4 Megapixel 30/60 fps Area Scan Cameras

Falcon 4M30 and 4M60

Camera User's Manual

PT-41-04M60-XX-R

PT-21-04M30-XX-R

DALSA

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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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Introduction to the 4 Megapixel Falcon Cameras

1.1 Camera Highlights

Features

- 4 megapixels, 2352 (H) x 1728 (V) resolution, CMOS area camera
- Global shutter (non-rolling) for crisp images
- 60 fps model or 30 fps model
- Vertical windowing for faster frame rate
- 7.4 µm x 7.4 µm pixel pitch
- 4 x 80 MHz or 2 x 80 MHz data rates
- Nominal broadband responsivity of 18.4 DN/(nJ/cm^2)
- Good NIR response
- 8 or 10 bit selectable output
- Dynamic range of 57 dB
- Base or Medium Camera Link™ interface
- RoHS and CE compliant

Programmability

- A simple ASCII protocol controls gain, offset, frame rates, trigger mode, test pattern output, and camera diagnostics.
- The serial interface (ASCII, 9600 baud, adjustable to 19200, 57600, 115200) operates through Camera Link.

Description

The 4 megapixel Falcon cameras are our most advanced high-speed area array cameras. With data rates up to 320 MHz, these cameras are capable of capturing low smear images at incredibly fast speeds. Programmable features and diagnostics are accessible through the Camera Link™ MDR26 connector.

Applications

The 4M Falcon cameras are ideal for applications requiring high speed, superior image quality, and high responsivity. Applications include:

- PCB inspection
- 3D solder paste inspection
- 2D and 3D wafer bump inspection
- Semiconductor wafer inspection
- Flat panel display inspection
- Industrial metrology
- Traffic management
- General machine vision

Models

The Falcon 4M camera is available in the following models:

Falcon 4M Camera Models Overview

Model Number	Description
PT-21-04M30-XX-R	4M resolution, 2 sensor taps, 30 frames per second, RoHS compliant.
PT-41-04M60-XX-R	4M resolution, 4 sensor taps, 60 frames per second, RoHS compliant.

1.2 Camera Performance Specifications

Camera Performance Specifications

Feature / Specification		Notes
Resolution	2352 (H) x 1728 (V) pixels	
Pixel Fill Factor	45%	
Effective fill factor with microlenses	60%	
# of Lines per Frame	1728 lines	
Output Format (# of taps)	2 (4M30) or 4 (4M60)	

Optical Interface		Notes
Back Focal Distance		
Sensor die to mounting plate	6.56 mm	5

Optical Interface		Notes
Sensor Alignment		
x	±0.10 mm	
y	±0.10 mm	
z	±0.25 mm	
Θz	±0.3°	
Lens Mount	F-mount adapter available	
Lens Mount Hole	M42 x 1	

Mechanical Interface		Notes
Camera Size	94 x 94 x 48 mm	
Mass	<550 g	
Connectors		
power connector	6 pin male Hirose	
data connector	2 x MDR26 female	

Electrical Interface		Notes
Input Voltage	+12 to +15 Volts	6
Power Dissipation	10 typ, 14 Watts max	
Operating Temperature	0 to 50 °C	1
Data Output Format	8 or 10 user selectable bits	
Output Data Configuration	Base or Medium Camera Link	

Operating Ranges		Notes
Minimum Frame Rate	1 Hz	
Maximum Frame Rate	60.4 Hz(4M60) 30.6 Hz (4M30)	4
Data Rate	80 MHz	
Dynamic Range (10 bits @ nominal gain)	682:1 typ.	2
Random Noise	1.5 typ, 2.0 max DN rms	
Broadband Responsivity	18.4 typ DN/(nJ/cm^2)	7
DC Offset	0 DN	7
Antiblooming	>1000x saturation	
FPN	0.5 typ, 1.0 max DN rms	
PRNU	1.5 typ, 2.6 max DN rms	8
Integral non-linearity	<2% DN	3
Saturation Equivalent Exposure	55 typ nJ/cm^2	
Noise Equivalent Exposure	80 typ pJ/cm^2	
Saturation Output Amplitude	1023 DN	

Test conditions unless otherwise noted:

- `sem 2` (exposure mode 2).

- **ssf 55** (55 frames per second rate).
- **set 2000** (2 millisecond exposure time).
- **sem 2** (Exposure mode 2) .
- Full frame/window.
- **clm 16** (4 tap, 10 bit).
- **sot 320** (80 MHz camera link strobe).
- **efd 1** (Snapshot mode 1).
- **snd 1** (Number of fast frame dumps = 1).
- Light Source: Broadband Quartz Halogen, 3250K (3050 to 3450), with a 750 nm cutoff filter .
- Ambient test temperature 25°C.
- Average output 840 DN.
- Flat field correction (FFC) turned on.

Notes:

1. Measured at the front plate.
2. Based on output at 1023 DN.
3. Output over 10-90%.
4. Snapshot mode 0 allows for marginally higher frame rates.
5. Optical distance.
6. +12V consumes the least amount of power.
7. With FFC on. Responsivity is not calibrated when FCC is turned off.
8. Measured at half saturation.

1.3 Cosmetic Specifications

Please note, for this section only, the following values are considered preliminary information and subject to change without notice.

Sensor Cosmetic Specifications

The following table highlights the current cosmetic specifications for the DALSA sensor used inside the Falcon 4M60 and 4M30 cameras. The monochrome sensor has 4 megapixels (2352 x 1728), global shuttering and is capable of 60 fps.

Sensor Cosmetic Specifications

Cosmetic Specification	Maximum Number of Defects
Hot pixel defects	1
Single pixel defects	100
Clusters defects	No limit (refer to the Note below)
Spot defects	1
Column defects	0
Row defects	0

Definition of cosmetic specifications

Hot pixel defect

Pixel whose signal, in dark, deviates by more than 400 DN (10 bits) from the average of all the pixels.

Single pixel defect

Pixel whose signal, at nominal light (illumination at 50% of saturation), deviates by more than ±30% from its neighboring pixels.

Cluster defect

A grouping of at most 8 pixel defects within an area of 3 x 3 pixels.

Spot defect

A grouping of 9 pixel defects within an area of 3 x 3 pixels.

Column defect

A column which has 12 pixel defects in a 1*12 kernel.

Row defect

An horizontal grouping of more than 4 pixel defects between at least 2 good pixels on both sides, where single good pixels between 2 defective pixels are considered defective.

Test conditions

- Digital gain – 1X.
- Nominal light = illumination at 50% of saturation.
- Frame Rate = 60 fps (Falcon 4M60), 30 fps (Falcon 4M30)
- Integration time = 15 ms
- Ambient Temperature of 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 12 clusters of 8 in size (12 x 8 = 96), but you could not have 13 clusters of 8 in size (13 x 8 = 104).

The probability of 12 clusters of 8 is negligible and is only used as an example.

Camera Cosmetic Specification

Beyond sensor cosmetic testing, the camera is placed under additional testing to more closely examine potential cosmetic defects due to the sensor glass. This test examines the difference between two images. One image is taken under collimated light and the second image is taken under diffuse light. Any difference represents blemishes on the glass rather than blemishes on the sensor die surface.

Camera Cosmetic Specifications - Glass

Cosmetic Spec	Difference Spec	Cluster Size	Max Number of Defects
Glass defects	5%	9	0

Definition of blemishes

Glass defects

A group of pixels exceeding the given cluster size and the difference between the collimated and diffuse light settings. Images are taken at nominal light (illumination at 50% of the linear range). A cluster is defined as a grouping of pixels. A grouping of pixels refers to adjacent pixels or pixels that touch.

In addition, the camera is examined against the following cosmetic specifications.

Camera Cosmetic Specifications – Sensor & Glass

Cosmetic Specification	Maximum Number of Defects
Dark pixel defects (>300DN)	50
Dark pixel defects (>600DN)	1
Single pixel defects	100

Definition of cosmetic specifications

Dark pixel defects

Pixel whose signal, in dark, exceeds the given threshold (10 bits).

Single pixel defect

Pixel whose signal, at nominal light (illumination at 50% of saturation), deviates by more than ±30% from its neighboring pixels.

Test conditions

- Digital gain – 1X.
- Nominal light = illumination at 50% of saturation.
- Frame Rate = 60 fps (Falcon 4M60), 30 fps (Falcon 4M30).
- Integration time = 15 ms.
- Ambient Temperature of 25°C.

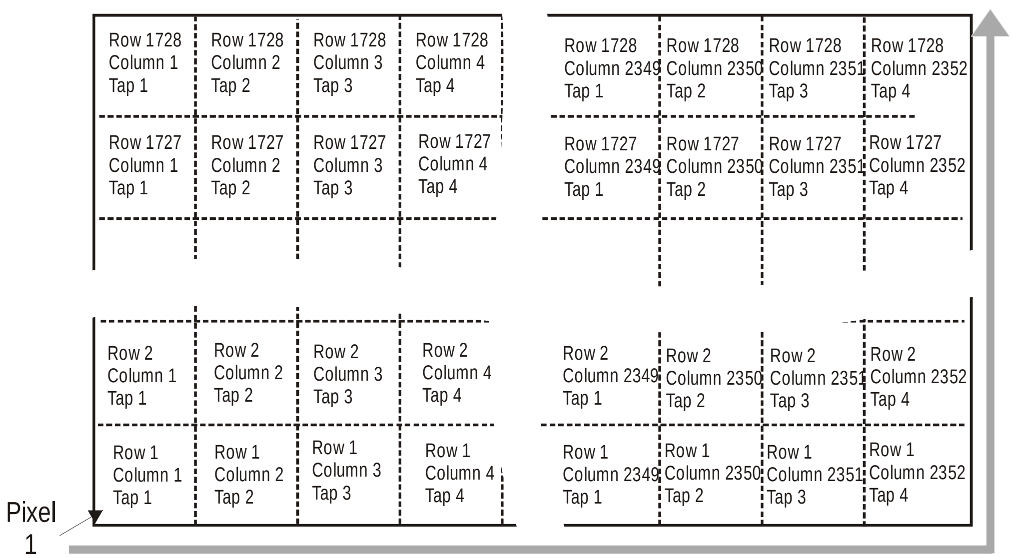
Note: all of the above sensor and camera cosmetic specifications are with flat field turned off (**`epc 0 0`**). There are no post-flat-field (**`epc 1 1`**) camera cosmetic specifications.

1.4 Image Sensor and Pixel Readout

The camera uses DALSA's new DCR2417M, 4 megapixel, 2352 x 1728 CMOS sensor.

Figure 1: 4 Tap 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.



Pixel read out direction is left to right then bottom to top

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 2352, 1728.

Figure 2: 4M60 Pixel Readout Detail

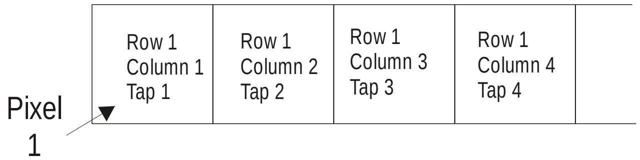
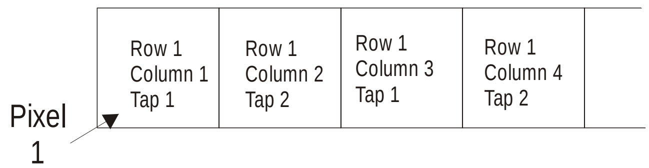
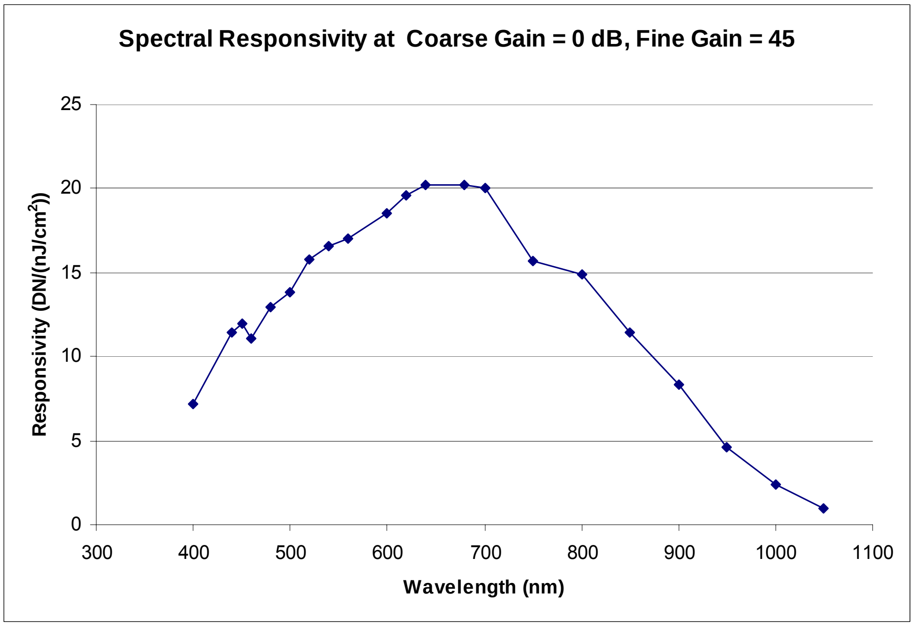


Figure 3: 4M30 Pixel Readout Detail



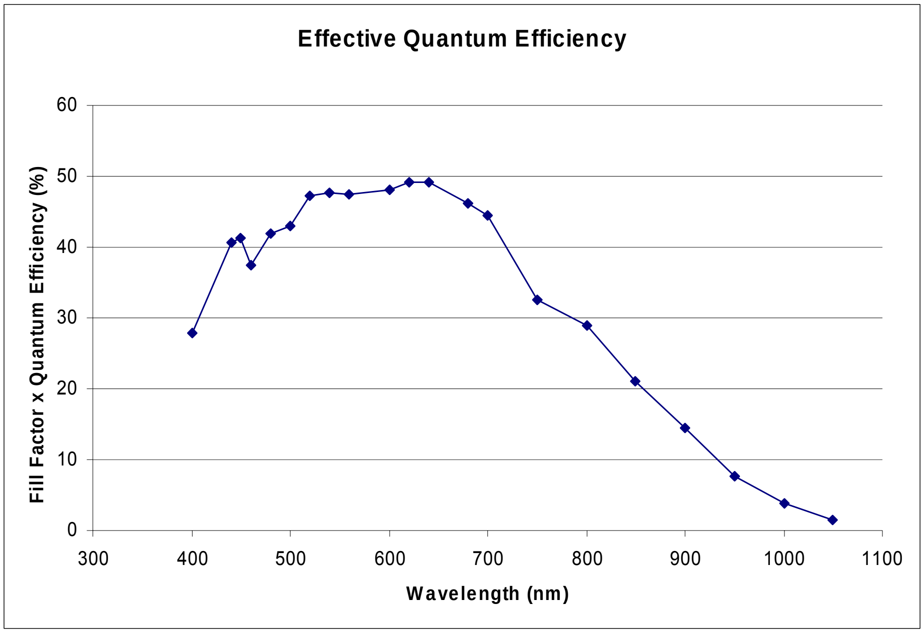
1.5 Responsivity

Figure 4: Spectral Responsivity



Note: Responsivity is calibrated with `fcc` on.

