
Dynamic Range	56 dB (monochrome) and 50 dB (color) with global shutter 62 dB (monochrome) and 54 dB (color) with rolling shutter
Operating Temp	0 °C to +50 °C, front plate temperature
Connectors and Mechanicals	
Size	100 mm (H) x 100 mm (W) x 67 mm (D)
Mass	< 1 kg
Data Connector	CLHS—single C2 7M1, CX4 connector
Power Connector	Hirose 12-pin circular
Supply Voltage	+ 12 V to + 24 V DC (± 5 %), 3.5 Amps

Power	< 35 W
Lens Mount	M95 x 1
Sensor Alignment	± 50 µm in X-Y directions

Mono Operating Ranges	Units	Value	Notes
Noise and Non-Uniformity Performance			
Full Well	e-	> 22, 000, global shutter > 27, 000, rolling shutter	
Dynamic Range	dB	53, global shutter 62, rolling shutter	
Random Noise	DN rms	7.0, global shutter 3.2, rolling shutter	Maximum, FFC enabled
FPN (w/o correction), global	DN rms	48	
PRNU (w/o correction), global	% rms	3.5	% measured signal level, nominally 50% output. FPN removed
Nominal Output Characteristics			
Broad Band Responsivity	DN / (nJ / cm²)	137, global shutter mono 117, rolling shutter mono 64, global shutter color 73, rolling shutter color	FFC enabled
SEE	nJ / cm²	30, global shutter mono 35, rolling shutter mono 64, global shutter color 56, rolling shutter color	FFC enabled
NEE	pJ/cm²	64, global shutter mono 30, rolling shutter mono 133, global shutter color 44, rolling shutter color	FFC enabled
Antiblooming		> 600 x saturation	
Integral non-linearity	%	3	From 10-90% of camera saturation

*DN = digital number (12-bit)

Notes:

1) Mono Light source: broadband, quartz halogen, 3250 K with 700 nm IR cut-off filter.
2) Color Light source: broadband, quartz halogen, 3250K with BG38 filter.
3) Responsivity with FFC enabled.
4) Mono camera PRNU w/o correction is measured at 50% output with FPN removed.
5) Integral non-linearity = Deviation from best fit line 10 to 90%/4096.

Environmental Specifications

Table 5: Environmental Specifications

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

Sensor Cosmetic Specifications

The following table lists the current cosmetic specifications for the Teledyne DALSA sensor used in the cameras.

Table 6: Blemish Specifications

Description	Definition	# of Defects
Column defect	A group of more than 20 contiguous pixels along a single column that deviate from the neighboring columns by: More than ±15% at 50% saturation with Flat-field correction ON and 1x gain. More than 20% of saturation in dark and 1x gain.	6
Row defect	A group of more than 20 contiguous pixels along a single row that deviate from the neighboring columns by: More than ±15% at 50% saturation with Flat-field correction ON and 1x gain. More than 20% of saturation in dark and 1x gain.	6
Cluster defect	A grouping of 2 to 16 inclusive defective pixels at a given test condition. A defective pixel is defined as 20% of saturation output when sensor is dark and ± 15% away from the average of the neighboring pixels of the same color measured at 20% to 80% of maximum output in steps of 10%. The maximum cluster defect size is 16.	34
Uncorrectable single defective pixel	At dark: Pixel level is elevated beyond 20% of saturation. At 50% saturation: Pixel level is ±15% away from its neighboring pixels with FFC on.	15,000

1. Cluster defects are separated by no less than one good pixel in any direction.
2. Column and row defects are separated by no less than two good columns and rows respectively.

Test Conditions

- Nominal light = illumination at 50% of saturation
- Temperature of Camera is 35 C
- Integration Time: 10 ms
- At nominal sensor gain (1x)

Responsivity & QE

The responsivity graph describes the camera's response to different wavelengths of light (excluding lens and light source characteristics).

The image sensor includes micro lenses to improve the collection efficiency of the active pixel area. The drawback to this is that the light collected varies with the angle of incidence, as shown in the Angle of Incidence figure, below. Pixel Response Non Uniformity (PRNU) can be calibrated in the field and takes into account the lighting and lens effects, and results in a more uniform output level.

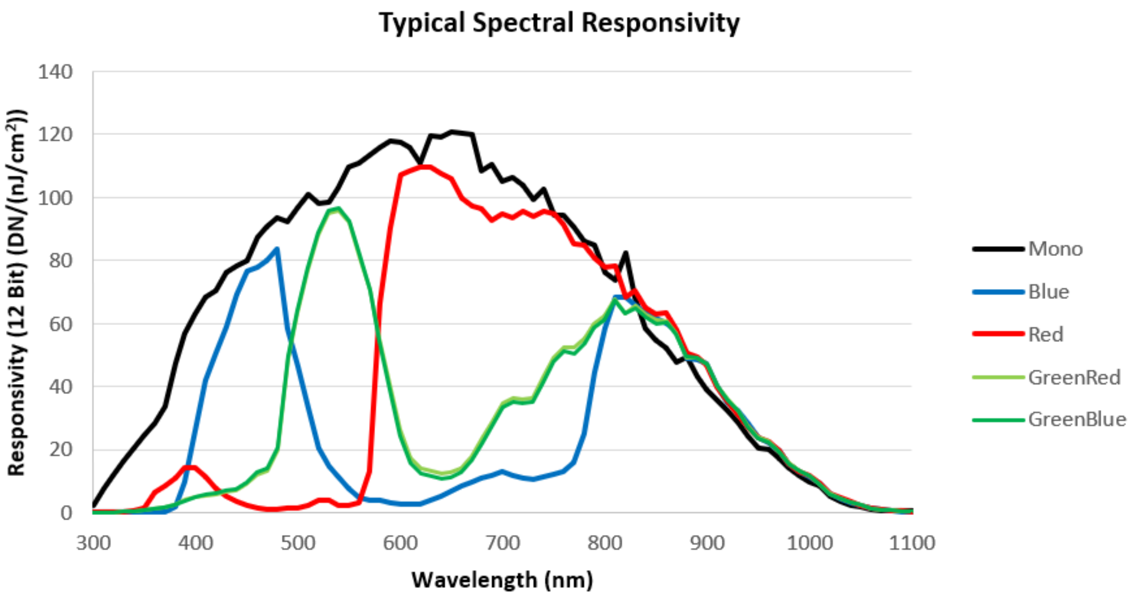


Figure 1: Spectral Responsivity

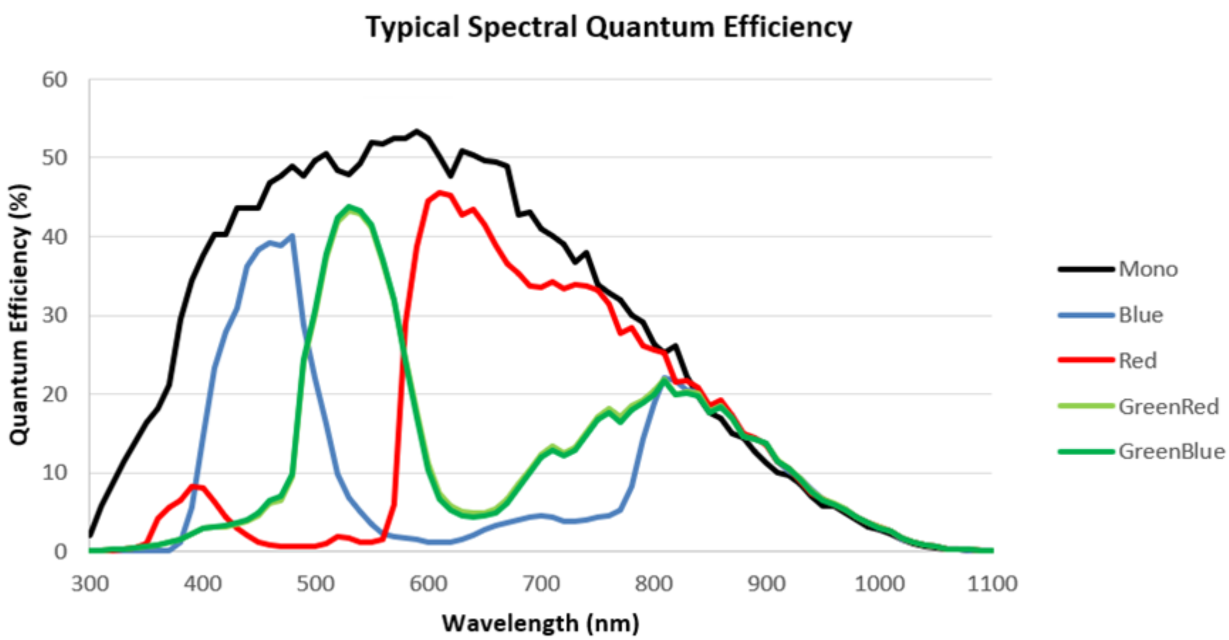


Figure 2: Typical Spectral Quantum Efficiency

Angle of Incidence

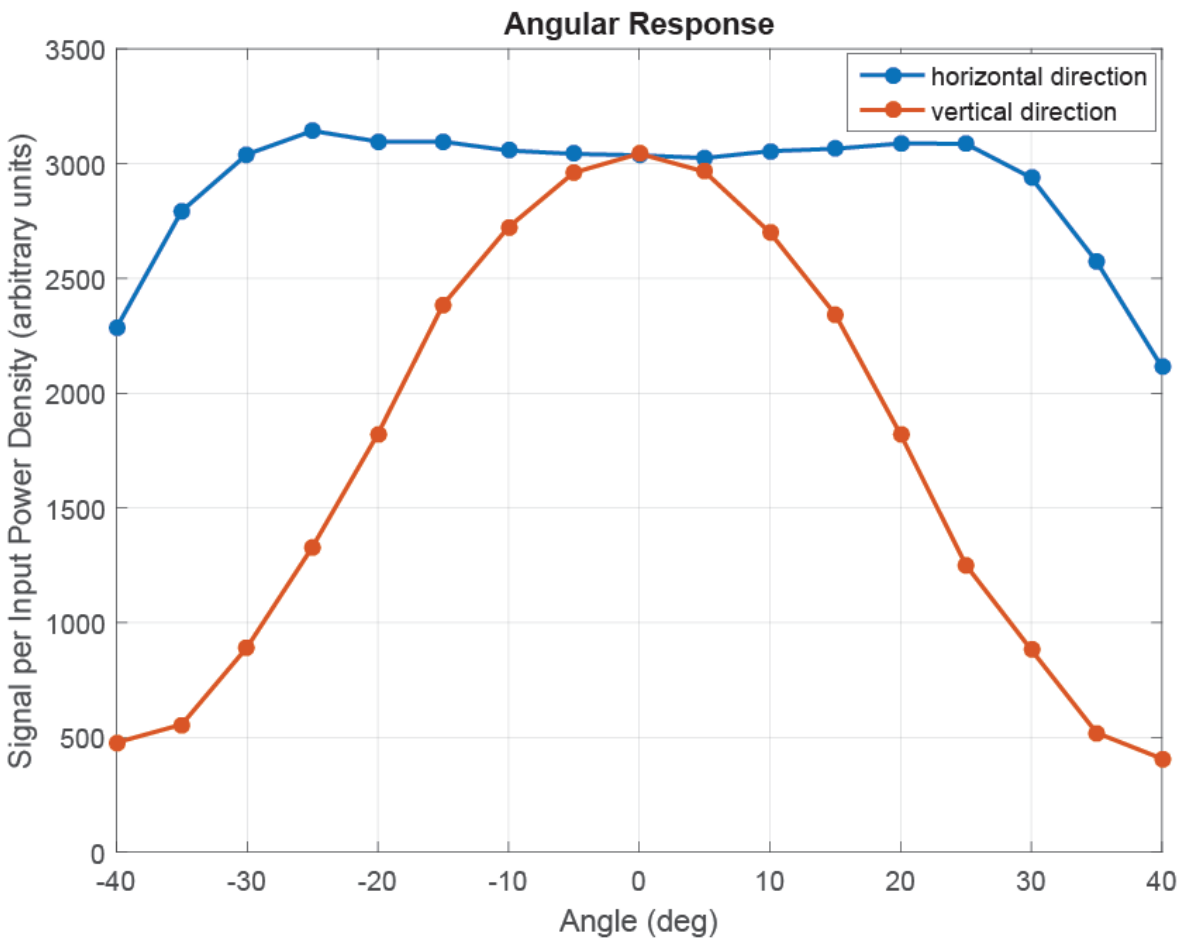


Figure 3: Angular Response

Flash Memory Size

Table 7: Memory

Camera	Flash Memory Size
FA-S0-86M16-01-R	500 MByte program storage 8,000 MByte correction coefficients
FA-S1-86M16-00-R	500 MByte program storage 8,000 MByte correction coefficients

Certifications & Compliance

Table 8: Radiated Emissions

Compliance
EN 55011, CISPR 11, EN 55022, EN 55032, CISPR 22, CISPR 32, FCC Part 15, and ICES-003 Class A Emissions Requirements.
EN 55024, and EN 61326-1 Immunity to Disturbance.

Shock & Vibration

The cameras meet or exceed the following specifications:

- Random vibration per MIL-STD-810F at 25 G^2/HZ [Power Spectral Density] or 5 RMS
- Shock testing 75 G peak acceleration per MIL-STD-810F

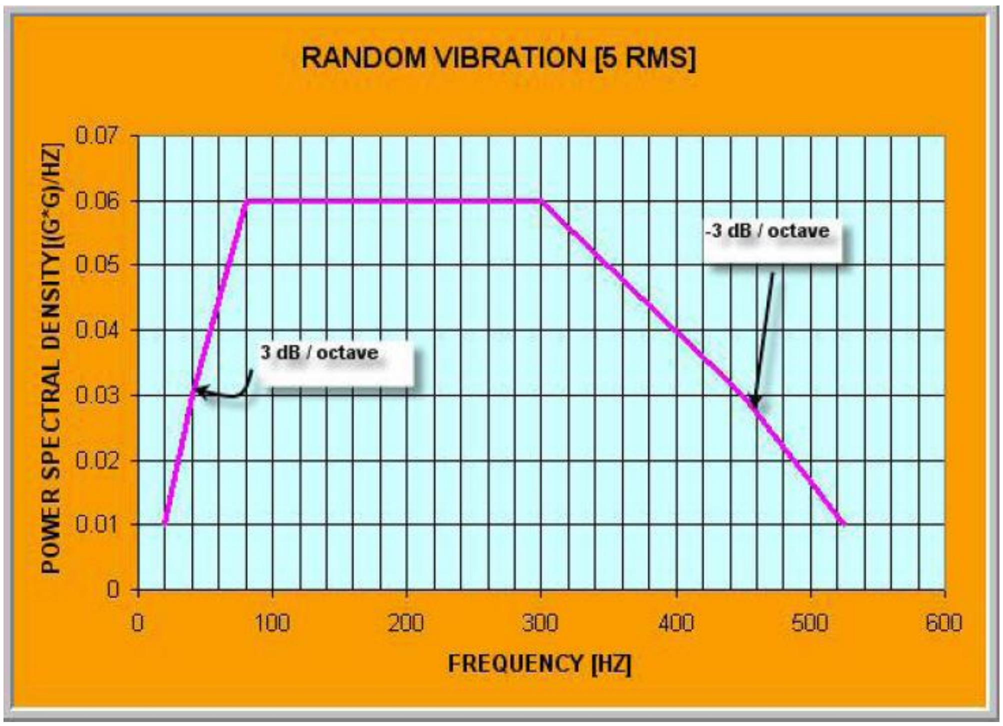


Figure 4: Random Vibration

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.genicam.org.

Camera Link HS

The camera is Camera Link HS version 1.0 compliant. Camera Link HS is the next generation of high performance communications standards and is used where a digital industrial camera interfaces with single or multiple frame grabbers with data rates exceeding those supported by Camera Link. The camera includes a Camera Link HS connector capable of supporting data rates up to 2.1 Gbytes / sec per second.

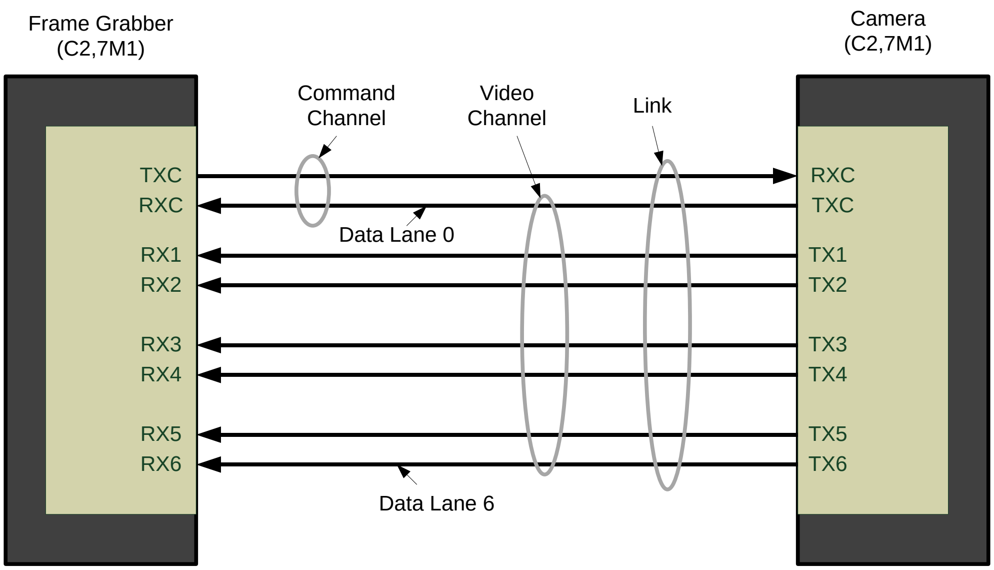


Figure 5. Single CLHS Connector Configuration

The command channel is used by the frame grabber to send command, configuration, and programming data to the camera and to receive command responses, status, and image data from the camera.

The designation C2, 7M1 defines the use of a SFF-8470 connector (C2) and up to 7 lanes of data with 1 command channel using M-Protocol (8b/10b) at the default speed of 3.125 Gb/sec.

Camera Link HS ROI Characteristics

The single ROI is customer entered and transmitted across all seven data lanes. There is a minimum of 96 pixels per data lane used.

CLHS limits the start and stop location of the ROI to a multiples of 32 pixels. The maximum line rate is limited by the sensor when not limited by the CLHS cable or by the PCIe transfer. The sensor is limited to a 125 kHz maximum line rate.

The CLHS cable has approximately 2.1 GByte / sec bandwidth for seven lanes. The XTIUM X8 frame grabber has about 3.2 GByte / sec across the PCIe bus and can support the full frame rate of the camera.

Sensor Block Diagram & Pixel Readout

Pixels are read from left to right, top to bottom. The data for each line is transferred from the sensor to 7 CLHS data lanes. CLHS is a packet-based protocol therefore the concept of taps or tap geometry does not apply; the frame grabber reconstructs the images based on the information contained in the packet, regardless of which data lane is used for the transfer.

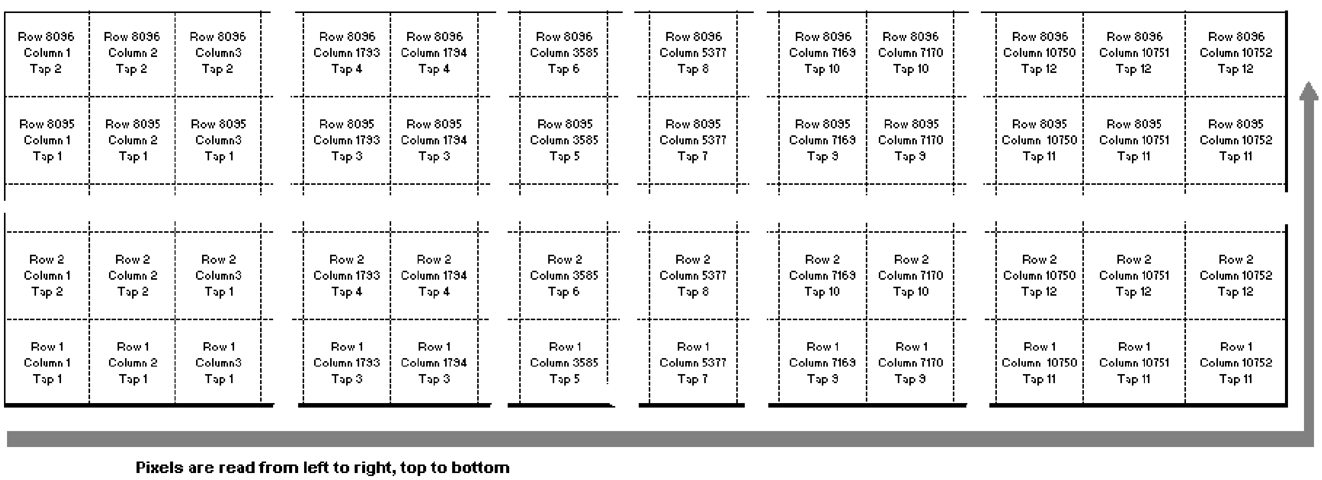


Figure 6: Pixel Readout of the Falcon 4 camera.

