4 Megapixel 31/62 fps Stop Action Area Scan Cameras

Stop Action 4M30 and 4M60

Camera User's Manual

PT-41-04M60

PT-21-04M30

PRELIMINARY

DALSA
technology with vision

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About DALSA

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

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

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Introduction to the 4 Megapixel Stop Action Cameras

1.1 Camera Highlights

Features

- 4 megapixels, 2352(H) x 1728(V) resolution
- Stop Action shutter (non-rolling shutter) for crisp images
- 62fps model or 31fps model
- Vertical windowing for faster frame rate
- 7.4µm x 7.4µm pixel pitch
- 4x80MHz or 2x80MHz data rates
- Nominal broadband responsivity of 11.6DN/(nJ/cm^2)
- 8 or 10 bit selectable output
- Dynamic range of 57dB
- Base or Medium Camera Link™ interface

Programmability

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

Description

This 4 megapixel, stop action camera is our most advanced stop action area array camera. With data rates up to 320MHz, this camera is 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 stop action camera is ideal for applications requiring high speed, superior image quality, and high responsivity. Applications include:

- PCB inspection
- Semiconductor wafer inspection
- Flat panel display inspection
- Industrial metrology
- Traffic management
- General machine vision

1.2 Camera Performance Specifications

Table 1: Camera Performance Specifications

Resolution	pixels	2352Hx1728V	
Pixel Fill Factor	%	45	
Effective fill factor with microlenses	%	60	
# of Lines per Frame	lines	1728	
Output Format (# of taps)		2 (4M30) or 4 (4M60)	
Back Focal Distance			
Sensor die to mounting plate	mm	6.56	5
Sensor Alignment			
x	mm	±0.10	
y	mm	±0.10	
z	mm	±0.25	
Θz	°	±0.2	
Lens Mount		C-mount or F-mount adapter available	
Lens Mount Hole		M42x1	
Camera Size	mm	94 x 94 x 48	
Mass	g	<550	

Connectors power connector data connector		 6 pin male Hirose 2 x MDR26 female	

Input Voltage	Volts	+12 to +15	6
Power Dissipation	W	7 typ, 12 max	
Operating Temperature	°C	0 to 50	1
Data Output Format	Bits	8 or 10 user selectable	
Output Data Configuration		Base or Medium Camera Link	

Minimum Frame Rate	Hz	1	1	
Maximum Frame Rate	Hz	62.1 (4M60) 31 (4M30)	62.1 (4M60) 31 (4M30)	4
Data Rate	MHz	80	80	
Dynamic Range (10 bits @ nominal gain)	Ratio	670:1	890:1	2
Random Noise	DN rms	1.3	1.1	
Broadband Responsivity	$DN/(nJ/cm^2)$	11.6	11.6	
DC Offset	DN	180	37	
Antiblooming		>1000x saturation	>1000x saturation	
FPN	DN rms	20	3	
PRNU	%	2	2	
Integral non-linearity	DN	<2%	<2%	3

Test conditions unless otherwise noted:

- ECE = Exposure control enabled. 60fps, 15 millisecond exposure time. Exposure mode 2 or 4
- ECD = Exposure control disabled. 60fps, Maximum exposure time. Exposure mode 3 or 7.
- Data Rate: 80 MHz
- Light Source: Broadband Quartz Halogen, 3250K, with 500-600 nm bandpass filter installed
- Ambient test temperature 25°C
- Full Frame
- Average output 840DN
- 10 bits

Notes:

1. Measured at the front plate.
2. Based on output at 1023DN

3. Output over 10-90%
4. Although the part number indicates that the maximum frame rate is 60fps, the actual maximum frame rate is 62fps.
5. Optical distance.
6. +12V consumes the least amount of power

1.3 Camera Blemish Specifications

Table 2: Camera Blemish Specifications

Pixel defects	TBD	
Cluster defects	TBD	
Column defects	0	
Row defects	0	

Definition of blemishes

Pixel defect

- Pixel whose signal, at nominal light (illumination at 50% of the linear range), deviates more than ±30% from its neighboring pixels.
- Pixel whose signal, in dark, deviates more than 300 DN from its neighboring pixels.

Cluster defect

- A grouping of at most 5 pixel defects within a sub-area of 3x3 pixels.

Column defect

- A column, which has more than 8 pixel defects in a 1x12 kernel.
- Column defects must be horizontally separated by 3 good columns.