Figure 5: Effective Quantum Efficiency



2

Camera Hardware Interface

2.1 Installation Overview

This installation overview assumes you have not installed any system components yet.

When setting up your camera, you should take the following 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. The camera may be damaged as a result.
6) Connect Camera Link and power cables.
7) After connecting cables, apply power to the camera.
8) Check the diagnostic LED. If the camera is operating correctly, the LED will flash for approximately 30 seconds and then turn solid green. See 2.2.1 LED Status Indicator 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.

A note on 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. As the Camera Link strobe frequency is increased, the maximum allowable cable length will decrease.

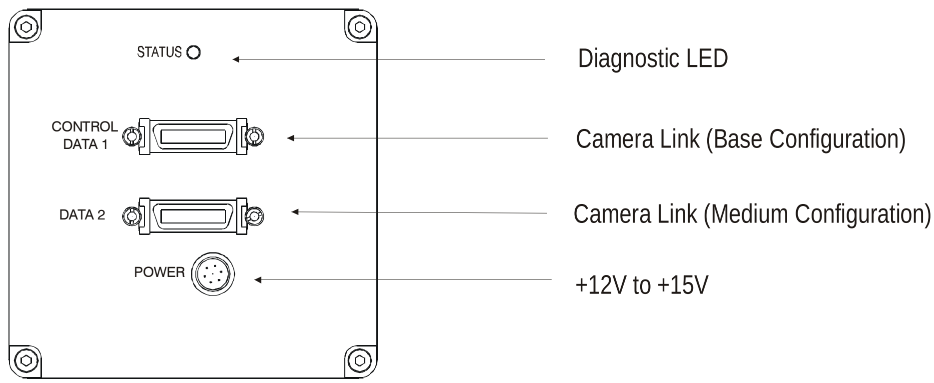
DALSA does not guarantee good imaging performance with low quality cables of **any** length. In general, DALSA recommends the use of high quality cables in lengths less than 10 meters.

2.2 Input/Output Connectors and LED

The camera uses:

- A diagnostic LED for monitoring the camera. See LED Status Indicator in section 2.2.1 LED Status Indicator for details.
- Two high-density 26-pin MDR26 connectors for Camera Link control signals, data signals, and serial communications. Refer to section 2.2.2 Camera Link
- Data Connector for details.
- One 6-pin Hirose connector for power. Refer to section 2.2.3 Power Connector for details.

Figure 6: Input and Output



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 2.2.3 Power Connector.

2.2.1 LED Status Indicator

The camera is equipped with a red/green LED used 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.

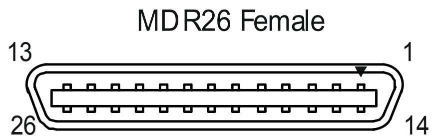
Status LED

Color of Status LED	Meaning
Flashing Green	Camera initialization or executing a time consuming command
Solid Green	Camera is operational and functioning correctly
Flashing Red	Fatal Error. System voltage out of tolerance.
Solid Red	Warning. Loss of functionality (e.g. external SRAM failure)

2.2.2 Camera Link

Data Connector

Figure 7: Camera Link MDR26 Connector



Mating Part: 3M 334-31 series
Cable: 3M 14X26-SZLB-XXX-0LC**

The Camera Link interface is implemented as either Base or Medium configuration in the Falcon 4M cameras.

Select the camera configuration with the `clm` command described in the section Setting the Camera Link Mode.

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, mv.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 MDR26 Connectors
Base	A, B, C	28	1	1
Medium	A, B, C, D, E, F	28	2	2

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

Medium Configuration	Port Definition					
Mode	**Port A Bits 0 thru 7**	**Port B Bits 0 thru 7**	**Port C Bits 0 thru 7**	**Port D Bits 0 thru 7**	**Port E Bits 0 thru 7**	**Port F Bits 0 thru 7**
Mode 15 4 Tap 8 bit	Tap 1 LSB..Bit 7	Tap 2 LSB..Bit 7	Tap 3 LSB..Bit 7	Tap 4 LSB...Bit 7	xxxxxxxx	xxxxxxxx
Mode 16 4 Tap 10 bit	Tap 1 LSB.. Bit 7	Tap 1 Bits 8,9 Tap 2 Bits 8,9	Tap 2 LSB..Bit 7	Tap 4 LSB…Bit 7	Tap 3 LSB…Bit 7	Tap 3 Bit 8,9 Tap 4 Bit 8,9

Camera Link Connector Pinout

Medium Configuration			Base Configuration		
Up to an additional 2 Channel Link Chips			One Channel Link Chip + Camera Control + Serial Communication		
Camera Connector	Right Angle Frame Grabber Connector	Channel Link Signal	Camera Connector	Right Angle Frame Grabber Connector	Channel Link Signal
1	1	inner shield	1	1	inner shield
14	14	inner shield	14	14	inner shield
2	25	Y0-	2	25	X0-
15	12	Y0+	15	12	X0+
3	24	Y1-	3	24	X1-
16	11	Y1+	16	11	X1+
4	23	Y2-	4	23	X2-
17	10	Y2+	17	10	X2+
5	22	Yclk-	5	22	Xclk-
18	9	Yclk+	18	9	Xclk+
6	21	Y3-	6	21	X3-
19	8	Y3+	19	8	X3+
7	20	100 ohm	7	20	SerTC+
20	7	terminated	20	7	SerTC-
8	19	Z0-	8	19	SerTFG-
21	6	Z0+	21	6	SerTFG+
9	18	Z1-	9	18	CC1-
22	5	Z1+	22	5	CC1+
10	17	Z2-	10	17	CC2+
23	4	Z2+	23	4	CC2-
11	16	Zclk-	11	16	CC3-
24	3	Zclk+	24	3	CC3+
12	15	Z3-	12	15	CC4+
25	2	Z3+	25	2	CC4-
13	13	inner shield	13	13	inner shield
26	26	inner shield	26	26	inner shield

Notes:

*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	Window toggle

Input Signals, Camera Link

The camera accepts control inputs through the Camera Link MDR26F connector.

The camera ships in internal sync, internal programmed integration (exposure mode 2), and Camera Link mode 16 (4M60) or 3 (4M30).

IMPORTANT:
Camera readout is triggered on the falling edge of EXSYNC.

EXSYNC

Frame rate can be programmed using the serial interface. The external control signal EXSYNC is optional and enabled through the serial interface. This camera uses the **falling edge of EXSYNC** to trigger frame readout. Section 3.3 Camera Output Format details how to set frame times, exposure times, and camera modes.

Output Signals, Camera Link

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 http://mv.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 8 MSB 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 68.

2.2.3 Power Connector

Figure 8: Hirose 6-pin Circular Male—Power Connector

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).

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 3 A.
- 12 V power supply. Nominal 0.85 A load resulting in ~20 A/s current ramp rate
- Power supply current limit needs to be set at >3 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.

Note: Performance specifications are not guaranteed if your power supply does not meet these requirements. See section 1.3 for power requirements.

WARNING: 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.

Visit the mv.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.

3

Software Interface: How to Control the Camera

All camera features can be controlled through the serial interface. The camera can also be used without the serial interface after it has been set up correctly. Functions available include:

- Controlling basic camera functions such as gain and sync signal source
- Data readout control
- Generating a test pattern for debugging
- The serial interface uses a simple ASCII-based protocol and the camera does not require any custom software.

Serial Protocol Defaults

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 9.6Kbps
- 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>

Setting Baud Rate

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:	• Power-on rate is always 9600 baud. • 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**

Camera Help Screen

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

To view the help screen, use the command:

Syntax:	**h**

The help screen lists all commands available. Parameter ranges displayed are the ranges available under the current operating conditions. The ranges depend on the current camera operating conditions, and you may not be able to enter these values.

Example Help Screen (4M60)

ccf	correction calculate fpn		
clm	camera link mode	m	2/3/15/16/
cpa	correction prnu algorithm	mi	2/4/:1-1023
csn	coefficient set number	i	0-15
css	correction set sample	m	32/64/128/256/512/1024/
dpc	display pixel coefficients	xyxy	1-2352:1-1728:1-2352:1-1728
edc	enable debounce circuit	m	0/1/
efd	enable frame dump	m	0/1/2/
epc	enable pixel coefficients	ii	0-1:0-1
gcm	get camera model		
gcp	get camera parameters		
gcs	get camera serial		
gcv	get camera version		
gfc	get fpn coefficient	xy	1-2352:1-1728

```
gpc   get prnu coefficient          xy      1-2352:1-1728
gsf   get signal frequency          m       1/4/
h     help
lpc   load pixel coefficient
rc    reset camera
rfs   restore factory settings
rpc   reset pixel coefficients
rus   restore user settings
sao   set analog offset             ti      0-0:0-511
sbr   set baud rate                 m       9600/19200/57600/115200/
sdo   set digital offset            ti      0-2:0-2048
sem   set exposure mode             m       2/3/4/6/7/
set   set exposure time             f       492-999989 [us]
sfc   set fpn coefficient           xyi     1-2352:1-1728:0-1023
snd   set number frame dumps        i       1-7
sot   set output throughput         m       260/320/
spc   set prnu coefficient          xyi     1-2352:1-1728:0-12287
ssb   set subtract background       ti      0-2:0-511
ssf   set sync frequency            f       1.0-60.4 [Hz]
ssg   set system gain               ti      0-2:0-65535
svm   set video mode                i       0-12
vt    verify temperature
vv    verify voltages
wfc   write fpn coefficients
wpc   write prnu coefficients
wse   window start end              iixyxy  0-0:1-1:1-1:1-1725:2352-2352:4-1728
wss   window set sequence           i       0-1
wts   window trigger source         m       1/2/
wus   write user settings
OK>
```

Retrieving Camera Settings

To retrieve current camera settings, use the command:

Syntax: **gcp**

3.1 First Power Up Camera Settings

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

PT-41-04M60

- Flat field coefficients enabled (calibrated in exposure mode 2, 55 fps, and an exposure time of 2 ms [non-concurrent readout and integration], snapshot mode 1, number of fast frame dumps = 1)
- Exposure mode 2
- 60 fps

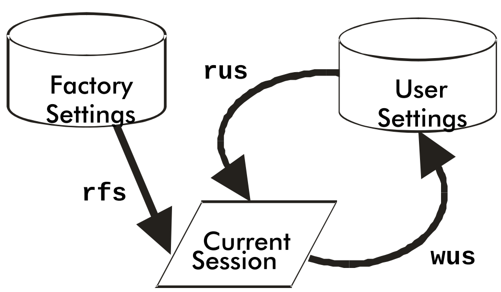
- 9995 µs exposure time
- Camera Link mode 16 (Medium configuration, 4 taps. 10 bits)
- 80 MHz pixel rate (320 MHz total throughput)
- Full window (2352 x 1728)
- Snapshot mode 1 enabled (EFD 1)

PT-21-04M30

- Flat field coefficients enabled (calibrated in exposure mode 2, 29 fps, and exposure time of 2 ms [non-concurrent readout and integration], snapshot mode 1, number of fast frame dumps = 1)
- Exposure mode 2
- 30 fps
- 14992 µs exposure time
- Camera Link mode 3 (Medium configuration, 2 taps. 10 bits)
- 80 MHz pixel rate (160 total throughput)
- Full window (2352 x 1728)
- Snapshot mode 1 (EFD 1)

3.2 Saving and Restoring Settings

Figure 9: Saving and Restoring Overview



Factory Settings

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

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

User Settings

You can save or restore your user settings to non-volatile memory using the following 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 where **csn** is pointing to. Example:

csn 10 (and choose coeff set 10)

wus

rc or power cycle

Coefficients from **csn 10** are restored

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**.

3.3 Camera Output Format

3.3.1 How to Configure Camera Output

The 4M Falcon cameras offer great flexibility when configuring your camera output. Using the **clm** 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 rate. These two commands work together to determine your final camera output configuration.

4M30 Data Readout Configurations

Camera Link Mode Configuration (Controlled by clm command)				Pixel Rate Configuration (Controlled by sot command)
Command	**Camera Link Configuration**	**Camera Link Taps**	**Bit Depth**	
clm 2	Base	2 Camera Link taps where: 1 = Taps 1+3 2 = Taps 2+4	8	**sot 130** = 65 MHz strobe **sot 160** = 80 MHz strobe
clm 3	Base	2 Camera Link taps where: 1 = Taps 1+3 2 = Taps 2+4	10	**sot 130** = 65 MHz strobe **sot 160** = 80 MHz strobe

4M60 Data Readout Configurations

Camera Link Mode Configuration (Controlled by clm command)				Pixel Rate Configuration (Controlled by sot command)
Command	**Camera Link Configuration**	**Camera Link Taps**	**Bit Depth**	
`clm 2`	Base	2 Camera Link taps where: 1 = Taps 1+3 2 = Taps 2+4	8	**`sot 130`** = 65 MHz strobe **`sot 160`** = 80 MHz strobe
`clm 3`	Base	2 Camera Link taps where: 1 = Taps 1+3 2 = Taps 2+4	10	**`sot 130`** = 65 MHz strobe **`sot 160`** = 80 MHz strobe
`clm 15`	Medium	4 Camera Link taps where: 1 = Tap 1 2 = Tap 2 3 = Tap 3 4 = Tap 4	8	**`sot 260`** = 65 MHz strobe **`sot 320`** = 80 MHz strobe
`clm 16`	Medium	4 Camera Link taps where: 1 = Tap 1 2 = Tap 2 3 = Tap 3 4 = Tap 4	10	**`sot 260`** = 65 MHz strobe **`sot 320`** = 80 MHz strobe

3.3.2 Setting the Camera Link Mode

Purpose: Sets the camera's Camera Link configuration, number of Camera Link taps and data bit depth. Refer to the tables above for a description of each Camera Link mode.

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

15: Medium configuration, 4 taps, 8 bit output (4M60 only)

16: Medium configuration, 4 taps, 10 bit output (4M60 only)

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`**

3.3.3 Setting the Camera Link Strobe Frequency

Purpose:	Sets the camera link strobe frequency. Refer to the How to Configure Camera Output section, above, for a description of how camera link strobe frequency relate to the camera's Camera Link mode.
Syntax:	**sot** ***m***
Syntax Elements:	***m*** If using Camera Link mode 2 or 3: **130**: 65 MHz camera link strobe with a total throughput of 130 MHz **160**: 80 MHz camera link strobe with a total throughput of 160 MHz If using Camera Link 15 or 16 (4M60 only): **260**: 65 MHz camera link strobe with a total throughput of 260 MHz **320**: 80 MHz camera link strobe with a total throughput of 320 MHz
Notes:	• To retrieve the current throughput, use the command **gcp** or **get sot.**
Example:	**sot 260**

3.4 Setting Exposure Mode, Frame Rate and Exposure Time

Overview

You have a choice of operating in one of three exposure modes. To select how you want the camera's frame rate to be generated:

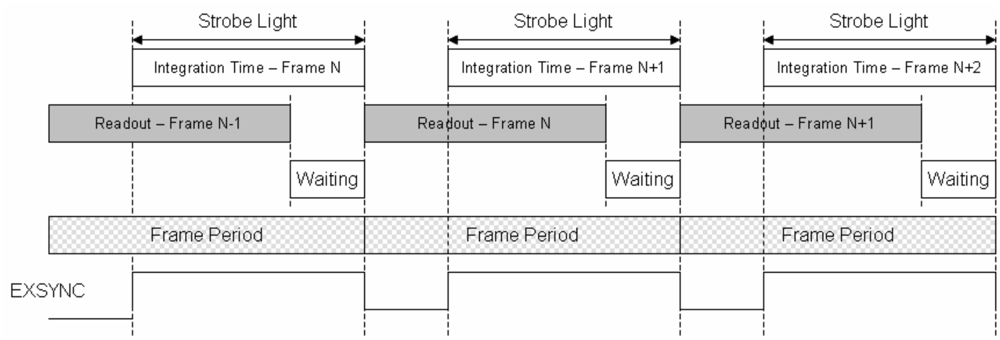
1.	You must first set the camera's exposure mode using the **sem** command.
2.	Next, if operating in exposure mode 2 use the command **ssf** to set the frame rate and the **set** command to set the exposure time if in exposure mode 2 or 6.

