Up to 1.4 Megapixels, High Speed CMOS Area Scan Cameras

Falcon XDR and HG Series

Camera User's Manual

Falcon 1.4M100 XDR Monochrome – FA-20-01M1H
Falcon 1.4M100 HG Monochrome – FA-21-01M1H
Falcon 1M120 HG Monochrome – FA-21-1M120
Falcon VGA300 HG Monochrome – FA-21-3HK3H
Falcon 1.4M100 XDR Color – FA-22-01M1H
Falcon 1.4M100 HG Color – FA-23-01M1H
Falcon 1M120 HG Color – FA-23-1M120
Falcon VGA300 HG Color – FA-23-3HK3H

DALSA

PoCL

Document Number: 03-032-20024-03

About DALSA

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 semiconductor products and services. DALSA's core competencies are in specialized integrated circuit and electronics technology, software, and highly engineered semiconductor wafer processing. Products and services include image sensor components; electronic digital cameras; vision processors; image processing software; and semiconductor wafer foundry services for use in MEMS, high-voltage semiconductors, image sensors and mixed-signal CMOS chips. DALSA is listed on the Toronto Stock Exchange under the symbol "DSA". The Company has its corporate offices in Waterloo, ON and over 1000 employees worldwide.

For further information not included in this manual, or for information on DALSA's extensive line of image sensing products, please call:

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Contents

1

Introduction to the Falcon XDR and HG Cameras

The Falcon camera family is a group of eight high performance cameras which are organized in two branches:

- XDR series
- HG series

They are also available in color (FA-22 and FA-23 series) or monochrome (FA-20 and FA-21 series) versions.

The XDR (eXtended Dynamic Range) series is optimized for high dynamic range and provides 1.4 megapixels at 100 fps. The XDR series includes monochrome and color versions of the Falcon 1.4M100 XDR.

The HG (High Gain) series consists of six camera models: the Falcon 1.4M100 HG, the Falcon 1M120 HG, and the Falcon VG A300 HG, all with monochrome or color versions. These cameras are optimized for both high speed and high responsivity. To achieve high responsivity, the analog gain setting for all three cameras was increased by 2.55 times relative to the Falcon XDR cameras. To achieve high speeds, the Falcon 1M120 and Falcon VGA300 cameras have optimized sensor timing and settings to achieve fast frame rates, with the option of only 8-bits output.

1.1 Camera Highlights

1.1.1 Features

- Three resolutions:
    - 1.4 megapixels, 1400(H) x 1024(V) resolution, 100fps, 8 or 10 bit
    - 1 megapixel, 1024(H) x 1024(V) resolution, 120fps, 8 bits
    - VGA resolution, 640(H) x 480(V) resolution, 300fps, 8 bits
- Extendend Dynamic Range (XDR) or High Gain (HG) versions
- Color or Monochrome versions
- Global shutter (non-rolling shutter) for crisp images
- Compact camera body – 44mm x 44mm x 44mm – fits into the smallest of places
- Base mini-Camera Link™ SDR26 cable interface for greater ease of use
- PoCL – Power over Camera Link –No need for a separate power supply
- Enhanced data drive capability – Achieves 80MHz data speeds with 10m cables (typical performance is 5.6 meters)
- Vertical windowing for faster frame rates
- 7.4µm x 7.4µm pixel pitch
- Good near-infrared (NIR) response
- 2x80MHz data rates
- Dynamic range of 55dB – XDR series; 48dB – HG series

1.1.2 Programmability

- Simple ASCII protocol controls gain, offset, frame rates, trigger mode, test pattern output, and camera diagnostics
- Serial interface (ASCII, 9600 baud, adjustable to 19200, 57600, 115200), through Camera Link

1.1.3 Description

The Falcon XDR and HG cameras provide high quality, high speed image capture in a compact design. The global shutter capability of the sensor makes these cameras capable of capturing low smear images at incredibly fast rates. Its small camera body, mini-Camera Link™ cabling and PoCL capability allow these cameras to fit into space-constrained applications. With its enhanced data drive capability, mini-Camera Link cables up to 10m in length can be used. Programmable features and diagnostics are accessible through the mini-Camera Link SDR26 connector.

1.1.4 Applications

The Falcon XDR and HG cameras are ideal for monochrome or color applications requiring high speed, superior image quality, and high responsivity, in space constrained areas. These features make Falcon cameras applicable to:

- PCB-AOI inspection
- Semiconductor wafer inspection
- Electronics inspection
- Flat panel display inspection
- Industrial metrology
- Traffic management
- Print registration control
- General machine vision

1.2 Camera Performance Specifications

Camera Model	Resolution	Maximum Frame Rate	Bit Depth	Dynamic Range	Color or Monochrome
1.4M XDR	1400Hx1024V	100fps	8 or 10 user selectable	55dB	Both
1.4M HG	1400Hx1024V	100fps	8 or 10 user selectable	48dB	Both
1M HG	1024Hx1024V	120fps	8	48dB	Both
VGA HG	640Hx480V	300fps	8	48dB	Both

Optical Interface	Units		Notes
Back Focal Distance	mm	17.52	4
Sensor Alignment x y z θz	 mm mm mm °	 +/- 100 microns +/- 100 microns +/- 150 microns +/- 0.2	
Lens Mount		C-mount	
Effective fill factor with microlenses	%	60	

	Units		Notes
Camera Size	mm	44 x 44 x 44	
Mass	g	105g	
Connectors power connector data connector		 6 pin male Hirose SDR26 female – mini Camera Link	

Electrical Interface	Units		Notes

Electrical Interface	Units		Notes
Input Voltage	Volts	+12V to 15V	
Power Dissipation	W	≤ 3	
Operating Temperature	°C	0 to 50	1
Output Data Configuration		Base mini-Camera Link	
Output Format (# of taps)		2 Tap Interleaved (odd/even)	

Mono Operating Ranges	Units		Notes
Data Rate	MHz	2 @ 80	
Random Noise	DN rms	1.7 (Falcon XDR) 3.2 (Falcon HG)	7
Broadband Responsivity	DN/(nJ/cm^2)	19 (Falcon XDR) 48 (Falcon HG)	
DC Offset	DN	1	5
Antiblooming		>1000 x Saturation	
FPN	DN rms	0.9 (Falcon XDR) 4.3 (Falcon HG)	5, 7
PRNU	DN rms	4.7 (Falcon XDR) 4.3 (Falcon HG)	5, 6, 7
Integral non-linearity	DN	≤ 2%	3

Color Operating Ranges	Units		Notes
Data Rate	MHz	2 @ 80	
Random Noise	DN rms	Red: 1.7 (Falcon XDR) Blue: 1.7 (Falcon XDR) Green: 1.7 (Falcon XDR) Red: 3.5 (Falcon HG) Blue: 3.5 (Falcon HG) Green: 3.6 (Falcon HG)	7
Broadband Responsivity	DN/(nJ/cm^2)	See Section 1.3	
DC Offset	DN	1	5

Color Operating Ranges	Units		Notes
Antiblooming		>1000 x Saturation	
FPN	DN rms	Red: 1.0 (Falcon XDR) Blue: 1.2 (Falcon XDR) Green: 0.7 (Falcon XDR) Red: 1.6 (Falcon HG) Blue: 2.1 (Falcon HG) Green: 1.1 (Falcon HG)	5, 7
PRNU	DN rms	Red: 2.3 (Falcon XDR) Blue: 2.7 (Falcon XDR) Green: 1.7 (Falcon XDR) Red: 3.5 (Falcon HG) Blue: 4.2 (Falcon HG) Green: 2.7 (Falcon HG)	5, 6, 7
Integral non-linearity	DN	≤ 2%	3

Test conditions unless otherwise noted:

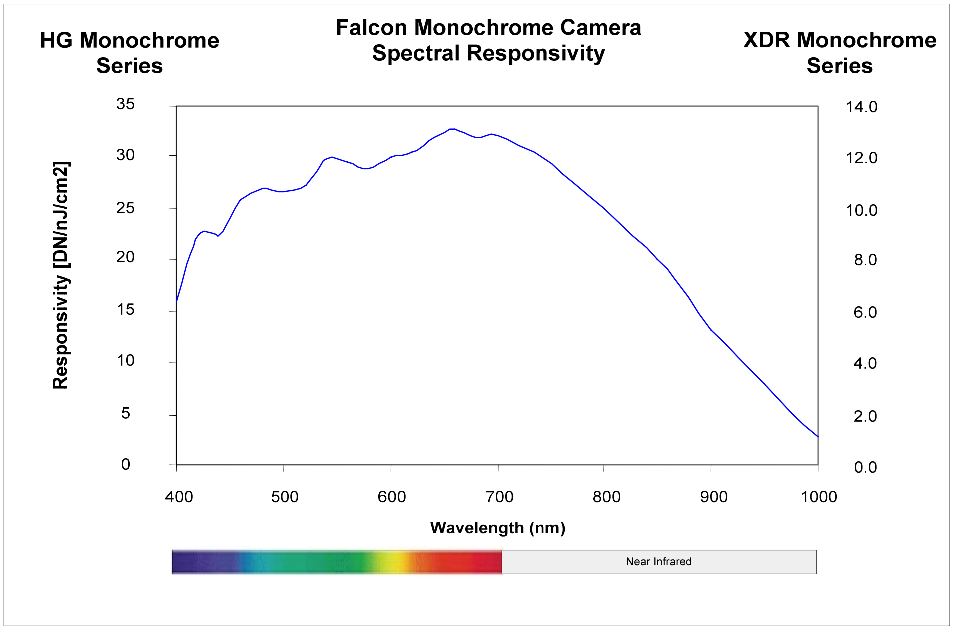
- Exposure mode 2 (`sem 2`)
- 100 fps (`ssf 100`)
- 9000 microsecond exposure time (`set 9000`)
- Light Source: Broadband Quartz Halogen, 3250K, with 750 nm cutoff filter
- Ambient test temperature 25°C
- Full Frame
- 10 bits

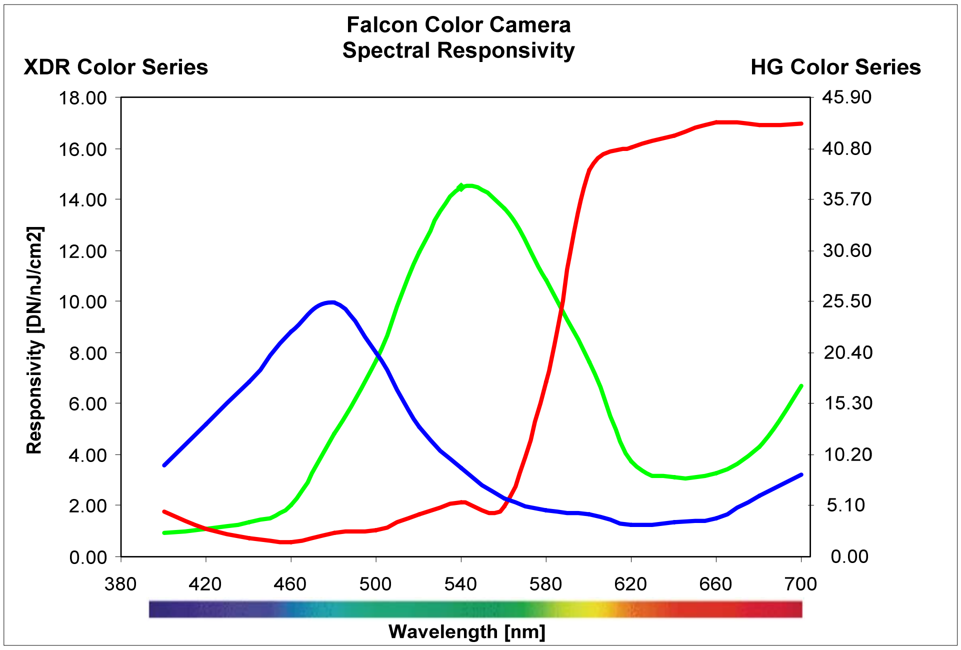
Notes:

1. Measured at the front plate.
2. Based on output at 1023DN
3. Output over 10-90%
4. Optical distance.
5. Flat-field correction applied with 9000 µs exposure at 50 fps in `sem 2`.
6. At 80% of camera saturation, 1x digital gain
7. Measurements done with 10 bits (Falcon 1.4M) and 8 bits (Falcon 1M and VGA)

1.3 Responsivity and Quantum Efficiency

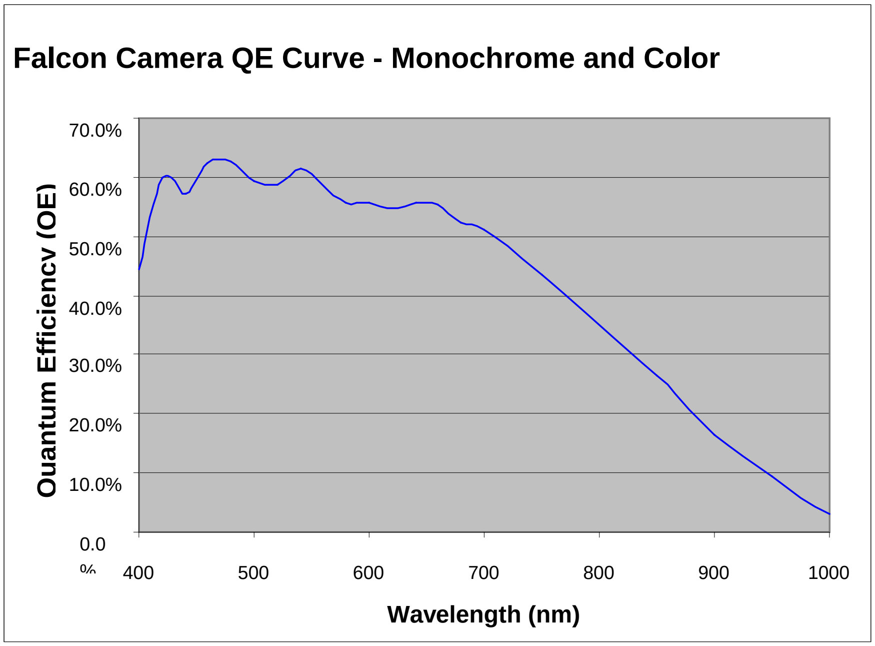
The responsivity graph describes the sensor response to different wavelengths of light (excluding lens and light source characteristics). Visible light spans wavelengths between 390-780 nanometers. Wavelengths below 390 nm are ultra-violet while those above 780 nm are termed infra-red.





Note: DALSA recommends using a 700nm cutoff filter with the HG and XDR color series cameras since the blue and green color filters become transparent above 700nm.

The quantum efficiency graph describes the fraction of photons at each wavelength that contribute charge to the pixel.



1.3.1 Sensor Cosmetic Specifications

The following table highlights the current cosmetic specifications for the DALSA sensor inside the Falcon cameras.

Monochrome Camera Blemish Specifications

Blemish Specifications	Maximum Number of Defects
Hot pixel defects	1
Single pixel defects	100
Clusters defects	No limit (see note)
Spot defects	0
Column defects	0
Row defects	0

Color Camera Blemish Specifications

Blemish Specifications	Maximum Number of Defects
Hot pixel defects	1
Single pixel defects	25 for each individual color (R, G1, G2, B)

Clusters defects	No limit (see note)
Spot defects	0
Column defects	0
Row defects	0

Definition of sensor cosmetic specifications

Hot pixel defect: Pixel whose signal, in dark, deviates by more than 400DN (10-bits) from its neighboring pixels.