Row defect

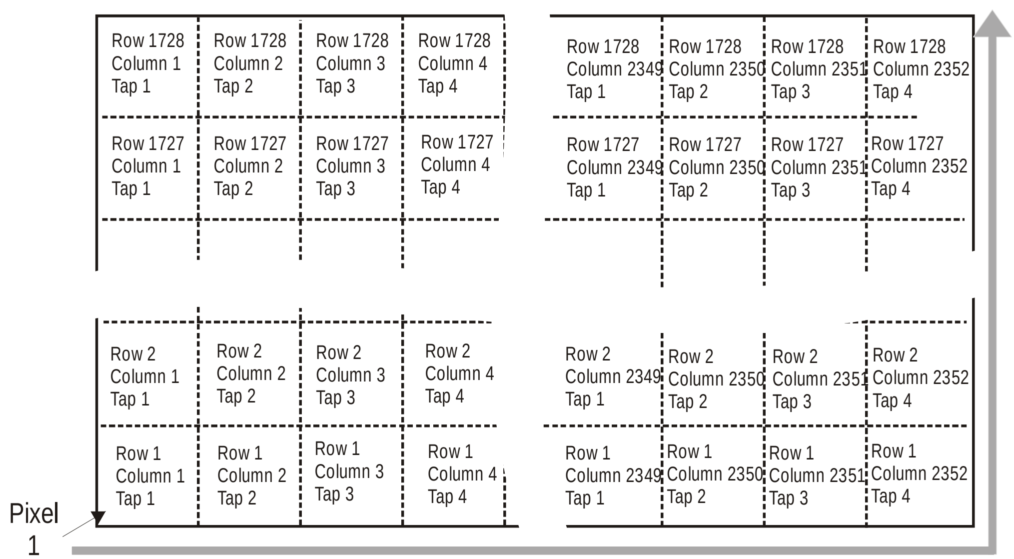
- A horizontal grouping of more than 8 pixel defects between at least 2 good pixels on both sides, where single good pixels between 2 defective pixels are considered as defective.

1.4 Image Sensor and Pixel Readout

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

Figure 1: 4 Tap Sensor Block Diagram

Note: As viewed from the front of the camera without lens.



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

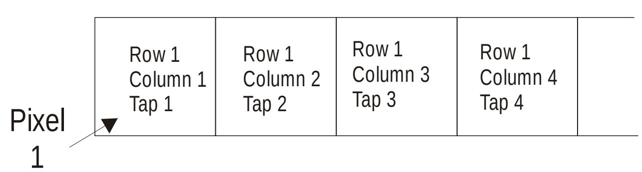
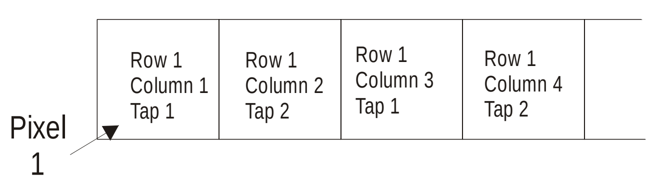