3.4.1 Non-concurrent vs. concurrent modes of operation

One of the main benefits of global shutter CMOS devices is that you have the choice to operate the camera where integration and readout are concurrent or where integration and readout are not concurrent. Integration refers to 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 60 fps camera, such as the Falcon 4M60, the readout period is around 16.6 ms.

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 4M60 camera is capable of reaching 60fps. A timing diagram helps to explain this mode of operation.

Concurrent Mode Timing Diagram

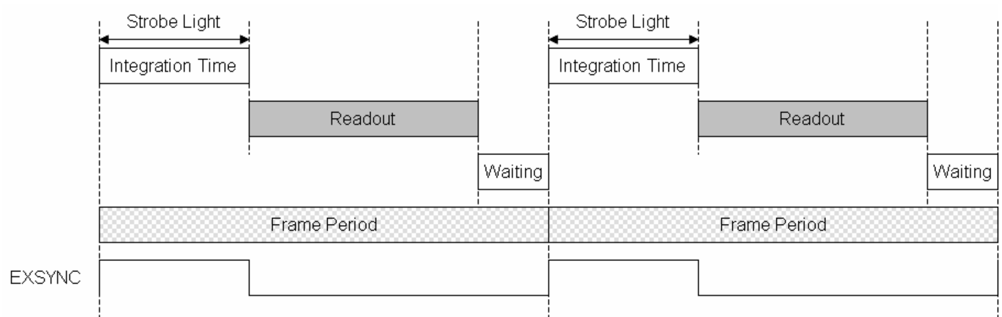


In concurrent mode, a low-to-high transition in the EXSYNC signal starts the integration time, and a high-to-low transition in the EXSYNC signal starts the readout of image data. As your frame period approaches the readout period, by reducing the Waiting time, the Falcon 4M60 camera approaches its maximum frame rate of 60 fps.

In non-concurrent mode the integration and readout period do not overlap. While this does impact your overall frame rate, the main benefit is that in non-concurrent mode you eliminate or minimize imaging artifacts. DALSA recommends that, when possible, operate the 4M60 camera in non-concurrent mode.

A timing diagram helps to explain the non-concurrent mode operation.

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 16.6 ms.

3.4.2 Setting the Exposure Mode

Purpose:	Sets the camera's exposure mode allowing you to control your sync, exposure time, and frame rate generation.
Syntax:	**sem** ***m***
Syntax Elements:	**m** Exposure mode to use. Factory default setting is 2.
Notes:	• Refer to • Exposure Modes for a quick list of available modes or to the following sections for a more detailed explanation. • To obtain the current value of the exposure mode, use the command **gcp**.
Related Commands:	**ssf**, **set**
Example:	**sem 4**

Exposure Modes

Mode	SYNC	Programmable Frame Rate	Programmable Exposure Time	Description
2	Internal	Yes	Yes	Internal frame rate and exposure time.
4	External	No	No	Smart EXSYNC.
6	External	No	Yes	EXSYNC pulse controlling the frame rate. Programmed exposure time.

Exposure Modes in Detail

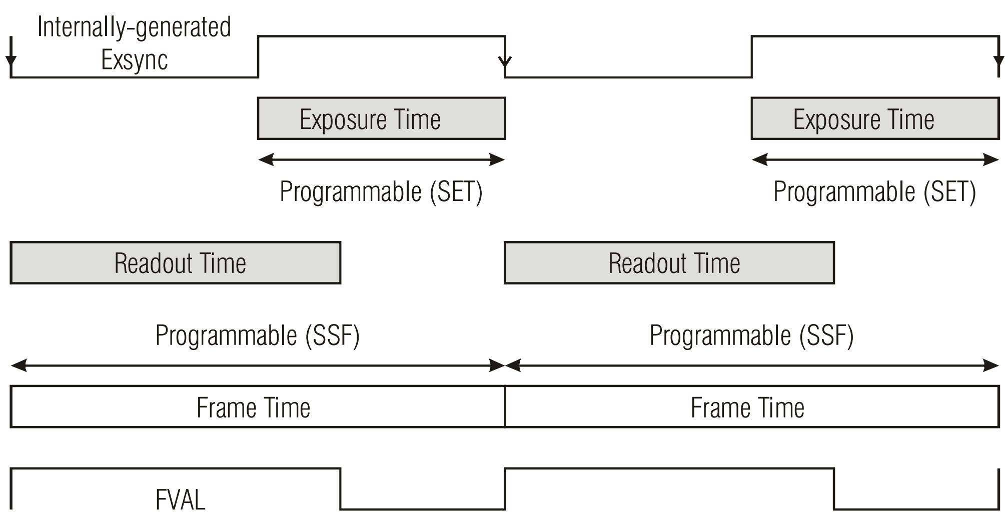
Mode 2: Internally Programmable Frame Rate and Exposure Time (Default)

The parameter being programmed (i.e. 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.

Refer to Allowable Exposure Time Increments on page 32 for details on minimum exposure time increments for this mode.

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

Figure 10: Mode 2.

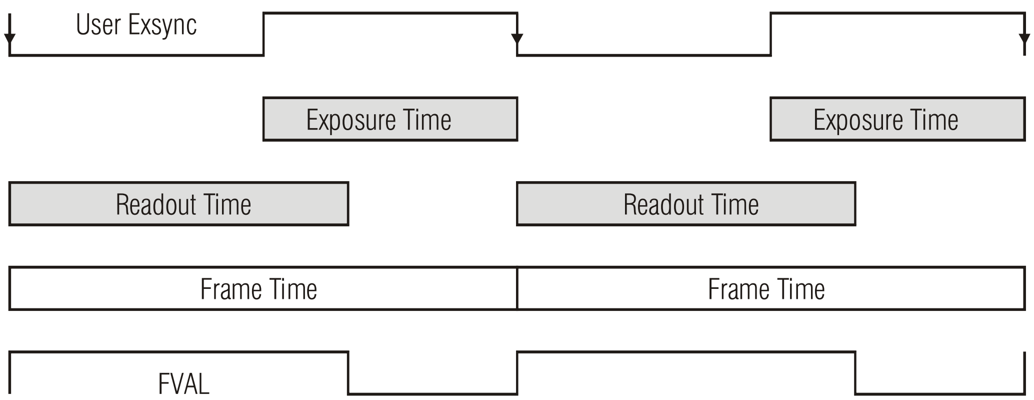


Mode 4: Smart EXSYNC, External Frame Rate and Exposure Time

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.

Refer to the Allowable Exposure Time Increments table on page 32 for details on minimum exposure time increments for this mode.

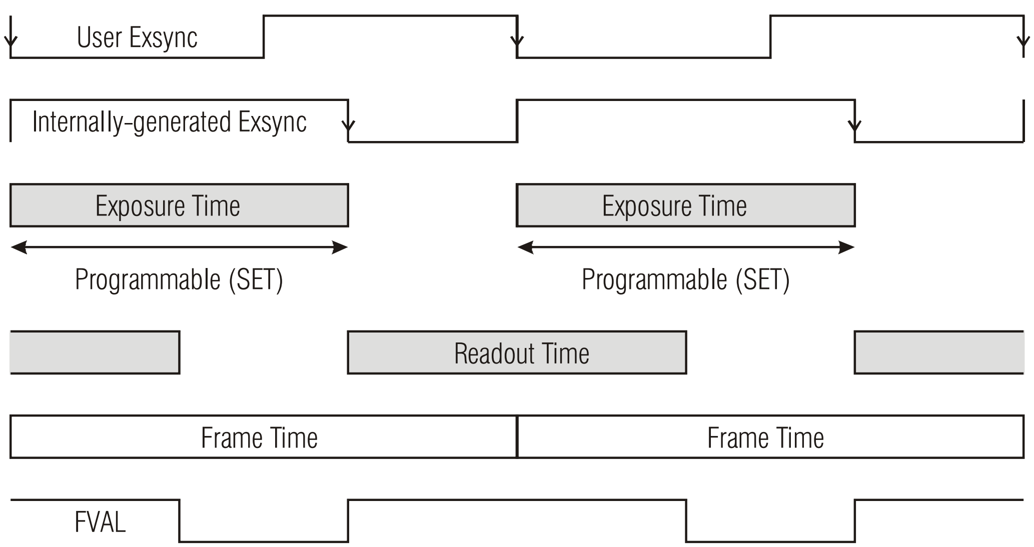
Figure 11: Mode 4.



Mode 6: External Frame Rate, Programmable Exposure Time

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

Figure 12: Mode 6.



3.4.2 Setting the Frame Rate

Purpose: Sets the camera's frame rate in frames per second (Hz).

Syntax: **`ssf f`**

Syntax Elements: ***f***

Set the frame rate in Hz in a range from **`1-60.4`** (4M60 full frame, 80 MHz cameralink strobe, efd 1) or **`1-30.6`** (4M30 full frame, 80 MHz cameralink strobe, efd 1). Range increases when using a vertical window of interest.

Notes:

- Camera must be operating in exposure mode 2.
- Allowable range is dependent on the current Camera Link mode, snapshot mode, number of fast frame dumps and window size. Refer to section above for more information on Camera Link modes. Refer to section 3.5 for more information on setting a window size.
- Changing the frame rate will automatically adjust the exposure time if necessary. The camera sends a warning when this occurs.
- Refer to section 3.3.3 Setting the for more information on how to set the cameralink strobe.
- When in SEM 2, the help screen (h) will shown the limits for SSF

Related Commands: **`sem`**, **`set`**

Example: **`ssf 25.0`**

3.4.3 Setting the Exposure Time

Purpose: Sets the camera's exposure time in µs.

Syntax: **`set f`**

Syntax Elements: ***f***

Floating point number in µs. Allowable range is 10-999989 µs. The following table lists allowable increments.

Notes:

- Camera must be operating in exposure mode 2.
- To retrieve the current exposure time, use the command **`gcp`**.
- If you enter an exposure time outside of a valid range, the input will not be accepted. Refer to the help screen (**`h`** command) for the valid range.
- 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 (only in sem 2). The camera adjusts the exposure without warning. Refer to Allowable Exposure Time Increments.
- Changing the exposure time will automatically adjust the frame rate if necessary. The camera sends a warning when this occurs.

Related Commands: **`sem`**, **`ssf`**, **`clm`**

Example: **`set 5500`**

Allowable Exposure Time Increments

Camera Link Mode (clm command)	Allowable Exposure Time Increments	
15 or **16**		
	18.513 µs (80/65 MHz camera link strobe)	when exposure time overlaps frame readout
	1 µs	when exposure time **does not** overlap frame readout
2 or **3**		
	37.038 µs (80 MHz camera link strobe) 45.638 µs (65 MHz camera link strobe)	when exposure time overlaps frame readout
	1 µs	when exposure time **does not** overlap frame readout

Note: Although you must be operating the camera in exposure mode 2 to use the set exposure time (**set**) command, the allowable exposure time increments listed above also apply to exposure mode 4 (Smart EXSYNC) or 6 when exposure time overlaps frame readout. This is because, in exposure mode 4, the falling edge is captured by the camera every 18.513 µs for example in the case of **clm 15** or **16, sot 320**. In exposure modes 4 or 6 the exposure time effectively has an uncertainty of the allowable time increment.

Refer to section 3.4 Exposure Correction for more information on the **clm** and **sot** (sets pixel rate) commands.

Refer to section Figure 10: Mode 2 on page 29 for an example where exposure time overlaps frame readout.

3.4.4 Enabling EXSYNC Debounce Circuit

Purpose:	When enabled, the camera does not respond to any pulses on the Exync input smaller than 1uS. The camera ships with this feature disabled.
Syntax:	**edc *i***
Syntax Elements:	***i*** EXSYNC debounce. **0** = EXSYNC debounce disabled **1** = EXSYNC debounce enabled
Notes:	▪ When disabled, the camera responds to the User EXSYNC input the same as previous camera versions (00-R and non-RoHS).
Example:	**edc 1**

3.5 Snapshot Modes

Purpose:	Optimizes camera timing for specific EXSYNC situations.
Syntax:	**efd *i***
Syntax Elements:	***i***
	Snapshot mode. **0** = Snapshot mode 0 (off) **1** = Snapshot mode 1 2 = Snapshot mode 2
Notes:	▪
Example:	**efd 1**

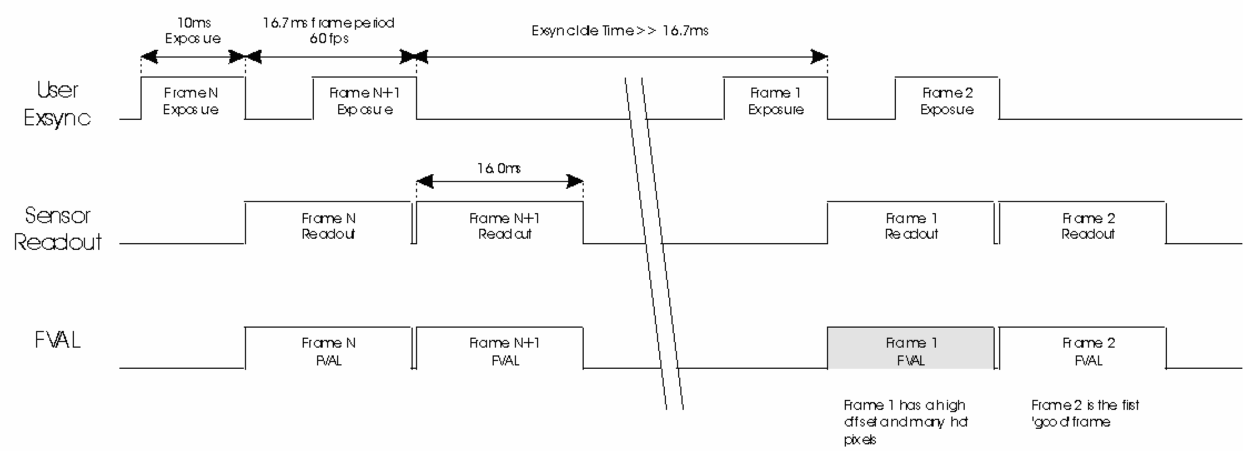
Snapshot Mode

The Falcon 4M60 and Falcon 4M30 cameras include a feature called Snapshot Mode. Snapshot Modes 1 and 2 allow the camera to produce usable images when intervals between EXSYNCs are large (>200 ms).