Single pixel defect: Pixel whose signal, at nominal light (illumination at 50% of the linear range), deviates by more than ±30% from its neighboring pixels.

Cluster defect: A grouping of at most 5 pixel defects within an area of 3*3 pixels.

Spot defect: A grouping of more than 5 pixel defects within an area of 3*3 pixels.

Column defect: A vertical grouping of more than 20 contiguous pixel defects along a single column.

Row defect: A horizontal grouping of more than 20 contiguous pixel defects along a single row.

Test conditions

- Digital gain – 1X.
- Nominal light = illumination at 50% of saturation.
- Frame Rate = 100fps
- Integration time = 9ms
- Temperature of camera front plate is 25°C

Note: While the number of clusters is not limited by a maximum number, the total number of defective pixels cannot exceed 100. Therefore, you could have 20 clusters of 5 pixels in size (20 x 5 = 100), but you could not have 21 clusters of 5 in size (21 x 5 = 105).

(The probability of 21 clusters of 5 is negligible and is only used as an example.)

1.3.2 Cosmetic Specification

Beyond sensor cosmetic testing, the Falcon cameras are placed under additional testing to more closely examine potential cosmetic defects due to the sensor glass.

Glass defects are considered to be a group of pixels exceeding the maximum % deviation below the mean and the cluster size specifications. Images are taken at nominal light (illumination at 50% of the linear range).

Monochrome Camera Specifications

Blemish Specifications	Maximum % deviation below the mean	Size	Maximum Number of Defects
Glass defects	8%	12	0

In addition, the camera is examined for the following blemish defects.

Blemish Specifications	Maximum Number of Defects
Hot pixel defects	1
Single pixel defects	100

Color Camera Specifications

Blemish Specifications	Maximum % deviation below the mean	Size	Maximum Number of Defects
Glass defects	20%	9	0

In addition, the camera is examined for the following blemish defects.

Blemish Specifications	Maximum Number of Defects
Hot pixel defects	1
Single pixel defects	25 for each individual color (R, G1, G2, B)

Test conditions

- Digital gain – 1X.
- Nominal light = illumination at 50% of saturation.
- Frame Rate = 100fps
- Integration time = 9000 µs
- Temperature of camera front plate is 25°C

Note: All of the above sensor and camera cosmetic specifications are with flat-field correction turned off (`epc 0 0`). There are no post flat-field (`epc 1 1`) camera cosmetic specifications.

1.4 Certifications

RoHS	Compliancy as per European directive RoHS Directive 2002/95/EC and People's Republic of Chin Electronic Industry Standard SJ/T11364-2006

1.5 Shock and Vibration Certifications

Falcon cameras are shock and vibration tested to ensure their performance in industrial environments. All cameras pass the following tests:

Test	**Standard**	**Description**
Sinusoidal vibrations with identification of critical frequency or frequencies	IEC 68-2-6 (1995) Test Fc	Frequency range: 10 to 2000 Hz Amplitude: 5 m/s^2 Frequency rate: 1 octave per minute Duration: 1 sweep cycle (to-and-fro)
Sinusoidal vibrations Endurance	IEC 68-2-6 (1995) Test Fc	Frequency range: 10 to 2000 Hz Amplitude: 100 m/s^2 Frequency rate: 1 octave per minute Duration: 2 sweep cycles (to-and-fro)
Shocks	IEC 68-2-27 (1987) Test Ea and guide	Shape: Half-sine Amplitude: 75 g Duration: 3 ms Number: 3 shocks (+) and 3 shocks (-)

2

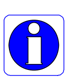
Camera Hardware Interface

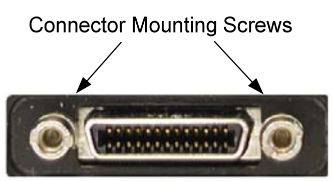
2.1 Installation Overview

When setting up your camera, you should take these steps:

1. Power down all equipment.
2. Following the manufacturer's instructions, install the frame grabber (if applicable). Be sure to observe all static precautions.
3. Install any necessary imaging software.
4. Before connecting power to the camera, test all power supplies.
5. Inspect all cables and connectors prior to installation. Do not use damaged cables or connectors or camera may be damaged.
6. Connect the mini-Camera Link and power cables.
7. After connecting cables, apply power to the camera.
8. Check the diagnostic LED. If camera is operating correctly, the LED will flash for 10 seconds and then turn solid green. See the section 2.2.1 LED Status Indicator on page 21 for a description of LED states.

You must also set up the other components of your system, including light sources, camera mounts, computers, optics, encoders, and so on. This installation overview assumes you have not installed any system components yet.

	**Note:** when unscrewing the mini-Camera Link cable from the Falcon camera, ensure the connector mounting screws do not become attached to the cable thumbscrews; in this case, simply screw the connector mounting screw back into the camera connector mounting



Camera Link cable quality and length

The maximum allowable Camera Link cable length depends on the quality of the cable used and the Camera Link strobe frequency. Cable quality degrades over time as the cable is flexed. Also, as the Camera Link strobe frequency is increased, the maximum allowable cable length will decrease.

The Falcon cameras have been designed such that at the highest strobe frequency the Falcon cameras are capable of driving cables 10m in length. This is to ensure system integrity since a typical Camera Link camera can only achieve 5.6m transmission distances.

DALSA does not guarantee good imaging performance with low quality cables of any length. In general, DALSA recommends the use of high quality cables in lengths for any cable length.

2.2 Input/Output Connectors and LED

The camera uses:

- A diagnostic LED for monitoring the camera. See the section 2.2.1 LED Status Indicator on page 21 for details.
- One high-density 26-pin SDR26 connector for Camera Link control signals, data signals, and serial communications. Refer to section 2.2.2 Camera Link Data Connector on page 21 for details. In addition, the PoCL capability of these cameras allows power to also be sent on the SDR26 connectors.
- One 6-pin Hirose connector for power (optional). Refer to section 2.2.5 Power Connector on page 25 for details.

Input/Output Connectors

⚠	**WARNING:** Ensure that all the correct voltages at full load are present at the camera end of the power (irrespective of cable length) according to the pinout defined in section 2.2.5 Power Connector on page 25. A common system problem is that the voltage drop across the power cable is large enough that the voltage at the camera does not meet the power input voltage specifications.

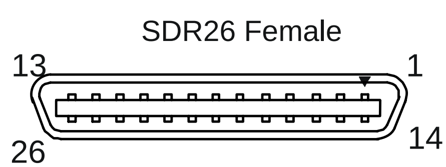
2.2.1 LED Status Indicator

The camera is equipped with an LED to display the operational status of the camera. The table below summarizes 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. Error and warning states are accompanied by corresponding messages further describing the current camera status.

Color of Status LED	Meaning
Off	Hardware malfunction or no power
Flashing Red (1 Hz)	Fatal error. Non-recoverable error (such as overheating).
Flashing Red (4 Hz)	Loading backup firmware
Solid Red	Warning. Loss of functionality. Operating condition out of specified range.
Flashing Blue (1 Hz)	Ready to download/Downloading files. Used for firmware update, LUT and FFC coefficients download.
Flashing Blue (4 Hz)	Writing to flash memory, do not power off. Used during firmware update and write user settings.
Flashing Green (1 Hz)	Camera initialization or executing a long command. LED shall flash green at least once each time a serial command is received.
Solid Green	Camera is operational and functioning correctly. Typically outputting images in free-running mode (internal sync, mode 2).

2.2.2 Camera Link Data Connector



Mini-Camera Link SDR26 Connector

The Camera Link interface is implemented as a Base Configuration in the Falcon cameras. You select the camera configuration with the `clm` command described in section 3.7 Setting Exposure Mode, Frame Rate and Exposure Time on page 36.

The following tables provide this camera's principal Camera Link information. See Appendix A for the complete DALSA Camera Link configuration table, and refer to the DALSA Web site, www.dalsa.com, for the official Camera Link documents.

Camera Link Hardware Configuration Summary

Configuration	8 Bit Ports Supported	Serializer Bit Width	Number of Chips	Number of SDR26 Connectors
Base	A, B, C	28	1	1

BASE Configuration	Port Definition		
Mode (set with `clm` command)	Port A Bits 0 thru 7	Port B Bits 0 thru 7	Port C Bits 0 thru 7
Mode 2 2 Tap 8 bit	Tap 1 LSB...Bit 7	Tap 2 LSB...Bit7	xxxxxxx
Mode 3 2 Tap 10 bit	Tap 1 LSB… Bit 7	Tap 1 Bits 8,9 Tap 2 Bits 8,9	Tap 2 LSB..Bit 7

Camera Link Connector Pinout

Base Configuration		
One Channel Link Chip + Camera Control + Serial Communication		
Camera Connector	Frame Grabber Connector	Channel Link Signal
1	1	inner shield or PoCL +12V PWR
14	14	inner shield or PoCL GND
2	25	X0-
15	12	X0+
3	24	X1-
16	11	X1+
4	23	X2-
17	10	X2+
5	22	Xclk-
18	9	Xclk+
6	21	X3-
19	8	X3+
7	20	SerTC+

Base Configuration		
One Channel Link Chip + Camera Control + Serial Communication		
Camera Connector	**Frame Grabber Connector**	**Channel Link Signal**
20	7	SerTC-
8	19	SerTFG-
21	6	SerTFG+
9	18	CC1-
22	5	CC1+
10	17	CC2+
23	4	CC2-
11	16	CC3-
24	3	CC3+
12	15	CC4+
25	2	CC4-
13	13	inner shield or PoCL GND
26	26	inner shield or PoCL +12V PWR

Note: Exterior Overshield is connected to the shells of the connectors on both ends.
3M part 14X26-SZLB-XXX-0LC is a complete cable assembly, including connectors.
Unused pairs should be terminated in 100 ohms at both ends of the cable.
Inner shield is connected to signal ground inside camera.

DALSA Camera Control Configuration

Signal	Configuration
CC1	EXSYNC
CC2	Reserved for future use
CC3	Reserved for future use
CC4	Reserved for future use

2.2.3 Input Signals, Camera Link

The camera accepts control inputs through the Camera Link SDR26F connector. The camera ships in internal sync, internal programmed integration (exposure mode 2), and Camera Link mode 2.

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 via the serial interface. Depending upon the mode of operation the high time of the EXSYNC signal can represent the integration period.

Section 3.7 Setting Exposure Mode, Frame Rate and Exposure Time on page 36 details how to set frame times, exposure times, and camera modes.

PoCL

When connected to a frame grabber that supports PoCL, the camera can be powered by the frame grabber through the CameraLink cable. The camera receives +12V DC power through pins 1 and 26, and returns to ground through pins 13 and 14. Refer to the Camera Link Connector Pinout section for a complete pinout description. If power is provided over PoCL, the camera automatically detects PoCL; no configuration is necessary.

To enable PoCL on the frame grabber, refer to your frame grabber's documentation.

Note: If power is supplied to both PoCL and the Hirose power connector, the camera will use the PoCL supply. However, DALSA recommends connecting only one power supply to the camera.

2.2.4 Output Signals, Camera Link Clocking Signals

These signals indicate when data is valid, allowing you to clock the data from the camera to your acquisition system. These signals are part of the Camera Link configuration and you should refer to the DALSA Camera Link Implementation Road Map, available at www.dalsa.com, for the standard location of these signals.

Clocking Signal	Indicates
LVAL (high)	Outputting valid line
DVAL (high)	Valid data
STROBE (rising edge)	Valid data
FVAL (high)	Outputting valid frame

- The camera internally digitizes to 10 bits and outputs the 8 most significant bits (MSB's) or all 10 bits depending on the camera's Camera Link operating mode.
- For a Camera Link reference and timing definitions refer to Appendix A on page 75.

2.2.5 Power Connector (Optional)

Hirose 6-pin Circular Male

Mating Part: HIROSE HR10A-7P-6S

Hirose Pin Description

Pin	Description	Pin	Description
1	12 to 15V	4	GND
2	12 to 15V	5	GND
3	12 to 15V	6	GND

The camera requires a single voltage input (12 to 15V). Ensure you measure a minimum of 12V at the camera power connector and not at the power supply. The voltage drop across power cables can be large enough to supply too low of a voltage to the camera for it to operate properly.

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

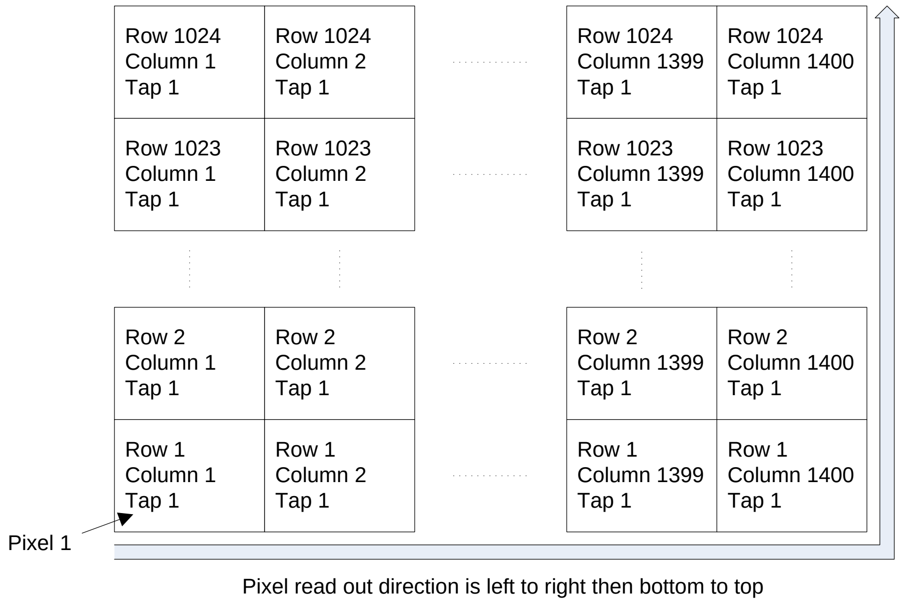
- Protect the camera with a fast-blow fuse between power supply and camera.
- Power surge limit at 500 mA.
- 12 V power supply. Nominal 0 to 3A load resulting in ~20 A/s current ramp rate
- Power supply current limit needs to be set at >2 A.
- Do not use the shield on a multi-conductor cable for ground.
- Keep leads as short as possible to reduce voltage drop. Long power supply leads may falsely indicate that the power supply is within the recommended voltage range even when the camera at the connector is actually being supplied with much less voltage.
- Use high-quality linear supplies to minimize noise.
- Use an isolated type power supply to prevent LVDS common mode range violation
- It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage the camera. Protect the camera with a fast-blow fuse between power supply and camera.
- Performance specifications are not guaranteed if your power supply does not meet these requirements

Note: If power is supplied to both PoCL and the Hirose power connector, the camera will use the PoCL supply. However, DALSA recommends connecting only one power supply to the camera..

Visit the www.dalsa.com Web site for a list of companies that make power supplies that meet the camera's requirements. The companies listed should not be considered the only choices.