Figure 3: 4M30 Pixel Readout Detail



1.5 Responsivity

Figure 4: Spectral Responsivity

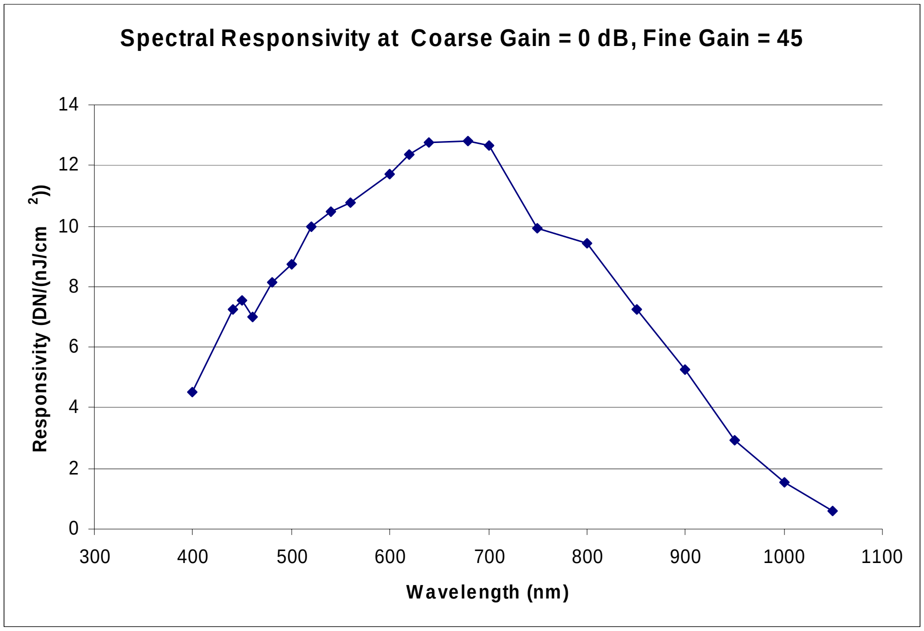


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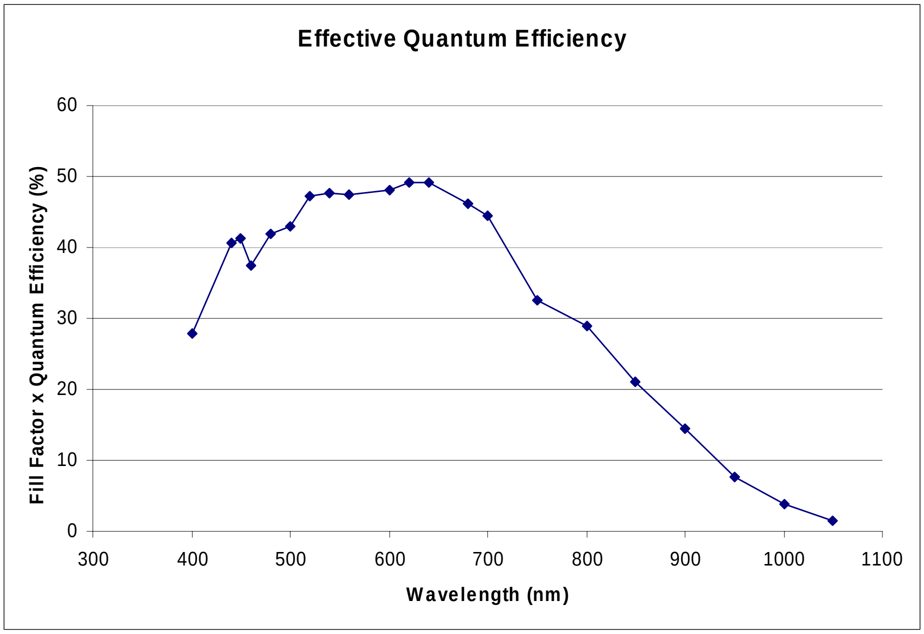
Figure 5: Effective Quantum Efficiency



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2

Camera Hardware Interface

2.1 Installation Overview

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

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

1. Power down all equipment.
2. Following the manufacturer's instructions, install the frame grabber (if applicable). Be sure to observe all static precautions.
3. Install any necessary imaging software.
4. Before connecting power to the camera, test all power supplies.
5. Inspect all cables and connectors prior to installation. Do not use damaged cables or connectors or the camera may be damaged.
6. Connect Camera Link and power cables.
7. After connecting cables, apply power to the camera.
8. Check the diagnostic LED. If camera is operating correctly, the LED will flash for 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.

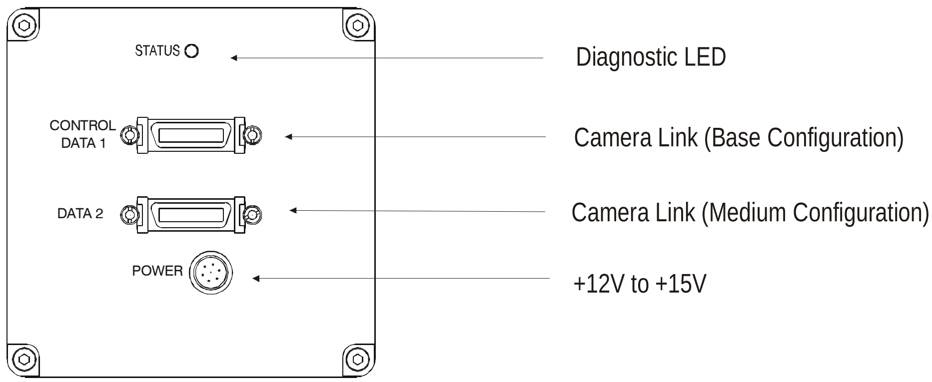
2.2 Input/Output Connectors and LED

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.