Previously only snapshot mode 0 was available (no fast frame dump) which would eventually result in a completely saturated 'first' image after a very long EXSYNC idle period (seconds), as shown below.

First Frame Elevated Offset - efd 0

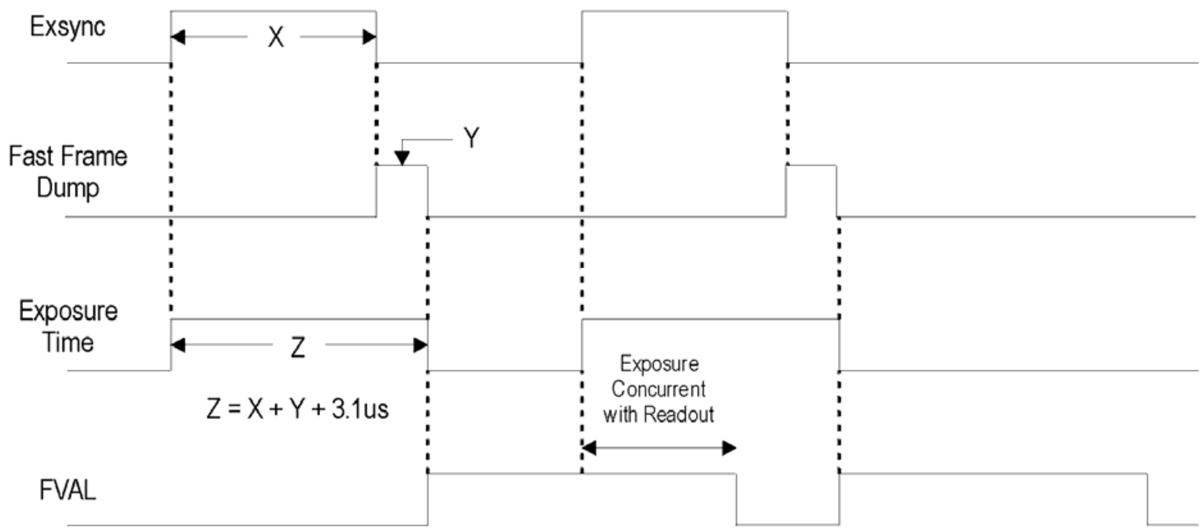
sem 4, External EXSYNC and exposure (smart EXSYNC)



By altering the internal timing, Snapshot Mode 1 performs a fast clearing of a frame concurrently with integration. Thus, any dark current that caused elevated dark offset levels, FPN or hot pixels, is cleared from the sensor prior to readout. The end result is that the camera produces a usable first image.

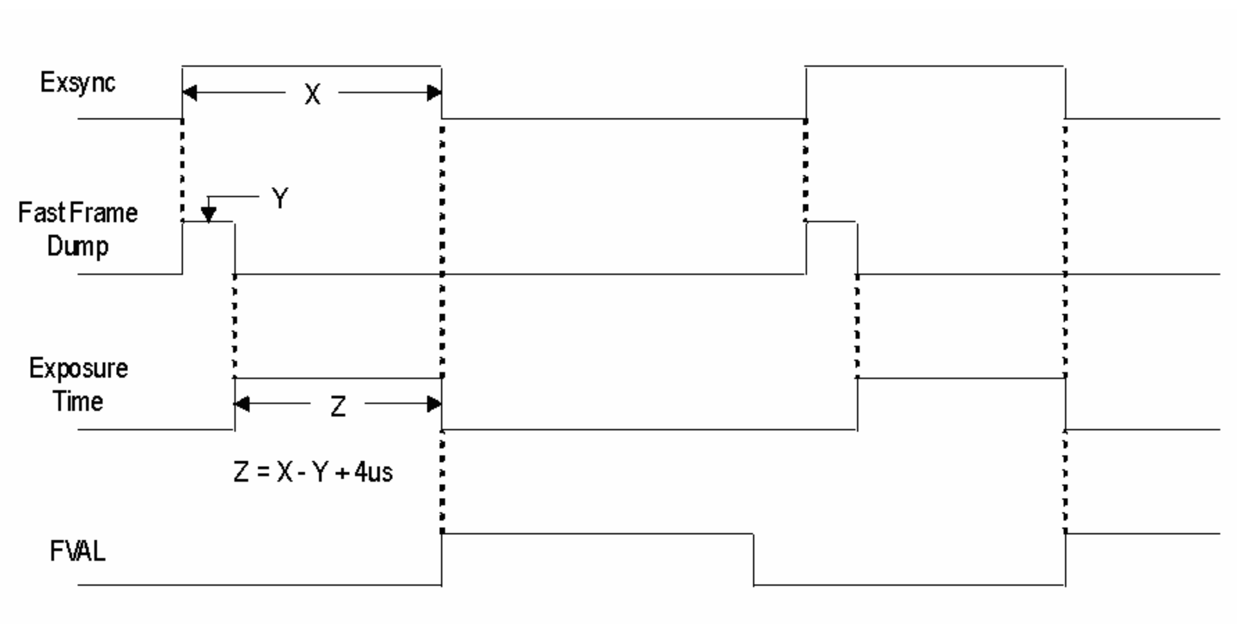
With Snapshot Mode 1, please note that the timing of EXSYNC with respect to the integration time has changed. The figure below illustrates Snapshot Mode 1 timing. The difference is that the Integration Time, Z, is now equal to the EXSYNC high time, X, plus the time it takes to clear the image, Y (plus 3.1 us of additional overhead). The total time to clear the frame is Y (approximately 500 us). Therefore, the minimum integration time in Snapshot Mode 1 is Y + 3.1 us. The exact value of Y is listed in the **gcp** screen as DUMP TIME.

Snapshot Mode 1. Exposure concurrent with readout is allowed



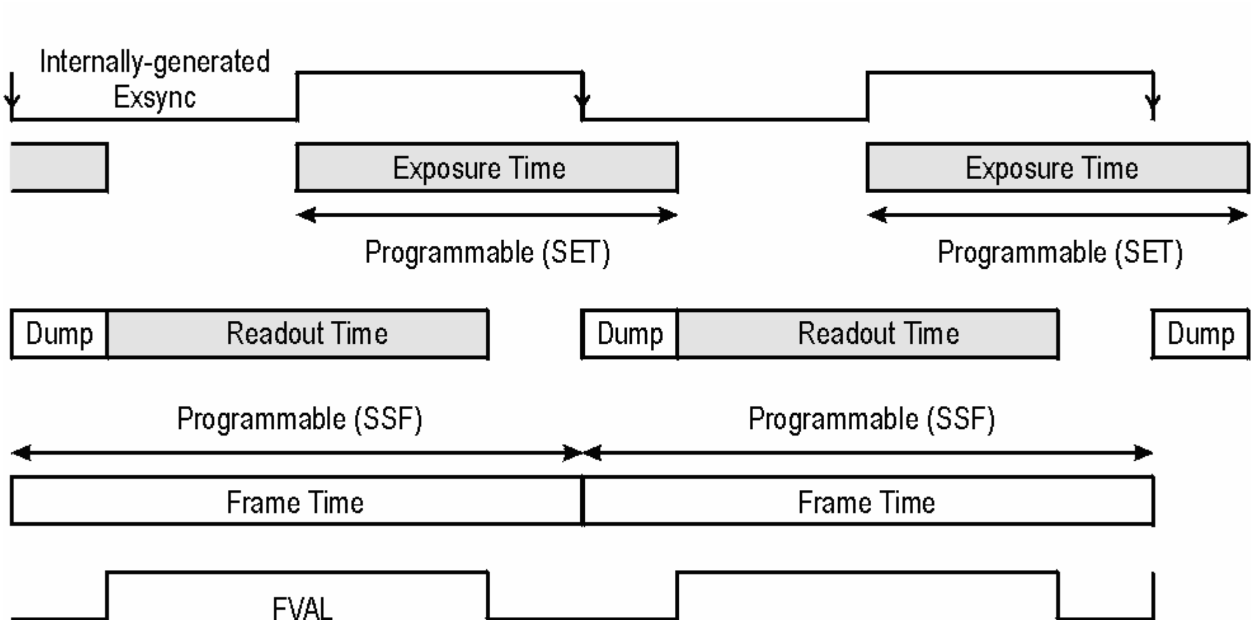
If, having a minimum integration time of about 500 us is not acceptable, then Snapshot Mode 2 can be used, below, which allows for integration times as low as 10 us at the expense of concurrent integration and readout. Therefore, it is recommended to only use Snapshot Mode 2 if your integration time must be below 500 us. This is also the reason why Snapshot Mode 1 is the default mode. The following figure shows the timing operation of Snapshot Mode 2. Notice that with Snapshot Mode 2 there is a delay of Y between the rise of integration and when exposure begins.

Snapshot Mode 2. Exposure concurrent with readout is NOT allowed

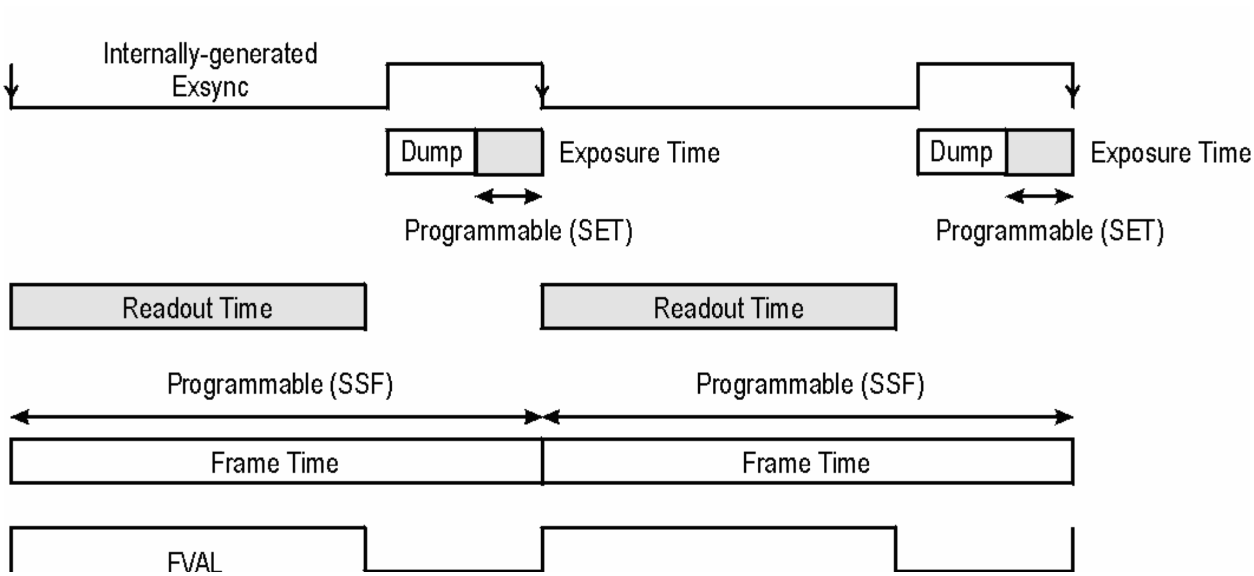


The following timing diagrams show how the timing changes when snapshot modes are enabled in **sem 2**.

sem 2, Snapshot Mode 1 (fast frame dump at falling edge of EXSYNC)



sem 2,. Snapshot Mode 2 (fast frame dump at rising edge of EXSYNC)



Determining the Y parameter

As mentioned, the Y parameter is around 500 us. The Y parameter depends upon the number of rows used, whether the camera outputs at 80 MHz or 65 MHz, and whether the camera being used is in 2 tap mode (Falcon 4M30) or 4 tap mode (Falcon 4M60). To obtain the Y parameter, execute the **`gcp`** command. The camera should respond and state:

"Frame Dump Time: 487.5 us".

The 487.5 us used here represents the Y parameter for the factory settings of the Falcon 4M60.

What do I do if I cannot use either Snapshot Mode?

DALSA recommends that the camera is operated using a Snapshot Mode. However, in some cases this may not be possible. Therefore, the camera can be setup to disable Snapshot Mode (**`efd 0`**) and return the camera to the mode used prior to the introduction of Snapshot Mode.

Different snapshot modes will produce different FPN and possibly different PRNU patterns. The user is encouraged to match the snapshot mode with their corresponding coefficients. This camera has 16 sets of coefficients, 8 factory and 8 user:

CSN	EFD
0, 3, 8, 11	1
1, 4, 9, 12	0
2, 5, 10, 13	2
6, 14	All coefficients = 0
7, 15	FPN/PRNU Test Pattern

FPN and PRNU coefficients for set 0 (**`csn 0`**) were calculated with EFD 1 and set 1 with EFD 0 as shown above, etc. Set 6 has all coefficients set to 0/1 (FPN / PRNU) and set 7 has coefficients calculated from test patterns SVM 7 and 8. Sets 8 to 15 are user-writable sets which mirror their factory counterparts as shown above.

Example:

- The user changes from snapshot mode 1 to 0.
- In order to load the appropriate coefficients we must first point to the right set by sending **`csn 1`**.
- The coefficients need to be then loaded into volatile memory by sending **`lpc`**.
- If the user wishes to load **`csn 1`** on camera power-up then these settings should be saved by sending **`wus`**.

Set Number of Frame Dumps

Purpose:	Sets the number of fast-frame dumps to be used within snapshot modes 1 or 2.
Syntax:	**snd *i***
Syntax Elements:	***i*** Set number of frame dumps. **1-7**
Notes:	Only enabled during Snapshot modes (**efd**) 1 or 2.
Example:	**snd 3**

When within snapshots modes 1 and 2 the user can choose to perform more than one fast frame dump during a dump sequence. In some cases increasing the number of fast frame dumps may help reduce the small residuals left behind after long EXSYNC idle times. In general the user is recommended to use the factory default setting: **snd 1**.

Note that increasing the number of dumps will decrease the maximum frame rate that can be achieved (this can be queried using the help screen in **sem 2**)..

3.6 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.

To allow quick activation of new window coordinates, the camera allows you to preset one sequence of window coordinates. These coordinates wait for a trigger and because they have been preprogrammed, the new window is activated extremely quickly.