2.3 Image Sensor and Pixel Readout

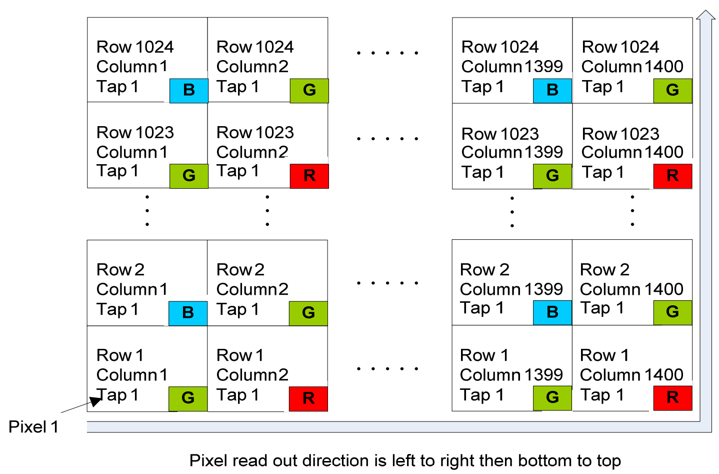
The camera uses DALSA's new DCR1410M, 1.4 mega pixel, 1400 x 1024 CMOS sensor.



Sensor Block Diagram

	Note: As viewed from the front of the camera without lens. The bottom of the camera has a ¼-20 tripod mount.

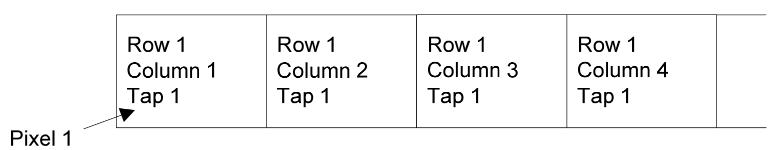
The color camera model has a Bayer filter applied to the CMOS sensor to allow for color separation. Each individual pixel is covered by either a red, green, or blue filter as shown in the figure below. The camera outputs raw color data--no color interpolation is performed. Full RGB images can be obtained by performing color interpolation on the frame grabber or host PC. The diagram below illustrates the case for the Falcon 1.4M100 camera. The Falcon 1M120 and Falcon VGA300 are identical to the Falcon 1.4M100, where Green is the filter on top of row 1, column 1, and the rest of the pixels are defined by the nature of the Bayer pattern.



Color Sensor Block Diagram

2.3.1 Camera Readout and Coordinates

The camera readout begins with pixel 1 and reads out successive pixels from left to right until the entire row is completed. This process is repeated with each successive row in the frame. Pixel coordinates are expressed as column and rows, where the first pixel's coordinates are 1, 1 and the last pixel's coordinates are 1400, 1024.



Falcon 1.4M Pixel Readout Detail

3

Serial Interface: How to Control the Camera

All camera features can be controlled through the serial interface, which is part of the Camera Link interface standard. The camera can also be used without the serial interface after it has been set up correctly. The serial interface uses a simple ASCII-based protocol and the camera does not require any custom software.

Functions available include:

- Controlling basic camera functions such as gain and sync signal source
- Data readout control
- Generating a test pattern for debugging

	Note: If you have installed the DALSA Sapera LT vision software package, you can use the CamExpert application to communicate with the camera. CamExpert provides a user-friendly graphical interface that allows you to directly adjust the camera parameters with typical window elements, such as drop-down lists, without using explicit serial commands.

Serial Protocol Defaults

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 9600 Kbps
- Camera does not echo characters

Command Format

When entering commands, remember that:

- A carriage return <*CR*> ends each command.
- The camera will answer each command with either <*CR*><*LF*> **`OK >`** or **`Error x: Error Message >`**. The **`>`** is always the last character sent by the camera.
- The camera accepts both upper and lower case commands.
- The following parameter conventions are used in the manual:

  i = integer value
  f = real number
  m = member of a set. Value must be entered exactly as displayed on help screen.
  s = string
  t = tap id
  x = pixel column number
  y = pixel row number

Example: to retrieve the current camera settings

`gcp` <CR>

3.1 Setting Baud Rate

The baud rate sets the speed in bps of the serial communication port.

Serial Command: sbr

Purpose:	Sets the speed in bps of the serial communication port.
Syntax:	• **`sbr`** ***m***
Syntax Elements:	• ***m*** Baud rate. Available baud rates are: **`9600`** (default), **`19200`**, **`57600`**, and **`115200`**.
Notes:	The **`rc`** (reset camera) command will *not* reset the camera to the power-on baud rate and will reboot using the last used baud rate.
Example:	• **`sbr 57600`**

3.2 Camera Serial Command Help Screen

For quick help, the camera can retrieve all available serial commands and parameters through the serial interface.

To view the help screen, use the serial command:

Syntax: • **h**

The help screen lists all commands available. Parameter ranges displayed are the ranges available under the current operating conditions. Note, that certain parameter settings can limit the available range of other parameters.

Example Help Screen

```
ccf  Correction calculate FPN
clm  Set camera link mode          m       2/3/ (8 bits/10 bits)
cpa  Correction PRNU algorithm     ii      2-2:256-1013
csn  Coefficient set number        i       0-1
css  Calibration sample size       m       32/64/128/256/512/1024/
epc  Enable pixel coefficients     ii      0-1:0-1
gcm  Get the camera model
gcp  Get the camera parameters
gcs  Get the camera serial number
gcv  Get the camera versions
get  Get command ...               s       Command name
gfc  Get FPN coefficient           xy      1-1400:1-1024
gh   Display the get help screen
gpc  Get PRNU coefficient          xy      1-1400:1-1024
gsf  Get sync. frequency           i       1-1
h    Display this help screen
lpc  Load pixel coefficients
rc   Reset the camera
rfs  Restore fact
rpc  Reset pixel coefficients
rus  Restore user settings
sbh  Set horizontal binning        i      1-2
sbr  Set the UART baud rate        m      9600/19200/57600/115200/
sbv  Set vertical binning          i      1-2
sdo  Set digital offset            ti     0-0:0-1023 DN
sem  Set exposure mode             m      2/4/6/9/10
set  Set exposure time             f      40-9719 (4000000 max)us
sfc  Set FPN coefficient           xyi    1-1400:1-1024:0-255
slc  Set LUT coefficient           ii     0-1023:0-1023
sle  Set LUT enable                i      0-1
smm  Set mirroring mode            i      0-1
sot  Set output throughput         m      80/160/ MHz
spc  Set PRNU coefficient          xyi    1-1400:1-1024:0-255
ssb  Set subtract background       ti     0-0:0-511
ssf  Set sync. frequency           f      0.1-101.9 Hz
ssg  Set system gain               ti     0-0:1024-8191
svm  Set video mode                i      0/4/5/6/7/8/
svm  Set Window Enable             ii     2-2;0-1
upd  Upload CBF file
```

```
vt   Verify temperature
vv   Verify voltage
wfc  Write FPN coefficients
wpc  Write PRNU coefficients
wse  Set window start end         iixyxy   0-0:1-1:0-1399:
                                           0-1023:1-1399:1-1023
wus  Write user settings
```

3.3 Retrieving Information About the Camera

To retrieve the camera model, use the command:

Syntax: • **gcm**

To retrieve the camera serial number, use the command:

Syntax: • **gcs**

To retrieve the camera firmware version, use the command:

Syntax: • **gcv**

3.3.1 Retrieving Camera Settings

To retrieve current camera settings, use the serial command:

Syntax: • **gcp**

To retrieve the value of a specific camera setting, use the command:

Purpose: Displays the value of the specified camera command.

Syntax: • **gcp *s***

Syntax Elements: • ***s***

string representing the command

Notes: "Get" supports any command that returns or specifies a setting. Action commands such as "wus" (write user settings) are not supported.

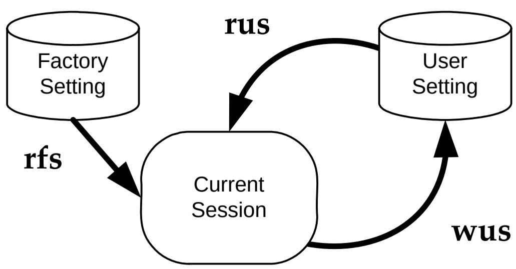
Example: • **get svm** – returns the video mode the camera is currently operating in

3.4 First Power Up Camera Settings

When the camera is powered up for the first time, it operates using the following factory settings:

- Flat field coefficients enabled (Factory FFC coefficients calibrated in exposure mode 2, 10 bit, 50 fps)
- Exposure mode 2
- 100 fps
- 9000 µs exposure time
- Camera Link mode 2 (Base configuration, 2 taps, 8 bits)
- 80Mpixels/s per tap
- Full resolution

3.5 Saving and Restoring Settings



Serial Commands for Saving and Restoring Settings

3.5.1 Factory Settings

You can restore the original factory settings at any time using the serial command `rfs`.

ℹ	**Note:** This command does not restore flat field coefficients. Refer to `lpc` command.

3.5.2 User Settings

You can save or restore your user settings to non-volatile memory using the following serial commands.

- To save all current user settings to non-volatile memory, use the command `wus`. The camera will automatically restore the saved user settings when powered up.
- To restore the last saved user settings, use the command `rus`.

Note: On power-up the camera will restore the FFC coefficients from the set indicated by the coefficient set number (`csn`); either 0 (factory calibrated set) or 1 (user calibrated set).

Current Session Settings

These are the current operating settings of your camera. These settings are stored in the camera's volatile memory and will not be restored once you power down your camera or issue a reset camera command (**`rc`**). To save these settings for reuse at power up, use the command **`wus`**.

3.6 Camera Output Format

3.6.1 How to Configure Camera Output

The Falcon cameras offer great flexibility when configuring your camera output. Using the **`clm`** serial command, you determine the camera's Camera Link configuration, number of output taps, and bit depth. Using the **`sot`** command, you determine the camera's output (pixel) rate. These two commands work together to determine your final camera output configuration.

Falcon Data Readout Configurations

Mode	Camera Link Configuration	Camera Link Taps	Bit Depth	Pixel Rate
2 (clm 2)	Base	2 Camera Link taps	8	40 MHz strobe (**sot 80**) 80 MHz strobe (**sot 160**)
3 (clm 3)	Base	2 Camera Link taps	10	40 MHz strobe (**sot 80**) 80 MHz strobe (**sot 160**)

Note: The Falcon 1M120 and Falcon VGA300 cameras only support an 80MHz output pixel rate (sot 160) and Camera Link configuration mode 2 (clm 2 (8 bits)).

Serial Command: clm

Purpose	Sets the camera's Camera Link configuration, number of Camera Link taps and data bit depth.
Syntax:	• **`clm`** ***m***
Syntax Elements:	• ***m*** Output mode to use: **2**: Base configuration, 2 taps, 8 bit output **3**: Base configuration, 2 taps, 10 bit output
Notes:	▪ To retrieve the current Camera Link mode, use the command `gcp` ▪ For details on line times and frame readout times when using a window of interest, refer to following table.
Example:	• **`clm 3`**

3.6.2 Setting the Camera's Pixel Rate

Serial Command: sot

Purpose:	Sets the camera's pixel rate.
Syntax:	• **`sot`** ***m***
Syntax Elements:	• ***m*** **80**: 40 MHz pixel rate with a total throughput of 80 MHz **160**: 80 MHz pixel rate with a total throughput of 160 MHz
Notes:	▪ To retrieve the current pixel rate, use the command `gcp` or `get sot`. ▪ The Falcon 1M120 and Falcon VGA300 cameras only support an 80MHz output pixel rate (sot 160).
Example:	• **`sot 80`**

3.7 Setting Exposure Mode, Frame Rate and Exposure Time

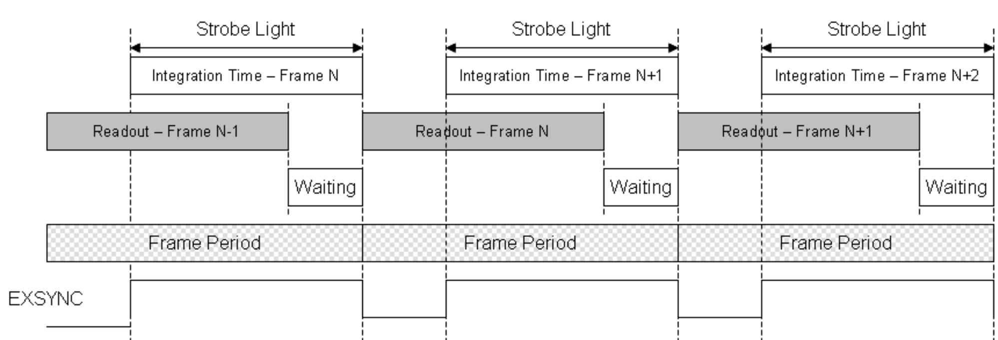
3.7.1 Non-Concurrent vs. Concurrent Modes of Operation

One of the main benefits of DALSA's global shutter CMOS devices is that you have the choice to operate the camera where integration and readout are concurrent (that is, they overlap for some duration) or where integration and readout are not concurrent (that is, they occur serially). Integration is defined as the time period that the camera can be exposed to light and is often referred to as exposure time. Readout refers to the time it takes to read out every pixel from the camera. For a 100 fps camera, such as the Falcon 1.4M100, the readout period is around 10.0ms.

Thus, a global shutter CMOS device, as found in the 1.4M100, is capable of running at 100fps with exposure times up to 10ms. Beyond 10ms, the exposure time exceeds the readout time and the frame rate drops. With rolling shutter CMOS devices only non-concurrent modes are possible and the integration time immediately impacts the frame rate, thus comparable 1.4 megapixel cameras with a 10ms exposure time would only run at 50fps.

Concurrent mode is when the camera is integrating the current frame (Frame 1) and at the same time is reading out the prior frame (Frame 0). By performing integration and readout in parallel, the Falcon 1.4M100 camera is capable of reaching 100fps even with exposure times up to 10ms. A timing diagram helps to explain this mode of operation.

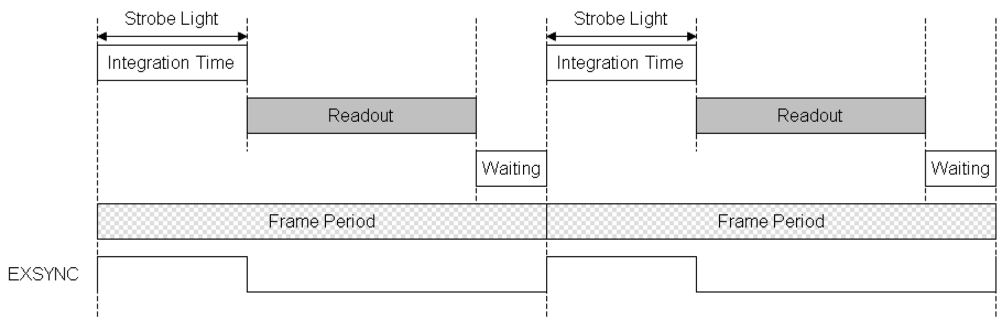
Concurrent Mode Timing Diagram



In concurrent mode, a low-to-high transition in the EXSYNC signal starts the integration time, and a high-to-low transition in the EXSYNC signal starts the readout of image data. As your frame period approaches the readout period, by reducing the Waiting time, the Falcon 1.4M100 camera approaches its maximum frame rate of 100fps.

In non-concurrent mode the integration and readout period do not overlap

Non-concurrent Mode Timing Diagram



In non-concurrent mode, a low-to-high transition in the EXSYNC signal starts the integration time, and a high-to-low transition in the EXSYNC signal starts the readout of image data. This is the same as in concurrent mode. The difference between these two modes is that you do not perform your next low-to-high transition of EXSYNC until readout has completed. The Waiting period can be reduced to 0 seconds by starting the low-to-high transition immediately after readout is complete. The readout time is a fixed amount of time that is dependant upon the mode of operation of the camera, but is typically around 10.0ms.