Note:

- As viewed looking at the front of the camera *without a lens*. (The Teledyne DALSA logo on the side of the case will be right-side up.)

Camera Setup

System Precautions & Cleaning

Precautions

Read these precautions and this manual before using the camera.

> Do not open the housing of the camera. The warranty is voided if the housing is opened.

- Confirm that the camera’s packaging is undamaged before opening it. If the packaging is damaged please contact the related logistics personnel.
- Keep the camera’s front plate temperature in a range of 0 °C to 50 °C during operation. The camera has the ability to 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 worst case conditions. The camera will stop outputting data if its internal temperature reaches 70 °C. Refer to section Verify Temperature for more information on the ‘Temperature’ feature and thermal management.
- Do not operate the camera in the vicinity of strong electromagnetic fields. In addition, avoid electrostatic charging, 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.

Cleaning the Device

To clean the device, 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 clean the surface of the camera housing, use a soft, dry cloth. 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.

Electrostatic Discharge and the CMOS Sensor

Image sensors and the camera bodies housing are susceptible to damage from electrostatic discharge (ESD). Electrostatic charge introduced to the sensor window surface can induce charge buildup on the underside of the window. If this occurs, the charge normally dissipates within 24 hours and the sensor returns to normal operation.

Software and Hardware Setup

Recommended System Requirements

To achieve best system performance, the following minimum requirements are recommended:

- High bandwidth frame grabber. For example, Teledyne DALSA Xtium PX8 CLHS series frame grabber: http://www.teledynedalsa.com/imaging/products/fg/#digital-cameralink.
- Operating systems: Refer to frame grabber documentation for supported platforms.

Setup Steps: Overview

Take the following steps in order to setup and run your camera system. They are described briefly below and in more detail in the sections that follow.

1. Install and Configure Frame Grabber and Software.
2. Connect Camera Link and Power Cables.
3. Establish communication with the camera.

Step 1: Install and Configure Frame Grabber and Software

Teledyne DALSA recommends its Xtium PX8 CLHS series frame grabber or equivalent. Follow the manufacturer's installation instructions.

A GenICam™ compliant XML device description file is embedded within the camera firmware allowing GenICam™ compliant application to know the camera's capabilities immediately after connection.

Installing Sapera LT gives you access to the CamExpert GUI, a GenICam™ compliant application. Sapera LT is available free of charge for download from the Teledyne Dalsa website.

Step 2: Connect Camera Link and Power Cables

The camera uses a Camera Link HS SFF-8470 (CX4) cable and a Hirose connector for power and IO connections.

- Connect the required Camera Link HS cable from the camera to the frame grabber installed on the computer.
- Connect a power cable from the camera to a power supply that can provide a constant voltage from +12 V to +24 V DC.

Note: the use of cables types and lengths other than those specified may result in increased emission or decreased immunity and performance of the camera.

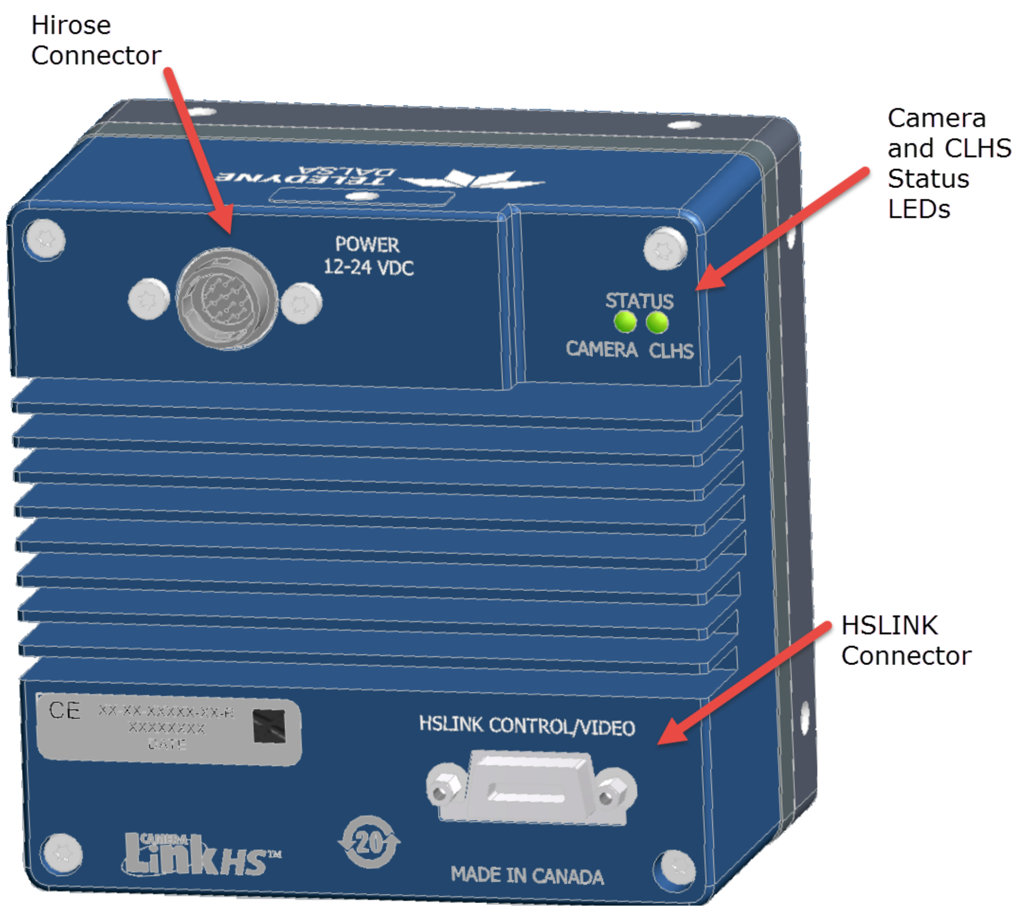


Figure 7: Input and Output, trigger, and Power Connectors

WARNING! Grounding Instructions
Static electricity can damage electronic components. It's critical that you discharge any static electrical charge by touching a grounded surface, such as the metal computer chassis, before performing handling the camera hardware.

Power Connector

WARNING: It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages may damage the camera. Input voltage requirement: +12 V to +24 V DC (± 5 %), 3.5 Amps. Before connecting power to the camera, test all power supplies.

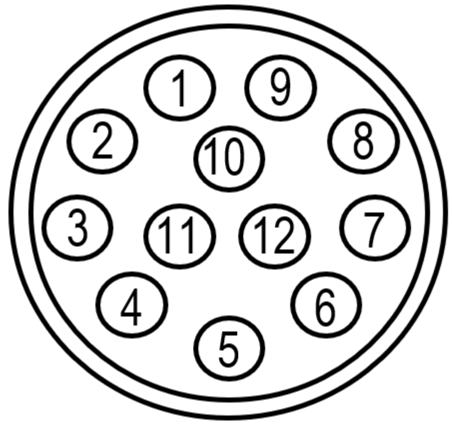


Figure 8: 12-pin Hirose Circular Male Power Plug—Power Connector

Table 9. Power Plug Pinout

Pin	Description	Pin	Description
1	GND	7	OUT2+
2	+12 V to +24 V DC	8	OUT2-
3	OUT1-	9	NC
4	OUT1+	10	NC
5	IN1-/Trigger	11	IN2+/Trigger
6	IN1+/Trigger	12	IN2-/Trigger

WARNING: When setting up the camera's power supplies follow these guidelines:

- Apply the appropriate voltages.
- Protect the camera with a 3.5 amp slow-blow fuse between the power supply and the camera.
- Do not use the shield on a multi-conductor cable for ground.
- Keep leads as short as possible in order to reduce voltage drop.
- Use high-quality linear supplies in order to minimize noise.

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

Camera Link Data Connector

The camera uses a Camera Link HS SFF-8470 (CX4) cable.

Input Signals, Camera Link

The camera accepts control inputs through the Camera Link HS SFF-8470(CX4) connector.

The camera ships (factory setting) in internal sync, and internally triggered integration.

Frame Start Trigger (EXSYNC)

The EXSYNC signal tells the camera when to integrate and readout the image. It can be either an internally generated signal by the camera, or it can be supplied externally by a CLHS Pulse Message software command or camera GPIO pin.

LED Indicators

The camera is equipped with 2 LEDs on the back to display the operational status of the camera. The tables below summarize the operating states of the camera and the corresponding LED states. When more than one condition is active, the LED indicates the condition with the highest priority.

Camera Status LED	**Meaning**
Off	No power or hardware malfunction
Red slow blinking	Camera in temporary shutdown (e.g. temperature). The communication channel is maintained but imaging is disabled
Red solid	Fatal error state. Device is not functional
Blue fast blinking	Firmware upgrade, file transfer
Blue slow blinking	Camera waiting for warm up to complete (Camera initialization)
Blue solid	Upgrading internal firmware, when acquisition is disabled. This happens when changing a camera feature that effects the image output (e.g. AOI, bit depth, etc.)
Green solid	Free-running acquisition
Green slow blinking	Calibration in progress
Orange slow blinking	Camera initializing
CLHS Status LED	**Meaning**
Off	No power or hardware malfunction
Orange solid	The frame grabber is holding this device in reset preventing any communication
Orange slow blinking	The devices have established communication and determined that they are not interoperable, and camera is initializing
Red solid	Fatal error state. Device is not functional.
Red slow blinking	Camera in temporary shutdown (e.g. temperature). The communication channel is maintained but imaging is disabled
Red fast blinking	Camera has CLHS link error.
Green solid	Link established and data transfer may take place.
Green fast blinking	Camera is losing trigger
Green slow blinking	Looking for Link

LED States on Power Up

The following LED sequence occurs when the Falcon 4 is powered up connected to a CLHS frame grabber.

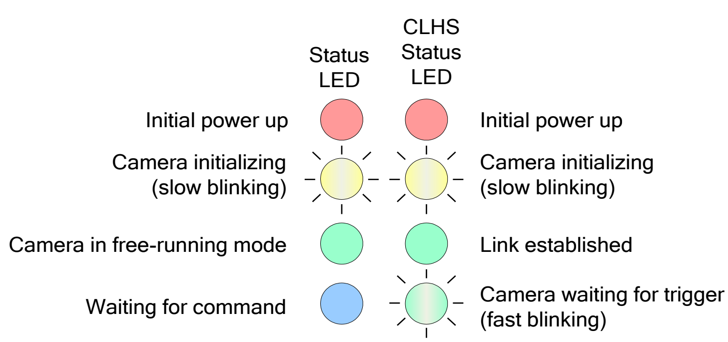


Figure 9: LED States on Power Up

Step 3: Establish Communication between the frame grabber and the camera

To establish communication with the camera following these steps in order:

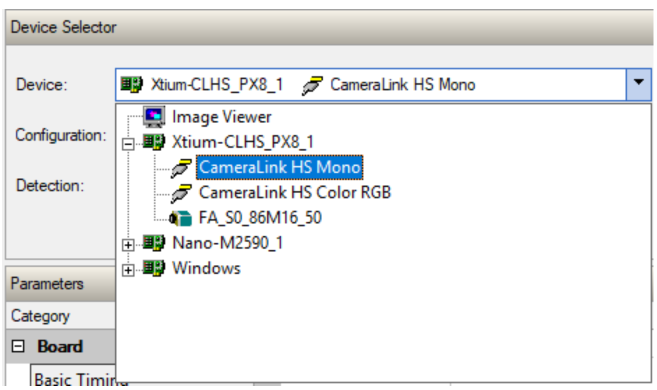
1. Power on the camera.
2. Connect to the frame grabber.
3. Connect to the camera.

1. Power on the camera

- Turn on the camera's power supply. You may have to wait up to 60 seconds for the camera to warm up and prepare itself for operation.
- The camera must boot fully before it will be recognized by the GenCP compliant application. In this ready-state, the CLHS LED will be green and the Camera LED will be green or blue (if using a Teledyne DALSA frame grabber). You are now ready to connect the frame grabber, step 2.

2. Connect to the frame grabber

- Start Sapera CamExpert (or an equivalent GenCP-compliant interface) by double-clicking the desktop icon created during the software installation.
- CamExpert will search for Sapera devices installed on your system. In the Devices list area on the left side of the GUI, the connected frame grabber will be shown.

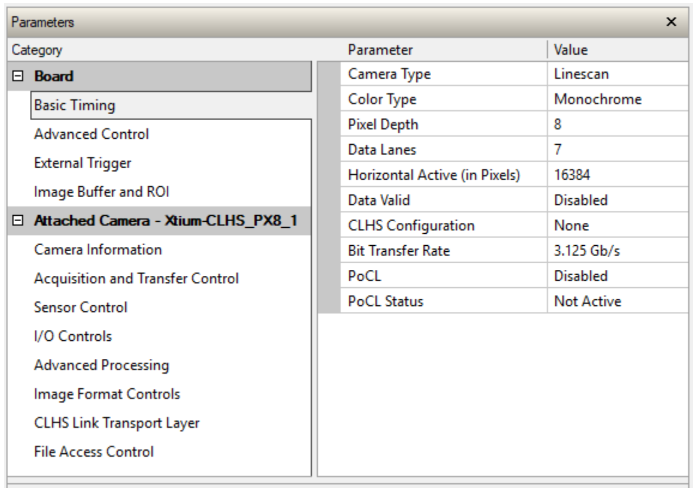


- Select the frame grabber device by clicking on its name.

Note: The first time you set up the camera you will need to establish a communication link between the camera and frame grabber; refer to the frame grabber documentation for information on installation and setup configuration.

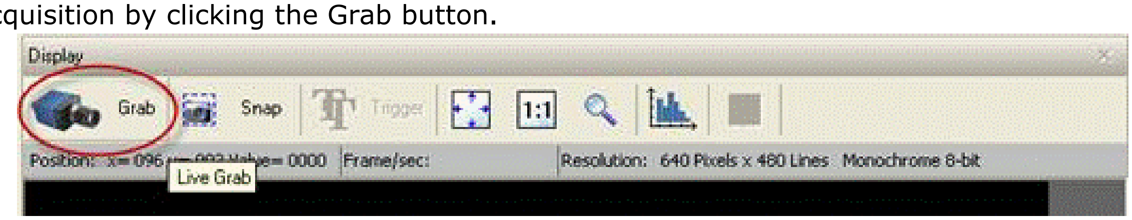
3. *Connect to the camera*

- CamExpert will search for Sapera devices installed on your system. In the Devices list area on the left side of the GUI, the connected Cabernet camera will be shown.
- When CamExpert detects a camera (as per the CLHS device discovery protocol), camera parameters are displayed along with the board parameters.



- When properly connected, the video status bar displays camera signals in green.

- Modify the camera and frame grabber parameter settings as required, and test the image acquisition by clicking the Grab button.



- Save the frame grabber configuration to a new *.ccf file.

Check LED Status

At this point, if the camera is operating correctly the LEDs will flash yellow for approximately 10 seconds and then turn solid green if acquisition is on, or camera LED stays blue, CLHS LED blinks green to wait for trigger

Software Interface

All the camera features can be controlled through CamExpert. For example, under the Sensor Control menu you can control the frame rate and exposure times.

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

Using CamExpert

The Sapera CamExpert tool is the interfacing tool for GenCP compliant Camera Link cameras, and is supported by the Sapera library and hardware. When used with a CLHS camera, CamExpert allows a user to test most of the operating modes. Additionally, CamExpert is able to save and reload the frame grabber configuration to simplify repeated power-up system configuration. Similarly, the camera is able to store the selected camera configuration in a user set which can be recalled each time the camera is repowered.

An important component of CamExpert is its live acquisition display window which allows immediate verification of timing or control parameters without the need to run a separate acquisition program.

Click on any parameter and a short description is displayed below the Category pane. Click on the button to open the help file for more descriptive information on CamExpert.

Note: The examples shown may not entirely reflect the features and parameters available from the camera model and camera mode used in your application.

CamExpert Panes

The various areas of the CamExpert tool are described in Figure 10: CamExpert Interface. Device Categories and Parameter features are displayed as per the device's XML description file. The number of parameters shown is dependent on the View mode selected (Beginner, Expert, Guru – see description below).

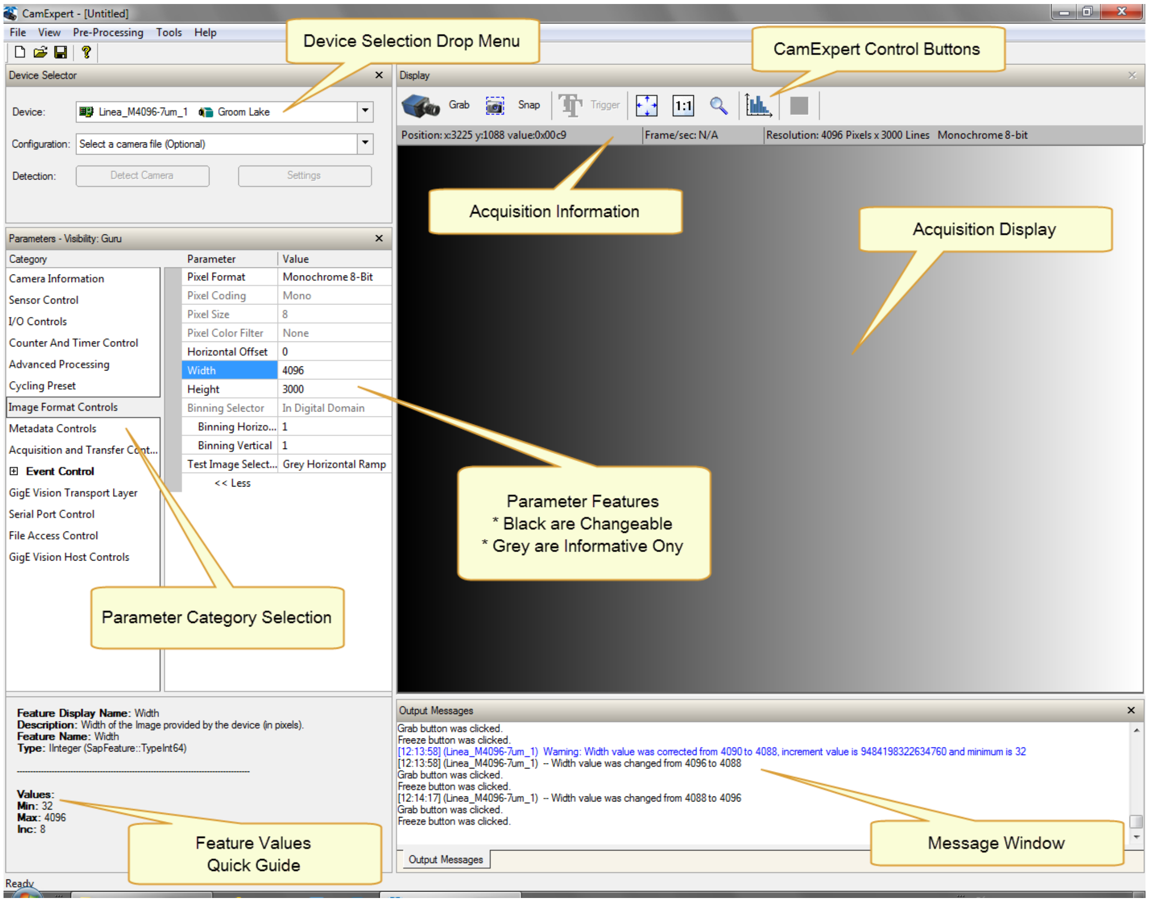
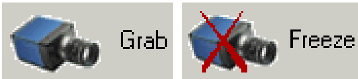
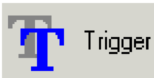
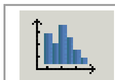


Figure 10: CamExpert Interface

- **Device Selector pane**: View and select from any installed Sapera acquisition device. After a device is selected, CamExpert will only present parameters applicable to that device. Optionally select a camera file included with the Sapera installation or saved by the user.
- **Parameters pane**: Allows viewing or changing 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:

	**Acquisition control button:** Click once to start live grab, click again to stop.
	**Single frame grab:** Click to acquire one frame from device.
	**Software trigger button:** With the I/O control parameters set to Trigger Enabled / Software Trigger type, click to send a single software trigger command.
	**CamExpert display controls:** (these do not modify the frame buffer data) Stretch (or shrink) image to fit, set image display to original size, or zoom the image to any size and ratio. This does not affect the acquisition.
	**Histogram / Profile tool:** Select to view a histogram or line/column profile during live acquisition.

- **Output pane**: Displays messages from CamExpert.

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.

Creating a Camera Configuration File in the Host

- When using the Teledyne DALSA Sapera SDK – the CCF is created automatically via a save.
- When using a 3rd party SDK application, if that SDK supports **GenAPI 2.4**, then the process is automatic. Simply follow the 3rd party *Save Camera* method as instructed.
- If the SDK is based on **GenAPI 2.3** or lower, the user must call the command DeviceFeaturePersistenceStart before using the SDK *Save Camera* method and the command DeviceFeaturePersistenceEnd at the end of the save function.