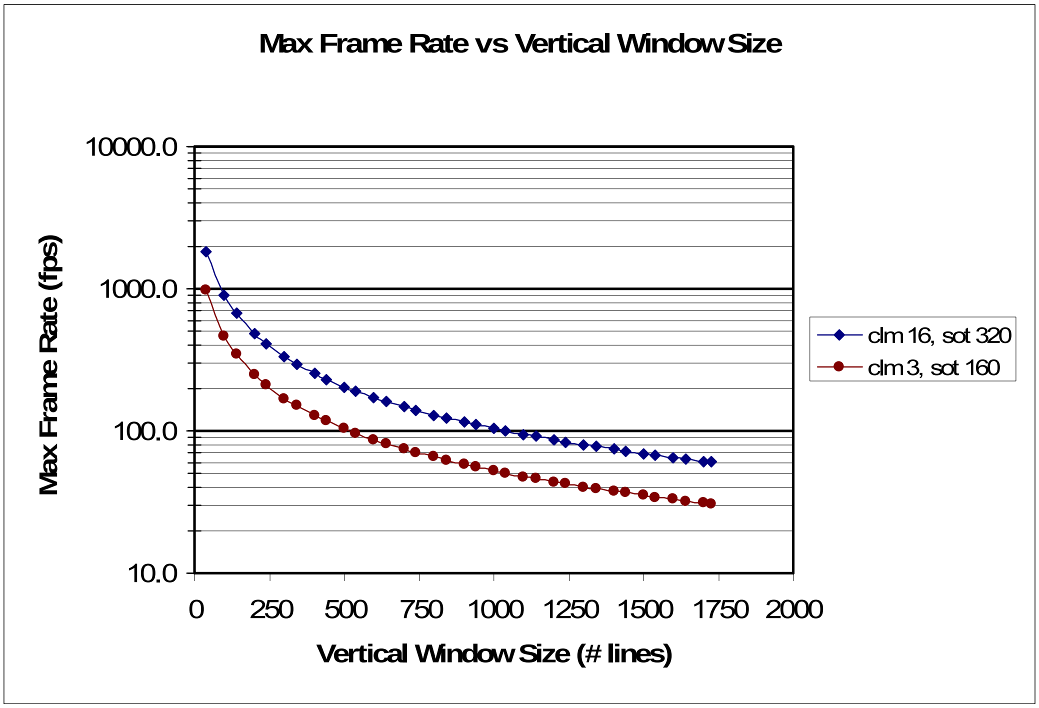
To set a window of interest

1. Set the window activation method— either software activated (**wts 1**) or hardware activated through CC4 (**wts 2**).
2. Set the window coordinates, using the command **wse 0 1 x y x y**.
3. Activate the window coordinates by:
   - o transitioning CC4 to its complementary logic state when using an external window control source (**wts** = **2**) .

     or
   - o transitioning to **wss 0** or **wss 1** depending on the complementary logic state when using an internal window control source (**wts** = **1**).
4. When, or if, necessary, repeat steps 2 and 3 to set and activate a new window.

The following graph illustrates the relationship of maximum frame rate versus sequence size.

Figure 14: Maximum Frame Rate versus Sequence Size (`efd 1, snd 1`)



Window Start End Command

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 start corner value. Since there is only a vertical (and not horizontal) window of interest in this camera, this value is always set to **`1`**.

y1

Window start pixel number in a range from **`1-1725`** and must belong to the following set: 1, 5, 9, …1725.

x2

Window end corner value. Since there is only vertical (and not horizontal) window of interest in this camera, this value is always set to **2352**.

y2

Window end pixel number in range from **2-1728** and must belong to the following set: 4, 8, 12, …1728.

Related Commands: **wss**, **wts**

Example: **wse 0 1 1 13 2352 544**

Table 1: Line Time and Frame Readout Time when using a Window of Interest

A rough estimate of the frame readout time, when using a large (100 lines+) window of interest, can be found using the following formula:

Frame Readout Time= (Number of Lines + 1) x Sensor Line Time

Where Sensor Line Time = 18.5us @ **CLM 15/16, SOT 320/260**

= 37.0us @ **CLM 2/3, SOT 160**

= 45.6us @ **CLM 2/3, SOT 130**

Setting the Window Sequence

Purpose: To allow quick activation of new window coordinates, the camera allows you to preset one sequence of window coordinates. These coordinates wait for a trigger and because they have been preprogrammed, the new window is activated extremely quickly.

This command sets the control method for toggling window sequences.

Syntax: **wts *i***

Syntax Elements: ***i***

1 New window sequence is triggered through software command **wss**.

2 New window sequence is triggered through Camera Link inputs (CC4).

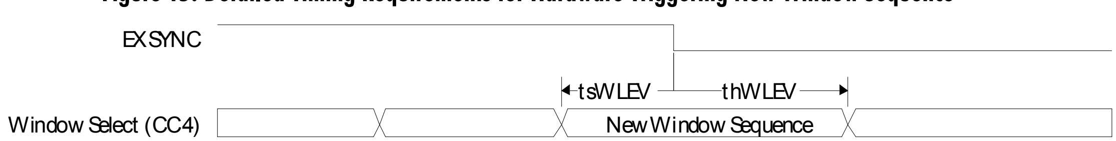
Related Commands: **wss**

Example: **wts 2**

Notes:

- If you are using a hardware trigger (**wts = 2**), refer to Figure 15 for timing requirements.
- If you are using a software trigger, refer to the next section for command syntax and timing requirements.

Figure 15: Detailed Timing Requirements for Hardware Triggering New Window Sequence



Timing Parameters

Symbol	Definition	Min	Max
thWLEV	Window Level Hold Time- The Window Control Signals must remain valid and constant after the EXSYNC falling edge for at least the thWLEV time.	3 EXSYNCs	NA
tsWLEV	Window Level Set Time- The Window Control Signals must remain valid and constant at least tsWLEV before the EXSYNC falling edge.	3 EXSYNCs	NA

Toggling Window Sequences Using a Software Trigger

Purpose: To allow quick activation of new window coordinates, the camera allows you to preset one sequence of window coordinates. These coordinates wait for a trigger and because they have been preprogrammed, the new window is activated extremely quickly.

This command loads a new window sequence.

Syntax: **`wss`** ***`m`***

Syntax Elements:

`m`

Window sequence trigger where changing from **`0`** to **`1`** (or vice versa) toggles the current window sequence being used.

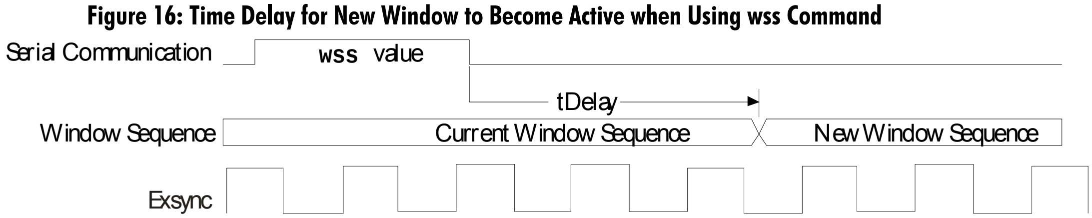
Related Commands: **`wts`**

Example: **`wss 0`**

Notes:

- There is a delay between the issue of the **`wss`** command and the time when the new window sequence is triggered (Figure 16)
- When toggling windows, the camera discards the first frame read out after the toggle. This prevents the camera from sending out erroneous data.
- Upon power up or reset of camera, the camera assumes that a **`wss 0`** has already been executed

Figure 16: Time Delay for New Window to Become Active when Using wss Command



Timing Parameters

Symbol	Definition	Min	Max
tDelay	This is the time delay that occurs to decode the **`wss`** command.	1 EXSYNC	3 EXSYNCs

3.7 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

Correction is implemented such that for each pixel:

V_{output} =[(V_{input} - FPN(pixel) - digital offset) * PRNU(pixel) – Background Subtract] x 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 (the factory temp is about 37°C, `vt` command). In snapshot mode 1, FPN coefficients are not particularly sensitive to changes in frame rate or integration time. In snapshot modes 0 and 2, FPN coefficients will be sensitive to changes in frame rate.

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

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.

For best results, ensure that:

1) 60 Hz ambient light flicker is sufficiently low not to affect camera performance and calibration results.

2) The average pixel should be at least 25% below the target output. If the target is too close, then some pixels may not be able to reach full swing (1023 DN) due to correction applied by the camera.

3) 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. If you change this value, it is recommended that you recalculate your coefficients.

Let's go through a flat field calibration example:

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

2) 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 4096**) and background subtract to 0 (**ssb 0 0**) as these are the defaults during FFC calibration.

3) Place the camera in the dark and send CCF, this performs the FPN correction and automatically save 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. This is important on the 4M60/30 due to the large dark offset values.

5) Illuminate the sensor, such that with EPC 1 0, it reaches 50-70% saturation.

6) Send **cpa 2 T** where T is typically 1.3X the average output level. This is important since if the target is too low (<1.1X), then some pixels may not be able to reach full swing (1023 DN) due to corrections applied by the camera.

Here is the factory calibration procedure for Snapshot Mode 1 (**efd 1**):

1) The camera is placed in **sem 2**, **sot 320**, **clm 16**, **efd 1**, **snd 1**, full window, **ssg 0 4096**, **ssb 0 0**, **sao 0 0**, **ssf 55**, **set 2000**. This last part is important, **ssf 55** and **set 2000** assures that the camera is in non-concurrent mode. In non-concurrent mode, readout and integration do not overlap thus eliminating some residual artifacts associated with concurrent mode.

2) The camera is placed in the dark and **ccf** is run

3) With **epc 1 0** the sensor is illuminated (Light Source: Broadband Quartz Halogen, 3250K, with a 750 nm cutoff filter) with a light level of 22.8 W/cm². This ensures each camera will have the same responsivity since the light level and target value are always the same. Typical output levels for the camera at this light level are 650.

4) The sensor window at this point has been cleaned thoroughly such that there are no significant blemishes present.

5) Send **cpa 2 840**. Typically this yields an average PRNU coefficient of about 1.3X.

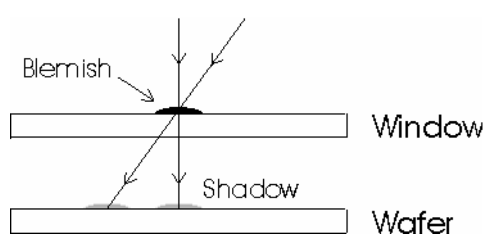
6) How can one match gain and offset values on multiple cameras?

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):

1) Starting from factory settings (**`sao 0 0, ssg 0 4096, 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.
2) Increase the offset (camera in dark) on all cameras (**`sao`** command) until they are the same and reach at least 4 DN (10 bit).
3) Illuminate to about 80% saturation (820 DN, 10 bit) and note the highest signal level among the set of cameras.
4) Increase the digital gain (**`ssg`**) on the cameras until they all reach the same output level (highest of all cameras).
5) Place camera in the dark and repeat step 2 to 4 until both dark offset and 80% sat signal levels are equal on all cameras.

An important note on window blemishes:

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



3.7.1 Selecting Factory or User Coefficients

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 number to use.

0-7 = Factory calibrated sets of FPN and PRNU coefficients. These coefficients cannot be erased or modified.

8-15 = User calibrated sets of FPN and PRNU coefficients. These coefficients **can** be deleted or modified.

Notes:

- The camera ships with factory calibrated FPN and PRNU coefficients saved to sets as follows:

CSN	EFD
0, 3, 8, 11	1
1, 4, 9, 12	0
2, 5, 10, 13	2
6, 14	All coefficients = 0
7, 15	FPN/PRNU Test Pattern

- When you first boot up the camera, the camera operates using set 8 (**csn 8**) enabled.

Example: **csn 0**

3.7.2 Enabling Pixel Coefficients

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 *i i***

Syntax Elements: ***i***

FPN coefficients.

0 = FPN coefficients disabled

1 = FPN coefficients enabled

i

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 0 1**

3.7.3 Selecting the Calibration Sample Size

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 lines to sample. Allowable values are **`32`**, **`64`**, **`128`** (factory setting), **`256`**, **`512`**, or **`1024`**.
Notes:	▪ To return the current setting, use the **`gcp`** command.
Example:	**`css 1024`**

3.7.4 Performing FPN Calibration

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 in order to obtain a 0DN output in the dark. Analog offset should therefore be set to 0 since it gets subtracted out during CCF. ▪ Set the digital gain (**`ssg`**) to X1 since during calibration it gets forced to X1 ▪ Perform FPN correction before PRNU correction. ▪ The **`ccf`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0-7`**). You must select the user coefficient set (**`csn 8-15`**) before you can perform FPN calibration. An error message is returned if you attempt to perform FPN calibration when using **`csn 0-7`**.
Example:	**`ccf`**

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 **2352**.

y

The pixel row number from **1** to **1728**.

i

Coefficient value in a range from **0** to **1023**.

Notes:

- The **sfc** command is not available when the camera is using the factory calibrated coefficients (**csn 0-7**). You must select the user coefficient set (**csn 8-15**) before you can perform FPN calibration. An error message is returned if you attempt to perform FPN calibration when using **csn 0-7**.

Example: **sfc 10 50**

3.7.5 Performing PRNU Calibration

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. Using 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 *x y***

Syntax Elements: ***x***

PRNU calibration algorithm to use:

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

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

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 greater than 1.2X than the average signal level when FPN correction is enabled (EPC 1 0). This is to ensure that full signal swing can be reached for most pixels.

y

Peak target value in a range from 1 to 1023DN. The target value must be greater than the current peak output value. If some pixels are below the target value then the PRNU coefficients for said pixels will be set to 1X (ie. PRNU coefficients can never be less than 1X). Similarly the maximum PRNU coefficient is 4X, if more is needed it will clip at 4X.

Notes:

- 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. FPN calibration is highly recommended, the use of SDO is not.
- The **cpa** command is not available when the camera is using the factory calibrated coefficients (**csn 0-7**). You must select the user coefficient set (**csn 8-15**) before you can perform PRNU calibration. An error message is returned if you attempt to perform PRNU calibration when using **csn 0-7**.

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 **2352**.

y

The pixel row number from **1** to **1728**.

i

Coefficient value in a range from **0** to **12287** where

PRNU multiplier = $1 + \left(\frac{i}{4096}\right)$

Notes:

- The **spc** command is not available when the camera is using the factory calibrated coefficients (**csn 0-7**). You must select the user coefficient set (**csn 8-15**) before you can perform PRNU calibration. An error message is returned if you attempt to perform PRNU calibration when using **csn 0-7**. To return the current **csn** number, send the command **get csn**.

Example: **`spc 10 50 500`**

3.7.6 Saving, Loading and Resetting Coefficients

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 0-7**). You must select the user coefficient set (**csn 8-15**) before you can perform PRNU calibration. An error message is returned if you attempt to perform PRNU calibration when using **csn 0-7**. 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 0-7**). You must select the user coefficient set (**csn 8-15**) before you can save FPN coefficients. An error message is returned if you attempt to save FPN coefficients when using **csn 0-7**. 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 and stores said coefficients to non-volatile memory.

Syntax: **`rpc`**

Notes:

- The **`rpc`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0-7`**). You must select the user coefficient set (**`csn 8-15`**) before you can reset pixel coefficients. An error message is returned if you attempt to reset pixel coefficients when using **`csn 0-7`**. To return the current **`csn`** number, send the command **`get csn`**.

3.7.7 Returning Pixel Coefficient Information

Returning FPN and PRNU Coefficients

Purpose: Returns all the current pixel coefficients in the order FPN, PRNU, FPN, PRNU… for the range specified by the ***x*** and ***y*** coordinates. The camera also returns the pixel number with every fifth coefficient.

WARNING: Do not display all pixel coefficients at one time. Keep the number of pixels small (a sample size of 10 x 10 pixel is recommended) to avoid waiting too long for the camera to return information. Coefficient output can be halted by sending any character (hitting any key on the keyboard).

Syntax: **`dpc x1 y1 x2 y2`**

Syntax Elements:

x1

Start column pixel to display in a range from **1** to **2352**.

y1

Start row pixel to display in a range from **1** to **1728**.

x2

End column pixel to display in a range from **1** to **2352**.

y2

End row pixel to display in a range from **1** to **1728**.