3.7.2 Setting the Exposure Mode and Time

You have a choice of operating in one of the following exposure modes.

Mode	EXSYNC	Programmable Frame Rate	Programmable Exposure Time	Description	Concurrent/ non-concurrent operation
2	Internal	Yes	Yes, minimum 40µs	Internal frame rate and exposure time.	Both
4	External	No	No, minimum 40µs	Smart EXSYNC. High time is the exposure time.	Both
6	External	No	Yes, minimum 40µs	Falling EXSYNC initiates integration. Exposure time is programmed into the camera.	Both
9	External	No	No, minimum 10µs	Smart EXSYNC. High time is the exposure time.	Non-concurrent only
10	External	No	Yes, minimum 10µs	Falling EXSYNC initiates integration. Exposure time is programmed into the camera.	Non-concurrent only

Non-concurrent mode occurs when integration and readout are performed serially. In concurrent mode integration and readout can overlap.

To set the exposure time, the camera must be operating in exposure mode 2, 6 or 10. If you enter an exposure time outside of a valid range, the input will be clipped to the min or max.

If you enter an exposure time which overlaps with the frame readout, the exposure time will automatically adjust to integral units of exposure time increments. The camera sends a warning when this occurs.

To select how you want the camera's frame rate to be generated:

- You must first set the camera's exposure mode.
- Next, depending on the specified exposure mode, set the frame rate and set the exposure time.

Exposure Mode Serial Command: sem

Purpose:	Sets the camera's exposure mode allowing you to control your EXSYNC signal, exposure time, and frame rate generation.
Syntax:	• **`sem`** ***`m`***
Syntax Elements:	• ***`m`*** Exposure mode to use. Factory setting is 2. Possible values are 2, 4, 6, 9, 10. For more information, refer to section 3.7.3 Exposure Modes in Detail.
Notes:	To obtain the current value of the exposure mode, use the command `gcp`.
Related Commands:	• **<u>ssf</u>, <u>set</u>**
Example:	• **`sem 4`**

Exposure Time Serial Command: set

Purpose:	Sets the camera's exposure time in µs.
Syntax:	• **`set`** ***`f`***
Syntax Elements:	• ***`f`*** Floating point number in µs. Allowable range is 40-4000000 µs.
Notes:	Camera must be operating in exposure mode 2, 6 or 10. To retrieve the current exposure time, use the command `get`

`set`.

If you enter an exposure time outside of a valid range, the input will be clipped to the min or max. Refer to the help screen (**h** command) for the valid range.

Changing the exposure time will automatically adjust the frame rate if necessary. The camera sends a warning when this occurs.

Related Commands:	• **sem**, **ssf**, **eec**, **clm**
Example:	• **set 5500**

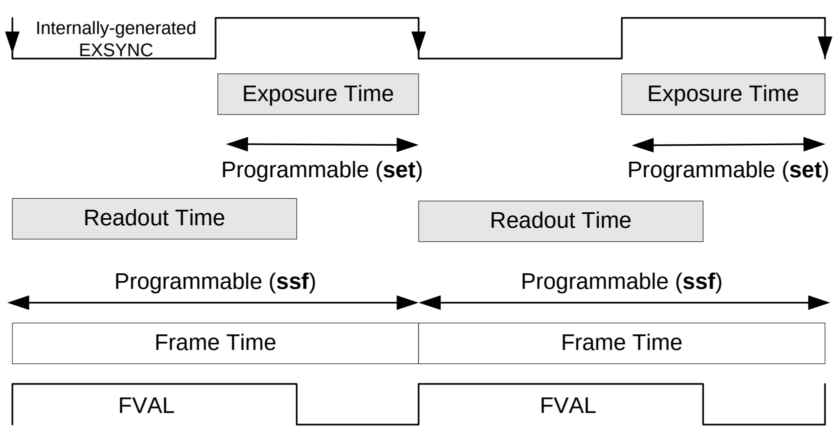
Refer to section 3.6.1 How to Configure Camera Output on page 34 for more information on the **clm** and **sot** (sets pixel rate) commands.

3.7.3 Exposure Modes in Detail

Mode 2: Internally Programmable Frame Rate and Exposure Time (Default)

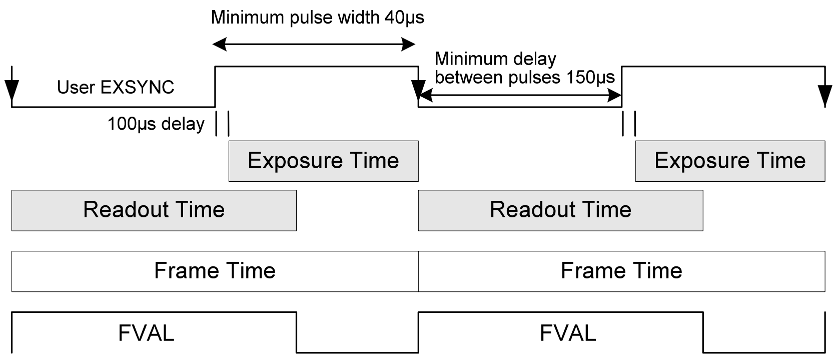
The parameter being programmed (that is, frame rate or exposure time) will be the driving factor so that when setting the frame rate, exposure time will decrease, if necessary, to accommodate the new frame rate. In reverse, the frame rate is decreased, if necessary, when the exposure time entered is greater than the frame period.

Note: The camera will not set the frame period shorter than the readout period.

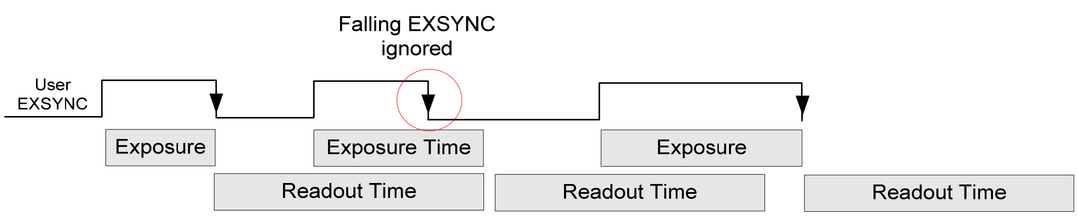


Mode 4: Smart EXSYNC, External Frame Rate and Exposure Time

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. There is a 100µs delay between the trigger and the start of the exposure. The minimum delay between consecutive exposure times is 150µs. The minimum pulse width (exposure time) is 40µs.

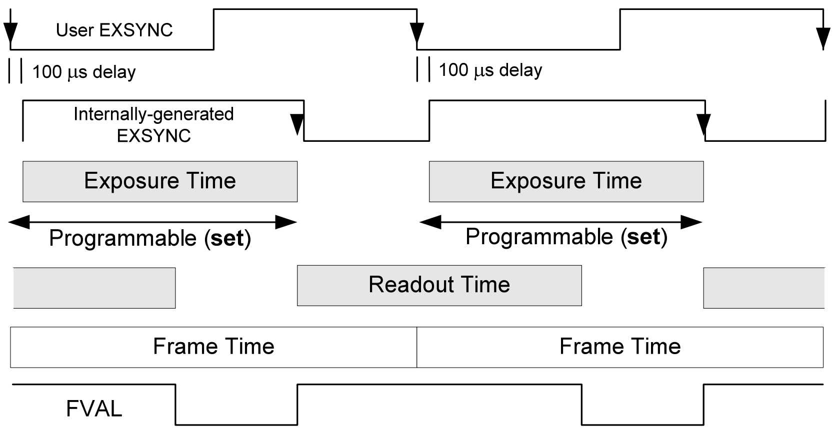


Note: The exposure and readout time can overlap. However, the camera will ignore the falling edge of EXSYNC if the camera is still reading out the prior frame, and extends the exposure time until the end of the previous readout.



Mode 6: External Frame Rate, Fixed Exposure Time

In this mode, the frame rate is triggered externally with the falling edge of EXSYNC generating the rising edge of a programmable exposure time. There is a 100µs delay between the trigger and the start of the exposure. The minimum trigger (EXSYNC) pulse width is 1µs. The minimum exposure time is 40µs.



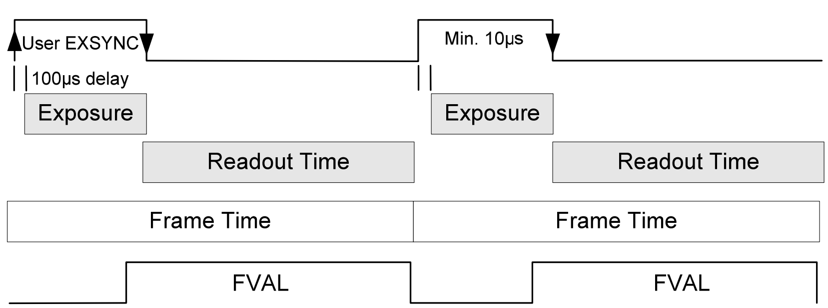
This mode supports both concurrent and non-concurrent operation. If the exposure time is greater than the readout time, it will accept a trigger 1µs after the previous exposure is finished.

If the exposure time is less than the readout time, then the minimum delay between consecutive exposure times is 150µs. Note that the exposure and readout time can overlap. However, if the camera is still reading out the prior frame, and a trigger is asserted, it will extend the exposure time until an EXSYNC is received after readout.

Mode 9: Sequential Smart EXSYNC, External Frame Rate and Exposure Time

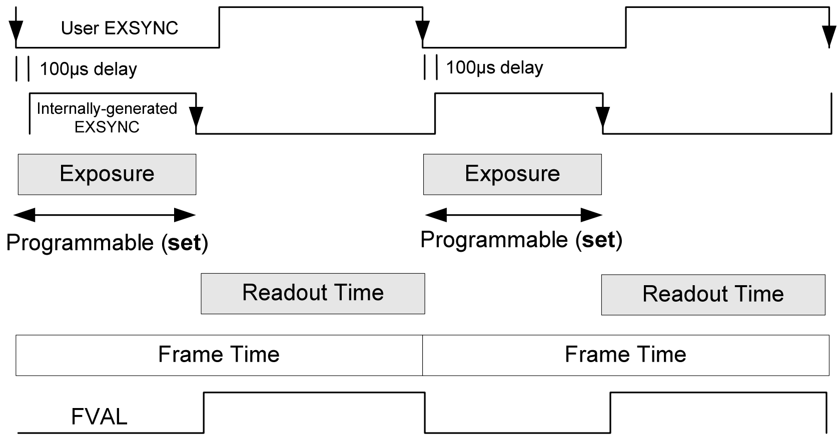
In this mode, EXSYNC sets both the frame period and the exposure time. The rising edge of EXSYNC marks the beginning of the exposure and the falling edge initiates readout. There is a 100µs delay between the trigger and the start of the exposure. The minimum exposure time is 10µs. The minimum delay between the end of readout and the next EXSYNC is 1µs.

Note: The exposure and readout time cannot overlap. In addition, the camera will ignore the falling edge of EXSYNC if the prior frame's integration or readout is not complete.



Mode 10: External Frame Rate, Fixed Exposure Time

In this mode, the frame rate is triggered externally using the EXSYNC falling edge. There is a 100µs delay between the trigger and the start of the exposure. The minimum exposure time is 10µs. The minimum delay between the readout and the next EXSYNC is 1µs. Note, the exposure and readout time cannot overlap.



3.7.4 Setting the Frame Rate

To set the camera frame rate, the camera must be operating in exposure mode 2. Changing the frame rate will automatically adjust the exposure time if necessary. The camera sends a warning when this occurs.

Refer to section 3.6.2 Setting the Camera's Pixel Rate on page 35 for more information on how to set the camera's pixel rate.

The allowable range of frame rates is dependent on the current Camera Link mode and window size. Refer to section 3.6.1 How to Configure Camera Output on page 34 for more information on Camera Link modes and section 3.8 Setting a Vertical Window of Interest on page 44 for more information on setting a window size.

Serial Command: ssf

Purpose:	Sets the camera's frame rate in Hz.
Syntax:	• **`ssf`** ***f***
Syntax Elements:	• ***f*** Set the frame rate in Hz in a range from **`0.1-101.9`** (full frame, 80 MHz pixel rate) or **`0.1-51.1`** (full frame, 40 MHz pixel rate). Range increases when using a smaller window of interest.
Related Commands:	• **sem**, **set**
Example:	• **`ssf 25.0`**

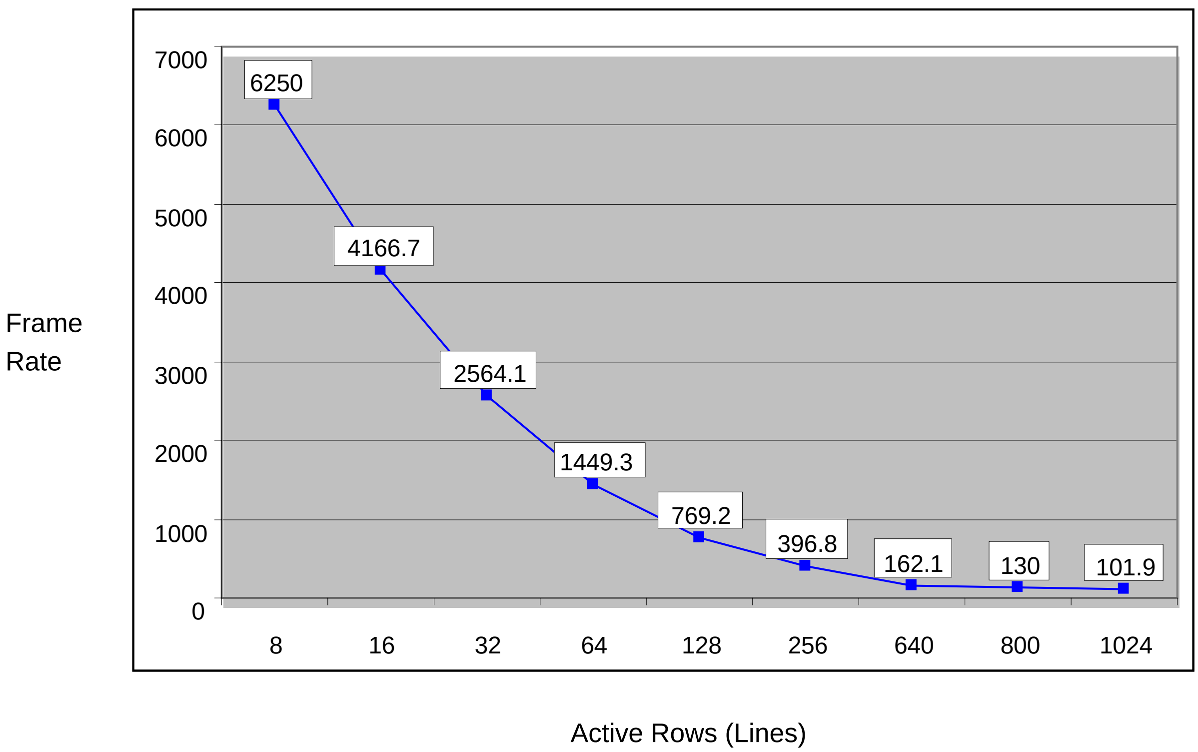
3.8 Setting a Vertical Window of Interest

A window of interest is a subset of a full frame image that is desired as output from the camera. Because the sensor is outputting only the designated window of interest, the benefit is an increase in frame rate and a reduction in data volume. You can set both the horizontal and vertical window, however only decreasing the vertical window increases the frame rate.