Camera Operation

Factory Settings

The camera ships and powers up for the first time with the following factory settings:

- Flat field coefficients enabled (calibrated in internal exposure mode, non-concurrent readout and integration).
- Defect concealment enabled.
- Internal exposure mode (internal frame rate and exposure time).
- 12 Hz frame rate and 10 msec exposure time.
- Dark row subtract enabled with the nominal background add value set

Check Camera and Sensor Information

Camera and sensor information can be retrieved via a controlling application—for example, the CamExpert GUI shown in the following examples. Parameters such as camera model, firmware version, sensor characteristics, and so forth, are read to uniquely identify the connected device.

The parameters used to select, load and save user sets are grouped together under the Camera Information category.

Verify Temperature

To determine the temperature at the camera, use the **Refresh Temperature** feature. The Device Temperature selector allows you to select which temperature sensor to read (FPGA, sensor board or sensor). The temperature returned is the internal temperature in degrees Celsius. For proper operation this value should not exceed 70 °C. If the camera exceeds the designated temperature it will stop imaging and the LED will turn red. After you have diagnosed and remedied the issue use the **Device Reset** function.

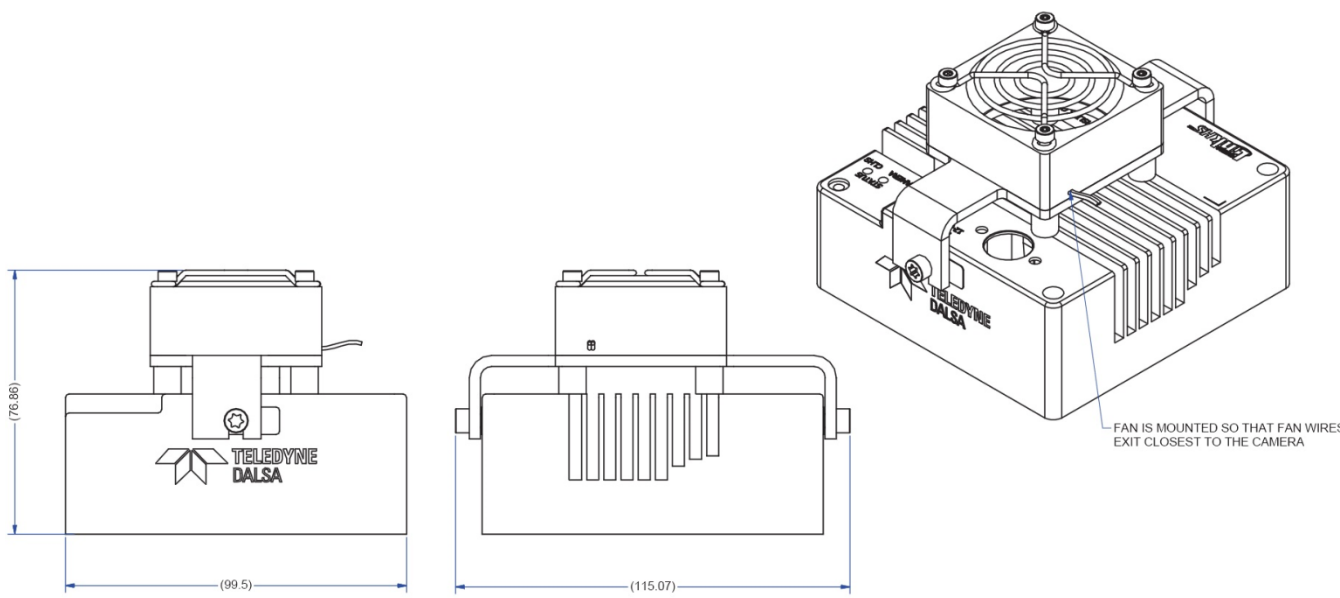
Thermal Management

The camera is designed to work with a maximum case temperature of 50 ºC. If the camera is left powered on a bench, without lens, heat sinking, or forced air movement, the camera will become *very* hot to the touch and will reduce its power dissipation by disabling the imaging function.

If this occurs, the LED turns red and communication with the camera is still available.

An accessory is available (part number AC-MS-00117-00-R, shown below) that mounts a fan to the camera case to force air flow over the camera’s heat sink. This accessory can be ordered from Teledyne DALSA.

The fan’s electrical connection is via 2 pigtail wires. The red wire is hooked to a +14 V to +24 V supply @ 150 mA max, 100 mA typ. The black wire is the power return. With a +24 V supply, the temperature on the sensor board will be about 25 degrees above ambient, as measured by the sensor board temperature sensor. A +14 V supply results in an approximately +30 ºC temperature rise above ambient.



Handling

Warning! Depending on the mounting design and the operating conditions the camera body could become hot. You must take precautions to ensure your safety and avoid touching the camera directly during operation.

Saving and Restoring Camera Settings

The Power-up Configuration parameter opens a dialog allowing you to specify the camera configuration to use on power up and to save current parameter settings.

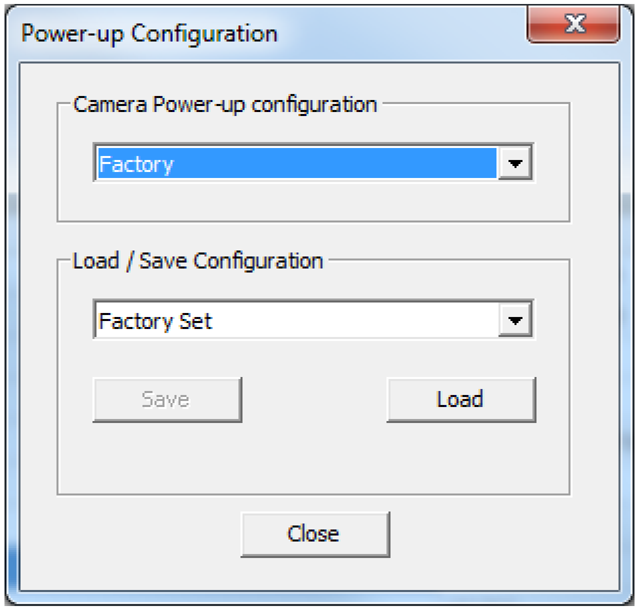


Figure 11: CamExpert Power-up Configuration Dialog

When the user changes a camera parameter, the settings are stored in the camera's *volatile* memory and will be lost if the camera resets or is powered down. To save these settings for reuse, they must be saved to the camera's non-volatile memory using the **User Set Save** parameter. Previously saved user setting (User Set 1 to 3) or the factory settings can be restored using the User Set Selector and User Set Load parameters.

Either the Factory or one of the User settings can be specified as the Default Set by selecting it in the User Set Default Selector. The chosen set is automatically loaded when the camera is reset or powered up. It should also be noted that the value of Default Selector will automatically get save in non-volatile memory whenever it is changed.

The relationship between these three settings is illustrated here:

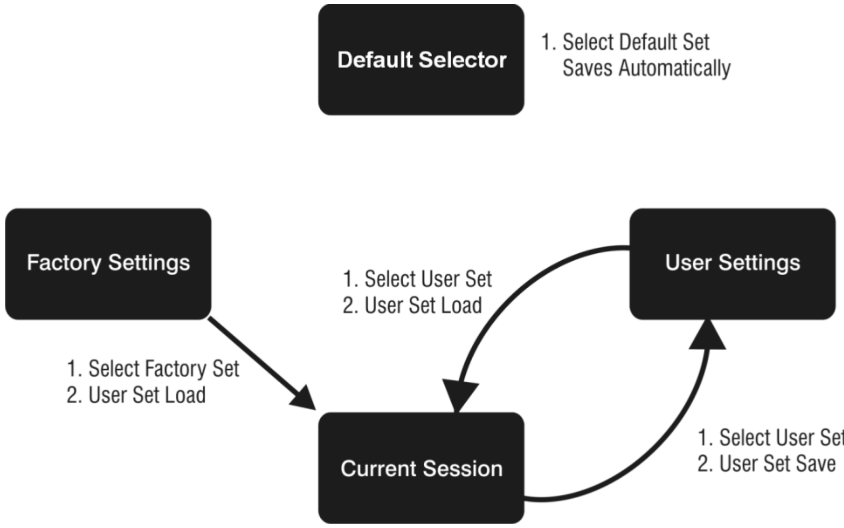


Figure 12: Relationship between the Camera Settings

	**Note**: If a test pattern is active when you save the **User Set**, the camera will turn off all digital processing upon restart.

For example:

- Set the test image selector to FPN Diagonal Pattern.
- Do FPN Calibration and save the coefficient set.
- Change the FFC mode to *ActiveAll.*
- Set the default selector to *UserSet1.*
- Save **User Set 1.**
- Power cycle the camera.
- Reconnect to the camera through CamExpert.
- The FFC mode will be *Off* when it should be *ActiveAll.*

Acquisition and Transfer Control Features

Use the commands grouped under the Acquisition and Transfer Control category to choose the acquisition mode, start and stop acquisitions, and to monitor the acquisition status.

The latest Teledyne DALSA frame grabber driver issues the acquisition start command by default.

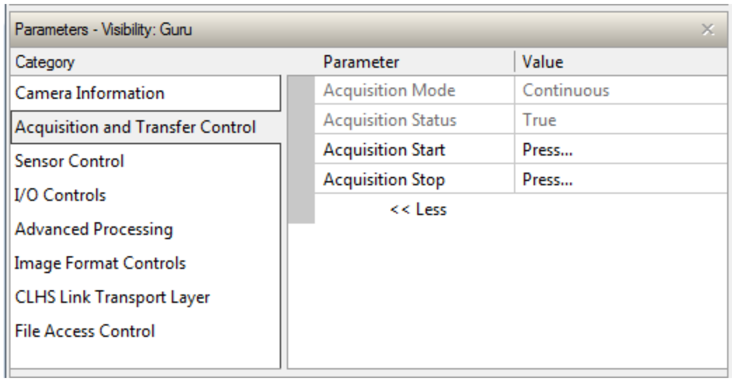


Figure 13: CamExpert Acquisition and Transfer Control Category

Test Patterns

When setting test patterns, the camera set the digital gains to 1x, the digital offsets to 0, and deactivates the flat field correction. This ensures that the test patterns appear as they should. At the same time, the camera saves the last set of values that were used for video processing and restores them when video output is restored.

Use CamExpert to easily enable and select any test pattern from the drop menu while the camera is not in acquisition mode. Select live grab to see the pattern output.

The Test Pattern feature is available in the Image Format Controls category:

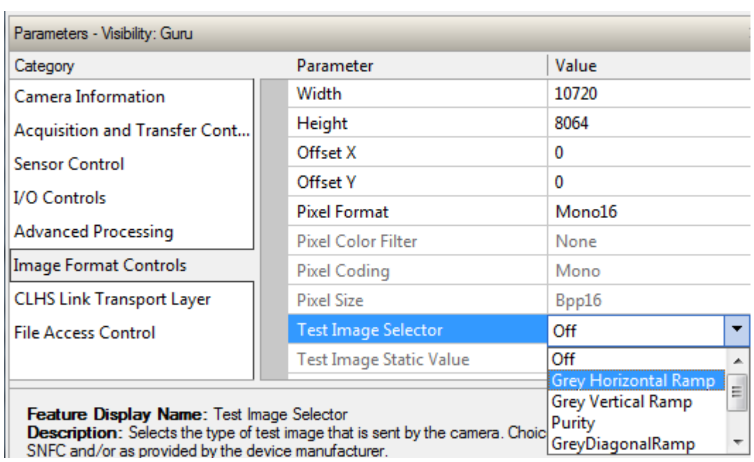
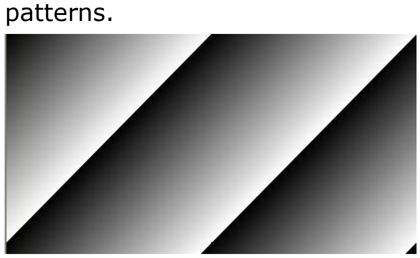
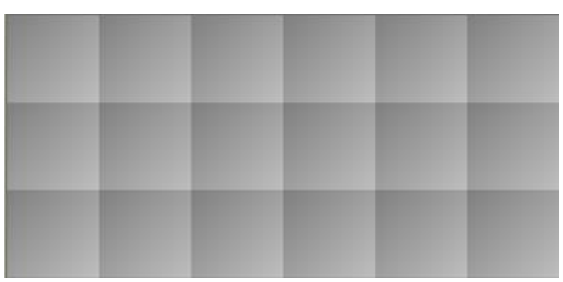


Figure 14: CamExpert Image Format Controls Category

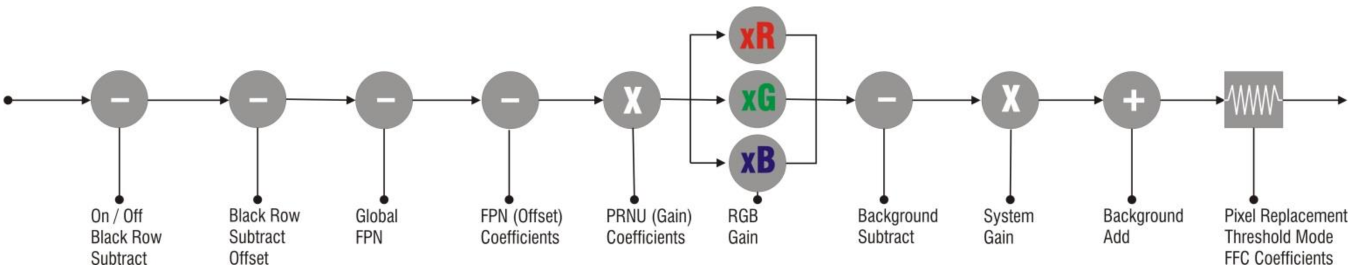
Table 10: Test Patterns

Test Pattern	Description
Grey Horizontal Ramp	Image is filled horizontally with an image that goes from the darkest possible value to the brightest. The ramp repeats every 4096 horizontal pixels. 
Grey Vertical Ramp	Image is filled vertically with an image that goes from the darkest possible value to the brightest. The ramp repeats every 4096 vertical pixels. 
Purity	Image is filled with an image that goes from the darkest possible value to the brightest by 1 DN increment per frame (12-bit output).
Gray Diagonal Ramp	This test pattern is the sum of the horizontal and vertical test patterns. 
Static Value	All pixels are set to ***testImageStaticValue*.**
PRNU	This is the 2 times the sum of a horizontal test pattern that repeats every 64 pixels and a vertical test pattern that repeats every 62 lines plus + ***testImageStaticValue.*** This test pattern can be used to test FPN and PRNU correction. 

Gain and Black Level Control Details

Gain and black level adjustments are available in the cameras. The analog black level and analog gain are factory calibrated and not adjustable by the user. It is possible to optimize the image by adjusting the digital offset controls and gain controls. The color camera features a per color gain ahead of the system gain block. The user can evaluate gain and black level using CamExpert.

Note: The sensor digitizes at 12-bits and transfers the data across the link as 12-bit. If the data is stored as 12-bit, then it is possible to optimize the image with post processing.



Features and Limitations:

- **Analog Black Level** offset is not available to the user.
- **Analog Gain** is not available to the user.
- **[Digital Before FFC]Global FPN** provides a constant component to the FPN Coefficients. This value is calibrated in the factory but it can be adjusted relative to the factory setting (factory setting). See the *BlackLevel* feature *DigitalAll1* [Digital Before FFC] option. The value is expressed as a floating point to allow for increased accuracy when processing a frame sum of more than 1 frame.
- **[Digital After FFC] Background Subtract** is a digital number that is used to reduce the baseline pixel value. When combined with the system gain, this value is used to increase contrast in the final output. See the *BlackLevel* feature *DigitalAll2* [Digital After FFC] option. The value is expressed as a floating point to allow for increased accuracy when processing a frame sum of more than 1 frame.
- **System (Digital) Gain** is expressed as a multiplication factor applied after the Color Gain (color camera only) and any FFC stages. When combined with the background subtract, this value is used to increase contrast in the final output.
- **Background Add** is a number added to the image data before it is clipped at zero. This value can be used to prevent the image clipping to zero. The factory uses the 2nd step FPN algorithm for color cameras, where a small amount of light equal to (approximately 50 DN) the least responsive channel is achieved and the FPN coefficient is recalculated. For a color camera, the more responsive channels have about 130 DN output. The Background Add is used to add this average level of signal back into the output value so that 0 light nominally results in 0 output. The 2 step FPN is used to reduce errors in pixel values at low light level due to nonlinear pixel behavior.

Exposure Controls

Exposure Control modes define the method and timing of how to control the sensor integration period. The integration period is the amount of time the sensor is exposed to incoming light before the video frame data is transmitted to the controlling computer.

- Exposure control is defined as the start of exposure and exposure duration.
- The start of exposure can be an internal timer signal (free-running mode), an external trigger signal, or a software function call trigger.
- The exposure duration can be programmable (such as the case of an internal timer) or controlled by the external trigger pulse width.

The camera can grab images in one of three ways. The three imaging modes are determined using a combination of the Exposure Mode parameters (including I/O parameters), Exposure Time and Frame Rate parameters.

Table 11: Imaging Modes

Description	Frame Rate	Exposure Time	Trigger Source
Internal frame rate and exposure time	Internal, programmable	Internal programmable	Internal
External frame rate and exposure time	Controlled by external pulse	External	External
EXSYNC pulse controlling the frame rate. Programmed exposure time.	Controlled by external pulse	Internal programmable	External

Internally Programmable Frame Rate and Internally Programmable Exposure Time (Default)

Frame rate has priority over exposure time when adjusting the frame rate or exposure time. When setting the frame rate, exposure time will decrease, if necessary, to accommodate the new frame rate. When adjusting the exposure time the range is limited by the frame rate.

Note: The camera will not set frame periods shorter than the readout period and the frame rate is limited to 12 Hz when sending 16-bit data and summing a single frame, due to cable bandwidth limitations.

Camera Features:

- TriggerMode = Off
- AcquisitionFrameRate = 16 (for example)
- ExposureMode = Timed
- ExposureTime = 10000 (for example)

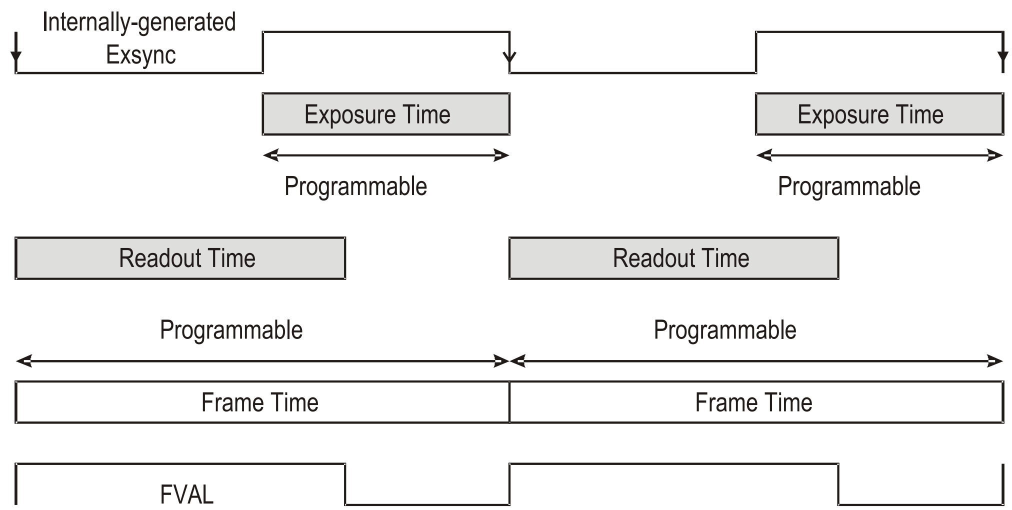


Figure 15: Internally Programmable Frame Rate and Exposure Time (Default)

External Frame Rate and External Exposure Time (Trigger Width)

In this mode, EXSYNC sets both the frame period and the exposure time. The rising edge of EXSYNC marks the beginning of the exposure and the falling edge initiates readout.