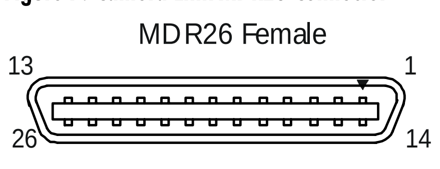
When more than one condition is active, the LED indicates the condition with the highest priority. Error and warning states are accompanied by corresponding messages further describing the current camera status.

Table 3: Status LED

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 a Base or Medium Configuration in the stop action 4M cameras. You select the camera configuration with the **`clm`** command described in section 3.3.2 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, vfm.dalsa.com, for the official Camera Link documents.

Table 4: Camera Link Hardware Configuration Summary

Base	A, B, C	28	1	1
Medium	A, B, C, D, E, F	28	2	2

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

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

Table 5: Camera Link Connector Pinout

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+
11	16	Zclk-
24	3	Zclk+
12	15	Z3-
25	2	Z3+
13	13	inner shield
26	26	inner shield

23	4	CC2-
11	16	CC3-
24	3	CC3+
12	15	CC4+
25	2	CC4-
13	13	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

Table 6: DALSA Camera Control 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 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://vfm.dalsa.com/, for the standard location of these signals.

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 55.

2.2.3 Power Connector

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

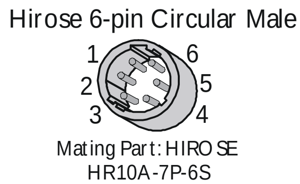


Table 7: Hirose Pin Description

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 2 A.
- 12 V power supply. Nominal 0.65 A load resulting in ~20 A/s current ramp rate
- Power supply current limit needs to be set at >2 A.
- Do not use the shield on a multi-conductor cable for ground.
- Keep leads as short as possible to reduce voltage drop. Long power supply leads may falsely indicate that the power supply is within the recommended voltage range even when the camera at the connector is actually being supplied with much less voltage.
- Use high-quality **linear** supplies to minimize noise.
- Use an isolated type power supply to prevent LVDS common mode range violation.

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

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    ii      2-2:256-1013
csn   coefficient set number       i       0-1
css   correction set sample        m       32/64/128/256/512/1024/
dpc   display pixel coefficients   xyxy    1-2352:1-1728:1-2352:1-
                                           1728
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/
sem	set exposure mode	m	2/3/4/7/
set	set exposure time	f	10-999989 [us]
sfc	set fpn coefficient	xyi	1-2352:1-1728:0-1023
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	1.0-62.1 [Hz]
ssg	set system gain	ti	0-2:0-65535
svm	set video mode	m	0/1/2/3/4/5/6/7/8/9/10/
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		

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:

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- Flat field coefficients enabled (calibrated in exposure mode 2, 55 fps, and exposure time of 2 ms)
- Exposure mode 2
- 60 fps
- 14992.6 µs exposure time
- Camera Link mode 16 (Medium configuration, 4 taps. 10 bits)

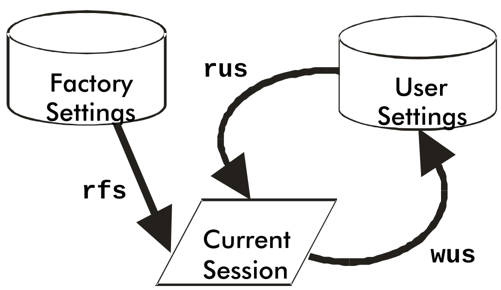
- 80 MHz pixel rate (320 total throughput)
- Full window (2352 x 1728)

PT-21-04M30

- Flat field coefficients enabled (calibrated in exposure mode 2, 29 fps, and exposure time of 2 ms)
- Exposure mode 2
- 30 fps
- 14992.6 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)

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`**.

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`**.

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 stop action 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.