3.8.1 Frame Rate vs. Active Lines

The following charts describes the frame rate vs. active rows achieved using an 80 MHz pixel clock and an exposure time of 40 µs.

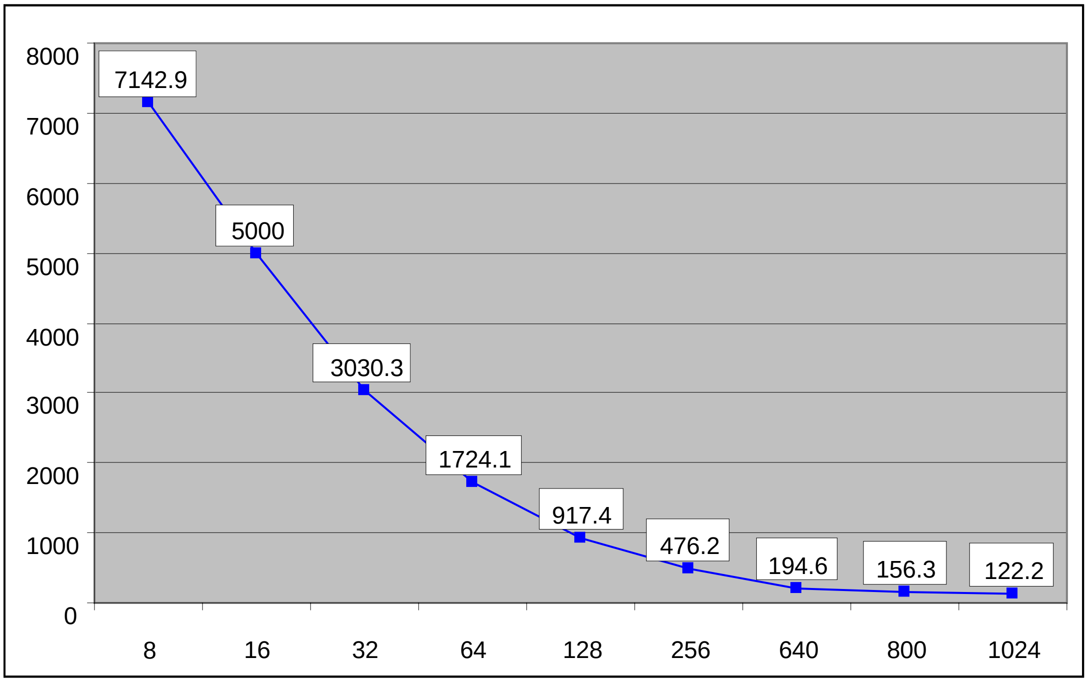
FA-2x-01M1H-00-R



Note: 8 is the smallest number of lines supported by the FA-2x-01M1H-00-R cameras.

FA-2x-1M120-00-R

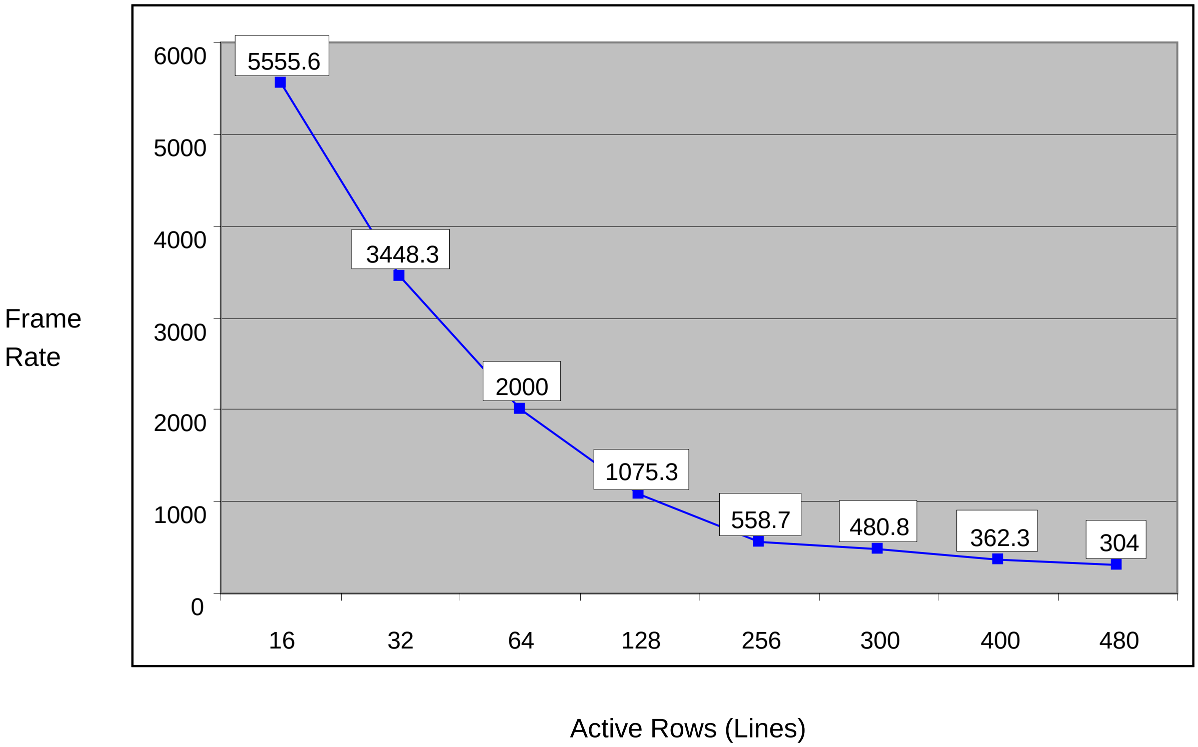
Frame Rate



Active Rows (Lines)

	Note: 8 is the smallest number of lines supported by the FA-2x-1M120-00-R cameras.

FA-2x-3HK3H-00-R



ⓘ	**Note:** 16 is the smallest number of lines supported by the FA-2x-3HK3H-00-R camera.

To calculate an approximate frame rate for a given number of lines, you can use the following equations.

Camera Model	Frame Rate vs Active Lines equation
FA-2x-01M1H-00-R	Frame rate = 47162 x (# active lines)$^{-0.8717}$
FA-2x-1M120-00-R	Frame rate = 54440. x (# active lines)$^{-0.8653}$
FA-2x-3HK3H-00-R	Frame rate = 67731 x (# active lines)$^{-0.8671}$

ⓘ	**Note:** In general, these equations provide a frame rate that is slightly slower than the actual frame rate (for less than 32 lines, the approximation may be higher), but should be sufficient to determine if the camera is fast enough for your application.

Serial Command: wse

To set a window of interest:

- Set the window coordinates, using the window start end command:
  `wse 0 1 x y x y`.

The maximum frame rate increases as you decrease the sequence size.

Purpose:	Sets a window of interest.
Syntax:	• **`wse q i x1 y1 x2 y2`**
Syntax Elements:	• **`q`** Window sequence id to use. In this camera, the sequence id is always 0.
	• ***`i`*** Window to set. You can only set one window, so this is always **`1`**.
	• ***`x1`*** Window horizontal start corner pixel number, in a range from **0** – **1399** and must belong to the following set: 1, 5, 9 , ... 1399.
	• ***`y1`*** Window vertical start corner pixel number, in a range from **`0-1023`**.
	• ***`x2`*** Window horizontal end corner pixel number, in a range from **`15-1399`** must belong to the following set: 15, 19 , ... 1399.. The minimum window width is 16 pixels.
	• ***`y2`*** Window vertical end pixel number in range from **`1-1023`**.
Example:	• **`wse 0 1 1 13 1399 1023`**

3.9 Flat Field Correction

This camera has the ability to calculate correction coefficients in order to remove non-uniformity in the image. This video correction operates on a pixel-by-pixel basis and implements a two point correction for each pixel. This correction can reduce or eliminate image distortion caused by the following factors:

- Fixed Pattern Noise (FPN)
- Photo Response Non Uniformity (PRNU)
- Lens and light source non-uniformity

The camera is shipped with pre-set factory correction coefficients in both the factory and user sets, such that in most applications there is no need to perform flat field correction. Note that factory calibration is performed with an exposure time of 9ms. However, if you are using a different exposure time and your application is sensitive to small pixel variations, it is recommended that you perform flat field correction at your typical exposure time.

Correction is implemented such that for each pixel:

$$V_{output} = [(V_{input} - FPN(\text{ pixel }) - \text{digital offset}) * PRNU(\text{pixel}) – \text{Background Subtract}] \times \text{System Gain}$$

where	V_{output}	=	digital output pixel value
	V_{input}	=	digital input pixel value from the sensor
	PRNU(pixel)	=	PRNU correction coefficient for this pixel
	FPN(pixel)	=	FPN correction coefficient for this pixel
	Background Subtract	=	background subtract value
	System Gain	=	digital gain value

The algorithm is performed in two steps. The fixed offset (FPN) is determined first by performing a calculation 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.

The white light (PRNU) calibration is performed next to determine the multiplication factors required to bring each pixel to the required value (target) for flat, white output. Video output is set slightly above the brightest pixel (depending on offset subtracted).

It is important to do the FPN correction first. Results of the FPN correction are used in the PRNU procedure. We recommend that you repeat the correction when a temperature change greater than 10°C occurs or if you change the frame rate or integration time.

PRNU correction requires 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. Alternatively, if you slightly defocus the camera you can effectively remove any grain and still achieve good PRNU correction.

	Note: If your illumination or white reference does not extend the full field of view of the camera, the camera will send a warning.

For best results, ensure that:

1. 60 Hz ambient light flicker is sufficiently low not to affect camera performance and calibration results.
2. The brightest pixel should be slightly below the target output. If the target is too close, then some pixels may not be able to reach their full swing (1023 DN dynamic range) due to the correction applied by the camera.
3. The camera will give a warning when 1% of pixels in the frame are at the maximum coefficient value. When a pixel is at the maximum coefficient value, it means the pixel could not be properly corrected. When 6.25% of pixels from a single row within the region of interest are clipped, flat field correction results may be inaccurate.
4. Correction results are valid only for the current analog offset values.

Flat Field Calibration Example Procedure

The following is a flat field calibration example, using serial commands:

1. The camera is placed in **`sem 2`**.
2. Settings such as frame rate, exposure time, and so forth, are set as close as possible to actual operating conditions. Set the digital gain to 1 x gain (**`ssg 0 1024`**) and background subtract to 0 (**`ssb 0 0`**) as these are the defaults during FFC calibration. In addition, ensure that you are in non-concurrent operation. In non-concurrent mode, readout and integration do not overlap, thus eliminating some residual artifacts associated with concurrent operation.
3. Place the camera in the dark and send the **`ccf`** command. This performs the FPN correction and automatically saves the FPN coefficients to non-volatile memory.
4. Set **`epc 1 0`**, which enables the FPN correction and verify the signal output is close to 0 DN. Leave **`epc 1 0`** for the next step since the **`cpa`** target assumes there is no FPN.
5. Illuminate the sensor, such that with **`epc 1 0`**, it reaches 50%-70% saturation.
6. Send **`cpa 2 T`** where T is typically 1.3 x the average output level. This is important since if the target it too low (< 1.1 x), then some pixels may not be able to reach full swing (1023 DN) due to corrections applied by the camera.
7. If satisfied by the results write the FPN coefficients and PRNU coefficients to memory (**`wfc`** and **`wpc`**).

How can one match gain and offset values on multiple cameras?

1. One way is of course to use flat field correction. All cameras would be set up under the same conditions including lighting and then calibrated with **`ccf`** and **`cpa`**. This can be time-consuming and complicated (especially the white target). Another way is to use analog offset and system gain (digital gain):
2. Starting from factory settings (**`sao 0  0`**, **`ssg 0  1024`**, **`epc 1  1`**), take note what the highest dark offset is among the set of cameras. If the highest dark offset is higher than about 16 DN (10 bit) you might want to consider recalibrating the FPN correction (**`ccf`**). Large differences in dark offset between the factory and user are typically caused by differences in temperature from factory to user. Large dark offsets will result in PRNU-correction-induced FPN and should therefore be avoided.
3. Increase the offset (camera in dark) on all cameras (**`sao`** command) until they are the same and reach at least 4 DN (10 bit).
4. Illuminate to about 80% saturation (820 DN, 10 bit) and note the highest signal level among the set of cameras.
5. Increase the digital gain (**`ssg`**) on the cameras until they all reach the same output level of the camera with the highest output found in step 3.
6. Place camera in the dark and repeat steps 2 to 4 until both dark offset and 80% saturation signal levels are equal on all cameras.
7. If satisfied by the results write the FPN coefficients and PRNU coefficients to memory (**`wfc`** and **`wpc`**).

Important Note on Blemishes: When flat field correction is performed, window cleanliness is paramount. The following figure 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 (sensor). 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 incident light remains unchanged then FFC works well.

However, when the angle of incidence changes significantly (for example, 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.

3.9.1 Flat Field Correction for Color Camera Models

Flat field correction can be used in the color cameras to both correct FPN and PRNU, as on mono cameras. However, we recommend that the user use the factory calibrated FFC coefficients for PRNU and FPN correction, and the digital color gain (`sdc` command) to perform white balancing.

For example, when a monochrome sensor images a uniform white target illuminated by a halogen light source, each pixel outputs approximately the same DN value. When the same target is imaged by a color sensor, the red pixels may produce more signal than the green pixels, which in turn produce more than the blue pixels.

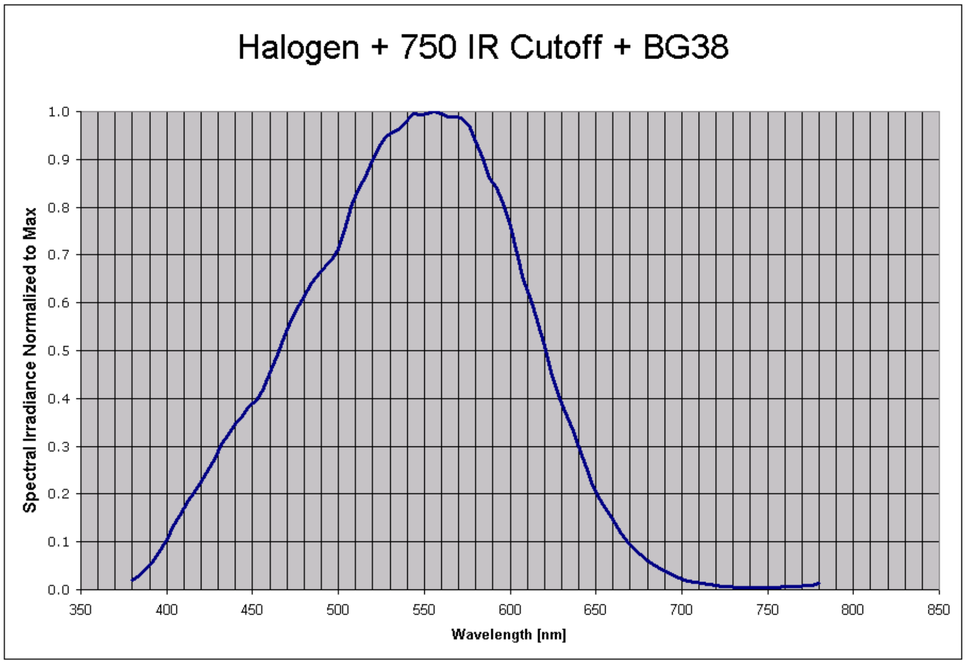
White balancing involves increasing the gain of the blue and green pixels such that they match the values from the red. When all color channels are matched the image will look white when interpolated by the frame grabber or host PC.