Camera Features:

- TriggerMode = On
- ExposureMode = Trigger Width
- TriggerSource = GPIO Input 1

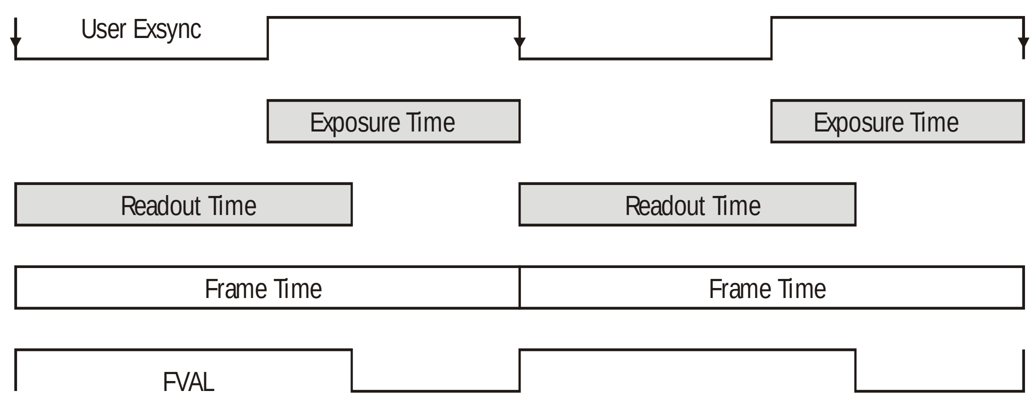


Figure 16: External Frame Rate and External Exposure Time (Trigger Width)

External Frame Rate, Programmable Exposure Time

In this mode, the frame rate is set externally with the falling edge of EXSYNC generating the rising edge of a programmable exposure time.

Camera Features:

- TriggerMode = On
- ExposureMode = Timed
- ExposureTime = 10000 (for example)
- TriggerSource = GPIO Input 1

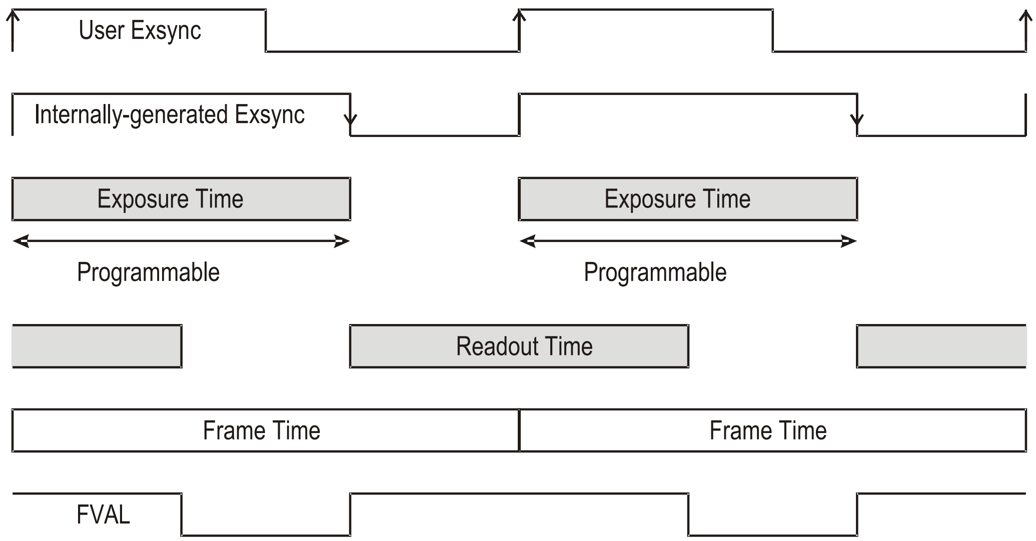


Figure 17: External Frame Rate, Programmable Exposure Time

Exposure Time

Exposure time is the amount of time that the sensor is allowed to accumulate charge before being read. The user can set the exposure time when the *ExposureMode* feature is set to *Timed*. The limitations on the maximum exposure time are listed below:

- External Exposure Time: 100 µs (min) to 1 second (max).
- Internal Exposure Time: (1 / frame rate) *0.95

Note: The maximum exposure time is dependent on the frame rate. To increase maximum exposure time, decrease the frame rate. If using an internal exposure time with an external trigger, it may be necessary to reduce exposure time to increase the frame rate.

Trigger Modes

The camera's image exposures are initiated by a trigger signal. The trigger event is either a programmable internal signal used in free running mode, an external input used for synchronizing exposures to external triggers, or a programmed function call message by the controlling computer. These triggering modes are described below.

- Free running (trigger disabled): The camera free-running mode has a programmable internal timer for frame rate and a programmable exposure period.
- External trigger: Exposures are controlled by an external trigger signal. The external trigger signal can be either a Camera Link HS trigger message or a general purpose input (for example, GPIO [2 : 1]. General purpose inputs are isolated by an opto-coupler input with a time programmable debounce circuit.
- Software trigger: An exposure trigger is sent as a control command via the command channel. Software triggers cannot be considered time accurate due to communications latency and sequential command jitter.

Internal Frame Rate

The frame rate is dependent on the number of rows in read, and the summing mode. Frame rate takes priority over exposure time. Maximum exposure time can be increased by lowering frame rate.

I/O Block Diagram

The following diagram describes the Input / Output features of the camera and how they are related.

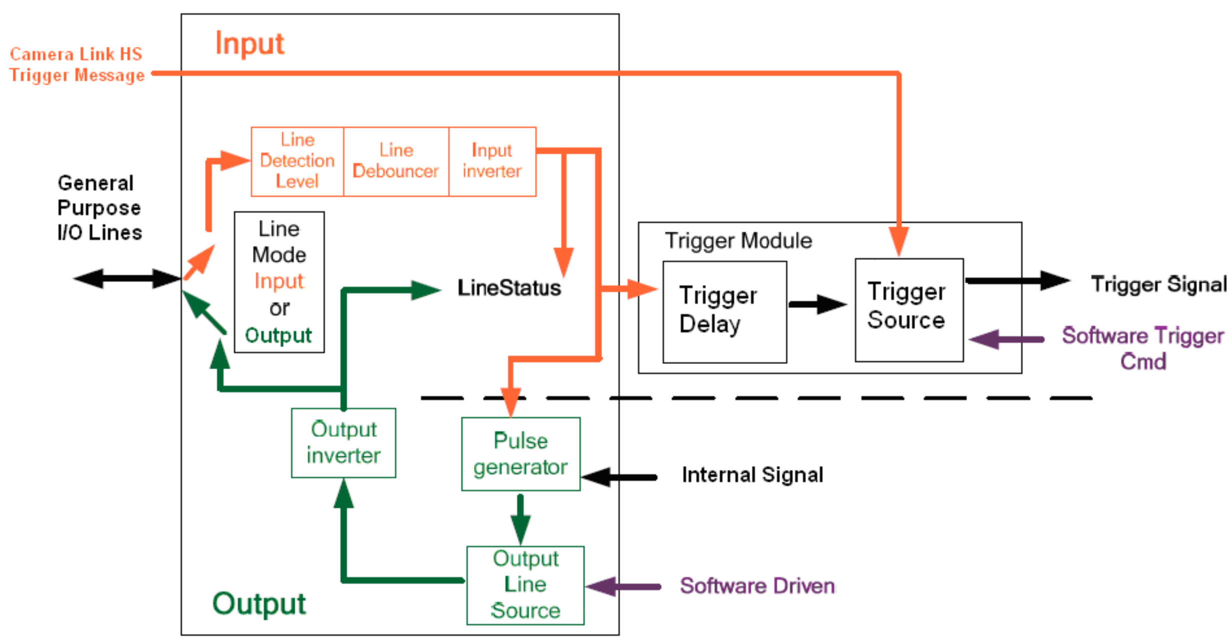


Figure 18 I/O Module Block Diagram

Opto-Coupled Inputs

The camera provides two sets of opto-isolated input signals. These can be used as external trigger sources. The signals should be in range from 2.4 V to 24 V, 5 V typical. See the *lineDetectionLevel* feature.

The delay between signals at the I / O pin and the internal timing core is a function of the signal swing and the typical latency @ 5V swing is 3.5 μs.

Refer to Figure 8: 12-pin Hirose Circular Male Power Plug—Power Connector for the connector pin out and electrical information. The cable shell and shield should electrically connect the camera chassis to the computer chassis for maximum EMI protection.

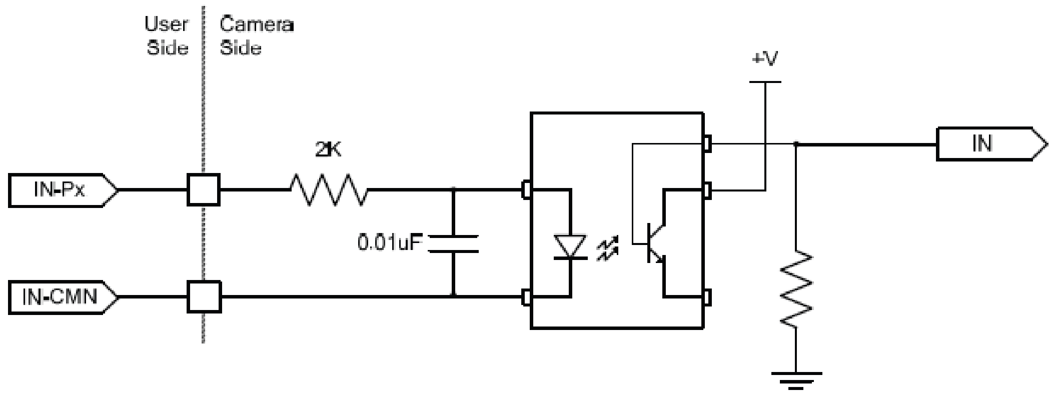


Figure 19 Opto-coupled input

Each input incorporates a signal debounce circuit (following the opto-coupler) to eliminate short noise transitions that could incorrectly be interpreted as a valid pulse. The duration is user programmable from 1 μs to 255 μs using CamExpert.

Opto-Coupled Outputs

The outputs are unpowered devices and require external power. The simplified diagram below demonstrates the need for a pull-up resistor (when using the outputs).

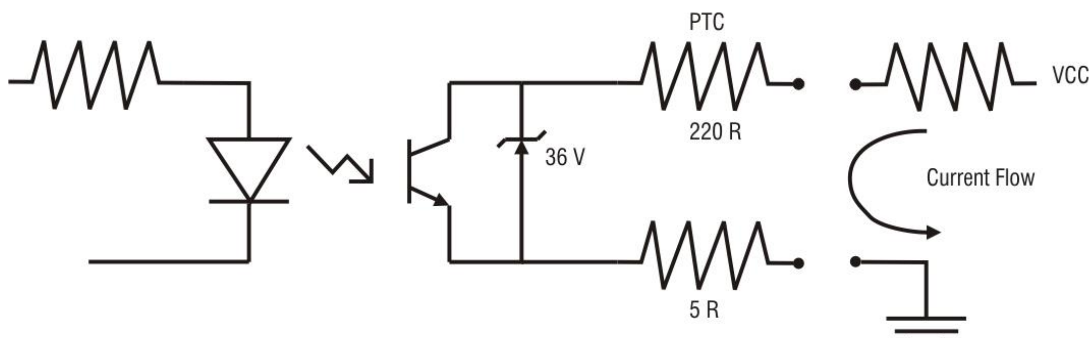


Figure 20: Simplified General Purpose Output Diagram

Flat Field Correction and Defective Pixel Detection Overview

The Flat Field correction function consists of using two coefficients per pixel which correct the gain and offset of the corresponding pixel. These corrections compensate for the Photo-response Non-uniformity (PRNU) and Fixed Pattern noise (FPN) attributes unique to each camera sensor. In addition, the camera supports replacement of defective pixels (hot, dead, blinking) with a value based on neighborhood pixels.

The Flat Field correction features are grouped in the Advanced Processing category:

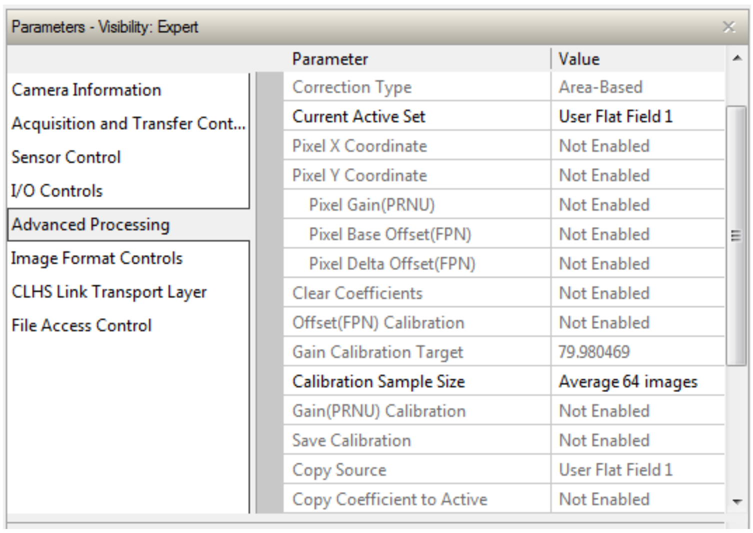


Figure 21: CamExpert Advanced Processing Category

Correction Function Block Diagram

The following simplified block diagram shows the processing chain that is applied to the image data (the flat field and defective pixel blocks are highlighted). Note that each processing block can be activated and deactivated independently. For example, the FPN and PRNU coefficients can be applied independently or together using the *flatfieldCorrectionMode*.

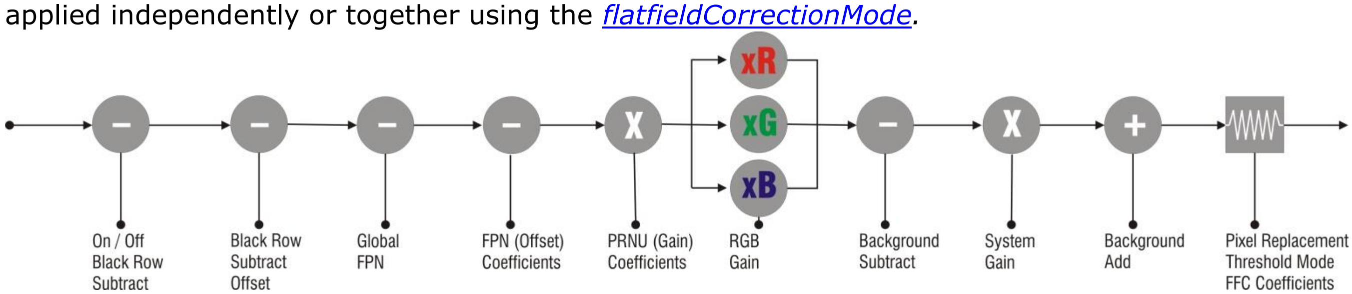


Figure 22 Flat field and defective pixel processing

Dark Row Subtract Algorithm

The dark row subtract algorithm can be enabled, disabled, or set to off. The camera ships from the factory with this feature enabled.

This algorithm improves the time stability of the FPN output from the sensor. The Dark Row Subtract Mode feature has 3 modes: Off, Disabled, Enabled.

When off, the dark rows from the image sensor are output in the first 32 rows of the image, the image is shifted by 32 rows, and the top 32 rows of the image are not output. This mode is used to measure and determine if any of the black rows are defective. Defective rows can be excluded from the dark row subtract average using the Dark Row Defect Mask feature.

When disabled, the normal image is passed through this module without change.

When enabled, the average of the non-defective dark rows from the current and previous frame are averaged on a per column basis and this average is subtracted from the raw sensor data. This results in the average output of the column to be near zero and, as a result, the Dark Row Subtract Digital Offset feature is used to add an offset back into the data so that no zero value clipping occurs and FPN coefficients are correctly calculated. The camera ships with a value of 50 DN and correction coefficients are calculated with the function enabled. Users need to ensure that the FPN / PRNU coefficients in use were calculated with the current setting of the Dark Row Subtract Algorithm.

Flat Field Correction Algorithm Description

Flat Field Correction Algorithm (feature: *flatfieldCorrectionAlgorithm*) applies the following FFC formula for correcting pixel values:

$$\mathbf{newPixelValue}_{x,y} = (\mathbf{sensorPixelValue}_{x,y} - \mathbf{FFCOffsetBase}_{x,y} - \text{normalized}\ \mathbf{FFCOffsetDelta}_{x,y}) * \mathbf{FFCGain}_{x,y}$$

Where:

- **x** & **y** are the Flat Field Correction Pixel coordinates. (See the *flatfieldCorrectionPixelXCoordinate* and *flatfieldCorrectionPixelYCoordinate* features.)
- **newPixelValue** is the pixel value after Flat Field Correction is applied.
- **sensorPixelValue** is the pixel value before Flat Field correction is applied.
- **FFCOffsetBase** is one offset coefficient value to subtract from the sensorPixelValue, this value is measured at minimal exposure time.
- **FFCOffsetDelta** is another offset coefficient value to subtract from the sensorPixelValue. This value is measured at current exposure time, and is the deviation from FFCOffsetBase. The normalization operation scales the stored **FFCOffsetDelta** by multiplying (current integration time) / (calibration integration time). FFCOffsetDelta is measured immediately after **FFCOffsetBase.**
- **FFCGain** is the gain coefficient value that is multiplied with the sensorPixelValue.

The implementation of this formula requires that both the FPN and PRNU coefficient are stored in 32 bits. Internally in Falcon4, we reserve 9 bits for the FFCOffsetBase, 9 bits for FFCOffsetDelta (FPN) coefficient and 14 bits for the FFCGain (PRNU) coefficient.

General Notes on FFC calibration

The camera comes calibrated with two factory sets, one for each shutter mode. In addition to the factory calibrations, the camera provides three user-configurable FFC sets. These can be calibrated and saved in the camera.

Another option is to perform the flat field correction in the frame grabber.

In either case, Teledyne DALSA recommends repeating the correction when a temperature change of greater than 10 °C occurs.

For best results, ensure that:

- Gain (PRNU) calibration has a clean, white reference. The quality of this reference is important for proper calibration. White paper is often not sufficient because the grain in the white paper will distort the correction. White plastic or white ceramic will lead to better balancing.
- Ambient light flicker (for example. fluorescent lights) is sufficiently low not to affect camera performance and calibration results.
- The average pixel should be at least 20 % below the target output. If the target is too close, then some pixels may not be able to reach full swing due to correction applied by the camera.
- When 6.25 % of pixels from a single row within the region of interest are clipped to zero or max value, flat field correction results may be inaccurate.
- Correction results are valid only for the Dark Row Subtract settings for which the coefficients were calculated. If you change this value, it is recommended that you recalculate your coefficients.
- Appendix D has more details.

Important Note on Command Timeout Errors

PRNU, FPN, and S1 calibration commands can take up to 5 minutes to run. CamExpert has a default timeout of 20 seconds per command, which is too short for the calibration commands to run fully. An error message will appear after the command has timed out specifying that the camera failed to set the feature value:

Error: SetFeatureValue fail to set information of "flatfieldCalibration S1 calibration" parameter.

However, the calibration command is still running if the Camera Status LED is green and blinking. Once this LED becomes a solid green, the calibration command has finished running. The user can also change the default timeout using the following steps:

You can change the default timeout by setting a command line argument in the short-cut:

- Right click on the short-cut in the start menu and select properties.
- Add –timeout 600 to increase the command timeout to 10 minutes (See below)
- Repeat for desktop short-cut

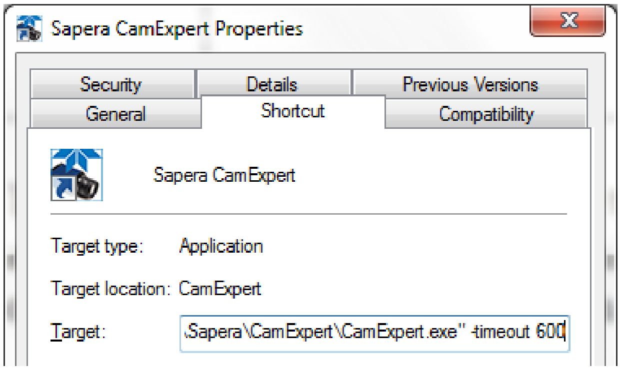


Figure 23: Setting the Camera's Timeout Value

Important Note on Window Blemishes

When flat field correction is performed, window cleanliness is paramount. The figure below shows an example of what can happen if a blemish is present on the sensor window when flat field correction is performed. The blemish will cast a shadow on the wafer. FFC will compensate for this shadow by increasing the gain. Essentially FFC will create a white spot to compensate for the dark spot (shadow). As long as the angle of the incident light remains unchanged then FFC works well. However, when the angle of incidence changes significantly (i.e. when a lens is added) then the shadow will shift and FFC will makes things worse by not correcting the new shadow (dark spot) and overcorrecting where the shadow used to be (white spot). While the dark spot can be potentially cleaned, the white spot is an FFC artifact that can only be corrected by another FFC calibration.

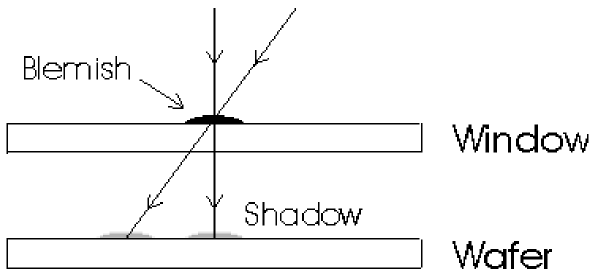


Figure 24: Window Blemishes

Performing an FFC Setup in the Camera

The calibration is performed in two steps. The offset FPN (base and Delta) is determined first by performing an averaging without any light. This calibration determines exactly how much offset to subtract per pixel in order to obtain flat output when the sensor is not exposed to light.
If the calibration finds any defective pixels, where its FPN base value is greater than Pixel Replacement Offset Threshold, or its PRNU value is greater than Pixel Replacement Gain Threshold, the pixel can be replaced if Pixel Replacement Mode is Active.