Table 8: 4M30 Data Readout Configurations

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

Table 9: 4M60 Data Readout Configurations

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's Pixel Rate

Purpose:	Sets the camera's pixel rate. Refer to Table 8and Table 9 for a description of how pixel rates relate to the camera's Camera Link mode.
Syntax:	**`clm`** ***m***
Syntax Elements:	***m***
	If using Camera Link mode 2 or 3: **`130`**: 65 MHz pixel rate with a total throughput of 130 MHz **`160`**: 80 MHz pixel rate with a total throughput of 160 MHz If using Camera Link 15 or 16 (4M60 only): 260: 65 MHz pixel rate with a total throughput of 260 MHz 320: 80 MHz pixel rate with a total throughput of 320 MHz
Notes:	• To retrieve the current pixel rate, 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 four 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 or 7, use the command **`ssf`** to set the frame rate and, if operating in exposure mode 2, use the **`set`** command to set the exposure time.

3.4.1 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 setting is 2.

Notes:

- Refer to Table 10: 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**.
- Changing from **sem 2** / **4** to **sem 3** / **7** may adjust the analog offset to the lower input level of the **sao** command. Refer to Setting Analog Offset on page 39 for details on setting the analog offset.

Related Commands: **ssf**, **set**

Example: **sem 3**

Table 10: Exposure Modes

2	Internal	Yes	Yes	Internal frame rate and exposure time. Exposure control enabled (ECE).
3	External	No	No	Maximum exposure time. Exposure control disabled (ECD).
4	External	No	No	Smart EXSYNC. Exposure control enabled (ECE).
7	Internal	Yes	No	Internal frame rate, maximum exposure time. Exposure control disabled (ECD).

Exposure Modes in Detail

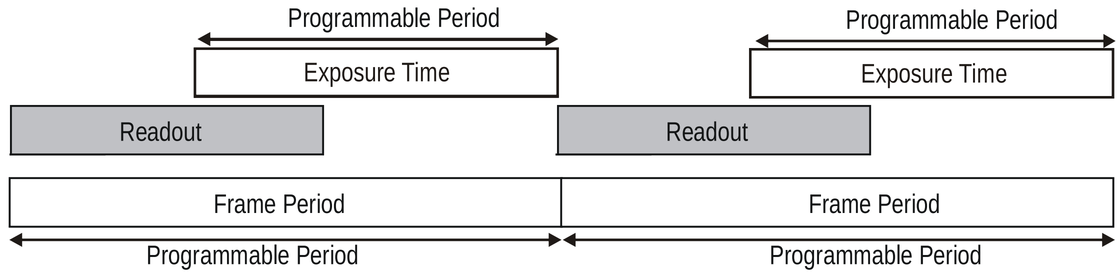
Mode 2: Internally Programmable Frame Rate and Exposure Time (Default)

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 Table 11: Allowable Exposure Time Increments on page 27 for details on minimum exposure time increments for this mode.

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

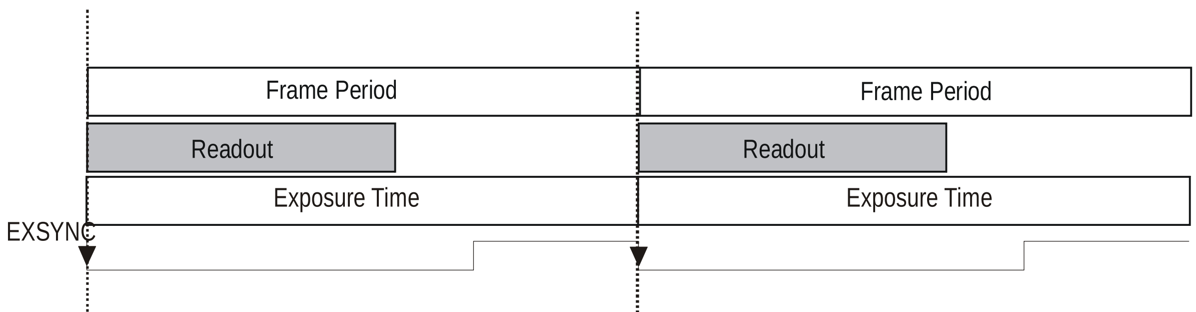
Figure 11: Mode 2 Timing



Mode 3: External Trigger with Maximum Exposure

Frame rate is set by the period of the external trigger pulses. The falling edge of the external trigger marks the beginning of the maximum exposure with exposure control disabled (ECD).

Figure 12: Frame Rate is set by External Trigger Pulses.