Example: **`dpc 10 30 20 40`**

3.8 Offset and Gain Adjustments

Setting Analog Offset

Purpose:	Sets the analog offset.
Syntax:	**`sao`** ***`t i`***
Syntax Elements:	***`t`*** Tap selection. Allowable value is **`0`** for all taps. ***`i`*** Analog offset value. Extreme range is **`0`** - **`511`** but dynamic range is dependent of the camera's current exposure mode and gain settings. A value of 100 does not equal an offset of 100DN.
Notes:	• When flat field correction is enabled the expectation is that in the dark the signal level is 0DN. Some users might required a non-zero dark output. This can be achieved by increasing analog offset. • Take care not to increase SAO too much with FFC enabled, otherwise a PRNU-induced FPN pattern will result. Keep the dark offset below 5 DN (10 bit). • The offset increases linearly with higher values. • Entering a large value offset will cause the camera to digitally saturate the output image. • The resulting analog offset value depends on other camera parameters such as temperature, frame rate, and exposure mode. • The upper input limit of the offset remains the same regardless of the exposure mode
Example:	**`sao 0 20`**

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 as set system gain **`ssg`**.

Subtracting Background

Purpose: Use the background subtract command if you want to improve your image in a low contrast scene. It 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

Sensor tap selection. Allowable range is **1** to **2**, or **0** for all taps.

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.

Related Commands: **ssg**

Example `ssb 0 25`

Setting Digital System Gain

Purpose:

1) 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:

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

2) Increases/decreases the camera's responsivity by increasing/decreasing the digital gain. **ssg** levels that create a digital gain below 1 will result in the camera not reaching 1023 DN.

Syntax:

ssg *t* *i*

Syntax Elements:

t

Sensor tap selection. Allowable range is **1** to **2**, or **0** for all taps.

i

Gain setting. The gain ranges are **0** to **65535**. The digital video values are multiplied by this value where:

$$\text{Digital Gain} = \frac{i}{4096}$$

For example, to set a digital gain of 1.0, ***i*** equals 4096.

Notes:

- Entering a large value gain will cause the camera to digitally saturate the output image
- Entering a zero value gain will cause the camera to force the pixels in the designated tap to be 0 DN
- Entering a value less than 4096 will cause the camera to not be able to digitally saturate

Related Commands: **ssb**

Example: **ssg 0 5000**

3.9 Generating a Test Pattern

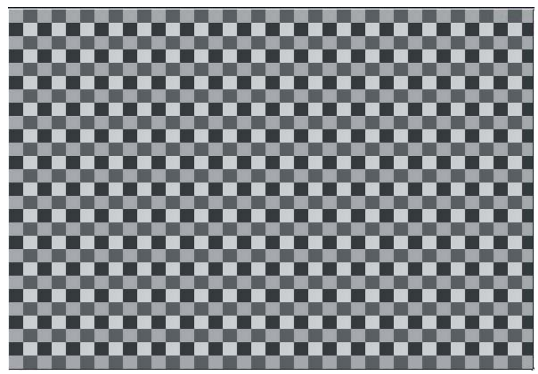
Purpose: Generates a test pattern to aid in system debugging. The test patterns are useful for verifying proper timing and connections between the camera and the frame grabber. The following table shows each available test pattern.

Syntax: **svm *i***

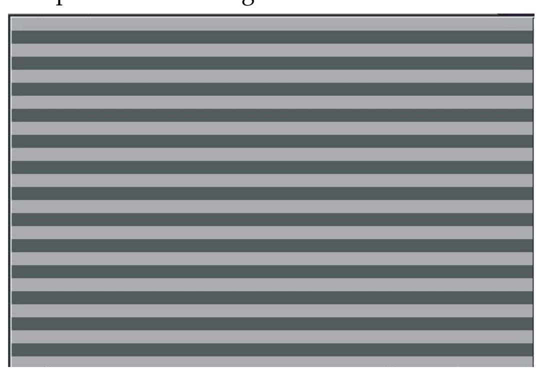
Syntax Elements: ***i***

0 Live Video.

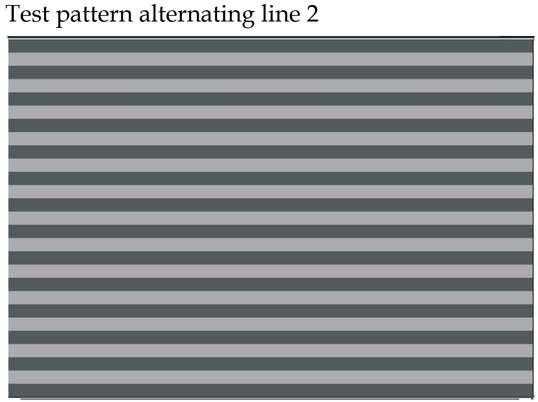
1 Test pattern checkerboard



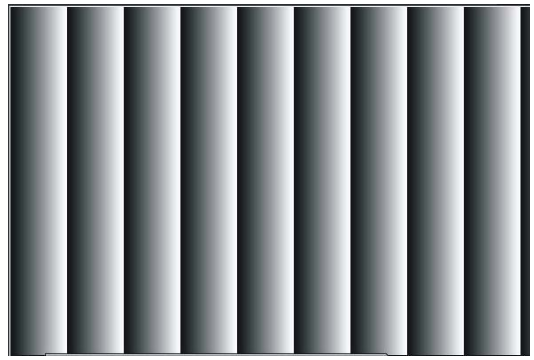
2 Test pattern alternating line 1



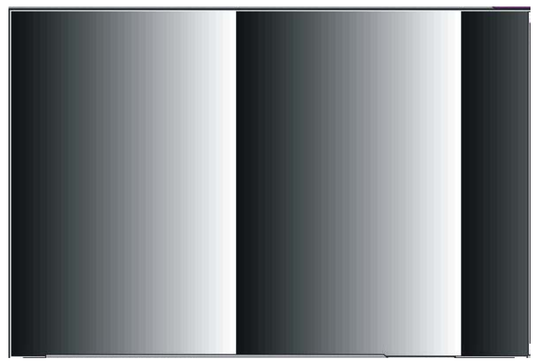
3 Test pattern alternating line 2



4 Test pattern horizontal ramp

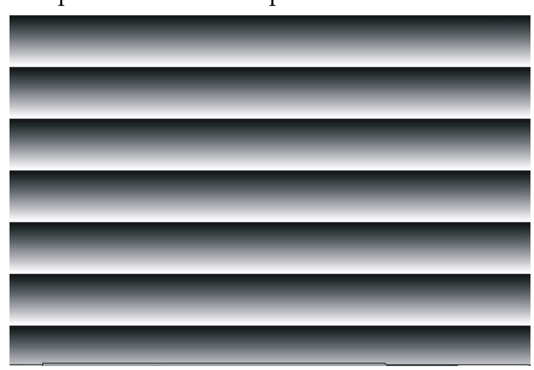


8 bit

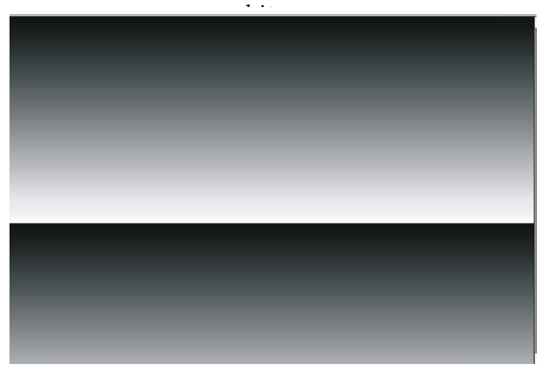


10 bit

5 Test pattern vertical ramp

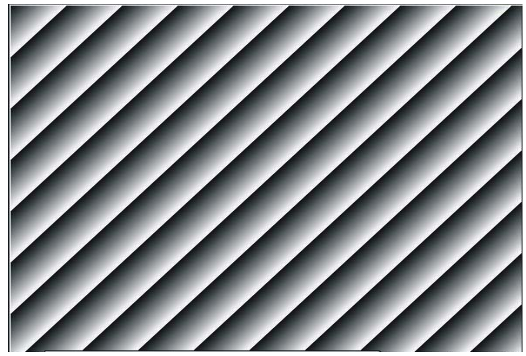


8

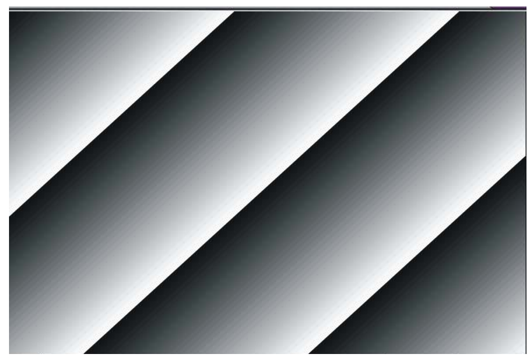


10 bit

6 Test pattern diagonal ramp



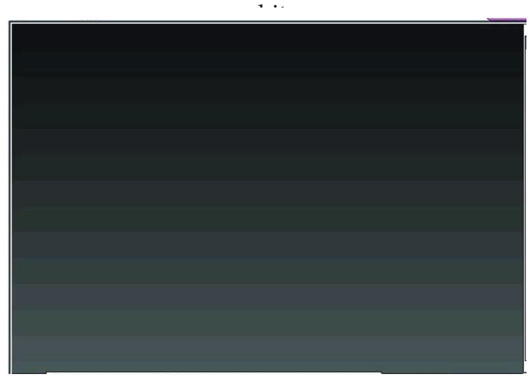
8 bit



10 bit

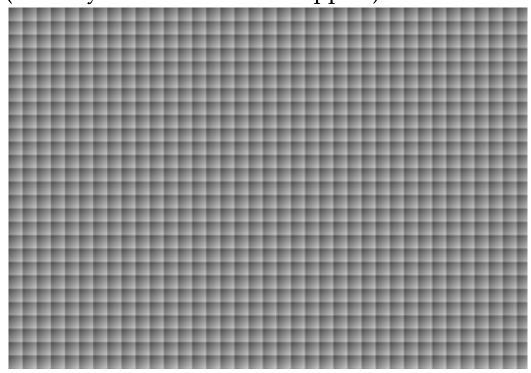
7 FPN test pattern
(Used by DALSA Product Support)

8

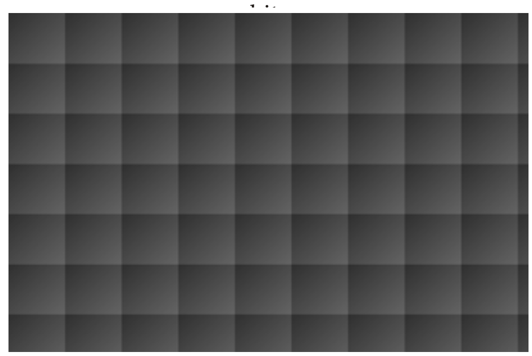


10 bit

8 FPN and PRNU test pattern
(Used by DALSA Product Support)

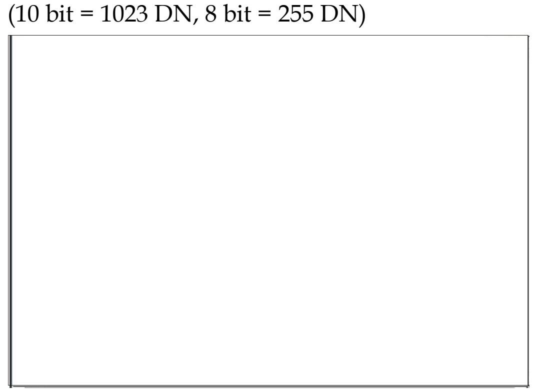


8 bit



10 bit

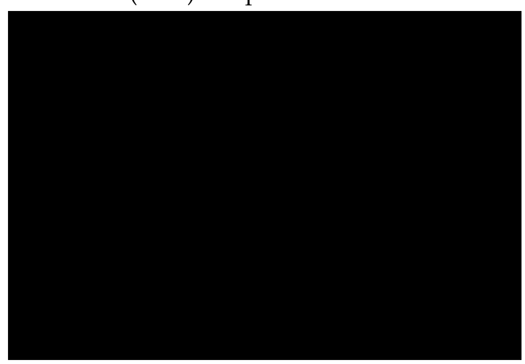
9 Fixed at max test pattern
(10 bit = 1023 DN, 8 bit = 255 DN)



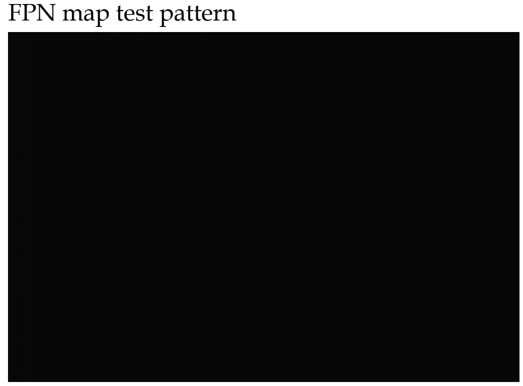
10 PRNU map test pattern

Base level 255 DN (10 bit). Apply PRNU coefficient multiple to it in order to see the PRNU coefficient map of the CSN set you are using.

11 Fixed dark (0DN) test pattern



12 FPN map test pattern



- Displays the FPN coefficients in each pixel. They range from 0 to 1023. This is you FPN coefficient map of the coefficient set you are currently using (**`csn`**).
- When switching the camera from video mode (**`svm 0`**) to one of the test pattern modes (**`svm 1`** thru **`8`**), the camera adjusts any digital gain (**`ssg`**), 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.