The gain (PRNU) calibration is performed next to determine the multiplication factors required to bring each pixel to the required value (target) for flat, white output. For the monochrome cameras, the target is determined by the user (See *flatfieldCalibrationTarget*).

It is important to do the FPN correction first. Results of the FPN correction are used in the PRNU procedure.

The following procedure provides a flat field calibration example:

1. The camera is placed in **internal exposure and frame rate**. Ensure that the area of interest (AOI) is set to the full window (that is, Width = SensorWidth and Height = SensorHeight)**.** No other exposure mode or AOI configuration will allow FFC calibration. See *ExposureMode*, *TriggerMode*, *OffsetX*, *OffsetY*, *Width*, *Height*.
2. Settings such as frame rate, exposure time, etc. are set as close as possible to the actual operating conditions. Set **system gain [All Digital] to 1** and **background subtract to 0**, as these are the defaults during FFC calibration. See *GainSelector*, *Gain*, *BlackLevelSelector*, and *BlackLevel*.
3. Select **correction active set to user flat field x**. Go to **flat field correction mode,** select **calibration**. See *flatfieldCorrectionCurrentActiveSet*, and *flatfieldCorrectionMode*.
4. Clear existing coefficients. See *flatfieldCalibrationClearCoefficient*.
5. It is recommended to set Dark Row Subtract function to Enabled as this corrects for column offsets every frame and improves camera stability over time. The FPN coefficient calculation result is impacted by the Dark Row Subtract. It is the user's responsibility to ensure the coefficient set in use was calculated with the current setting of the Dark Row Subtract function. When enabling the Dark Row Subtract function, the DarkRowSubtract Digital Offset should be set to 50.
6. Place the camera in the dark (e.g. cover the lens), select **FPN Calibration Step No** as First Step and run **FPN Calibration**. This performs the FPN correction and saves the FPN coefficients to temporary memory. See *flatfieldCalibrationFPN*. *flatfieldFPNCalStep* Calibration mode enables both FPN and PRNU correction. Verify signal output is close to 0 DN.
7. Illuminate the sensor to 65% saturation for monochrome cameras. For color cameras, try to adjust the light level equally above and below 55% for the most and least responsive color. Ensure a high-quality white reference is used.
8. Set the Flat Field Calibration Algorithm to PRNU: Customer Target.
9. Set **flat field target** to 80 % saturation (monochrome only). For color cameras, set the flat field target to 1.2x the average of the highest responding color. See *flatfieldCalibrationTarget*.

10. Run **Gain (PRNU) calibration**. See *flatfieldCalibrationPRNU*.
A defective pixel will be replaced if Pixel Replacement Mode is Active. A defective pixel is defined as a pixel whose FPN base value is greater than Pixel Replacement Offset Threshold or / and whose PRNU value is greater than Pixel Replacement Gain Threshold.

11. **Save** the flat field calibration: *flatfieldCalibrationSave*.

More information is found in Appendix C.

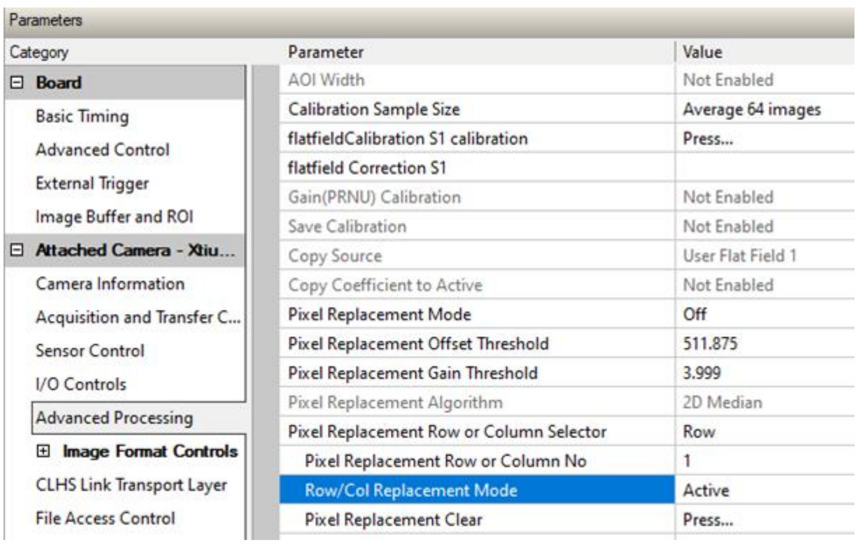
Defective Pixel Detection and Replacement

The camera has three methods of replacing pixels.

1. Single pixel replacement uses the FFC coefficients to mark pixels that will be replaced.
2. Defective columns or rows marked as defective use the median filter algorithm to replace the defect pixel.
3. The dynamic pixel replacement method uses a median filter to replace a given pixel value with the median value when its original value is above / below a threshold when compared to adjacent pixels of the same color.

These three methods can be individually controlled. However, Pixel Replacement Mode controls both Pixel Replacement Mode and Row/Col Replacement Mode. This means that to enable the Row/Col Replacement mode, the Pixel Replacement Mode must be set to Active.

The example screenshot below shows Pixel Replacement Mode set to Off while Row/Col Replacement Mode is set to Active for Row 1. In this configuration, while Row 1 is set to be replaced, it will not be replaced because Pixel Replacement Mode is set to Off; to replace row 1 Pixel Replacement Mode must be changed to Active.



In the default factory settings the Pixel Replacement Mode is set to Off. The user must change Pixel Replacement Mode to Active for the factory set replacements take effect in the image output. To have Pixel Replacement Mode set to Active on startup the user must set this mode to Active and save it to a user set.

Single Pixel Replacement

This is a technique for the elimination of dead or hot pixels.

The camera uses the FFC coefficients to indicate which pixels need to be replaced. If a pixel has a Gain (PRNU) coefficient that is greater than the *defectivePixelReplacementGainThreshold* then the pixel will be marked for replacement. Additionally, a pixel will be replaced if its Base Offset (FPN) coefficient that is greater than the offset pixel replacement threshold (*defectivePixelReplacementOffsetThreshold*). Lowering these thresholds will remove more pixels with high gain and offset coefficients.

Most hot and dead pixels will be identified when an FPN or PRNU calibration is performed in camera. The user can also manually mark a pixel for replacement by setting its Pixel Base Offset to 511.

The replacement algorithm is shown below in the Median Filter section.

Defective Columns and Row Replacement

Defective rows and columns are marked during factory calibration but users can add or remove defective rows and columns to / from the list. By default, the rows and columns marketed to be replaced align with the factory defect map that is stored in the camera. The Row/Col Replacement Mode can be set to Off, which does not replace the defective rows and columns, or Active to hide defective rows and columns. To clear all rows and columns from the list, use the Pixel Replacement Clear function.

To add or remove a defective Row or Column, use the following steps:

1) Select Row or Column using the Pixel Row or Column Selector.
2) Set the Row or Column Id using the Pixel Replacement Row or Column Number field.
3) Set Row/Col Replacement Mode to Active or Off as desired. Note: this will be applied to the currently selected Row or Column Id from step 2).
4) The modified list can be saved in a user set.

Teledyne DALSA recommends that the user update the user defect map file after making changes to the row/col replacement to keep track of which rows or columns are set to be replaced in the user set.

The median filter algorithm, described in the following section, is used to replace defection rows and columns.

Median Filter

Enable the median filter by setting the medianFilter to Active (Image Format Controls). Setting this filter to Off disables the medianFilter.

When the Median Filter is Active, then the Median Filter Threshold value controls the decision to replace the pixel value. Replacement occurs when a pixel's current value differs from the median value of a 3 x 3 kernel by more than the threshold value. The pixel is replaced by the median value of a 3 x 3 kernel.

The algorithm is described below for monochrome cameras. Color cameras use the pixels of same color in the matrix.

1. 3X3 2D median filter algorithm
   a. First step calculation the 5 elements median value Pm1 and Pm2

P1	P2	P3
P4	P5	P6
P7	P8	P9

=>

P1		P3
	P5	
P7		P9

=> Med{P1, P3, P5, P7, P9} => Pmx;

P1	P2	P3
P4	P5	P6
P7	P8	P9

=>

	P2	
P4		P6
	P8	

=> Med{P2, P4, P6, P8} => Pmc;

   b. Second step calculation the 3 elements median

   Med{P5, Pmx, Pmc} => Pm;

   c. Third step check the threshold(8-bit value and default=255)

```
if (|P5 – Pm| > threshold) then
    P5 output <= Pm;
else
    P5 output <= P5;
end if;
```

2. Defect Pixel Replacement 3x3 2D Replacement

   Each pixel with input defect flag associated if the flag is 1 the pixel will be do the 2D median filter but without check threshold.

File Access via the CamExpert Tool

Click on the "Setting…" button to show the file selection menu.

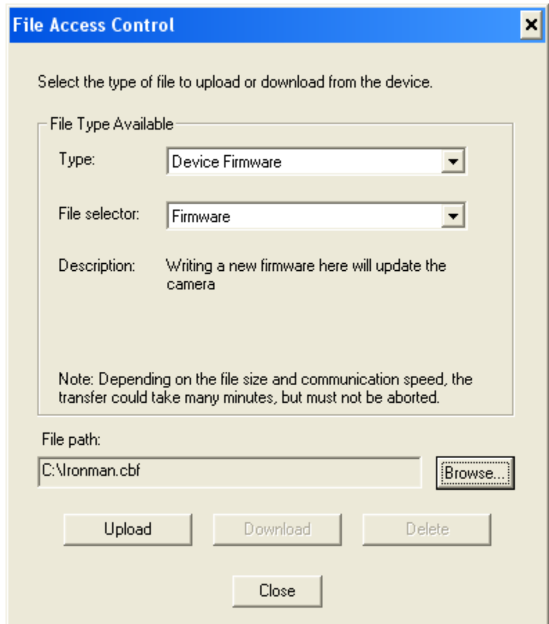
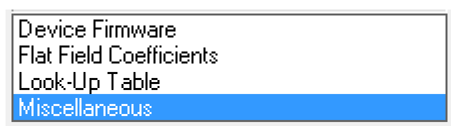


Figure 25 Initial File Access Control Dialog

From the Type drop menu, select the file type that will be uploaded to the camera.

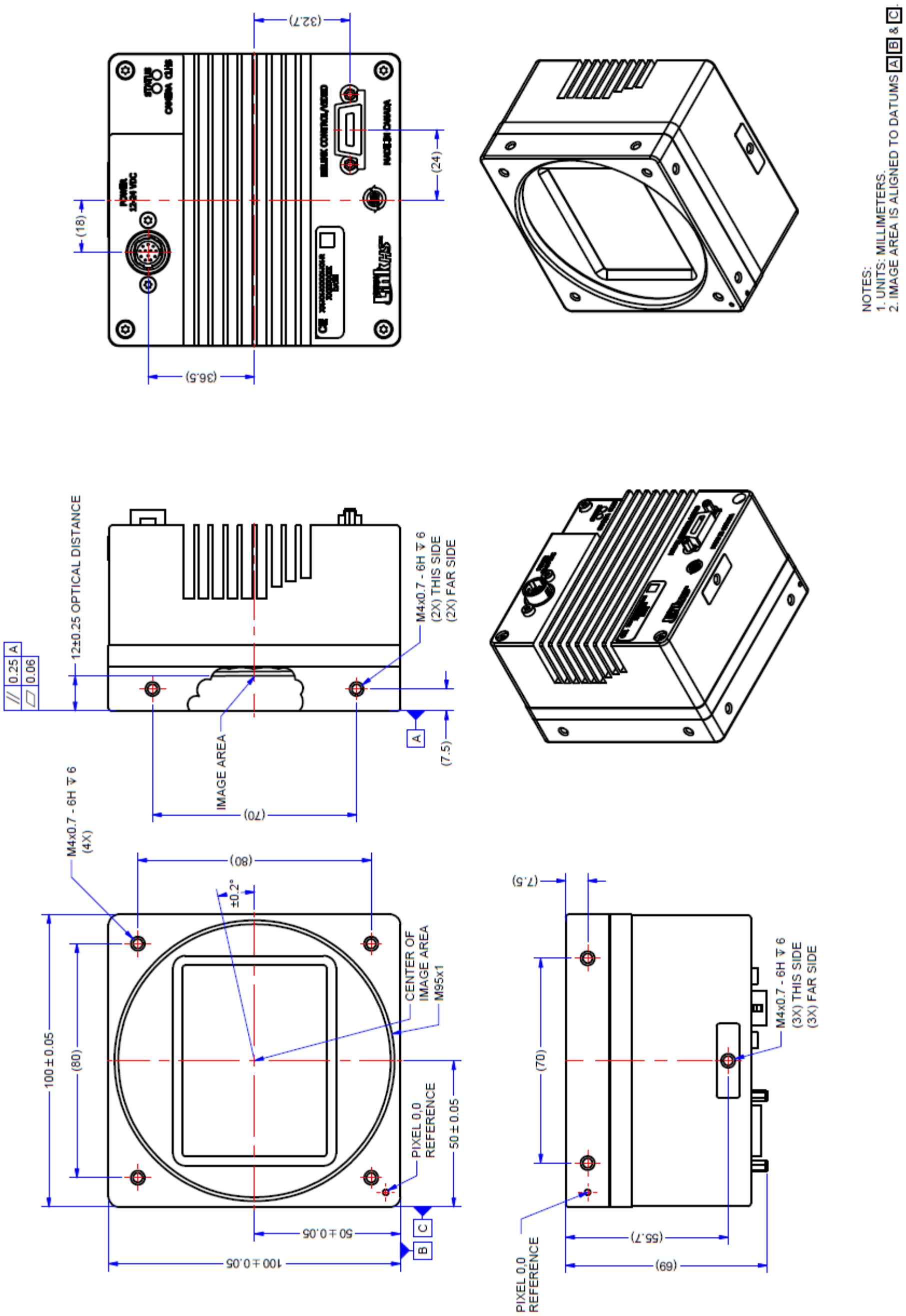


From the File Selector drop menu, select the camera memory location for the uploaded data. This menu presents only the applicable data locations for the selected file type.

Click the Browse button to open a typical Windows Explorer window.
Select the specific file from the system drive or from a network location.
Click the Download button to execute the file transfer from the Falcon4.
Note that firmware changes require a device reset command.

Technical Specifications

Mechanicals



EC & FCC Declaration of Conformity

We:
Teledyne DALSA inc.
605McMurray Road,
Waterloo, Ontario, Canada,
N2V 2E9

Declare under sole legal responsibility that the following products conform to the protection requirements of council directive 2004/108/EC (2014/30/EU after April 2016) on the approximation of the laws of member states relating to electromagnetic compatibility and are CE-marked accordingly:

FA-SO-86M16-01-R and FA-S1-86M16-00-R

The products to which this declaration relates are in conformity with the following relevant harmonized standards, the reference numbers of which have been published in the Official Journal of the European Communities:

EN55032 (2012)	Electromagnetic compatibility of multimedia equipment — Emission requirements
EN55011 (2009) with A1(2010)	Industrial, scientific and medical equipment — Radio-frequency disturbance characteristics — Limits and methods of measurement
EN 61326-1 (2013)	Electrical equipment for measurement, control and laboratory use — EMC requirements — Part 1: General requirements
EN 55024 (2010)	Information technology equipment — Immunity characteristics — Limits and methods of measurement

Further declare under our sole legal responsibility that the product listed also conforms to the following international standards:

CFR 47	Part 15 (2008), subpart B, for a class A product. Limits for digital devices
ICES-003	Information Technology Equipment (ITE) — Limits and Methods of Measurement
CISPR 11	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement
CISPR 32	Electromagnetic compatibility of multimedia equipment - Emission requirements

Note: this product is intended to be a component of a larger system.

Waterloo, Canada. 2015 Apr.13

Hank Helmond
Director, Quality Assurance

Appendix A: GenICam Commands

This appendix lists the available GenICam camera features. Access these features using the CamExpert interface.

Parameters in gray are read only, either always or due to another parameter being disabled. Parameters in black are user set in CamExpert or programmable via an imaging application.

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.

Additionally the Standard & View column will indicate which parameter is a member of the custom DALSA Features Naming Convention (denoted by **DFNC**), versus the GenICam Standard Features Naming Convention (SFNC not shown) along with their view attribute.

Camera Information Category

The camera information group provides general information about the camera. Parameters such as camera model and firmware version uniquely identify the connected device. As well, temperature can be monitored and user sets can be saved and loaded to and from the camera's non-volatile memory using the features grouped here.

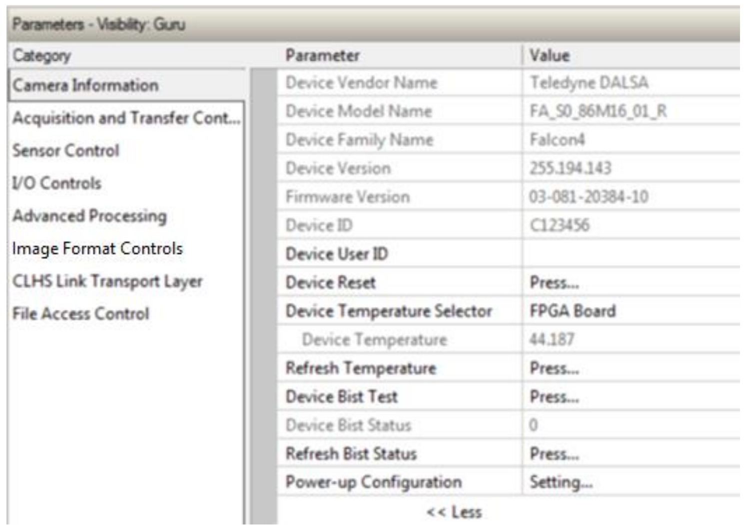


Figure 26 CamExpert Camera Information Category

Camera Information Feature Descriptions

Display Name	**Feature & Values**	**Description**	**Standard & View**
Device Vendor Name	DeviceVendorName	Displays the device vendor name. (RO)	Beginner
Device Model Name	DeviceModelName	Displays the device model name. (RO)	Beginner
Device Family Name	DeviceFamilyName	Displays the device family product name. (RO)	Beginner
Device Version	DeviceVersion	Displays the device version. This tag will also highlight if the firmware is a beta or custom design. This is an automatically generated number that specifically identifies the software build. (RO)	Beginner
Firmware Version	DeviceFirmwareVersion	Displays the currently loaded firmware version number. Firmware files have a unique number and have the .cbf file extension. (RO)	Beginner
Device ID	DeviceID	Displays the device's factory set camera serial number. (RO)	Beginner

Device User ID	DeviceUserID	Feature to store a user-programmable identifier of up to 15 characters. The default factory setting is the camera serial number. (RW)	Beginner
Device Temperature Selector	DeviceTemperatureSelector	Select the source where the temperature is read. (RW)	Beginner
FPGA Board	*FPGABoard*	*Read FPGA Board temperature.*	
Sensor Board	*SensorBoard*	*Read sensor board temperature.*	
Sensor	*Sensor*	*Read sensor temperature.*	
Device Reset	DeviceReset	Resets the device to its power up state. (W)	Beginner
Device Temperature	DeviceTemperature	Displays the device temperature in degrees Celsius. Depending on the host application (e.g. GUI). This value is a polled value and may automatically be updated every second. Otherwise the value will only be updated upon connection or when the Refresh Temperature selector is pressed.	Beginner
Refresh Temperature	readTemperature	Refreshes the temperature reading. (W)	Beginner DFNC
Device Bist Test	DeviceBistTest	Command to perform an internal test which will determine the device status. (W)	Beginner DFNC
Device Bist Status	deviceBistStatus	BIST errors are indicated in binary values indicating pass/fail (0/1) at the bit position. Available BIST error codes include: • Bit16: FPGA echo error • Bit17: under temperature • Bit18: over temperature • Bit19: sensor link lock error	Beginner DFNC
Refresh Bist Status	deviceRefreshBist	Refresh BIST status.	Beginner DFNC
Device Voltage	DeviceVoltage	The applied voltage to the image sensor. (RO)	Beginner
User Set Default Selector	UserSetDefaultSelector	Selects the camera configuration set to load and make active on camera power-up or reset. The camera configuration sets are stored in camera non-volatile memory. (RW)	Beginner
Factory	*Factory*	Load factory-calibrated defaults.	
UserSet1 to UserSet 4	*UserSet1 to UserSet4*	Select the user defined configuration (UserSet1 to UserSet8) as the Power-up Configuration.	
User Set Selector	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 features settings previously saved by the user. (RW)	Beginner

Factory Set	*Factory*	Select the default camera feature settings saved by the factory.	
User Set 1 *to* *User Set 4*	*UserSet1* *to* *UserSet4*	Select the User Defined Configuration space (UserSet1 to UserSet8) to save to or load from features settings previously saved by the user.	
User Set Load	UserSetLoad	Loads the camera configuration set specified by the User Set Selector feature, to the camera and makes it active. (W)	Beginner
User Set Save	UserSetSave	Saves the current camera configuration to the user set specified by the User Set Selector feature. The user sets are located on the camera in non-volatile memory. Disabled when *flatfieldCorrectionMode* = Calibration or *UserSetSelector* = Factory. (W)	Beginner
Device Reset	DeviceReset	Resets the device to its power up state. (W)	Beginner
DFNC Major Rev	deviceDFNCVersionMajor	Major revision of Dalsa Feature Naming Convention which was used to create the device's XML. (RO)	DFNC Invisible
DFNC Minor Rev	deviceDFNCVersionMinor	Minor revision of Dalsa Feature Naming Convention which was used to create the device's XML. (RO)	DFNC Invisible
Device FPAG Info	deviceFPAGInfo	FPGA version information (date : time)	DFNC Invisible

Acquisition and Transfer Control Category

The acquisition and transfer control category, as shown by CamExpert, group acquisition and transfer specific parameters.