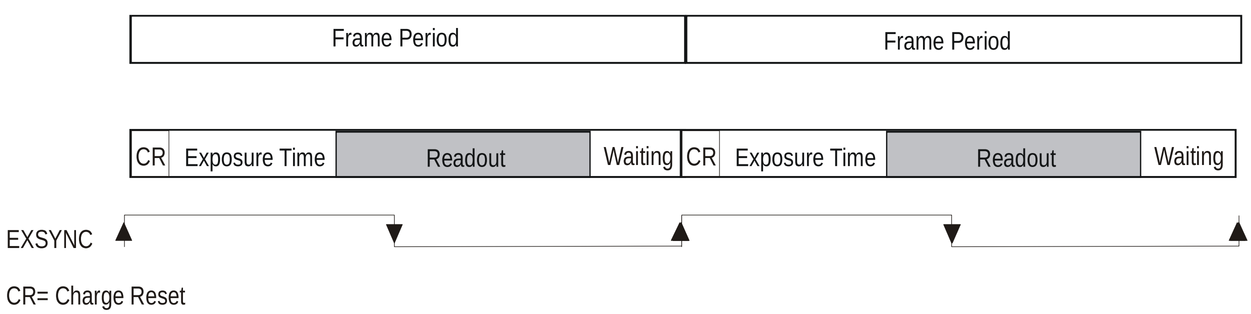


Mode 4: Smart EXSYNC, External Frame Rate and Exposure Time

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

Table 11: Allowable Exposure Time Increments on page 27 for details on minimum exposure time increments for this mode.

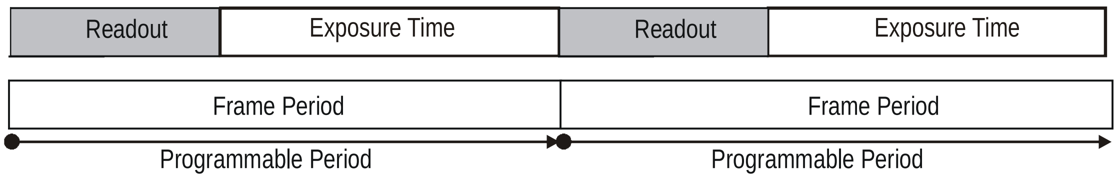
Figure 13: Trigger Period is Repetitive and Greater than Read Out Time.



Mode 7: Internal Frame Rate, Maximum Exposure Time

In this mode, the frame rate is set internally with a maximum exposure time with exposure control disabled (ECD).

Figure 14: Programmable Frame Rate with Maximum Exposure Time



3.4.2 Setting the Frame Rate

Purpose: Sets the camera's frame rate in Hz.

Syntax: **`ssf f`**

Syntax Elements: ***f***

Set the frame rate in Hz in a range from **`1-62.1`** (4M60 full frame, 80 MHz pixel rate) or **`1-31`** (4M30 full frame, 80 MHz pixel rate). Range increases when using a window of interest.

Notes:

- Camera must be operating in exposure mode 2 or 7.
- Allowable range is dependent on the current Camera Link mode and window size. Refer to section for more information on Camera Link modes. Refer to section 3.5 Setting a Vertical Window of Interest 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 Camera's Pixel Rate for more information on how to set the camera's pixel rate

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

Example: **`ssf 25.0`**

3.4.3 Setting the Exposure Time

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

Syntax: **`set f`**

Syntax Elements: ***`f`***

Floating point number in µs. Allowable range is 10-999989 µs. See Table 11 below for 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. The camera sends a warning when this occurs. Refer to Table 11: 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`**, **`eec`**, **`clm`**

Example: **`set 5500`**

Table 11: Allowable Exposure Time Increments

`15` or **`16`**		
	18.475 µs (80 MHs pixel rate) 22.875 µs (65 MHs pixel rate)	when exposure time overlaps frame readout
	1µs	when exposure time **does not** overlap frame readout
`2` or **`3`**		
	37.000µs (80 MHs pixel rate) 45.600 µs (65 MHz pixel rate)	when exposure time overlaps frame readout
	1µs	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) when exposure time overlaps frame readout.

This is because, in exposure mode 4, the falling edge is captured by the camera every 18.475µs (**clm 15** or **16**) or 37.000µs (**clm 2** or **3**).

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

Refer to section Figure 11: Mode 2 Timing on page 25 for an example where exposure time overlaps frame readout.