Here is an example of a typical FFC calibration operation using a halogen light source:

The camera is placed in **`sem 2`** (no other exposure mode will allow FFC calibration).

1. Settings such as frame rate, exposure time, etc., are set as close as possible to the actual operating conditions. Set digital gain to x1 (**`ssg 0 1024`**) and background subtract to 0 **(`ssb 0 0`**), as these are the defaults during FFC calibration.
2. Place the camera in the dark and send the **`ccf`** command, this function performs the FPN correction and automatically saves the FPN coefficients to non-volatile memory.
3. Set **`epc 1 0`** to enable the FPN correction and verify that the signal output is close to 0 DN. Leave **`epc 1 0`** for the next step.
4. Illuminate the sensor, such that with **`epc 1 0`**, the red channel (i.e. red pixels) reaches 50-70 % saturation. Here we assume that the red channel is the brightest and the blue channel the weakest.
5. Use **`sdc 1/2/3/4`** commands to gain up each individual color in order to bring it to the same brightness level as red. Enable color gains using **`ecg 1`**. Verify white balance and iterate the same step if required.
6. Send **`cpa 2 T`** where T is typically 1.3x the average red channel output level. This step is important because if the target is too low (< 1.1x), then some pixels may not be able to reach full swing (1023 DN) due to other corrections applied by the camera. Also ensure that the blue channel is not too dim.

In the factory, for color cameras only, we use a halogen light followed by a BG38 to act as a light source. The effective color temperature of this light is about 5200 K and its spectral distribution is shown in the figure below.



Spectral distribution of light source used during calibration of color cameras only. This corresponds roughly to a 5200 K color temperature.

3.9.2 Selecting Factory or User Coefficients

Serial Command: csn

Purpose: Selects the coefficient set to use. The camera ships with a factory calibrated set of FPN and PRNU coefficients. The factory coefficients cannot be erased or modified.

Syntax:

- **`csn`** ***`i`***

Syntax Elements:

- ***`i`***

  Coefficient set to use.

  `0` = Factory calibrated set of FPN and PRNU coefficients. These coefficients cannot be erased or modified.

  `1` = User calibrated set of FPN and PRNU coefficients. These coefficients **can** be deleted or modified.

Notes: The camera ships with the factory calibrated FPN and PRNU coefficients saved to both set 0 and set 1. When you first boot up the camera, the camera operates using set 1 (**`csn 1`**) enabled.

To retrieve the current coefficient set number, use **get csn**.

Example:

- **`csn 0`**

3.9.3 Enabling Pixel Coefficients

Serial Command: epc

Purpose: The camera ships with the FPN and PRNU coefficients enabled, but you can enable and disable FPN and PRNU coefficients whenever necessary.

Syntax:

- **`epc`** ***`i1 i2`***

Syntax Elements:

- ***`i1`***

  FPN coefficients.

  `0` = FPN coefficients disabled

  `1` = FPN coefficients enabled

- ***`i2`***

PRNU coefficients.

0 = PRNU coefficients disabled

1 = PRNU coefficients enabled

Notes: The coefficient set that you are enabling or disabling is determined by the **csn** value. Refer to the previous section for an explanation of the **csn** command.

Example:
- **epc 1 1**

3.9.4 Selecting the Calibration Sample Size

Serial Command: css

Setting the Number of Frames to Sample

Purpose: Sets the number of frames to sample when performing pixel coefficient calculations. Higher values cause calibration to take longer but provide the most accurate results.

Syntax:
- **css *i***

Syntax Elements:
- ***i***

  Number of frames to sample. Allowable values are **32** (default), **64**, **128** , **256**, **512**, or **1024**.

Notes: To return the current setting, use the **gcp** command.

Example:
- **css 1024**

3.9.5 Performing FPN Calibration

Serial Commands: ccf , sfc

Calibrating All Camera Pixels

Purpose: Performs FPN calibration and eliminates FPN noise by subtracting away individual pixel dark current.

Syntax:
- **ccf**

Notes: Before performing this command, stop all light from entering the camera. (Tip: cover lens with a lens cap.)

The goal is to subtract all non-uniformities and offsets to obtain a 0 DN output in dark. Analog offset should be set to 0 since it gets subtracted out during FPN calibration.

Set the digital gain to 1 x gain (**`ssg 0 4096`**) since during calibration it is forced to 1 x gain.

Perform FPN correction before PRNU correction.

The **`ccf`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can perform FPN calibration. An error message is returned if you attempt to perform FPN calibration when using **`csn 0`**.

If you are operating the camera in test pattern mode (**`svm 1-8`**), you must turn off exposure correction (**`eec 0`**) prior to running the **`ccf`** command.

The LED flashes green while coefficients are computed. After completion, the LED should return to solid green, unless an error occurred during calibration.

Example:

- **`ccf`**

FPN correction can only be performed in exposure modes **`sem 2, sem 9`** and **`sem 10`**.

Calibrating Individual Pixels

Purpose: Sets an individual pixel's FPN coefficient.

Syntax

- **`sfc x y i`**

Syntax Elements:

- ***`x`***

The pixel column number from **`1`** to **`1400`**.

- ***`y`***

The pixel row number from **`1`** to **`1024`**.

- ***`i`***

Coefficient value in a range from **`0`** to **`255`**.

Notes: The **`sfc`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can perform FPN calibration. An error message is returned if you attempt to perform FPN calibration when using **`csn 0`**.

Example:

- **`sfc 10 50`**

3.9.6 Performing PRNU Calibration

Serial Commands: cpa, spc

Purpose: Performs PRNU calibration to a targeted, user defined value and eliminates the difference in responsivity between the most and least sensitive pixel creating a uniform response to light. To use this command, you must provide a calibration target.

Executing these algorithms causes the **`ssb`** command to be set to 0 (no background subtraction) and the **`ssg`** command to 4096 (unity digital gain). The pixel coefficients are disabled (**`epc 0 0`**) during the algorithm execution but returned to the state they were prior to command execution.

Syntax:

- **`cpa`** ***`i1 i2`***

Syntax Elements:

- ***`i1`***

  PRNU calibration algorithm to use:

  2 = Calculates the PRNU coefficients using the entered target value as shown below:

$$\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - (\text{FPN}_i + \textbf{sdo} \text{ value})}$$

  The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. It is important that the target value (set with the next parameter) is set to be at least equal to the highest pixel across all cameras so that all pixels can reach the highest pixel value during calibration.

- ***`i2`***

  Peak target value in a range from **256 to 1013** DN. The target value must be greater than the current peak output value.

Notes: PRNU correction can only be performed in exposure mode **sem 2**, **sem 9** or **sem 10**.

Calibrate FPN before calibrating PRNU. If you are not performing FPN calibration then issue the **`rpc`** (reset pixel coefficients) command and set the **`sdo`** (set digital offset) value so that the output is near zero under dark.

The **`cpa`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can perform PRNU calibration. An error message is returned if you attempt to perform PRNU calibration when using **`csn 0`**.

Example:

- **`cpa 2 700`**

Calibrating Individual Pixels

Purpose: Sets an individual pixel's PRNU coefficient.

Syntax

- **`spc`** ***`x y i`***

Syntax Elements:

- ***`x`***

The pixel column number from **`1`** to **`1400`**.

- ***`y`***

The pixel row number from **`1`** to **`1024`**.

- ***`i`***

Coefficient value in a range from **`0`** to **`255`** where

PRNU coeff = $1 + \left(\frac{i}{256}\right)$

Notes: The **`spc`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can perform PRNU calibration. An error message is returned if you attempt to perform PRNU calibration when using **`csn 0`**. To return the current **`csn`** number, send the command **`get csn`**.

Example:

- **`spc 10 50 200`**

3.9.7 Saving, Loading and Resetting Coefficients

Serial Commands: wpc, wfc, lpc, rpc

Saving the Current PRNU Coefficients

Purpose:	Saves the current PRNU coefficients to non-volatile memory.
Syntax:	• **`wpc`**
Notes:	The **`wpc`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can perform PRNU calibration. An error message is returned if you attempt to perform PRNU calibration when using **`csn 0`**. To return the current **`csn`** number, send the command **`get csn`**.
Example:	• **`wpc`**

Saving the Current FPN Coefficients

Purpose:	Saves the current FPN coefficients to non-volatile memory.
Syntax:	• **`wfc`**
Notes:	The **`wfc`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can save FPN coefficients. An error message is returned if you attempt to save FPN coefficients when using **`csn 0`**. To return the current **`csn`** number, send the command **`get csn`**.
Example:	• **`wfc`**

Loading Pixel Coefficients

Purpose:	Loads the last saved user coefficients or original factory coefficients from non-volatile memory.
Syntax:	• **`lpc`**
Notes:	The coefficient set that you are loading is determined by the **`csn`** value. Refer to the section, Selecting Factory or User Settings, for an explanation of the **`csn`** command. To return the current **`csn`** number, send the command **`get csn`**.
Example:	• **`lpc`**

Resetting the Current Pixel Coefficients

Purpose: Resets the current user coefficients to zero. This command also resets saved coefficients to zero, resulting in raw video without correction being output from the camera.

Syntax:

- **`rpc`**

Notes: The **`rpc`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can reset pixel coefficients. An error message is returned if you attempt to reset pixel coefficients when using **`csn 0`**. To return the current **`csn`** number, send the command **`get csn`**.

3.10 Gain Adjustments

3.10.1 Factory Calibrated Analog Gains

The camera has a factory calibrated analog gain setting. Adjustment of analog gain is not available to the user, however, digital gain is available using the set system gain serial command, **`ssg`**.

3.10.2 Setting Digital System Gain for Monochrome Cameras

Serial Command: ssg

Purpose: Increases the overall gain of the camera.

Improves signal output swing after a background subtract. When subtracting a digital value from the digital video signal, using the **`ssb`** command, the output can no longer reach its maximum. Use this command to correct for this where:

$$\text{ssg value} = \frac{\text{max output value}}{\text{max output value - ssb value}}$$

Syntax:

- **`ssg`** ***`t i`***

Syntax Elements:

- ***`t`***

Sensor tap selection. This is always **0** for all taps.

- ***i***

Gain setting. The gain ranges are **1024** to **8191**. The digital video values are multiplied by this value where:

$$\text{Digital Gain} = \frac{i}{1024}$$

For example, to set a digital gain of 2.0, ***i*** equals 2048.

Notes: Entering a large value gain will cause the camera to digitally saturate the output image

Example:

- **`ssg 0 1024`**

3.10.3 Enabling Color Gain

Purpose: Use the enable color gain command in order to use white balance feature in color cameras. Disabling the color gain feature will not change the individual color gains, it will simply by-pass the color gain stage.

Syntax: **ecg *i***

Syntax Elements: ***i***

The allowable range is **0** or **1**. 0 = disable, 1 = enable.

Example: **`ecg 1`**

3.10.4 Setting Digital Gain for Color Cameras

Purpose: Use the set digital color gain command in order to white balance color cameras.

Syntax: **sdc *t i***

Syntax Elements: ***t***

Color selection. The allowable range is **1** to **4**. 1 = Red, 2 = Green (Red), 3 = Green (Blue), and 4 = Blue.

i

Gain setting. The gain ranges are **1024** to **8191**. The digital video values are multiplied by this value where:

$$\text{Digital Gain} = \frac{i}{1024}$$

For example, to set a digital gain of 2.0, ***i*** equals 2048.

Notes: Entering a large value gain will cause the camera to digitally saturate the output image

Example: **`sdc 1 1024`**

3.10.5 Subtracting Background

Serial Command: ssb

Purpose: Use the background subtract command if you want to improve your image in a low contrast scene. This command is useful for systems that process 8 bit data but want to take advantage of the camera's 10 bit digital processing chain. You should try to make your darkest pixel in the scene equal to zero.

Syntax:

- **`ssb`** ***t i***

Syntax Elements:

- ***t***

  Color selection. The allowable range is **1** to **4**, or **0** for all taps. 1 = Red, 2 = Green (Red), 3 = Green (Blue), 4 = Blue

- ***i***

  Subtracted value in a range in DN from **0** to **511**.

Notes:

- When subtracting a digital value from the digital video signal the output can no longer reach its maximum. Use the **ssg** command to correct for this where:

$$\text{ssg value} = \frac{\text{max output value}}{\text{max output value - ssb value}}$$

-
- See the following section for details on the **ssg** command.
- Entering a large value background will cause the camera to digitally clip the output image.
- On a color camera the `ssb` command can be used to perform offset adjustment on each color. This may be required as the gain on each color is typically different.
- On the monochrome model, use the 'all tap' setting (**`0`**) to adjust the overall offset.
- Note that **`ssb`** can only be used to DECREASE offset. The **`sao`** command can be used to globally increase offset.

Related Commands:

- **ssg**

Example **`ssb 0 25`**

3.11 Generating a Test Pattern

The Falcon camera includes a built in test pattern generator that can be used to confirm camera connections or driver installations, without the need for a camera lens or proper lighting. The pattern generator inserts video just after the sensor A/D converter, therefore Falcon processing such as the LUT act on the generator images or on sensor images.

Serial Command:svm

Purpose: Generates a test pattern to aid in system debugging. The test patterns are useful for verifying proper timing and connections between the camera and the frame grabber. The following table shows each available test pattern.

Syntax:

- **`svm`** ***`i`***

Syntax Elements:

- ***`i`***

  `0` Video.

  `4` Test pattern horizontal ramp

  `5` Test pattern vertical ramp

  `6` Test pattern diagonal ramp:

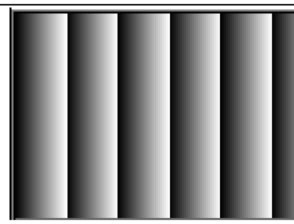
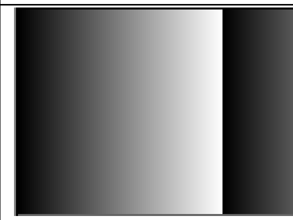
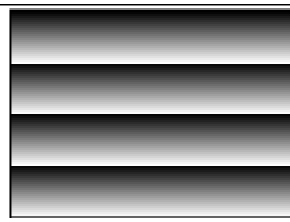
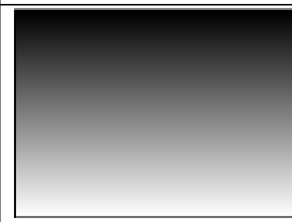
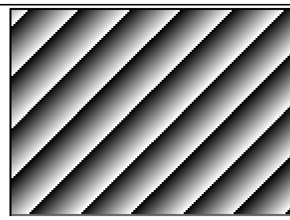
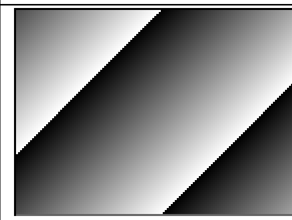
  `7` Reserved for DALSA product support.

  `8` Reserved for DALSA product support.