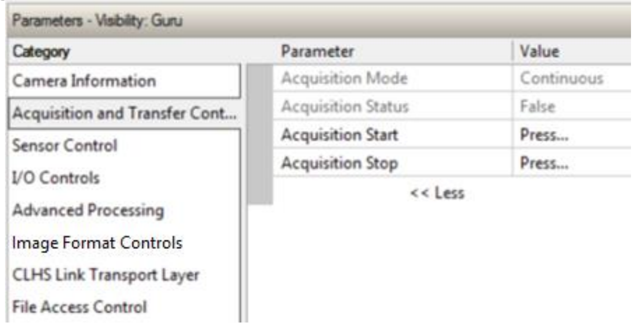


Figure 27 CamExpert Acquisition and Transfer Control Category

Acquisition and Transfer Control Feature Descriptions

Display Name	**Feature & Values**	**Description**	**Standard & View**
Acquisition Mode	AcquisitionMode	Acquisition mode of the camera.	Beginner
Continuous	*Continuous*	*Frames are captured continuously until stopped with the Acquisition Stop command.*	
Acquisition Status	AcquisitionStatus	This feature reports if the camera is currently transmitting image data. < RO >	Beginner
Acquisition Start	AcquisitionStart	Starts the acquisition of the device. The number of frames captured is specified by Acquisition Mode feature.	Beginner
Acquisition Stop	AcquisitionStop	Stops the acquisition of the device at the end of the current frame(s) sequence.	Beginner

Sensor Control Category

The camera sensor controls, as shown by CamExpert, group sensor specific parameters.

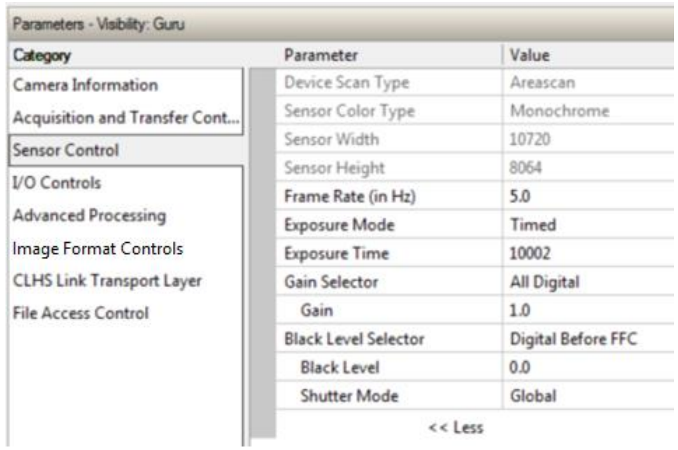


Figure 28 CamExpert Sensor Control Category

Sensor Control Feature Descriptions

Display Name	**Feature & Values**	**Description**	**Standard & View**
Device Scan Type	DeviceScanType	Scan type of the sensor. < RO>	Beginner
Area scan	*Areascan*	2D area scan sensor.	
Sensor Color Type	sensorColorType	Defines the camera sensor color type. < RO >	Beginner DFNC
Monochrome Sensor	*Monochrome*	Sensor color type is monochrome. (RO)	
CFA Bayer Sensor	*CFA_Bayer*	Sensor color type is Bayer Pattern.(RO)	
Sensor Width	SensorWidth	Defines the sensor width in active pixels. < RO>	Expert
Sensor Height	SensorHeight	Defines the sensor height in active lines. < RO>	Expert

Frame Rate (in Hz)	AcquisitionFrameRate	Specifies the camera internal frame rate, in Hz. (Read-only when *TriggerMode* = "On") 1 to x Hz (where x is a calculated maximum) The maximum value of the frame rate is the result of a complicated formula and is dependent on the following features: *Height, summingMode, pixelformat* Note that any user entered value is automatically adjusted to a valid camera value.	Beginner
Exposure Mode *Timed* *Trigger Width*	ExposureMode *Timed* *TriggerWidth*	Sets the operation mode for the camera's exposure. The exposure duration time is set using the Exposure Time feature and the exposure starts with a LineStart event. Uses the width of the trigger signal pulse to control the exposure duration. Use the Trigger Activation feature to set the polarity of the trigger. The Trigger Width setting is active when the Trigger Mode is On and a signal (e.g. Line 1) is selected as the trigger source. These features are found in the I/O Control category.	Beginner
Exposure Time	ExposureTime	Sets the exposure time (in microseconds) when the Exposure Mode feature is set to Timed.	Beginner
Gain Selector *All Digital* *Digital Red* *Digital Blue* *Digital Green Blue* *Digital Green Red*	GainSelector *DigitalAll* *DigitalRed* *DigitalBlue* *DigitalGreenBlue* *DigitalGreenRed*	Selects which channel's gain is controlled when adjusting gain features. Apply a digital gain adjustment to the entire image. *Bayer Camera Only.* Red pixels. *Bayer Camera Only.* Blue pixels. *Bayer Camera Only.* Green pixels that share same row as blue. Green pixels that share the same row as red.	Beginner
Gain	Gain	Sets the selected gain as an amplification factor applied to the image. (RW)	Beginner
Black Level Selector *Digital Before FFC* *Digital After FFC* *Background Add*	BlackLevelSelector *DigitalAll1* *DigitalAll2* *BackgroundAdd*	Selects which black level (i.e. dark offset) is controlled when adjusting the black level feature.(RW) Global FPN. Apply black level adjustment to all digital channels or taps, before flat field correction. Background Subtract. Apply black level adjustment to all digital channels or taps, after flat field correction. Add a digital value to the image before FFC (tbc)	Beginner
Black Level	BlackLevel	Sets the Black level (offset) in DN selected by the BlackLevelSelector (RW)	Expert

Shutter Mode	shutterMode	Determines the exposure mode used by the sensor (RW)	Guru
Global	*Global*	All pixels integrate simultaneously and then held constant until they can be read. This is at the cost of higher noise.	
Rolling	*Rolling*	The rows of the sensor integrate light at slightly different times. This can cause image artifacts. Especially if the scene is moving.	

I/O Control Category

The camera's I / O controls, as shown by CamExpert, group features used to configure external inputs and acquisition actions based on those inputs, plus camera output signals to other devices.

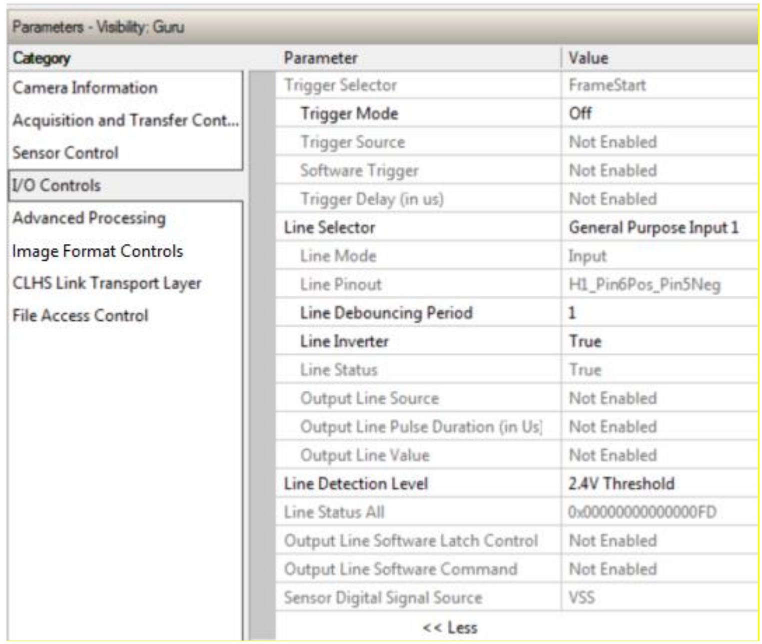


Figure 29 CamExpert I/O Control Category

I/O Controls Feature Descriptions

Display Name	Feature & Values	Description	Standard & View
Trigger Selector	TriggerSelector	Displays the type of trigger to configure with the various Trigger features. <RO>	Beginner
FrameStart	*FrameStart*	Selects a trigger starting the capture of a single frame.	
Trigger Mode	TriggerMode	Enables and disables external frame trigger.(RW)	Beginner
Off	*Off*	Use an internal trigger.	
On	*On*	Use an external trigger. This option is not available while in Calibration Mode.	

Trigger Source	TriggerSource	Specifies the internal signal or input line to use as the trigger source. (RW) The trigger mode must be set to On.	Beginner
Software	*Software*	Software trigger through the TriggerSoftware command.	
LinkTrigger0	*LinkTrigger0*	CLHS trigger message from the FG.	
Line1	*Line1*	General Purpose Input Line 1	
Line2	*Line2*	General Purpose Input Line 2	
Software Trigger	TriggerSoftware	Generate an internal trigger. Available when the trigger mode is enabled and the trigger source is equal to Software.(W)	Beginner
Trigger Delay	TriggerDelay	Specifies the delay in microseconds to apply after the trigger reception before activating it. Possible values are: 0 - 1*10^6µs	Beginner
LineSelector	LineSelector	Selects the logical line of the device to configure.(RW)	Beginner
General Purpose Input 1	*Line1*	General Purpose Input 1	
General Purpose Input 2	*Line2*	General Purpose Input 2	
General Purpose Output 1	*Line3*	General Purpose Output 1	
General Purpose Output 2	*Line4*	General Purpose Output 2	
Line Mode	LineMode	Returns if the selected physical pin is used as an input or output signal. <RO>	Beginner
Input	*Input*	The selected physical pin is used as an input.	
Output	*Output*	The selected physical pin is used as an output.	
Line Pinout	linePinAssociation	Gets the physical pin location associated with the logical line. The H1 prefix refers to the Hirose Power and input cable (see Figure 8). <RO>	DFNC Beginner
H1_Pin6Pos_Pin5Neg	*H1_Pin6Pos_Pin5Neg*	General Purpose Input 1: Hirose Pin 6 Positive, Pin 5 Negative.	
H1_Pin11Pos_Pin12Neg	*H1_Pin11Pos_Pin12Neg*	General Purpose Input 2: Hirose Pin 11 Positive, Pin 12 Negative.	
H1_Pin3_Pin4	*H1_Pin3_Pin4*	General Purpose Output 1: Hirose Pin 3, Pin 4.	
H1_Pin7_Pin8	*H1_Pin7_Pin8*	General Purpose Output 2: Hirose Pin 7, Pin 8.	

Line Debouncing Period	lineDebouncingPeriod	Specifies the minimum length of an input line voltage transition before recognizing a signal transition. Available when the Line Selector is set to an input. Each input line stores its own debouncing period.(RW) Possible values are: 1 to 255 µs.	DFNC Beginner
Line Inverter	Line Inverter	Controls whether to invert the selected input or output line signal. (RW)	Beginner
True	*True*	Invert signal.	
False	*False*	Do not invert signal.	
Line Status	LineStatus	Returns the current status of the selected input or output line. This is a polled feature that requires the host to poll the camera for the latest value.(RO)	Beginner
True	*True*	Selected signal is high.	
False	*False*	Selected signal is low.	
Output Line Source	outputLineSource	Selects which internal signal or software control state to output on the selected line. The pulse is defined by *outputLinePulseDelay and outputLinePulseDuration.(RW)* Note: the *Line Mode* feature must be set to *Output*.	DFNC Beginner
Off	*Off*	The output line is open.	
Software Controlled	*SoftwareControlled*	The value of the output line is determined by *outputLineValue, outputLineSoftwareLatchControl* and / or *outputLineSoftwareCmd.*	
Pulse On: Start of Exposure	*PulseOnStartofExposure*	Generate a pulse when the sensor actually starts exposing its pixels. (Slight delay after EXSYNC).	
Pulse On: End of Exposure	*PulseOnEndofExposure*	Generate a pulse when the sensor stops exposing its pixels.	
Pulse On: Start of Readout	*PulseOnStartofReadout*	Generate a pulse when the sensor starts reading its pixels.	
Pulse On: End of Readout	*PulseOnEndofReadout*	Generate a pulse when the sensor stops reading its pixels.	
Pulse On: GP Input 1	*PulseOnInput1*	Generate a pulse when the General Purpose Input 1 goes active.	
Pulse On: GP Input 2	*Pulse OnInput2*	Generate a pulse when the General Purpose Input 2 goes active.	
Output Line Pulse Duration (in µs)	outputLinePulseDuration	Sets the duration of the output pulse (RW) 1 to100, 000 µs Note: LineMode feature must be set to Output and outputLineSource is not equal to Off or SoftwareControlled.	DFNC Beginner

<table>
<tr><td>Output Line Value</td><td>outputLineValue</td><td>Selects the state of the output on the selected line. (RW) The Value will be applied immediately if the outputLineSoftwareLatchControl feature is equal to OFF.
The Value will be applied when the outputLineSoftwareCmd feature is set if the outputLineSoftwareLatchControl feature is equal to LATCH.
Note: LineMode feature must be set to Output and outputLineSource set to SoftwareControlled.</td><td>DFNC
Beginner</td></tr>
<tr><td>Active</td><td>Active</td><td>Sets the Output circuit to close.</td><td></td></tr>
<tr><td>Inactive</td><td>Inactive</td><td>Inactive - Sets the Output circuit to open.</td><td></td></tr>
<tr><td>Line Detection Level</td><td>lineDetectionLevel</td><td>The voltage at which the signal is treated as a logical high. Available when the Line selector is set to a general purpose input (GPI). (RW)
Note: This value is for both general purpose inputs (i.e. setting this value sets it for both Line 1 and Line 2).</td><td>DFNC
Beginner</td></tr>
<tr><td>2.4V Threshold</td><td>Threshold_2_4</td><td>2.4V threshold: for TTL inputs</td><td></td></tr>
<tr><td>Threshold_6_0</td><td>Threshold_6_0</td><td>6V threshold: for 12V input</td><td></td></tr>
<tr><td>Threshold_12_0</td><td>Threshold_12_0</td><td>12V threshold: for 24V input</td><td></td></tr>
<tr><td>Line Status All</td><td>LineStatusAll</td><td>Returns the current status of all available line signals, at time of polling, in a single bitfield. This is a polled feature that requires the host to poll the camera for the latest value. <RO>
The order is Line1(LSB), Line2, Line3, Line4/
<table>
<tr><th>7 to 4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>Not used</td><td>Line 4</td><td>Line 3</td><td>Line 2</td><td>Line 1 (LSB)</td></tr>
</table></td><td>Beginner</td></tr>
<tr><td>Output Line Software Latch Control</td><td>outputLineSoftwareLatch Control</td><td>The software latch allows the user to set more than 1 output simultaneously(RW)
OutputLine that are currently in Software Latch control will only set with the value in OutputLineValue with the outputLineSoftwareCmd feature.</td><td>DFNC
Beginner</td></tr>
<tr><td>Off</td><td>Off</td><td>Changes to the output line value are applied immediately.</td><td></td></tr>
<tr><td>Latch</td><td>Latch</td><td>Changes to the output line value are applied when the Output Line Software Command is triggered.</td><td></td></tr>
</table>

<table>
<tr><td rowspan="7">Output Line Software Command</td><td rowspan="7">outputLineSoftwareCmd</td><td colspan="2">Contains a bit field representing whether to apply to cached outputLineValue values. (W)</td><td rowspan="7">DFNC
Beginner</td></tr>
<tr><td>Value</td><td></td></tr>
<tr><td>0</td><td>Do not apply any value</td></tr>
<tr><td>1</td><td>Apply outputLineValue of Output1</td></tr>
<tr><td>2</td><td>Apply outputLineValue of Output2</td></tr>
<tr><td>3</td><td>Apply outputLineValue of Output1 and Output2</td></tr>
<tr><td colspan="2">Note: LineMode feature must be set to Output and outputLineSource is set SoftwareControlled.</td></tr>
</table>

Advanced Processing Control Category

The camera’s Advanced Processing controls, as shown in CamExpert, group parameters used to configure Defective Pixel Detection, Flat Field calibration.

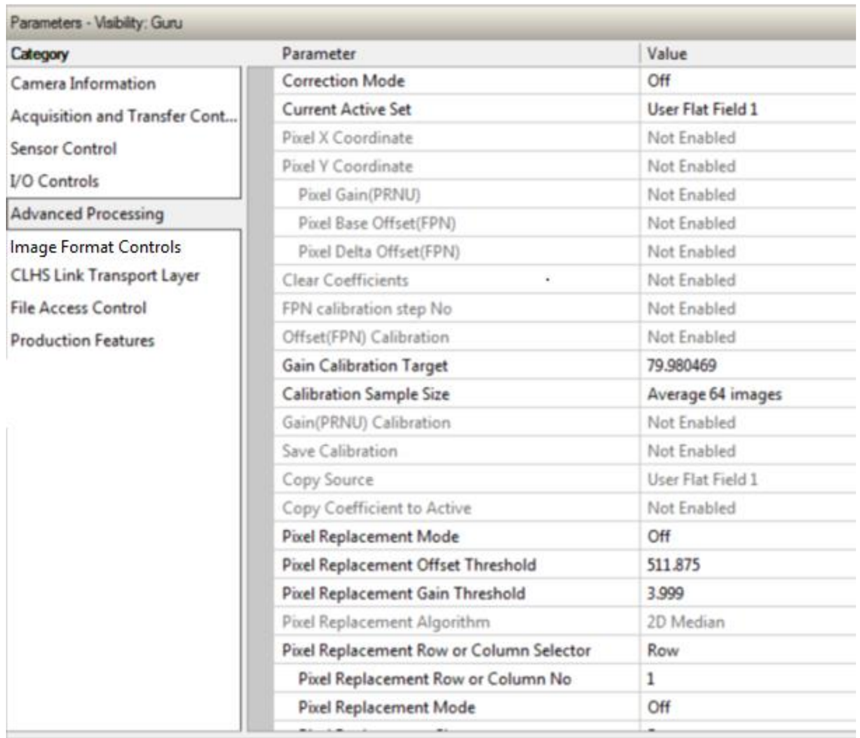


Figure 30 CamExpert Advanced Processing Category

Advanced Processing Control Feature Descriptions

Display Name	Feature & Values	Description	Standard & View
Correction Mode	flatfieldCorrectionMode	Sets the mode for flat field correction.(RW)	DFNC Beginner
Off	*Off*	Flat field correction is disabled.	
Active	*ActiveAll*	Flat field correction is enabled. FPN and PRNU correction is active.	
Active, FPN Only	*ActiveFPNOnly*	FPN correction is active.	
Active, PRNU Only	*ActivePRNUOnly*	PRNU correction is active.	
Calibration	*Calibration*	The camera is configured to calibration mode (Only available when TriggerMode = Off, flatfieldCorrectionCurrentActiveSet is not FactoryFlatfield,). The device may automatically adjust some features in the camera when calibration mode is enabled. The features that are automatically adjusted are device specific. The device will not restore these features when the flat field correction mode is changed from calibration mode to another mode. It is not available for FactoryFlatfield1 [Global Shutter Factory Flat Field] FactoryFlatfield2 [Rolling Shutter Factory Flat Field]. It is not available for external mode, and it is not available for AOI smaller than 2048 horizontal.	
Current Active Set	flatfieldCorrectionCurrentActiveSet	Specifies the current set of flat field coefficients to use. This feature cannot be changed while the camera is in flat field calibration mode. Read-Write (Read-Only when in Calibration Mode).	DFNC Beginner
Global Shutter Factory Flat Field	*FactoryFlatfield1*	Factory calibrated flat field for Global Shutter Mode	
Rolling Shutter Factory Flat Field	*FactoryFlatfield2*	Factory calibrated flat field for Rolling Shutter Mode.	
User Flat Field 1 to User Flat Field 3	*UserFlatfield1 to UserFlatfield3*	User Flat Field 1 to User Flat Field 3: User configurable flat field sets	
Pixel X Coordinate	flatfieldCorrectionPixelXCoordinate	Specifies the X coordinate of the flat field pixel coefficient to access. (RW) To configure, set Correction Mode to Calibration. Range: 1 to *SensorWidth*	Beginner
Pixel Y Coordinate	flatfieldCorrectionPixelYCoordinate	Specifies the Y coordinate of the flat field pixel coefficient to access. (RW) To configure, set Correction Mode to Calibration. Range: 1 to *SensorHieght*	DFNC Beginner
Pixel Gain(PRNU)	flatfieldCorrectionGain	Sets the gain to apply to the currently selected pixel. Range is from 1 to 4, as float. To configure, set Correction Mode to Calibration.	
Pixel Base Offset(FPN)	flatfieldCorrectionOffsetBase	Sets the offset to apply to the currently selected pixel. It is measured at the minimal exposure time at dark.	Beginner