3.5 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.

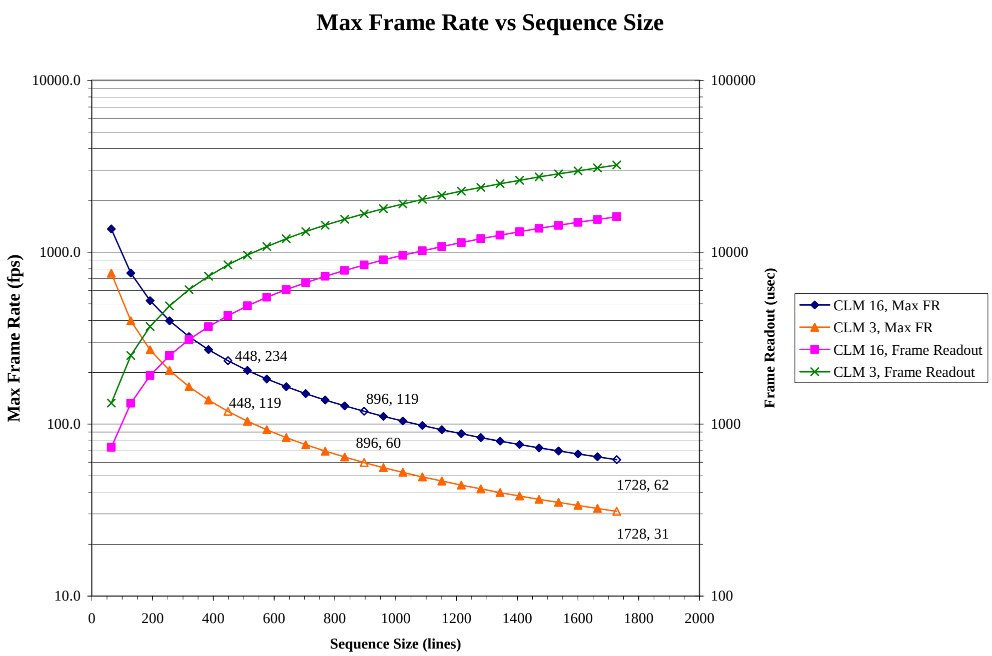
To set a window of interest:

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 16: Maximum Frame Rate versus Sequence Size



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

To calculate frame readout time when using a window of interest, use the following formula:

Frame Readout Time= Number of Lines x Line Time where ***Number of Lines*** is the total number of lines from all windows from the current sequence. You can retrieve the number of lines by sending the **gcp** command

Refer to section 3.5 Setting a Vertical Window of Interest for more information on the setting window

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 17 for timing requirements.
- If you are using a software trigger, refer to the next section for command syntax and timing requirements.

Figure 17: Detailed Timing Requirements for Hardware Triggering New Window Sequence

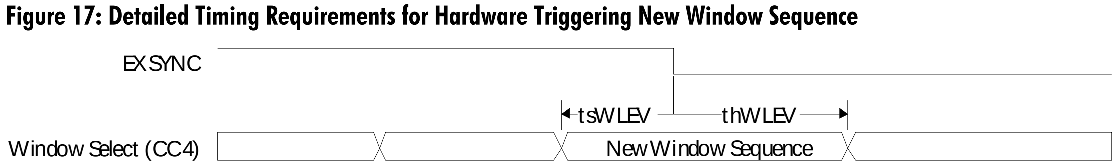


Table 13: Timing Parameters

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.	TBD	TBD
tsWLEV	Window Level Set Time- The Window Control Signals must remain valid and constant at least tsWLEV before the EXSYNC falling edge.	TBD	TBD

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 18)
- 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 18: Time Delay for New Window to Become Active when Using wss Command

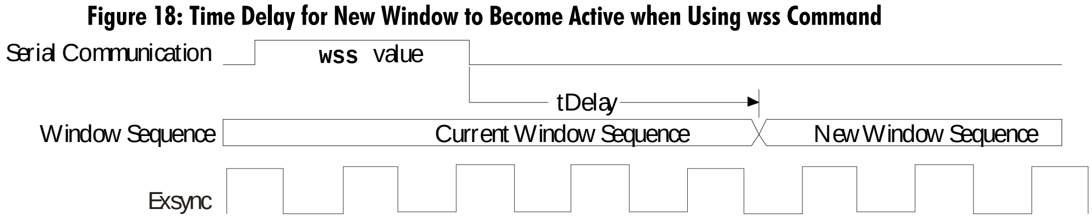


Table 14: Timing Parameters

tDelay	This is the time delay that occurs to decode the **`wss`** command.	TBD	TBD

3.6 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 or if you change the frame rate or integration time.