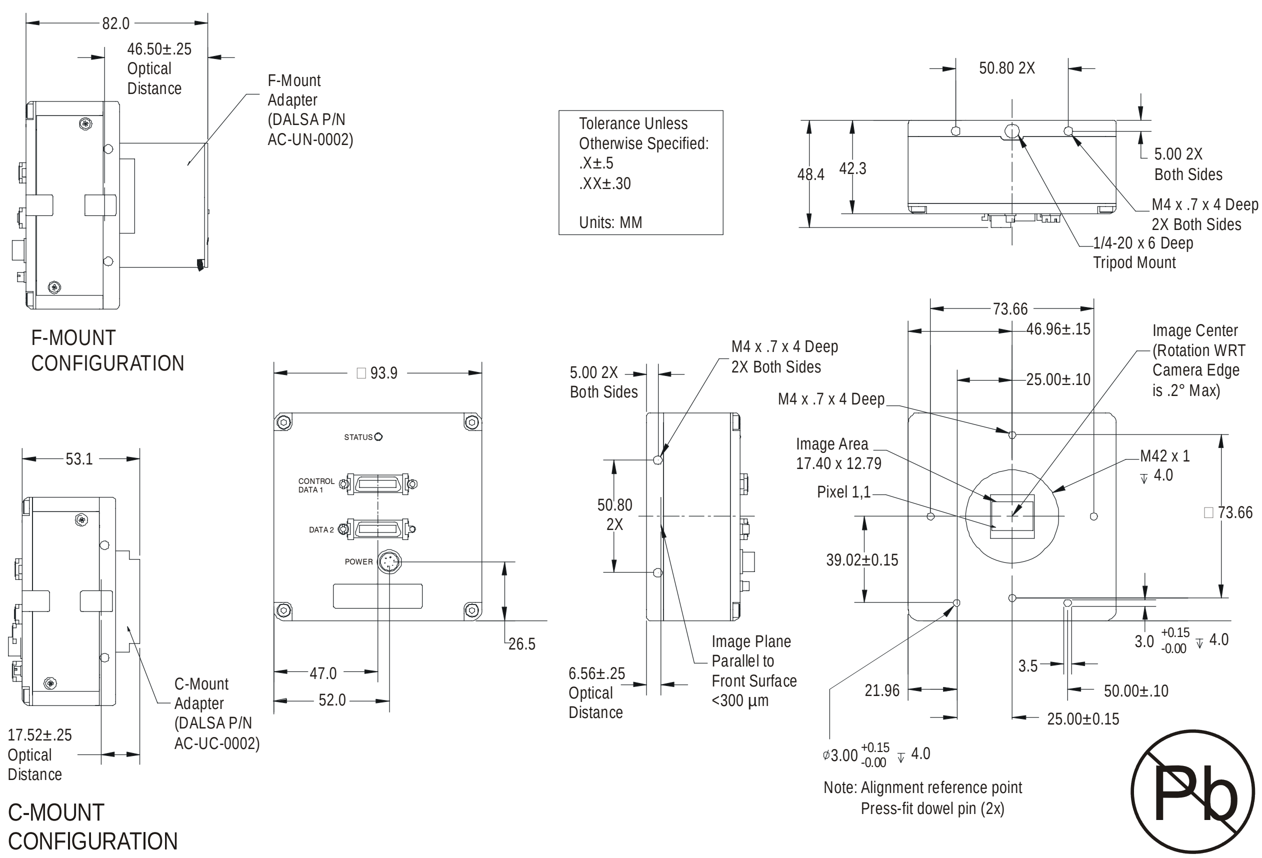
Example: `svm 2`

4

Optical and Mechanical Considerations

4.1 Mechanical Interface

Figure 18: Camera Mechanical Dimensions (all models)



Please note: For optimal camera performance, the camera should be cooled by applying forced air flow or by attaching the camera to a heatsink. If a heatsink is attached, the optimal surface is the top of the camera. DALSA accessory part number AC-MS-0102 provides heatsinks that will attach to two sides of the camera to provide additional cooling.

4.2 Lens Mounts

Configuration	Flange Back Focal Length (sensor die to adapter)
M42	6.56 ±0.25 mm
F-Mount	46.50 ±0.25 mm
C-Mount*	17.52 ±0.25 mm

*Note that the use of a C-Mount lens requires a C-mount adapter, and may cause vignetting due to the size of the image sensor.

4.3 Optical Interface

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. DALSA's Web site, http://mv.dalsa.com/, provides an introduction to this potentially complicated issue. See "Radiometry and Photo Responsivity" and "Sensitivities in Photometric Units" in the CCD Technology Primer found under the Application Support link.

It is often more important to consider exposure than illumination. The total amount of energy (which is related to the total number of photons reaching the sensor) is more important than the rate at which it arrives. For example, 5μJ/cm^2 can be achieved by exposing 5mW/cm^2 for 1 ms just the same as exposing an intensity of 5W/cm^2 for 1 μs.

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. However, they also require a camera with excellent sensitivity.
- 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.

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 750 nm. Examples are the Schneider Optics™ B+W 489, which includes a mounting ring, the CORION™ LS-

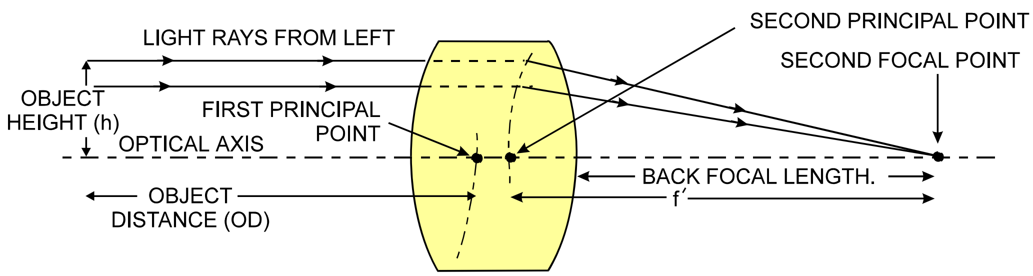
750, which does not include a mounting ring, and the CORION™ HR-750 series hot mirror.

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.

Figure 19: Primary Points in a Lens System



Magnification and Resolution

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

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

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 45 mm, 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 450 mm (0.450 m).

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

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

Your steps in dealing with a technical problem should be to try the general and specific solutions listed in this section first. If these solutions do not resolve your problem, see section 5.4 on getting product support.

5.1 Common Solutions

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. Verify the connector pinout and that all grounds are connected. Refer to section 2.2.3 Power Connector 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 3.9 for further information on running test patterns.

5.2 Troubleshooting Using the Serial Interface

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.

Verify Parameters

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

Verify Factory Calibrated Settings

To restore the camera's factory settings send the **rfs** command. To restore the camera's factory calibrated FFC coefficients, first pick the appropriate set (**csn 0** to **7**) and then send **lpc** to load said set.

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

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

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 (e.g. EXSYNC, if camera is using an internal signal for synchronization).

Line Dropout, Bright Lines, or Incorrect Frame rate

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

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.

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 dry, filtered compressed air. 'Canned' air can cause droplets to be deposited on the window which may result in visible spots after they dry.
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 (alcohol). 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 2-4 using a clean tissue until the entire window has been cleaned.

5. Blow off any adhering fibers or particles using dry, filtered compressed air.

5.4 Product Support

If there is a problem with your camera, collect the following data about your application and situation and call your DALSA representative.

Note: You may also want to photocopy this page to fax to DALSA.

Customer name	
Organization name	
Customer phone number **fax number**	
Complete Product Model Number (e.g. PT-41-04M60...)	
Complete Camera Serial Number	
Your DALSA Agent or Dealer	
Acquisition System hardware (frame grabber, host computer, light sources, etc.)	
Acquisition System software (version, OS, etc.)	
Power supplies and current draw	
Data rate used	
Control signals used in your application, and their frequency or state (if applicable)	☐ EXSYNC ☐ BIN ☐ MCLK ☐ Other _______
Results when you run the gcp command	*please attach text received from the camera after initiating the command*
Detailed description of problem encountered.	*please attach description with as much detail as appropriate*

In addition to your local DALSA representative, you may need to call DALSA Technical Sales Support:

	North America	Europe	Asia
Voice:	519-886-6000	+49-8142-46770	519-886-6000
Fax:	519-886-8023	+49-8142-467746	519-886-8023

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 from http://mv.dalsa.com) details how DALSA standardizes its use of the Camera Link interface.

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.

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.

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 http://mv.dalsa.com/ Web site.

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 mv.dalsa.com Web site.

DALSA Camera Control Configuration

4M Falcon Cameras	Camera Link Name
EXSYNC	CC1
Reserved for future use	CC2
Reserved for future use	CC3
Window Toggle	CC4

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 http://mv.dalsa.com/ Web site.

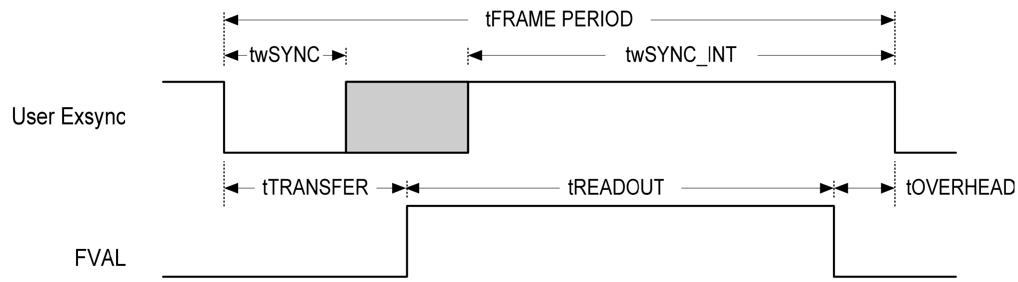
Power

Power will not be provided on the Camera Link connector. The camera will receive power through a separate cable. Camera manufacturers will define their own power connector, current, and voltage requirements.

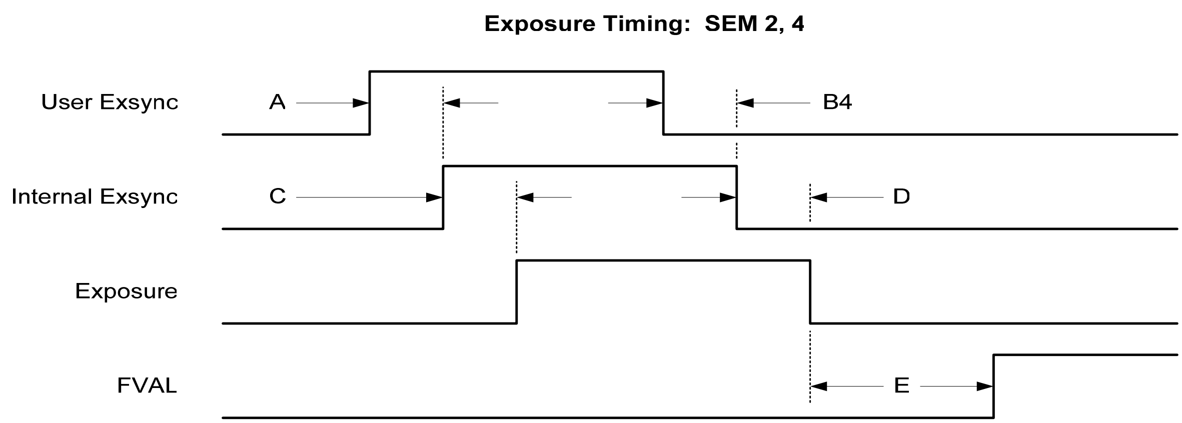
Camera Link Video Timing

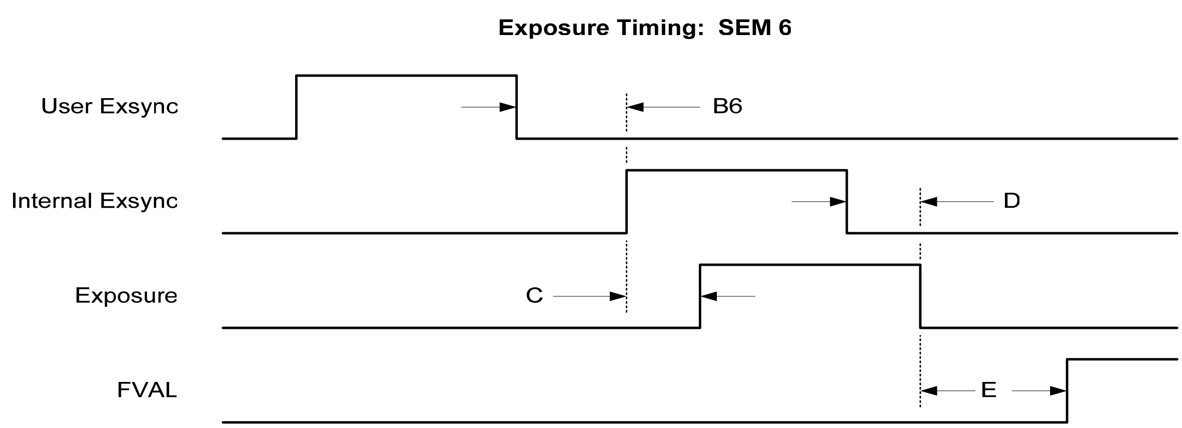
IMPORTANT:
This camera uses the *falling* edge of EXSYNC to trigger line readout, unlike previous DALSA cameras, which used the rising edge.

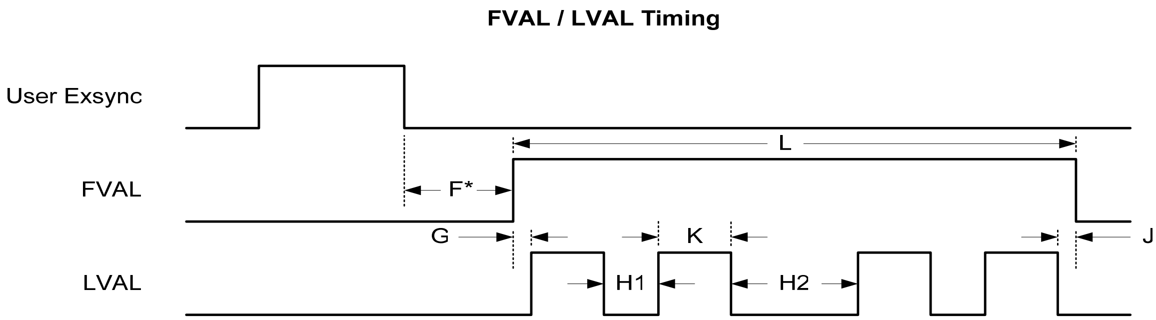
Figure 20: Standard Timing (Input and Output Relationships)



Exposure Timing







Note: User EXSYNC not present in **sem 2**.

Original Falcon 4M30 and 4M60 User Timing (-00-R and non-RoHS cameras)

	Operating Conditions	SEM												
	EDC		0											
	CLM		16			3			16			3		
	SOT		320			160			260			130		
	SSF	2	50			28.8			50			23.7		
	frame rate - ext controlled	4,6	5											
	SET	2	2000			566			2000			601		
	SET	6	2000			686			2000			2000		
	EFD		**0**	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**
	Exposure Timing													
A	User Exsync ↑ to Internal Exsync ↑	4	85n	186n	485u	85n	186n	559u	85n	186n	502u	85n	186n	594u
B4	User Exsync ↓ to Internal Exsync ↓	4	123n	486u	247n	123n	560u	247n	123n	504u	247n	123n	594u	247n
B6	User Exsync ↓ to Internal Exsync ↑	6	123n	286n	484u	123n	286n	558u	123n	286n	502u	123n	286n	594u
C	Internal Exsync ↑ to Exposure ↑	2,4,6	112n		1.40u	112n		1.40u	112n		1.40u	112n		1.40u
D	Internal Exsync ↓ to Exposure ↓	2,4,6	3.11u											
E	Exposure ↓ to FVAL ↑	2,4,6	57.0u			112u			70.2u			138u		
	LVAL / FVAL Timing													
F4	User Exsync ↓ to FVAL ↑	4	60.2u	546u	60.2u	60.2u	546u	60.2u	73.4u	578u	73.4u	142u	736u	142u
F6	User Exsync ↓ to FVAL ↑	6	2.06m		2.54m	2.10m		2.67m	2.06m		2.55m	2.14m		2.73m
tFL, G	FVAL ↑ to LVAL ↑	2,4,6	0											
tLVAL_LOW1, H1	LVAL ↓ to LVAL ↑ (LVAL low 1)	2,4,6	1.87u			3.78u			2.30u			4.66u		
tLVAL_LOW2, H2	LVAL ↓ to LVAL ↑ (LVAL low 2)	2,4,6	1.94u			3.82u			2.50u			4.76u		
tLF, J	LVAL ↓ to FVAL ↓	2,4,6	0											
tLINE, K	LVAL ↑ to LVAL ↓	2,4,6	7.35u			14.7u			9.04u			18.1u		
tREADOUT, L	FVAL ↑ to FVAL ↓	2,4,6	15.99m			32.00m			19.8m			39.42m		
	Max Frame Rate Timing													
	SSF (max FR)	2	62.2Hz	60.4Hz	60.3Hz	31.1Hz	30.6Hz	30.6Hz	50.3Hz	49Hz	49Hz	25.2Hz	24.9Hz	24.9Hz
	Max Exposure	2	16051u	16530u	52u	32109u	32635u	32u	19850u	20377u	49u	39629u	40107u	31u
twSYNC	Internal Exsync ↓ to Internal Exsync ↑	2	29.2u		16.6m	47.8u		32.6m	33.7u		20.4m	56.4u		40.2m
twSYNC_INT	Internal Exsync ↑ to Internal Exsync ↓ (min)	2	10u	492u	10u	10u	566u	10u	10u	510u	10u	10u	601u	10u
tTRANSFER	Internal Exsync ↓ to FVAL ↑	2	60.2u			116u			73.4u			142u		
tOVERHEAD	FVAL ↓ to Internal Exsync ↓ (max FR)	2	24.2u	504u	532u	42.2u	568u	568u	13.5u	542u	542u	115u	594u	594u
tFRAME PERIOD	Internal Exsync ↓ to Internal Exsync ↓	2	16.07m	16.55m	16.58m	32.16m	32.68m	32.68m	19.89m	20.42m	20.42m	39.68m	40.16m	40.16m

Notes:

* Units in seconds.
* Additional operating conditions: full window readout, snd 1.
* User EXSYNC operates asynchronous to the camera timing and therefore has an uncertainty period of +/-2 clocks (80 MHz clock = 12.5 nS, 2 clocks = ± 25 nS).
* When the debounce circuit is enabled (`edc 1`) increase timing values A, B4, B6, F4 and F6 by 1.07 uS.