		To use, set the Correction Mode feature to Calibration.	
Pixel Delta Offset(FPN)	flatfieldCorrectionOffsetDelta	Sets the offset to apply to the currently selected pixel. Measured at the current exposure time at dark with a subtraction of flatfieldCorrectionOffsetBase. Range is 0 to 511, as float. Read-Write when in Calibration Mode.	
Clear Coefficients	flatfieldCalibrationClearCoefficient	This feature is used to clear all the current FPN and PRNU coefficients in the selected Active Set. (W) Read-Write when in Calibration Mode	DFNC Expert
FPN calibration step No	flatfieldFPNCalStep	This feature selects the FPN calculation method. (RW)	DFNC Expert
First Step	*First*	When the Offset Calibration is commanded, the base FPN value and the delta FPN value are calculated.	
Second Step	*Second*	When the Offset Calibration is commanded the base FPN value is calculated and not the delta FPN. The purpose is to enable calibration with a small amount of light to avoid the nonlinear behavior near zero illumination. A recommended illumination level is 50 DN.	
Offset (FPN) Calibration	flatfieldCalibrationFPN	Performs fixed pattern noise (FPN) calibration. FPN calibration eliminates fixed pattern noise by subtracting all non-uniformities and dark current to obtain near 0 DN output in the dark (no light exposed to the sensor). This currently can take up to 5 minutes. Read-Write when in Calibration Mode	DFNC Expert
AutoBrightness OffsetX	autoBrightnessOffsetX	Bayer Camera Only. Sets the start of the area in the x direction for pixels included in the color PRNU Target average.(RW) Has minimum value 0 and increments in multiples of 32. Non multiples of 32 are rounded down to the nearest multiple. The autoBrightnessWidth may need to be reduced to increase this value. The minimum width is 64. autoBrightnessOffsetX <= 10720- autoBrightnessWidth.	DFNC Beginner
AutoBrightness OffsetY	autoBrightnessOffsetY	Bayer Camera Only. Sets the start of the area in the y direction for pixels included in the color PRNU Target average.(RW) Is automatically increased if the OffsetY is increased and has minimum value OffsetY+2. This parameter increments in multiples of 2 The autoBrightnessHeight may need to be reduced before this value can be increased. autoBrightnessOffsetY <= OffsetY+Height -4-autoBrightnessHeight.	DFNC Beginner
AutoBrightness Height	autoBrightnessHeight	Bayer Camera Only. Determines the number of rows to include in the average used to set the PRNU targets for color sensors.(RW) The minimum autoBrightnessHeight is 4 rows and the maximum is Height-4. The autoBrightnessheight is increased in multiples of 2 and	DFNC Beginner

		if an odd number is entered, the entry will be rounded down when possible. Also the AutoBrightnessOffsetY may need to be decreased before increasing this parameter. autoBrighitnessHeight =<OffsetY+Height-2-autoBrightnessOffsetY	
AutoBrightness Width	autoBrightnessWidth	Determines the number of columns to include in the average used to set the PRNU targets for color sensors. (RW) The minimum autoBrightnessWidth is 64 columns and the maximum is Width is 10720. The width is increased in multiples of 32 and entries will be rounded down to a multiple of 32. Also, the AutoBrightnessOffsetX may need to be decreased before increasing this parameter. autoBrighitnessWidth <= 10720 -autoBrightness	DFNC Beginner
Flatfield Calibration Algorithm *PRNU: Customer Target*	flatfieldCorrectionAlgorithm *PRNU_Customer_Target*	Selects the algorithm to use for calibration of flat field PRNU coefficients. (RW) The following formula is used to calculate the flatfield corrected pixel: Monochrome During operation: correctedPixelValuex,y = (sensorPixelValuex,y – DarkRowSubtract-FFCOffsetx,y –currentIntTime/CalIntTime*DeltaFPNxy) * FFCGain[x][y] * The FPN coefficients must be calculated with the intended DarkRowSubtractMode (on or off) FFCOffsetx,y = the average offset value per pixel that is measured when the sensor is dark at the minimum integration time, with or without the DarkRowSubtract function enabled. DeltaFPNxy is average value per pixel measured at the calibration integration time –the FPNoffsetxy FFCGainxy is calculated under approximately 50% illumination and is the result of the following calculation FFCGainxy = Target/(Average signalxy – DarkRowSubtract- FFCOffsetx,y – currentIntTime/CalIntTime*DeltaFPNxy) It is recommended that the target be set 20% higher than the average scene value. Color During operation the equation, when enabled is correctedPixelValuex,y = (sensorPixelValuex,y – DarkRowSubtract-FFCOffsetx,y –currentIntTime/CalIntTime*DeltaFPNxy) * FFCGain[x][y] The dark offsets are calculated as above.	DFNC Beginner

		The PRNU coefficient is calculated using customer entered per color targets. It is recommended these values be 1.2x the measured color average. FFCGainxyr/g/b = Targetr/g/b/(Average signalxy – DarkRowSubtract- FFCOffsetx,y – currentIntTime/CalIntTime*DeltaFPNxy) White balance gains are set to unity and saved with the coefficient set.	
PRNU: Auto Color Gain	*PRNUautoColorGain*	The calculation equations are the same as above, however the target value is determined by the camera over the Area of Interest controlled by the entries of the AutoBrightnessXXX parameters. The target value is Targetx = Averagex*1.2 Where x is the specific color/ or mono. In this mode the white balance gains are stored with the PRNU coefficients and are set as WBgain most responsive color =1, WBgainColor1/2= MostresponsiveColor / (Color1/2Avg)	
Gain Calibration Target Selector	flatfieldColorTargetSelector	Selects the color PRNU target that the Gain Calibration Target is applied to. (RW) Mono cameras do not have this selector.	DFNC Expert
Red Target	*TargetRed*	*Select calibrate target to digital red channel.*	
Green Target	*TargetGreen*	*Select calibrate target to digital green channel.*	
Blue Target	*TargetBlue*	*Select calibrate target to digital blue channel.*	
Gain Calibration Target	flatfieldCalibrationTarget	Sets the target pixel value for the gain (PRNU) calibration for the respective color when in calibration mode, method 1. (RW) It is specified as a percentage of the output range (for example, 2048 DN for 12-bits = 50%). Range is 0 to 100 %, as float. All three colors need to be entered for the color camera and a single value entered for the monochrome camera. It is recommended the flatfieldCalibrationTarget = colorAverage*1.2. PRNU calculation method 2 uses image statistics to calculate the target values and flatfieldCalibrationTarget is not used. For Color Cameras: method 1 sets the white balance gain factors to unity for the PRNU coefficient set, while Method 2 stores the white balance gain factors needed to achieve white balance.	DFNC Expert
Calibration Sample Size	flatfieldCalibrationSampleSize	The number of images to average to perform the calibration.(RW)	DFNC Beginner
Average 256 images	*Avg256*	*Average 256 images. Recommended for PRNU calculation.*	
Average 128 images	*Avg128*	*Average 128 images. Recommended for FPN calculation.*	
Average 64 images	*Avg64*	*Average 64 images.*	
Average 32 images	*Avg32*	*Average 32 images.*	
Average 16 images	*Avg16*	*Average 16 images.* *Read-Write when in Calibration Mode.*	

Gain(PRNU) Calibration	flatfieldCalibrationPRNU	Performs photo response non-uniformity (PRNU) calibration. (W) PRNU calibration eliminates the difference in responsivity between the most and least sensitive pixel, creating a uniform response to light. Pixels that fall outside gain range of 1 to 4 for their color are marked as defective. Write when in Calibration Mode	DFNC Expert
Save Calibration	flatfieldCalibrationSave	Saves the current flat field coefficients in the Active Set to the corresponding non-volatile memory. (W) The color camera also stores the individual color gains and system gain. Write when in Calibration Mode.	DFNC Expert
Copy Source *Global Shutter Factory Flat Field* *Rolling Shutter Factory Flat Field* *User Flat Field 1 to User Flat Field 3*	flatfieldCoefficientsCopySource *FactoryFlatfield1* *FactoryFlatfield2* *UserFlatfield1 to UserFlatfield3*	Selects the flatfield coefficients set to copy to the current Active Set. Read-Write when in Calibration Mode *Factory calibrated flat field for Global Shutter Mode* *Factory calibrated flat field for Rolling Shutter Mode.* *User Flat Field 1 to User Flat Field 3: User configurable flat field sets*	DFNC Expert
Copy Coefficient to Active	flatfieldCoefficientsCopyInCurrent	Copies the currently selected by flatfieldCoeffiecientsCopySource to the Active Set. Write when in Calibration Mode	DFNC Expert
Pixel Replacement Mode *Off* *Active*	defectivePixelReplacementMode *Off* *Active*	Enable or disable pixel replacement. (RW) If Active: If FPNx,y > defectivePixelReplacementOffsetThreshold OR PRNUx,y > defectivePixelReplacementGainThreshold, then Pixelx,y is replaced using the algorithm below. *Disable pixel replacement* *Enable defective pixel replacement*	DFNC Expert
Pixel Replacement Offset Threshold	defectivePixelReplacementOffsetThreshold	The FFC base + integration time scaled delta offset value (FPN) above which the pixel are deemed hot pixels and replaced. This value can be adjusted to replace more or fewer pixels. (RW) Possible values are:1 to 4096, as float	DFNC Guru
Pixel Replacement Gain Threshold	defectivePixelReplacementGainThreshold	The FFC gain value (PRNU) above which the pixel are deemed dead pixels and replaced. This value can be adjusted to replace more or fewer pixels.(RW) Possible values are:1 to 4, as float	DFNC Guru
Pixel Replacement Algorithm	defectivePixelReplacementAlgorithm *2D Median*	Selects the pixel replacement algorithm. (RO) There is a separate register to enable/disable Pixel Replacement. *The median filter algorithm determines the median value of the same color pixels in the immediate surroundings of the pixel in question. If the median value differs from the value of the pixel in question by more than the value entered into the medianfilterthreshold register, then the median value replaces the current pixel value.* *If the current pixel is marked as defective, then the median value*	DFNC Expert

		replaces the current value regardless of the calculation.	
Pixel Replacement Row or Column Selector *Row* *Column*	rowColInterpolationSelector *DefecticeRow* *DefectiveColumn*	Determines if the Pixel Replacement Row or Column Number is for Rows or Columns (RW) *Selects row processing configuration to edit.* *Selects column processing configuration to edit*	DFNC Expert
Pixel Replacement Row or Column No	rowColInterpolationTableIndex"	The column or row which is selected to be defined as having the median filter active or not active for the pixels in the column or row.(RW)	DFNC Expert
Row/Col Replacement Mode *Off* *Active*	defectiveRow/ColReplacementMode *Off* *Active*	When set to Active the entire row or column of pixel values are replaced with the median value. This is an independent control from the FPN/PRNU defect threshold. (RW) *Disable defective row/col replacement.* *Enable defective row/col replacement.*	DFNC Expert
Pixel Replacement Clear	PixelReplacementClear	Clears all Active rows and columns from being included in the defect replacement and sets them to Off.	DFNC Expert
FPN Base Defect Count	flatfieldCalibrationFPNBaseDefectCount	Reports the number of defect pixels detected in FPN base calibration.	DFNC Guru
FPN Delta Defect Count	flatfieldCalibrationFPNDeltaDefectCount	Reports the number of defect pixels detected in FPN delta calibration.	DFNC Guru
PRNU Defect Count	flatfieldCalibrationPRNUDefectCount	Reports the number of defect pixels detected in PRNU delta calibration.	DFNC Guru
Dark Row Subtract Mode *Off* *Disabled* *Enabled*	DarkRowSubtractMode *Off* *Disabled* *Enabled*	The dark row subtract function measures the sensor dark row pixels and forms an average for each column which is subtracted, according to selected mode, from the pixel data. This module corrects for column based offsets and uses at most 28 of the 32 available sensor dark rows. (RW) It should be noted that FPN coefficients should be calculated and used under the same Dark Row Subtract Mode. The black rows are output on image row 0 to 31, followed by the normal image rows shifted 32 rows. The highest 32 rows of image are not displayed. The values of the pixels are not altered by the Dark Row Subtract Module. The video data is passed through without being modified or shifted. The average of the DarkRowAverageCurrentFrame and the previous DarkRowAverageCurrentFrame is found and then subtracted from all the image pixels. VideoOut(x,y) = Raw(X,y) –(DarkRowAverageCurrentFrame(x)/2 + DarkRowAveragePreviousFrame(x)/2)	
Dark Row Subtract Digital Offset	DarkRowSubtractDigitalOffset	The value entered is added to the 12-bit data and is used to ensure that the data leaving the Dark Row Subtract Module is > 0. This allows for correct FPN coefficient calculation. (RW)	DFNC Guru
Dark Row Defect Mask	DarkRowDefectMask	This is a mask which can exclude any dark row of the 16 dark rows at the bottom of the image sensor (row 0 to 15) or at the top of the	DFNC Guru

		image sensor (row 16 to 31). The bit mask is one hot and rows 0,15,16 and 31 are always marked as excluded. Mandatory set bits are shown below: (Bit 31…..Bit0) Mask = 0x80018001	
Dark Row Defect Threshold	DarkRowDefectThreshold	The value entered is checked against every dark pixel. If a single pixel is found to be greater than the threshold, then the entire row is dynamically excluded from the DarkRowAverageCurrentFrame.	DFNC Guru

Image Format Controls Category

The camera Image Format controls, as shown by CamExpert, group parameters used to configure camera pixel format, and image cropping. Additionally, a feature control to select and output an internal test image simplifies qualifying a camera setup without a lens.

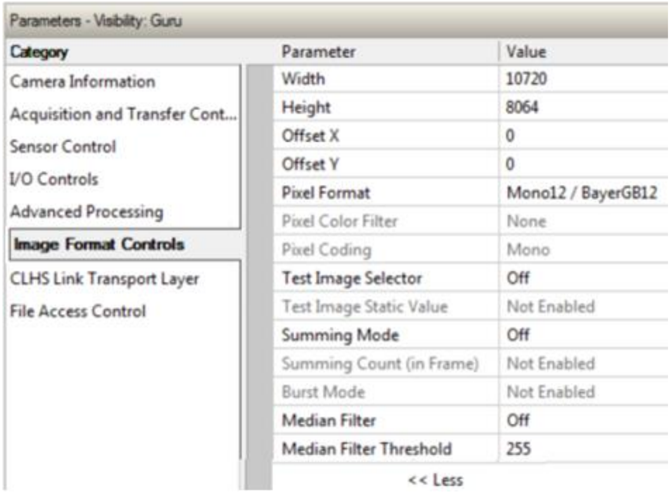


Figure 31 CamExpert Image Format Control Category

Image Format Control Feature Descriptions

Display Name	**Feature & Values**	**Description**	**Standard & View**
Width	Width	Width of the Image provided by the device which ranges up to the SensorWidth in multiples of 32 pixels (in pixels).(RW)	Beginner
Height	Height	Height of the Image provided by the device (in lines) which ranges up to the SensorHeight in multiple of 2 rows.(RW)	Beginner
Offset X	OffsetX	Horizontal offset from the Sensor Origin to the Area Of Interest (in pixels). (RW) Note Width must be reduced first. The offset is a multiple of 32 pixels.	Beginner
Offset Y	OffsetY	Vertical offset from the Sensor Origin to the Area Of Interest (in pixels). Note Height must be reduced first and is a multiple of 2 rows.	Beginner
Pixel Format	PixelFormat	Output image pixel coding format of the sensor.	Beginner
Mono12/BayerGB12	*Mono12*	*Mono12 or BayerGB 12-Bit*	
Mono16/BayerGB16	*Mono16*	*Mono16 or BayerGB 16-Bit*	

Pixel Color Filter	PixelColorFilter	Indicates the type of color filter applied to the image. <RO>	Beginner
BayerGB	*BayerGB*	Color Sensor (color camera)	
None	*None*	No filter applied on the sensor (monochrome camera)	
Pixel Coding	PixelCoding	Output image pixel coding format of the sensor. <RO>	Beginner
BayerGB	*BayerGB*	*Color Sensor*	
Mono	*Mono*	*Monochrome format*	
Test Image Selector	TestImageSelector	Selects the type of test image output by the camera. See the Test Patterns section for more information. Flatfield correction will be disabled if the user selects the PRNU value.	Beginner
Off	*Off*	Image is from the camera sensor.	
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.*	
Purity	*Purity*	*Image is filled with an image that goes from the darkest possible value to the brightest by 1 DN increment per frame.*	
Grey Diagonal Ramp	*GreyDiagonalRamp*	*Image is filled horizontally and vertically with an image that goes from the darkest possible value to the brightest by 1 DN increment per pixel.*	
Static Value	*Static Value*	*User-specified static value. The value is set using the testImageStaticValue feature.*	
PRNU	*PRNU*	*This is 2 times the sum of a horizontal test pattern that repeats every 64 pixels and a vertical test pattern that repeats every 62 lines plus + testImageStaticValue. This test pattern can be used to test FPN and PRNU correction.*	
Test Image Static Value	testImageStaticValue	Pixel value to use for test image when the *TestImageSelector* feature is set to "Static Value". Read-Write when TestImageSelector is either PRNU, or StaticValue. Possible values are: 0 to 4095	DFNC Beginner
Summing Mode	summingMode	Enables camera summing mode.	DFNC Guru
Off	*Off*	*The camera will output 1 frame at a time.*	
Active	*Active*	*The camera will sum 2 or more frames and output the summed image*	
Summing Count (in frame)	summingCount	Specifies the number of frames to sum. Read-Write when summingMode is Active. Possible values are: 2 to 8, in increments of 1.	DFNC Guru
Burst Mode	summingBurst	Enables camera summing burst mode. This mode effects the maximum frame rate (i.e. AcquistionFrameRate). Read-Write when summingMode is Active.	
Active	*Active*	*When the camera is triggered (either internally or externally), it will generate a series (summingCount) of internal triggers at the maximum frame rate. For example, when the camera is set to a frame rate of 1 Hz in this mode, and the summingCount = 4, the camera will generate 4 triggers at the maximum frame rate every second.*	

Off	*Off*	*The camera to average the specified number of frames (summingCount) as it receives the internal or external frame triggers.*	
Median Filter *Active* *Off*	medianFilter *Active* *Off*	Enable 3X3 2D median filter. This filter applies on the whole image. *Active: The camera will use 3x3 2D median filter* *The camera will not use 3x3 2D median filter*	DFNC Guru
Median Filter Threshold	medianFilterThreshold	Specifies the median filter threshold. If the difference between the current pixel and median of its neighbor pixels is greater than this value, the current pixel will be replaced. Possible values are 0 to 2048, in increments of 1.	DFNC Guru

CLHS Link Transport Layer Category

The camera’s CLHS Link Transport Layer category groups parameters used to document and configure the Camera Link HS input and output of the camera.

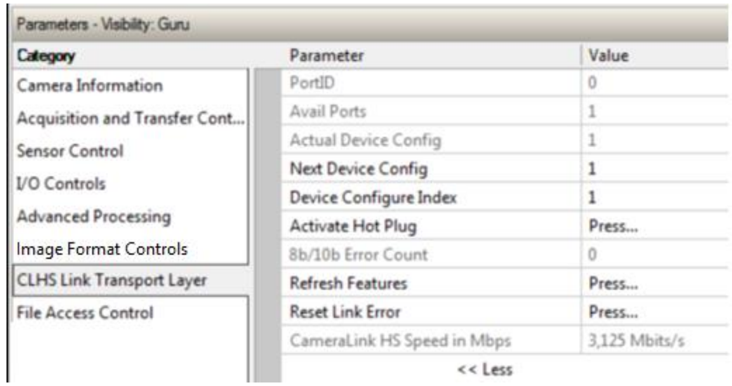


Figure 32 CamExpert CHLS Link Transport Layer Category

Camera Link Transport Layer Feature Descriptions

Display Name	Feature & Values	Description	Standard & View
PortID	PortID	The logical number of the CLHS port used. A CLHS port is defined as a command channel and may include the video channel carried by a cable. <RO> Possible values are: 0 to 4294967295	DFNC Beginner
Avail Ports	AvailPorts	Number of ports available on this device. <RO>	DFNC Beginner
Actual Device Config	ActualDeviceConfig	The current index of the device configuration. <RO>	DFNC Beginner
Next Device Config	NextDeviceConfig	The next configuration of the device to use on the next hot plug event. Possible values are 1 or 2.	DFNC Beginner
Device Configurre Index	DeviceConfigureIndex	Index selector for the device configuration. Possible values are 1 or 2.	DFNC Beginner
Activate Hot Plug	ActivateHotPlug	Performs a Hot Plug event. This event will cause the camera to: • disconnect from the frame grabber • load the configuration specified by *NextDeviceConfig* if it has changed since the last connection • reconnect to the frame grabber.	DFNC Beginner

8b/10b ErrorCount	LinkErrorCount	Indicates the number of low level data errors on the connection between the camera and frame grabber. <RO> Possible values are: 0 to 4294967295	DFNC Beginner
Refresh Features	RefreshFeatures	Refresh features on the CLHS Link Transport Layer page.	DFNC Beginner
Reset Link Error	ResetLinkError	Resets the Link Error Counter to 0.	DFNC Beginner
CameraLink HS Speed in Mbps	clDeviceClockFrequency	Indicates the Camera Link HS clock frequency. The CLHS clock runs at 3125 Mbits/second.	DFNC Beginner

File Access Control Category

The File Access control in CamExpert allows the user to quickly upload various data files to the connected camera. The supported data files are for camera firmware updates, Flat Field coefficients, debug files, logs, defect maps.