  When switching the camera from video mode (**`svm 0`**) to one of the test pattern modes (**`svm 4`** thru **`8`**), the camera "turns off" any digital gain (**`ssg`**), and background subtract (**`ssb`**) settings currently being used. The **`gcp`** screen does not turn off these settings and displays the settings used prior to switching to test pattern mode. When returning to video mode (**`svm 0`**), the digital gain, background subtract and exposure control settings are returned to their prior state.

Example:

- **`svm 5`**

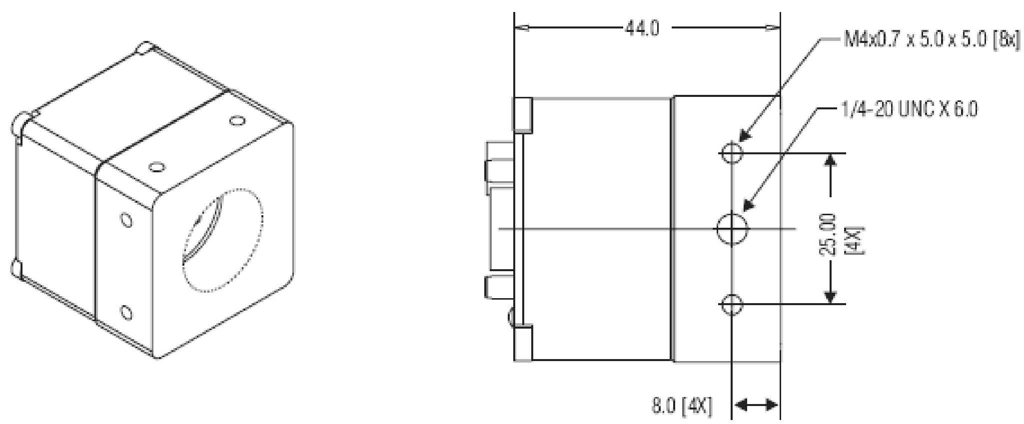
Test Pattern	8-Bit	10-Bit
Horizontal Ramp (**svm** 4)		
Vertical Ramp (**svm** 5)		
Diagonal Ramp (**svm** 6)		

4

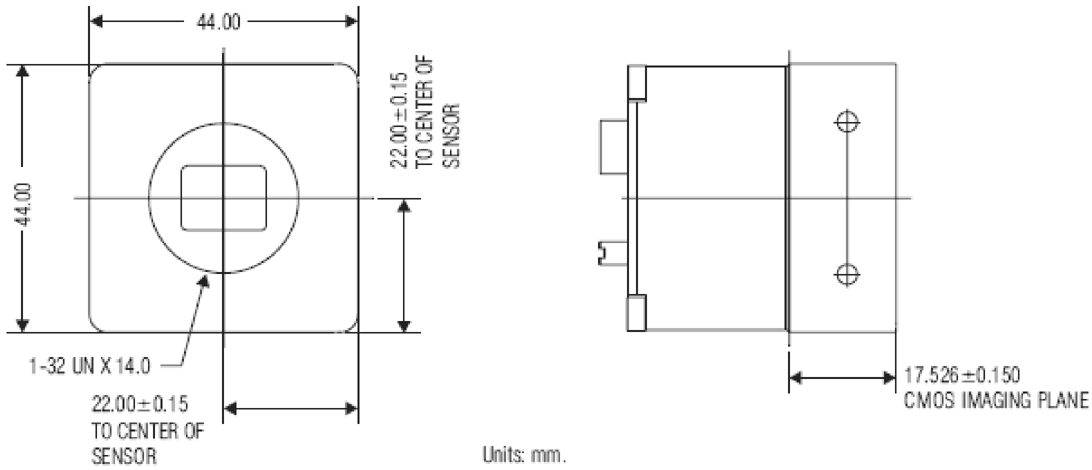
Optical and Mechanical Considerations

4.1 Mechanical Interface

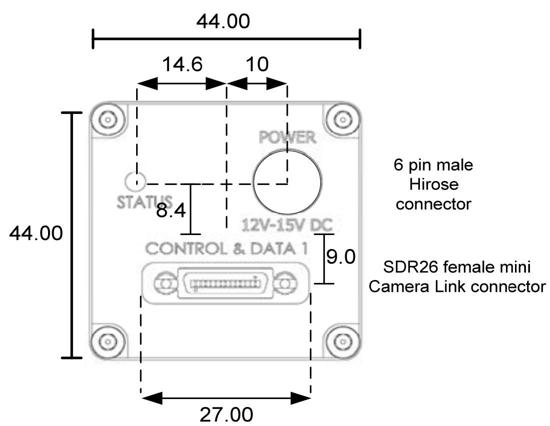
ⓘ	**Note:** All measurements in mm. Tolerances are indicated by decimals: .XX = ± 0.05 .X = ± 0.15



Side Mechanical Dimensions (in mm)



Camera Front and Side Mechanical Dimensions (in mm)

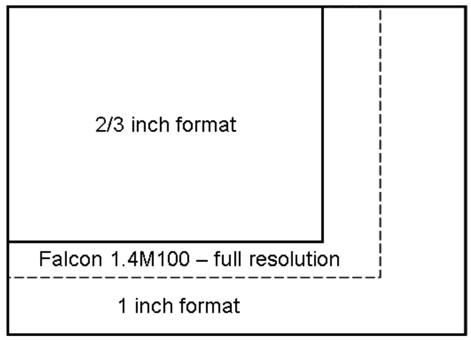


Back Panel

For optimal camera performance, the camera can be cooled by applying forced air flow or by attaching the camera to a material that can conduct heat away from the camera.

4.2 Lens Mounts

Configuration	Flange Back Focal Length (sensor die to adapter)
C-Mount	17.526



Maximum Falcon 1.4M100 Resolution	C-Mount Sensor Format
1400 x 1024	Fits inside 1" format
1189 x 891	2/3" format
864 x 648	1/2" format
648 x 486 (close to VGA)	1/3" format
432 x 324	1/4" format

Note: The use of certain C-mount lenses will cause vignetting due to the size of the image sensor. With the Falcon 1.4M100 HG camera at full resolution the dimensions of the active area used in the camera is 10.36mm x 7.58mm, with a diagonal of 12.84mm. Thus, you will require a 1" C-mount lens. Similarly the Falcon 1M120 camera at full resolution requires a 1" C-mount lens. But the Falcon VGA300, at full resolution, can use a 1/3" C-mount lens.

4.3 Optical Interface

4.3.1 Illumination

The amount and wavelengths of light required to capture useful images depend on the particular application. Factors include the nature, speed, and spectral characteristics of objects being imaged, exposure times, light source characteristics, environmental and acquisition system specifics, and more.

It is often more important to consider exposure than illumination when calculating the total amount of energy (which is related to the total number of photons reaching the sensor). For example, $5\mu J/cm^2$ can be achieved by either exposing $5mW/cm^2$ for 1ms or exposing an intensity of $5W/cm^2$ for $1\mu s$.

4.3.2 Light Sources

Keep these guidelines in mind when setting up your light source:

- LED light sources are relatively inexpensive, provide a uniform field, and longer life span compared to other light sources. Compared to Halogen light sources, LED's provide more blue and less red photons.
- Halogen light sources generally provide very little blue relative to IR.
- Fiber-optic light distribution systems generally transmit very little blue relative to IR.
- Some light sources age; over their life span they produce less light. This aging may not be uniform—a light source may produce progressively less light in some areas of the spectrum but not others.

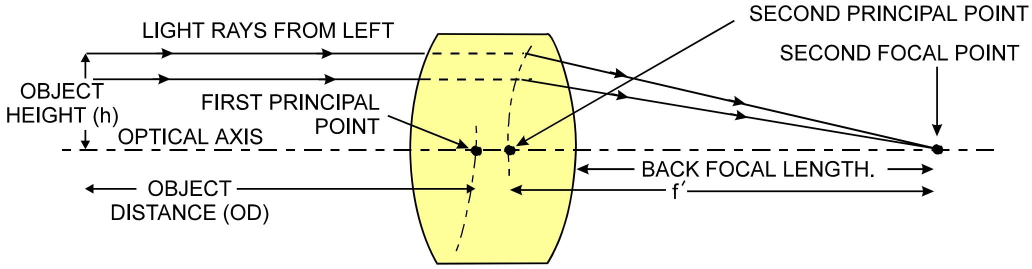
4.3.3 Filters

Digital cameras are extremely responsive to infrared (IR) wavelengths of light. To prevent infrared from distorting the images you scan, use a "hot mirror" or IR cutoff filter that transmits visible wavelengths but does not transmit wavelengths over 750nm. Examples are the Schneider Optics™ B+W 489, which includes a mounting ring, the CORION™ LS-750, which does not include a mounting ring, and the CORION™ HR-750 series hot mirror. Any good manufactured IR filter can be used.

4.3.4 Lens Modeling

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

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



Primary Points in A Lens System

4.3.5 Magnification and Resolution

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

$$m = \frac{h'}{h}$$

where m is the magnification, h' is the image height (pixel size) and h is the object height (desired object resolution size).

By similar triangles, the magnification is alternatively given by:

$$m = \frac{f'}{OD}$$

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

$$\frac{h'}{h} = \frac{f'}{OD}$$

This is the governing equation for many object and image plane parameters.

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

$$\frac{10\mu m}{100\mu m} = \frac{45mm}{OD} \qquad OD = 450mm\,(0.450m)$$

5

Troubleshooting

The information in this chapter can help you solve problems that may occur during the setup of your camera. Remember that the camera is part of the entire acquisition system. You may have to troubleshoot any or all of the following:

- power supplies
- frame grabber hardware & software
- light sources
- operating environment
- cabling
- host computer
- optics
- encoder

Your steps in dealing with a technical problem should be:

7. Try the general and specific solutions listed in sections 5.1, 5.2, and 5.3.
8. If these solutions do not resolve your problem, see Technical Support on page 71 for information on getting product support.

5.1 Common Solutions

5.1.1 Connections

The first step in troubleshooting is to verify that your camera has all the correct connections.

Power Supply Voltages

Check for the presence of all voltages **at the camera power connector, not the power supply connector.** The voltage drop across the power cable can be large enough such that the voltage at the camera no longer meets specifications. Verify the connector pinout and that all grounds are connected. Refer to section 2.2.5 Power Connector on page 25 for details.

Note: Avoid hot plugging long power cables into the camera.

Data Clocking/Output Signals

To validate cable integrity, have the camera send out a test pattern and verify it is being properly received. Refer to section 3.11 Generating a Test Pattern for further information on running test patterns.

5.2 Troubleshooting Using the Serial Interface

5.2.1 Communications

To quickly verify serial communications send the **h** (help) command. By sending the **h** and receiving the help menu, the serial communications are verified. If further problems persist, review Appendix B for more information on communications.

5.2.2 Verify Parameters

To verify the camera setup, send the **gcp** (get camera parameters) command. To retrieve valid parameter ranges, send the **h** (help) command.

5.2.3 Verify Factory Calibrated Settings

To restore the camera's factory settings send the **rfs** command.

After executing this command send the **gcp** command to verify the factory settings.

5.2.4 Verify Timing and Digital Video Path

Use the test pattern feature to verify the proper timing and connections between the camera and the frame grabber and verify the proper output along the digital processing chain.

5.3 Specific Solutions

5.3.1 No Output or Erratic Behavior

If your camera provides no output or behaves erratically, it may be picking up random noise from long cables acting as antennae. Do not attach wires to unused pins. Verify that the camera is not receiving spurious inputs (for example EXSYNC, if camera is using an internal signal for synchronization).

5.3.2 Line Dropout, Bright Lines, or Incorrect Frame rate

Verify that the frequency of the internal sync is set correctly.

5.3.3 Noisy Output

Check your power supply voltage outputs for noise. Noise present on these lines can result in poor video quality. Low quality or non-twisted pair cable can also add noise to the video output.

5.3.4 Dark Patches

If dark patches appear in your output the optics path may have become contaminated. Clean your lenses and sensor windows with extreme care.

1. Take standard ESD precautions.
2. Wear latex gloves or finger cots
3. Blow off dust using a filtered blow bottle or dry, filtered compressed air.
4. Fold a piece of optical lens cleaning tissue (approx. 3" x 5") to make a square pad that is approximately one finger-width
5. Moisten the pad on one edge with 2-3 drops of clean solvent—either alcohol or acetone. Do not saturate the entire pad with solvent.
6. Wipe across the length of the window in one direction with the moistened end first, followed by the rest of the pad. The dry part of the pad should follow the moistened end. The goal is to prevent solvent from evaporating from the window surface, as this will end up leaving residue and streaking behind.
7. Repeat steps 2-6 using a clean tissue until the entire window has been cleaned.
8. Blow off any adhering fibers or particles using dry, filtered compressed air.

Appendix A: Camera Link™ Reference, Timing, and Configuration Table

Camera Link is a communication interface for vision applications. It provides a connectivity standard between cameras and frame grabbers. A standard cable connection will reduce manufacturers' support time and greatly reduce the level of complexity and time needed for customers to successfully integrate high speed cameras with frame grabbers. This is particularly relevant as signal and data transmissions increase both in complexity and throughput. A standard cable/connector assembly will also enable customers to take advantage of volume pricing, thus reducing costs.

The camera link standard is intended to be extremely flexible in order to meet the needs of different camera and frame grabber manufacturers.

The DALSA Camera Link Implementation Road Map (available in the Knowledge Center at www.dalsa.com) details how DALSA standardizes its use of the Camera Link interface.

A.1 LVDS Technical Description

Low Voltage Differential Signaling (LVDS) is a high-speed, low-power general purpose interface standard. The standard, known as ANSI/TIA/EIA-644, was approved in March 1996. LVDS uses differential signaling, with a nominal signal swing of 350mV differential. The low signal swing decreases rise and fall times to achieve a theoretical maximum transmission rate of 1.923 Gbps into a loss-less medium. The low signal swing also means that the standard is not dependent on a particular supply voltage. LVDS uses current-mode drivers, which limit power consumption. The differential signals are immune to ±1 V common mode noise.

A.2 Camera Signal Requirements

This section provides definitions for the signals used in the Camera Link interface. The standard Camera Link cable provides camera control signals, serial communication, and video data.

A.3 Video Data

The Channel Link technology is integral to the transmission of video data. Image data and image enable signals are transmitted on the Channel Link bus. Four enable signals are defined as:

• FVAL—Frame Valid (FVAL) is defined HIGH for valid lines.

• LVAL—Line Valid (LVAL) is defined HIGH for valid pixels.

• DVAL—Data Valid (DVAL) is defined HIGH when data is valid.

• Spare— A spare has been defined for future use.

All four enable signals must be provided by the camera on each Channel Link chip. All unused data bits must be tied to a known value by the camera. For more information on image data bit allocations, refer to the official Camera Link specification on the www.dalsa.com Web site.

A.4 Camera Control Signals

Four LVDS pairs are reserved for general-purpose camera control. They are defined as camera inputs and frame grabber outputs. Camera manufacturers can define these signals to meet their needs for a particular product.

All four enable signals must be provided by the camera on each Channel Link chip. All unused data bits must be tied to a known value by the camera. For more information on image data bit allocations, refer to the official Camera Link specification on the www.dalsa.com Web site.