Revised Falcon 4M30 and 4M60 User Timing (-01-R and higher cameras)

	Operating Conditions	**SEM**												
	EDC		0											
	CLM		16			3			16			3		
	SOT		320			160			260			130		
	SSF	2	50			28.8			50			23.7		
	frame rate - ext controlled	4,6	5											
	SET	2	2000			566			2000			601		
	SET	6	2000			686			2000			2000		
	EFD		**0**	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**
	Exposure Timing													
A	User Exsync ↑ to Internal Exsync ↑	4	149n	249n	485u	149n	249n	559u	149n	249n	485u	149n	249n	594u
B4	User Exsync ↓ to Internal Exsync ↓	4	186n	486u	311n	186n	560u	311n	186n	486u	311n	186n	594u	311n
B6	User Exsync ↓ to Internal Exsync ↑	6	237n	337n	484u	237n	337n	558u	237n	337n	484u	237n	337n	594u
C	Internal Exsync ↑ to Exposure ↑	2,4,6	109n		1.40u	109n		1.40u	109n		1.40u	109n		1.40u
D	Internal Exsync ↓ to Exposure ↓	2,4,6	3.11u											
E	Exposure ↓ to FVAL ↑	2,4,6	80.9u			136u			80.8u			164u		
	LVAL / FVAL Timing													
F4	User Exsync ↓ to FVAL ↑	4	84u	570u	84u	140u	700u	140u	84u	570u	84u	167u	762u	167u
F6	User Exsync ↓ to FVAL ↑	6	2.07m		2.56m	2.13m		2.70m	2.08m		2.56m	2.16m		2.75m
tFL, G	FVAL ↑ to LVAL ↑	2,4,6	0											
tLVAL_LOW1, H1	LVAL ↓ to LVAL ↑ (LVAL low 1)	2,4,6	100n						123n					
tLVAL_LOW2, H2	LVAL ↓ to LVAL ↑ (LVAL low 2)	2,4,6	3.70u			7.52u			292n			9.32u		
tLF, J	LVAL ↓ to FVAL ↓	2,4,6	0											
tLINE, K	LVAL ↑ to LVAL ↓	2,4,6	7.35u			14.7u			9.04u			18.1u		
tREADOUT, L	FVAL ↑ to FVAL ↓	2,4,6	15.99m			32.00m			15.99m			39.42m		
	Max Frame Rate Timing													
	SSF (max FR)	2	62.2Hz	60.4Hz	60.3Hz	31.1Hz	30.6Hz	30.6Hz	62.2Hz	60.4Hz	60.3Hz	25.2Hz	24.9Hz	24.9Hz
	Max Exposure	2	16051u	16530u	52u	32109u	32635u	32u	16051u	16530u	52u	39629u	40107u	31u
twSYNC	Internal Exsync ↓ to Internal Exsync ↑	2	29.2u		16.6m	47.8u		32.6m	29.2u		16.6m	56.4u		40.2m
twSYNC_INT	Internal Exsync ↑ to Internal Exsync ↓ (min)	2	10u	492u	10u	10u	566u	10u	10u	492u	10u	10u	601u	10u
tTRANSFER	Internal Exsync ↓ to FVAL ↑	2	84.2u			140u			84.2u			167u		
tOVERHEAD	FVAL ↓ to Internal Exsync ↓ (max FR)	2	2.05u	482u	510u	21.8u	548u	548u	-1.4u	478u	506u	94.4u	574u	574u
tFRAME PERIOD	Internal Exsync ↓ to Internal Exsync ↓	2	16.08m	16.56m	16.58m	32.16m	32.69m	32.69m	16.07m	16.55m	16.58m	39.68m	40.16m	40.16m

Notes:

* Units in seconds.
* Additional operating conditions: full window readout, snd 1.
* User EXSYNC operates asynchronous to the camera timing and therefore has an uncertainty period of +/-2 clocks (80 MHz clock = 12.5 nS, 2 clocks = ± 25 nS).
* When the debounce circuit is enabled (`edc 1`) increase timing values A, B4, B6, F4 and F6 by 1.07 uS.

Appendix B

Error Handling and Command List

B1 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 3.

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

All Available Commands

Command	Syntax	Parameters	Description
correction calibrate FPN	**ccf**		Performs FPN calibration and eliminates FPN noise by subtracting away individual pixel dark current.
camera link mode	**clm**	**m**	Output mode to use: **2**: Base configuration, 2 taps, 8 bit output **3**: Base configuration, 2 taps, 10 bit output **15**: Medium configuration, 4 taps, 8 bit output (4M60 only) **16**: Medium configuration, 4 taps, 10 bit output (4M60 only)
calculate PRNU algorithm	**cpa**	**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.

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

Command	Syntax	Parameters	Description
coefficient set number	**csn**	**i**	Selects the coefficient set to use: **0-7** = Factory calibrated sets of FPN and PRNU coefficients. These coefficients cannot be erased or modified. **8-15** = User calibrated sets of FPN and PRNU coefficients. These coefficients **can** be deleted or modified. <table><tr><td>CSN</td><td>EFD</td></tr><tr><td>0, 8</td><td>1</td></tr><tr><td>1, 9</td><td>0</td></tr><tr><td>2, 10</td><td>2</td></tr><tr><td>3, 11</td><td>1</td></tr><tr><td>4, 12</td><td>0</td></tr><tr><td>5, 13</td><td>2</td></tr><tr><td>6, 14</td><td>All coefficients = 0</td></tr><tr><td>7, 15</td><td>FPN/PRNU Test Pattern</td></tr></table>
calibration sample size	**css**	**m**	Sets the number of lines to sample when performing FPN and PRNU calibration where **m** is **32**, **64**, **128** (factory setting), **256**, **512**, or **1024**
display pixel coefficients	**dpc**	**x1y1 x2y2**	Displays the pixels coefficients in the order FPN, PRNU, FPN, PRNU… x1y1 = pixel start address x2y2 = pixel end address in the range from 1, 1 to 2352, 1728.
enable debounce circuit	**edc**	**m**	When enabled (EDC 1) filters EXSYNC from the user to suppress any glitches less than 1us in width.
enable frame dump	**efd**	**m**	Enables various snapshot modes EFD 0 – snapshot mode disabled EFD 1 – snapshot mode 1, FFD on falling edge of EXSYNC EFD 2 – snapshot mode 2, FFD on rising edge of EXSYNC
enable pixel coefficients	**epc**	**i i**	Enables or disables FPN and PRNU coefficients. The first parameter sets the FPN coefficients where **i** is: **0** = FPN coefficients disabled **1** = FPN coefficients enabled The second parameter sets the PRNU coefficients where **i** is: **0** = PRNU coefficients disabled **1** = PRNU coefficients enabled
get camera model	**gcm**		Read the camera model number.
get camera parameters	**gcp**		Read all of the camera parameters.

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

Command	Syntax	Parameters	Description
get camera serial	**gcs**		Read the camera serial number.
get camera version	**gcv**		Read the firmware version and FPGA version.
get fpn coefficient	**gfc**	xy	Read the FPN coefficient at address xy, where xy falls in the range from 1, 1 to 2352, 1728.
get prnu coefficient	**gpc**	xy	Read the PRNU coefficient at address xy, where xy falls in the range from 1, 1 to 2352, 1728.
get command parameter	**get**	**s**	Display value of camera command**s**
get sync frequency	**gsf**	**m**	Display the frequency and HIGH time of CC1-CC4. **1**: Camera Link input (CC1) **4**: Camera Link input (CC4)
help	**h**		Display the online help
load pixel coefficients	**lpc**		Loads the previously saved pixel coefficients from non-volatile memory determined by the **csn** value. **0-7** = Factory calibrated coefficients **8-15** = User coefficient sets
reset camera	**rc**		Reset the entire camera (reboot).
restore factory settings	**rfs**		Restore the camera's factory settings. Note: this does NOT restore factory FFC coefficients (use **lpc** for this).
reset pixel coefficients	**rpc**		Resets the FPN and PRNU coefficients to 0/1 respectively.
restore user settings	**rus**		Restore the camera's last saved user settings. Note: this does NOT restore FFC coefficients (use **lpc** for this).
set analog offset	**sao**	**t i**	Set the analog offset. **t** = Tap selection. Allowable value is **0** for all taps. **i** = Analog offset value. Allowable range is **0** -**511**.
set baud rate	**sbr**	**m**	Set the speed of the serial communication port. Baud rates: **9600**, **19200**, **57600**, and **115200**. Default baud: 9600
set digital offset	**sdo**	**t i**	Used as a substitute when no FPN correction is performed. Not recommended in general. **t** = Tap selection. Allowable value is **0** for all taps. **i** = Offset in the range from **0** to **1023**

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

Command	Syntax	Parameters	Description
set exposure mode	**sem**	**m**	Set the exposure mode. Available values are: **2**: Internal programmable frame rate and exposure time using commands `ssf` and `set` 4: Smart EXSYNC, frame rate and exposure time controlled by CC1 (user EXSYNC) 6: Frame rate controlled by CC1, exposure time controlled by **set**
set exposure time	**set**	**f**	Sets the exposure time to a floating point number in µs. Allowable range depends on snapshot mode, window size, cameralink mode, etc..
set fpn coefficient	**sfc**	**xyi**	Set the FPN coefficient. where xy falls in the range from 1, 1 to 2352, 1728. **i**= FPN value in the range **0** to **1023**.
set number frame dumps	**snd**	**i**	Sets the number of fast frame dumps when either snapshot modes 1 or 2 are active (**efd** 1 or 2, respectively).
set output throughput	**sot**	**m**	Sets the camera's total throughput in mega-pixels per second. Valid values are: 130, 160, 260 and 320.
set prnu coefficient	**spc**	**xyi**	Set the PRNU coefficient. Where xy falls in the range from 1, 1 to 2352, 1728. **i**= PRNU value in the range **0** to **12287**.
set subtract background	**ssb**	**ti**	Subtract this value from the output signal. **t** = Tap selection. Allowable value is **0** for all taps. **i** = Subtracted value in a range from **0** to **511**.
set sync frequency	**ssf**	**f**	Sets the frame rate in Hz to a value from **1** to **60.4** (4M60) or **1** to 30.6 (4M30).
set system gain	**ssg**	**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.

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

Command	Syntax	Parameters	Description
set video mode	**svm**	**m**	Sets the camera's video mode. 0: Video mode 1: Test pattern checkerboard 2: Test pattern alternating line 1 3: Test pattern alternating line 2 4: Test pattern horizontal ramp 5: Test pattern vertical ramp 6: Test pattern diagonal ramp 7: Test pattern FPN 8: Test pattern PRNU 9: Test pattern fixed 1023 10: Test pattern PRNU map 11: Test pattern fixed 0 12: Test pattern FPN map
verify temperature	**vt**		Display the internal temperature of the camera.
verify voltage	**vv**		Display some internal voltages supplied to the camera.
write fpn coefficients	**wfc**		Write current FPN coefficients to non-volatile memory. The set within non-volatile memory will have been previously selected using the **csn** command.
write prnu coefficients	**wpc**		Write current PRNU coefficients to non-volatile memory. The set within non-volatile memory will have been previously selected using the **csn** command.
window start end	**wse**	**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. Since there is only vertical window of interest in this camera, this value is always set to **1**. **y1** is window start pixel number in a range from **1-1725** and must belong to following set: 1, 5, 9, …1725 **x2** is window end corner value. Since there is only vertical window of interest in this camera, this value is always set to **2352**. **y2** is window end pixel number in range from **4-1728** and must belong to the following set: 4, 8, 12, …1728

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

Command	Syntax	Parameters	Description
window set sequence	**wss**	**i**	Toggles the current window sequence when switching between **wss 0** and **wss 1** or vice versa.
window trigger source	**wts**	**m**	Defines the source for the window sequence. Available values are: 1: Software command **wss** 2: Camera Link input (CC4)
write user settings	**wus**		Write all of the user settings to non-volatile memory.

Appendix C

EMC Declaration of Conformity

We,	**DALSA** **605 McMurray Rd.,** **Waterloo, ON** **CANADA N2V 2E9**

declare under sole responsibility, that the product(s):

4M30 and 4M60

fulfill(s) the requirements of the standard(s)

EMC:	**ICES-003 (Canada)** **FCC Part 15 (USA)** **EN 61326: 1997** **EN 55022: 1998** **EN 55024: 1998** **IEC 61326** **CISPR 22** **CISPR 24**

This product complies with the requirements of the EMC Directive 89/336/EEC and carries the CE mark accordingly.

Place of Issue	Waterloo, ON, CANADA
Date of Issue	December 2006
Name and Signature of authorized person	**Hank Helmond** **Quality Manager, DALSA Corp.**

Appendix D

Revision History

Revision Number	Change Description
00	Preliminary release. RoHS version of manual created from standard version (03-032-10121-09). New to this manual: -Added EMC compliance as Appendix C. -Removed "Stop Action" from the manual cover and headers, replaced with "Falcon." -Added a note concerning Camera Link cable length and quality, page 14. -Timing diagrams, SEM 2, 4, and 6 revised, page 29. -RoHS and CE compliant information added.
01	-Added camera cosmetic blemish section, page 10. Please note that the information in this section is considered "preliminary" at the time of printing and subject to change. -Added snapshot mode section, page 33. -Revised flat field correction description, page 42. -Revised mechanical drawing, page 60.

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