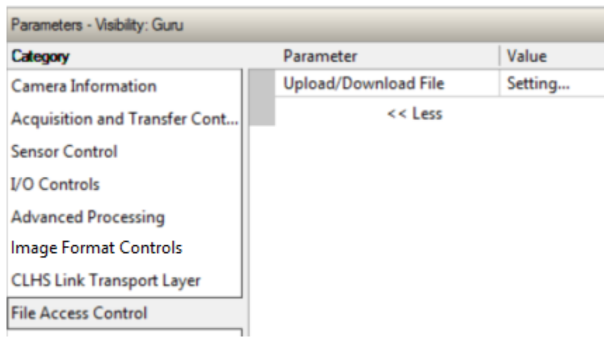


Figure 33 CamExpert File Access Control Category

File Access Control Feature Descriptions

Display Name	Feature & Values	Description	Standard & View
File Selector	FileSelector	Selects the file to access. The file types which are accessible are device-dependent.	Guru
Firmware	*Firmware1*	Writing a new firmware here will update the camera.	
User Flat Field 1 *to* *User Flat Field 3*	*FlatFieldCoefficients1* *to* *FlatFieldCoefficienets3*	A tiff containing the flat field correction coefficients (i.e. gain and offset)	
Factory Global Flatfield	*FlatFieldCoefficientsFact1*	A tiff containing the factory flat field correction coefficients for global shutter operation (i.e. gain and offset)	

Factory Rolling Flatfield	*FlatFieldCoefficientsFact2*	A tiff containing the factory flat field correction coefficients for rolling shutter operation (i.e. gain and offset)	
Logs	*Logs*	Download camera logs. This is a zipped file	
Factory Defect Map	FactoryDefectMap	Download camera defect map.	
User Defect Map	UserDefectMap	File that allows user to test file transfer.	
File Size	FileSize	Represents the size of the selected file in bytes.	Guru
File Open Mode	FileOpenMode	Selects the 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 Operation Selector	FileOperationSelector	Selects the target operation for the selected file in the device. This operation is executed when the File Operation Execute feature is called.	Guru
Open	*Open*	Select the Open operation - executed by FileOperationExecute.	
Close	*Close*	Select the Close operation - executed by FileOperationExecute	
Read	*Read*	Select the Read operation - executed by FileOperationExecute.	
Write	*Write*	Select the Write operation - executed by FileOperationExecute.	
Delete	*Delete*	Select the Delete operation - executed by FileOperationExecute.	
File Operation Execute	FileOperationExecute	Executes the operation selected by File Operation Selector on the selected file.	Guru
File Access Offset	FileAccessOffset	Controls the mapping offset between the device file storage and the file access buffer.	Guru
File Access Length	FileAccessLength	Controls the mapping length between the device file storage and the file access buffer.	Guru
File Operation Status	FileOperationStatus	Displays the file operation execution status. (RO)	Guru
Success	Success	The last file operation has completed successfully.	
Failure	Failure	The last file operation has completed unsuccessfully for an unknown reason.	
File Unavailable	FileUnavailable	The last file operation has completed unsuccessfully because the file is currently unavailable.	
File Invalid	FileInvalid	The last file operation has completed unsuccessfully because the selected file in not present in this camera model.	
File Operation Result	FileOperationResult	Displays the file operation result. For Read or Write operations, the number of successfully read/written bytes is returned. (RO)	Guru
File Access Buffer	FileAccessBuffer	Defines the intermediate access buffer that allows the exchange of data between the device file storage and the application.	Guru

Appendix B: Cleaning the Sensor Window

Recommended Equipment

- Glass cleaning station with microscope within clean room.
- 3M ionized air gun 980 (http://solutions.3mcanada.ca/wps/portal/3M/en_CA/WW2/Country/)
- Ionized air flood system, foot operated.
- Swab (HUBY-340CA-003) (http://www.cleancross.net/modules/xfsection/article.php?articleid=24)
- Single drop bottle (FD-2-ESD)
- E2 (Eclipse optic cleaning system (www.photosol.com)

Procedure

- Use localized ionized air flow on to the glass during sensor cleaning.
- Blow off mobile contamination using an ionized air gun.
- Place the sensor under the microscope at a magnification of 5x to determine the location of any remaining contamination.
- Clean the contamination on the sensor using one drop of E2 on a swab.
- Wipe the swab from left to right (or right to left but only in one direction). Do this in an overlapping pattern, turning the swab after the first wipe and with each subsequent wipe. Avoid swiping back and forth with the same swab in order to ensure that particles are removed and not simply transferred to a new location on the sensor window. This procedure requires you to use multiple swabs.
- Discard the swab after both sides of the swab have been used once.
- Repeat until there is no visible contamination present.

Appendix C: Internal Flat Field Calibration Algorithms

The camera provides the user with the ability to perform a custom flat field calibration. This appendix gives details of the calibration algorithms. All calibration is performed on averaged image data to reduce noise.

Dark Row Subtract

It is recommended that the Dark Row Subtract Algorithm is enabled during camera operation and calibration. The FPN coefficients are impacted by this setting and it is the user's responsibility to ensure that the coefficients in-use were calculated with the current setting of the Dark Row Subtract function.

The Dark Row Subtract Offset should be set to 50 DN when the Dark Row Subtract Algorithm is enabled. This adds a constant 50 DN to all pixel values after the Dark Row Subtract Algorithm, ensuring pixel values are not clipped to zero and FPN coefficients are calculated correctly.

The Dark Row Subtract Algorithm measures the dark rows of the image sensor and forms an average of the ADC offset per column. This average accounts for drift in the ADC value which is subtracted from pixels of the column and results in more stable images, but with a small penalty in read noise.

Offset (FPN) Calibration

Offset calibration is performed when the sensor is not exposed to light.
The camera supports a 2-step FPN calibration algorithm. The first step measures the ADC offsets and photo site integration time dependent dark current. The 2nd step is performed with a small amount of light (50 DN) on the sensor which helps to linearize the camera's response above this light level. Many systems do not require the 2nd step of FPN calibration.

The offset values are calculated as follows when the first step of FPN calculation is performed:

- The camera averages several (see flatfieldCalibrationSampleSize) images (128 frames recommended).
- The offset correction is calculated at each pixel in the dark. It has 2 components: FPN base and FPN delta.
- FPN base is measured at minimal exposure time, and is simply the average value for each pixel in the dark.
- FPN delta is measured at current exposure time, and is the average deviation from FPN base for each pixel in the dark.

Gain (PRNU) Calibration

The flat field gain calibration is performed after the offset calibration, when the sensor is exposed to a flat light source. The gain on each pixel is adjusted to achieve a target value. There are two methods for selecting the correction target: PRNU Customer Target or PRNU Auto Color Gain.

PRNU customer target allows the customer to enter the expected output value after PRNU calibration. For a monochrome camera a single value, % of full scale, is entered, while the color camera enables entry of 3 unique color target values.

Selecting PRNU Auto Color Gain enables the area of interest to be specified using the Auto Brightness, X, Y, Offset and Height, and Width values over which the average of each color is measured and the target set to 1.2 the average value. As a final step for the PRNU Auto Color Gain, the white balance gains are calculated and stored with the coefficient set.

For the monochrome cameras the process is as follows:

- The camera averages several (see *flatfieldCalibrationSampleSize*) images.
- For each pixel of the averaged image (256 frame average is recommended):
    - Subtract the previously calibrated offset values (FPN), which is composed of FPN base and normalized FPN delta
    - Calculate the multiplication factor necessary to achieve the target value. The target value is calculated using *flatfieldCalibrationTarget*.

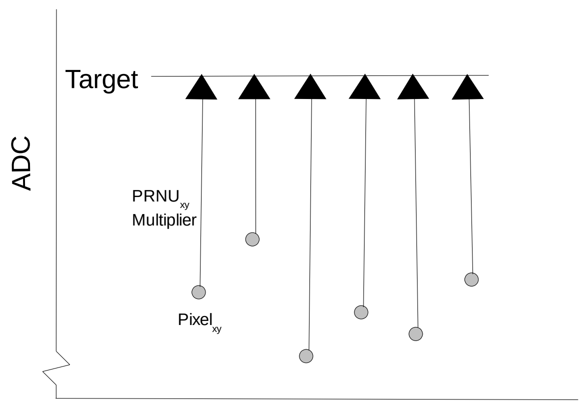


Figure 34 Monochrome Flat Field Gain Calibration

    - If the calculated gain is less than 1 then the pixel is marked as defective. A large number of marked pixels may indicate a poorly chosen target or exposure setting.
- If the calculated pixel gain is not correctable (that is, greater than 4), it will be clipped at 4.
- Once the gain values are calculated, the values are used to correct the image.
- During camera operation the FPN and PRNU defect threshold is programmable and results in a different number of replaced pixels.

Color Camera Gain (PRNU) Calibration

The flat field gain calibration is performed after the offset calibration, when the sensor is exposed to a flat light source. The gain on each pixel is adjusted to achieve a user-entered per-color target value (flatfieldCorrectionAlgorithm = PRNU_Customer_Target) or 1.20 above the specific color's average (flatfieldCorrectionAlgorithm = PRNU_Auto_Gain). In PRNU_Auto_Gain, the gain required to match the output of the highest responding color is saved with the coefficient set and is shown by the gain register when selecting its color.

PRNU calculation algorithm PRNU_Customer_Target requires the user to enter per-color targets before commanding PRNU calculation. Setting all the color targets equal will result in the PRNU coefficients including the white balance gain. It is recommended that users enter values for each color about 20% higher than the color's average.

The PRNU_Auto_Gain algorithm is performed differently for color cameras and makes use of FPGA capabilities to measure the average of each color over a specified area of interest. The user interface uses the autoBrightnessROISelector / width / height / OffsetX / OffsetY to enter the parameters used to determine the region in which the imaging statistics are gathered. The correction coefficients are calculated over the entire image.

The process of PRNU calculation is:

1) Set the camera to use an internal frame rate and integration time close to the final values.
2) Make the camera dark and perform FPN calculation. This is the same for the monochrome cameras.
3) Add uniform white light so that the most responsive color and least responsive color are equally above and below 55% of output level with FPN correction on and PRNU correction off, and with the color and system gains set to unity.
4) Set the region over which the averages are calculated (autoBrightnessROISelector / width / height / OffsetX / OffsetY)
5) Command PRNU calculation.

The camera's micro code now commands the FPGA to capture the frame average statistic for each color using a single frame.

The micro then finds:

TargetRed = 1.2*AverageR,
TargetBlue = 1.2*AverageB,
TargetGreenBlue = 1.2*AverageGreenBlue (Green pixels in the blue row)
TargetGreenRed = 1.2*AverageGreenRed (Green pixels in the red row)

The micro code then commands the FPGA to perform PRNU calculation.

Micro calculates the color gains and ensures they are stored with the coefficient set.

GainMaxColor = 1 (assume R for this example, as easier to write the description)
GainGR = AvgR/AvgGR
GainGB = AvgR/AvgGB
GainB = AvgR/AvgB

User Interface Rules

- autoBrightnessHeight:minimum 4 rows
- autoBrightnessWidth: minimum 64 columns
- autoBrightnessOffsetX: multiple of 32
- autoBrightnessOffsetY: multiple 2.

The minimum autoBrightnessOffsetY =2+ OffsetY (Avoid the first row of data)
The maximum autoBrightnessHeight is such that the last 2 rows of the output data are omitted.

autoBrightnessHeight < Height -4

The autoBrightnessOffset, width and height are automatically pushed smaller with image ROIs but don't automatically increase.

If increasing the autoBrightnessOffsetY, it may be that the autoBrightnessHeight needs to first be reduced before the Y offset can be increased. Remember that the autoBrightnessOffsetY must be a multiple of 2 and if an odd number is entered then the value is rounded down, if it does not conflict with the rule autoBrightnessOffsetY> 2+OffsetY. If the requested offsetY can be increased, but not in its entirety due to the height limitation, then the entered value is automatically adjusted to achieve the maximum allowed without decreasing the autoBrightnessHeight.

autoBrightnessOffsetY = Trunc (CustomerEnteredStatisticOffsety/2) *2

Given that autoBrightnessOffsetY >=OffsetY +2 and autoBrightnessOffsetY <=Offsety+Hieght-2-autoBrightnessHeight

autoBrightnessOffsetx = Trunc((CustomerEnteredStatisticOffsetx)/32)*32 +1 Width must first be reduced before the offsetx can be increased.

autoBrightnessOffsetx <= 10720- autoBrightnessWidth
autoBrightnessWidth = Trunc(CustomerEnteredWidthx/32)*32>=64 <= 10720

Appendix D: FFC File Format

FFC File Format

FFC file is downloaded / uploaded as shown in the following figure:

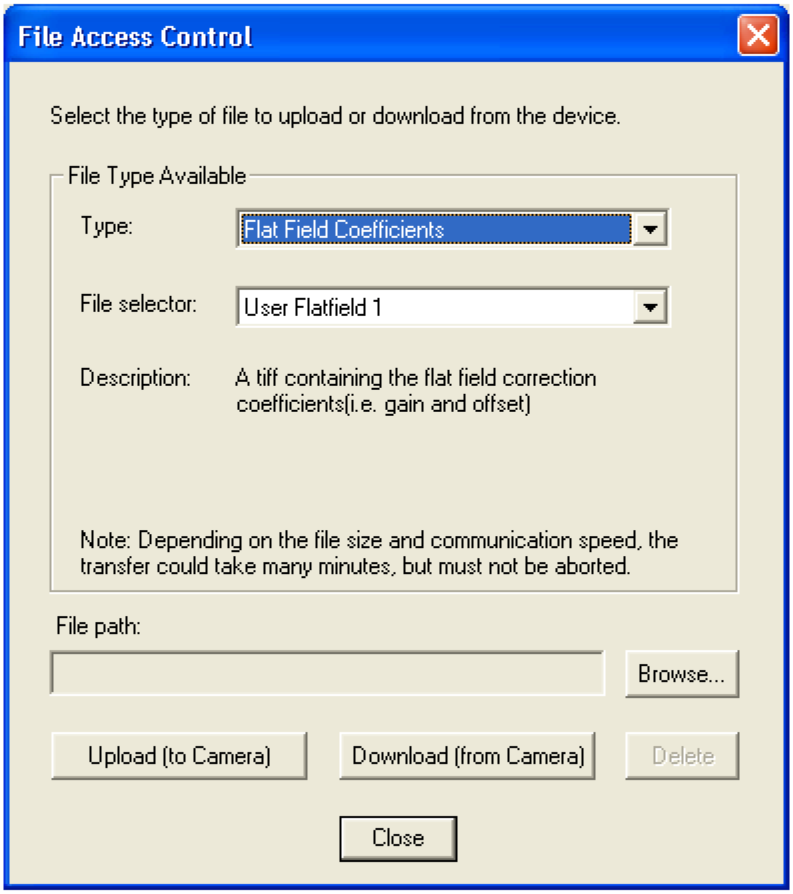


Figure 35: CamExpert File Access Control Dialog

Table 12: FCC File Format

Byte Offset	Name	Value/Note
0	Signature	"SAPERA_FFC "
16	Version	
20	Header size	
24	Base OffsetBits	Number of bits of FPN base component: 9
28	PRNU Gain Bits	Number of bits of PRNU gain
32	Aoi width	Width of area interest
36	Aoi height	Height of area interest
40	Aoi left	Left of area interest
44	Aoi top	Top of area interest
48	Sensor width	Width of sensor absolute region
52	Sensor height	Height of sensor absolute region
56	Sensor left	Left of sensor absolute region
60	Sensor top	Top of sensor absolute region
64		Reserved for other Teledyne Dalsa cameras
164	nCalTime	Measured exposure time when doing Delta FPN calibration
168	nBaseTime	Measured exposure time when doing BASE FPN calibration
172	ADCOffset	Used during FPN calibration
176	Sensor width	10752
180	nCoeffFileSize	Cofficient data size in bytes
184	spare	Reserved for future use
256 ~ …	FFC data	Each pixel has 4 bytes. Bit0~bit8 is FPN Base, Bit9~bit16 is FPN delta, Bit17~Bit31 is PRNU.

The file downloaded to PC is a raw image file, which combines each FPN base, FPN delta, and PRNU into a double word. Teledyne Dalsa provides a standalone command line application (FFC_Codec.exe) to decode this raw image into 3 readable .tif files.

The usage of FFC_Codec.exe is as follows:

```
decode   Source File(Binary in camera)    Target Files(FPN_Base (tif), Delta
FPN(tif), PRNU FFC(tif))\n");
example: FFC_Codec.exe  "decode"  "FlatFieldCoefficients.tif"  "fpn_base.tif"
"fpn_delta.tif" "prnu.tif";

encode   Source File Files(FPN_Base (tif), Delta FPN(tif), PRNU FFC(tif))
Target File(Binary in camera)
example: FFC_Codec.exe  "encode"   "fpn_base.tif"  "fpn_delta.tif"  "prnu.tif"
"encoded.tif"
```

Note that when running encode, target file must exist. This is used to extract FFC header info. The initial target file is the FFC raw file downloaded from camera.

After decode the source binary file, one can use other image processing software to view this target tiff file.

Camera Defect Map

The camera defect map file is a text file that contains information on row, column, and cluster defects found during the camera test. This text file is for information purposes only and is not used with any internal camera function.

There are two copies of the file loaded into the camera: a factory version that the user has read-only access to, and a user version that can be overwritten.

The header section at the top of the file (see example below) contains the camera model number, serial number, date when it was tested / the defects were found, and the device firmware in the camera at the time.

The file reports all defects found under rolling shutter, followed by all defects found under global shutter.

The information recorded for each row defect is the top row of the defect, the bottom row of the defect, and the size (number of rows) of the defect. Most row defects are only a single row so the top and bottom row will be the same and the size will be one.

Column defects are reported the same way as row defects except the leftmost and rightmost defective columns are used instead of top and bottom rows for each defect.

For cluster defects the center X and Y coordinates of each defect are recorded along with the number of defective pixels.

For all measurements the top left pixel of the image is (0, 0).

```
Defect Map File

Model Number: FA-S0-86M16-50-R
Serial Number: 18014093
Defects found on 2016-02-23
Device Version: 255.137.660

Defects found under rolling shutter:

No row defects found.

No column defects found.

Cluster Defects: ( X, Y ), Area
Cluster1:   ( 523, 4335 ), 4
Cluster2:   ( 379, 5332 ), 7
Cluster3:   ( 3374, 6515 ), 7
Cluster4:   ( 3776, 6636 ), 97

Defects found under global shutter:

No row defects found.

No column defects found.

Cluster Defects: ( X, Y ), Area
Cluster1:   ( 524, 4335 ), 6
Cluster2:   ( 379, 5333 ), 9
Cluster3:   ( 3374, 6515 ), 7
Cluster4:   ( 3776, 6636 ), 98
```

Revision History

Number	Change	Date
00	Initial release of preliminary version to support early consignment cameras	8 November 2016
01	• Fan mounting accessory (AC-MS-00117-00-R) listed • Performance specifications table revised • Cosmetic sensor specifications revised • Angle of Incidence graph added • Flash memory size values added • Thermal management section added • Gain and black level controls diagram revised • Opto-coupled outputs diagram revised • Correction function block diagram revised • Command listed revised to reflect current camera operation	19 April 2017
02	• Revised dynamic range values, including color specifications. • PRNU value revised from 2.8 to 3.5. • Updated spectral responsivity and QE graphs.	2 March 2018
03	• Revised QE and Responsivity graphs	3 May 2018
04	• General update	August 21, 2020
05	• Pixel replacement mode for row column replacement renamed to row/col replacement mode.	Nov 20, 2020

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