DALSA Camera Control Configuration

Falcon Stop Action Cameras	Camera Link Name
EXSYNC	CC1
Reserved for future use	CC2
Reserved for future use	CC3
Reserved for future use	CC4

A.5 Communication

Two LVDS pairs have been allocated for asynchronous serial communication to and from the camera and frame grabber. Cameras and frame grabbers should support at least 9600 baud. These signals are

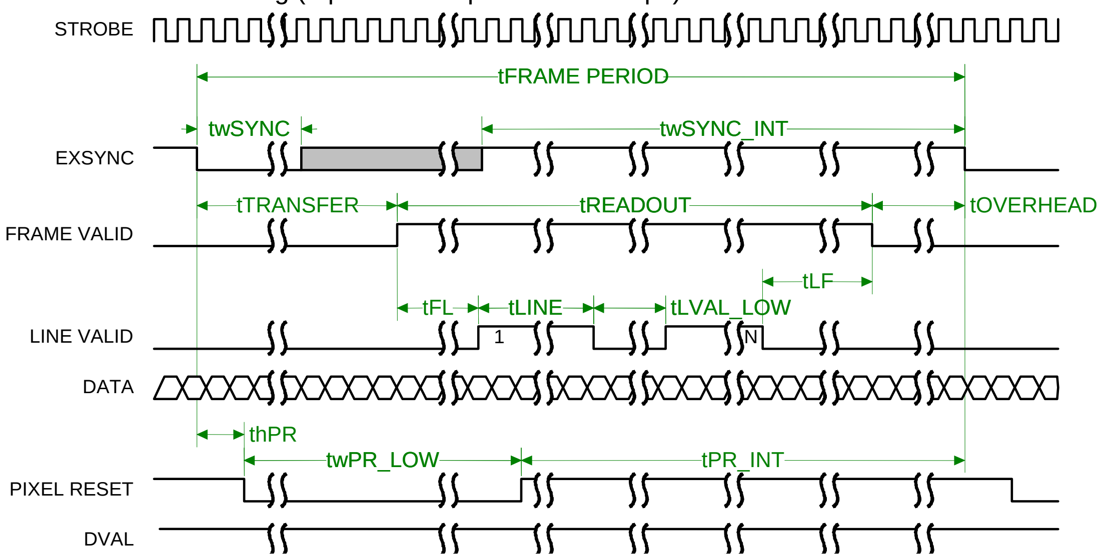
• SerTFG—Differential pair with serial communications to the frame grabber.

• SerTC—Differential pair with serial communications to the camera.

The serial interface will have the following characteristics: one start bit, one stop bit, no parity, and no handshaking. It is recommended that frame grabber manufacturers supply both a user interface and a software application programming interface (API) for using the asynchronous serial communication port. The user interface will consist of a terminal program with minimal capabilities of sending and receiving a character string and sending a file of bytes. The software API will provide functions to enumerate boards and send or receive a character string. See Appendix B in the Official Camera Link specification on the www.dalsa.com Web site.

A.6 Camera Link Video Timing

Falcon Standard Timing (Input and Output Relationships)



		FA-20-01M1H-00-R FA-21-01M1H-00-R			FA-21-1M120-00-R			FA-21-3HK3H-00-R		
Symbol	Units	Min	Typ.	Max	Min	Typ	Max	Min	Typ	Max
tw_{SYNC}	us'	12			12			12		
tw_{SYNC_INT}	us	10			10			10		

$t_{FRAME\ PERIOD}$	ms	9.81			8.18			3.294		
$t_{TRANSFER}$	us	65.2			64			61.6		
$t_{READOUT}$	us	76		9702	63		8090	107.2		3216
$t_{OVERHEAD}$	us	43			26.2			16.2		
t_{LINE}	us	0.436		8.8	1.64		7.636	2.843		6.436
t_{FL}	clocks		20			20			20	
$t_{LVAL\ LOW}$	us	0.64			0.26			0.262		
t_{LF}	clocks		0			0			0	
th_{PR}	ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
tw_{PR_LOW}	ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
t_{PR_INT}	ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Symbol	Definition
twSYNC	The minimum width of the EXSYNC pulse. When in SMART EXSYNC mode, the minimum width is greater to allow for the photosites to be properly reset.
twSYNC_INT	Te integration time when the “SMART EXSYNC” feature is available and turned on. Note, the minimum time is necessary to guarantee proper operation.
t FRAME PERIOD	The minimum frame time made up of tTransfer, tREADOUT plus tOVERHEAD
tTRANSFER	The time from the reception of the falling edge of EXSYNC to the rising edge of FVAL.
tREADOUT	The time that frame valid is high
tOVERHEAD	The number of pixels that must elapse after the falling edge of FVAL before the EXSYNC falling edge can occur.
tLINE	The line time
tFL	Number strobes between FVAL rising and the first LVAL rising edge.
tLVAL_LOW	Number strobes that LVAL is low during readout
tLF	Number of strobes between last LVAL falling and FVAL falling edge.

A.7 Bit Assignments According to Configuration

The following table describes the bit assignments for both 8-bit and 10-bit 2 tap base configuration (clm 2 and clm 3). The two taps are interleaved and provide consecutive pixels simultaneously (for example, with the 8-bit configuration, port A starts with pixel 0 and port B pixel 1, and so on).

Port/bit	8-bit	10-bit
Port A0	A0	A0
Port A1	A1	A1
Port A2	A2	A2
Port A3	A3	A3
Port A4	A4	A4
Port A5	A5	A5
Port A6	A6	A6
Port A7	A7	A7
Port B0	B0	A8
Port B1	B1	A9
Port B2	B2	Not used
Port B3	B3	Not used
Port B4	B4	B8
Port B5	B5	B9
Port B6	B6	Not used
Port B7	B7	Not used
Port C0	Not used	B0
Port C1	Not used	B1
Port C2	Not used	B2
Port C3	Not used	B3
Port C4	Not used	B4
Port C5	Not used	B5
Port C6	Not used	B6
Port C7	Not used	B7

Appendix B: Error Handling and Command List

B.1 All Available Commands

As a quick reference, the following table lists all of the commands available to the camera user. For detailed information on using these commands, refer to Chapter 4.

Parameter types are identified as:

t = tap id
i = integer value
f = real number
s = string
m = member of a set

Syntax	Command	Params	Description
ccf	correction calibrate FPN		Performs FPN calibration and eliminates FPN by subtracting away individual pixel dark current.
clm	camera link mode	**m**	Output mode to use: **2**: Base configuration, 2 taps, 8 bit output **3**: Base configuration, 2 taps, 10 bit output
cpa	calculate PRNU algorithm	**i i**	Performs PRNU calibration according to the selected algorithm. The first parameter is the algorithm where **i** is: **2** = Calculates the PRNU coefficients using the entered target value $\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - (\text{FPN}_i + \textbf{sdo}\ \text{value})}$ This algorithm is useful for achieving uniform output across multiple cameras.

Syntax	Command	Params	Description
csn	coefficient set number	**i**	Selects the coefficient set to use, either: **0** = Factory calibrated set of FPN and PRNU coefficients. These coefficients **cannot** be erased or modified. **1** = User calibrated set of FPN and PRNU coefficients. These coefficients **can** be deleted or modified.
css	calibration sample size	**m**	Sets the number of lines to sample when performing FPN and PRNU calibration where **m** is **32**(factory setting), **64**, **128** , **256**, **512**, or **1024**
ecg	enable color gain	**i**	Enables or disables digital color gains 0 = Disabled 1 = Enabled
eoc	enable offset correction	**i**	Enables or disables temperature color offset correct 0 = Disabled 1 = Enabled
gcp	get camera parameters		Read all of the camera parameters.
gcs	get camera serial		Read the camera serial number.
gcv	get camera version		Read the firmware version and FPGA version.
get	get command parameter	**s**	Display value of camera command **s**
gfc	Get FPN Coefficient	**x y**	**x** = 1-1400 **y** = 1-1024
gh	get help		Display the get help screen
gsf	get sync frequency	**i**	Displays the frames per second. (i = 1)
h	help		Display the online help

Syntax	Command	Params	Description
lpc	Load pixel coefficients		
ocf	Set offset correction factor	f	Allows user to manually set the temperature color offset correction factor i.e. slope. Minimum = 1.00 Maximum = 4.00
rc	reset camera		Reset the entire camera (reboot).
rct	Read calibration temperature		Display the temperature at which the camera was calibrated
rfs	restore factory settings		Restore the camera's factory settings.
rpc	reset pixel coefficients		Resets the pixel coefficients to factory settings.
rus	restore user settings		Restore the camera's last saved user settings.
sbh	set horizontal binning	**i**	Sets the horizontal binning. **1**: no binning **2:** each pixel value is formed from 2 adjacent pixels, effectively reducing the frame width in half.
sbr	set baud rate	**m**	Set the speed of the serial communication port. Baud rates: **9600**, **19200**, **57600**, and **115200**. Default baud: 9600.
sbv	set vertical binning rate	**i**	Sets the vertical binning. **1**: no binning **2:** each pixel value is formed from 2 adjacent pixels on consecutive lines, effectively reducing the frame height in half.

Syntax	Command	Params	Description
sdc	Set digital color gain	t i	Allows user to manually set digital color gains for individual colors. The allowable range is **1** to **4**. 1 = Red, 2 = Green (Red), 3 = Green (Blue), and 4 = Blue. Minimum = 1024 Maximum = 8191
sdo	set digital offset	**t i**	Set the digital offset as a DN, which is added to the digital video signal. **t**: tap selector: this is always 0 (all taps) **i**: the digital offset (0-1023 DN)
sem	Set exposure mode	**m**	Set the exposure mode. Available values are: **2**: Internal SYNC, programmable frame rate and exposure time using commands ssf and set. **4**: Smart EXSYNC. **6**: External frame rate, fixed exposure time **9**: Sequential Smart EXSYNC. **10**: Sequential external frame rate, fixed exposure time
set	set exposure time	**f**	Sets the exposure time to a floating point number in µs. Allowable range is **250-4194303** µs.
sfc	Set FPN Coefficient	**x y i**	**x** = 1-1400 **y** = 1-1024 **i** = 0-255
slc	set LUT coefficient	**i i**	Specifies the LUT input pixel value and output value. All other pixel values are then calculated linearly. **i** :Input pixel value. Possible values are **0-1023**. **i** : Output pixel value. Possible values are **0-1023**.
sle	set LUT enable	**i**	Enables or disables the camera LUT. **0**: LUT disabled **1**: LUT enabled

Syntax	Command	Params	Description
smm	set mirroring mode"	i	Enables or disables mirroring mode: **0**: disabled **1**: enabled
sot	set output throughput	m	Sets the output throughput. Possible values are **80** or **160** MHz.
spc	Set PRNU coefficient	x y i	**x** = 1-1400 **y** = 1-1024 **i** = 0-255
ssb	Set subtract background	t i	**t** = 0-0 **i** = 0-511
ssf	set sync frequency	f	Sets the frame rate in Hz to a value from **0.095** to **102.354**.
ssg	set system gain	t i	Sets the digital gain. **t** = Tap selection. Allowable value is **0** for all taps. **i** = Gain value is specified from **0** to **65535**. The digital video values are multiplied by this number.
svm	set video mode	m	Sets the camera's video mode. **0**: Video mode **4**: Test pattern horizontal ramp **5**: Test pattern vertical ramp **6**: Test pattern diagonal ramp **7**: Test pattern FPN **8**: Test pattern PRNU
upd	upload CBF file		Updates the camera firmware with the selected file
vt	verify temperature		Returns the current temperature of the camera.
vv	verify voltage		Returns the 1.2 V, 2.5V, and 3.3V measurements.
wct	Write calibration temperature	f	To be used each time the camera is calibrated. Use vt to verify camera temperature at calibration and use wct to save the calibration temperature. The allowable range is 0.0 to 99.9.

Syntax	Command	Params	Description
wfc	write FPN coefficients		Saves the FPN coefficients
wpc	write PRNU coefficients		Saves the PRNU coefficients
wse	window start end	i i x1 y1 x2 y2	Sets the window start and stop pixels where: **i** is the window sequence id. It is always **0** in this camera. **i** is the number of windows to set. It is always **1** in this camera. **x1** is window start corner value. Ranges from **0-1399**. **y1** is window start pixel number. Ranges from **0-1023**. **x2** is window end corner value. Ranges from **15-1399**. **y2** is window end pixel number . Ranges from **15-1023**.
wus	write user settings		Write all of the user settings to non-volatile memory.

B.2 Error Messages

As a quick reference, the following table lists all of the error and warning messages the camera user could experience.

Error \ Warning Code	Camera Response
1	Error 1: Invalid command>
2	Error 2: Command parameters incorrect or out of range>
3	Error 3: Internal camera error>
4	Error 4: Camera memory check failure>
5	Error 5: Command unavailable in this mode>
6	Error 6: Unable to configure camera>
7	Error 7: The camera's temperature is outside the specified operating range>
8	Error 8: Failure while attempting to restore the camera settings>
9	Not used
10	Error 10: General timeout error>
11	Not used
12	Not used
13	Error 13: SPI device not responding>
14	Error 14: Unable to read/write to the internal config device>
15	Error 15: Invalid baudrate>
16	Error 16: Failure downloading file
17	Warning 17: Related parameters adjusted>
18	Error 18: FFC coefficients memory failure>
19	Not used
20	Not used
21	Not used
22	Not Used
23	Error 23: Settings not saved>
24	Not Used
25	Warning 25: Analog Offset automatically adjusted>
26	Error 26: One or more voltages outside specified operating range>

27	Error 27: Reserved factory coefficient set, change coefficient set number>
28	Warning 28: Coefficient may be inaccurate A/D clipping has occurred>
29	Warning 29: Greater than 1% of coefficients have been clipped>
30	Error 30 : ECC failure>
31	Error 31 : ECC failure and set corrupt>
32	Error 32 : ECC failure and set not available>
33	Error 33 : Set not available>
34	Error 34: Incorrect number of parameters>
35	Error 35: Incompatible camera model>
36	Error 36: Incompatible firmware>
37	Error 37: File transfer cancelled>
38	Error 38: Invalid CBF file>
39	Warning 39: Clipped to min/max>
40	Warning 40: Changed to nearest valid value>

Appendix C: EMC Declaration

C.1 EMC Declaration of Conformity

DALSA's FA-2x cameras meet the requirements outlined below which satisfy the EMC requirements for CE marking, the FCC Part 15 Class B requirements, and the Industry Canada requirements.

Models: FA-20-01M1H   FA-22-01M1H FA-21-01M1H   FA-23-01M1H FA-21-1M120   FA-23-1M120 FA-21-3HK3H   FA-23-3HK3H
The CE Mark Evaluation of the DALSA FA-2x cameras, which are manufactured by DALSA Inc., meets the following requirements:
EN 55022, EN 55011, CISPR-11, CISPR-22, ICES-003 Class B, and FCC Part 15 Emissions Requirements. EN 61326-1 and EN 55024 Immunity to Disturbances. EN 61000-3-2 Power Frequency Harmonic Current Emissions. EN 61000-3-3 Flicker Voltage.
Date of issue: February 2010

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential environment.

Changes or modifications not expressly approved by DALSA could void the user's authority to operate the equipment.

Name and Signature of authorized person

Hank Helmond
Quality Manager, DALSA Corp.

Technical Support

Any support question or request can be submitted via our web site:

Technical support form via our web page: Support requests for imaging product installations, Support requests for imaging applications	http://www.dalsa.com/mv/support
Product literature and driver updates	http://www.http://www.dalsa.com/mv/download

Index