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 brightest pixel should be slightly below the target output.
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.

3.6.1 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 to use.

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

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

Notes:

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

Example: **`csn 0`**

3.6.2 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`**

3.6.3 Selecting the Calibration Sample Size

Setting the Number of Lines 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`**

3.6.4 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.)
- Perform all analog and digital adjustments before performing FPN correction.
- Perform FPN correction before PRNU correction.
- The **`ccf`** command is not available when the camera is using the factory calibrated coefficients (**`csn 0`**). You must select the user coefficient set (**`csn 1`**) before you can perform FPN calibration. An error message is returned if you attempt to perform FPN calibration when using **`csn 0`**.

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**). You must select the user coefficient set (**csn 1**) before you can perform FPN calibration. An error message is returned if you attempt to perform FPN calibration when using **csn 0**.

Example: **sfc 10 50**

3.6.5 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 *i i***

Syntax Elements: ***i***

PRNU calibration algorithm to use:

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

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

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

i

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

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

Example: **cpa 2 700**

Calibrating Individual Pixels

Purpose: Sets an individual pixel's PRNU coefficient.

Syntax **spc *x y i***

Syntax Elements:

x

The pixel column number from **1** to **2352**.

y

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

i

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

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

Notes:

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

Example: **spc 10 50 500**

3.6.6 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**). You must select the user coefficient set (**csn 1**) before you can perform PRNU calibration. An error message is returned if you attempt to perform PRNU calibration when using **csn 0**. To return the current **csn** number, send the command **get csn**.

Example: **wpc**

Saving the Current FPN Coefficients

Purpose: Saves the current FPN coefficients to non-volatile memory.

Syntax: **wfc**

Notes:

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

Example: **wfc**

Loading Pixel Coefficients

Purpose: Loads the last saved user coefficients or original factory coefficients from non-volatile memory.

Syntax: **lpc**

Notes:

- The coefficient set that you are loading is determined by the **csn** value. Refer to the section, Selecting Factory or User Settings, for an explanation of the **csn** command. To return the current **csn** number, send the command **get csn**.

Example: **lpc**

Resetting the Current Pixel Coefficients

Purpose: Resets the current user coefficients to zero. This command also resets saved coefficients to zero.

Syntax: **rpc**

Notes:

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

3.6.7 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.

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**

3.7 Offset and Gain Adjustments

Setting Analog Offset

Purpose: Sets the analog offset. The analog offset should be set so that it is at least 3 times the rms noise value at the current gain. The analog offset is factory calibrated and is applicable to exposure mode **sem 2/4** but no calibration is assumed for exposure mode **sem 3/7**.

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.

Notes:

- The offset increases linearly with higher values. A value of 100 does not equal an offset of 100DN.
- 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.
- The lower input limit of the offset for **sem 3/7** is set at 24 and for **sem 2/4** is set at 0.

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**.

The calibration is applicable to exposure mode **sem 2/4** but no calibration is assumed for exposure mode **sem 3/7**.

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

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

Syntax: **ssg *t* *i***

Syntax Elements: ***t***

Sensor tap selection. 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

Related Commands: **ssb**

Example: **ssg 1 15**

3.8 Generating a Test Pattern

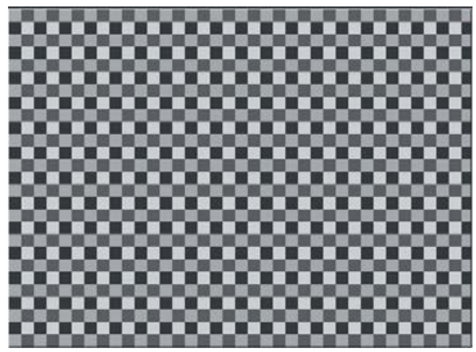
Purpose: Generates a test pattern to aid in system debugging. The test patterns are useful for verifying proper timing and connections between the camera and the frame grabber. The following table shows each available test pattern.

Syntax: **`svm i`**

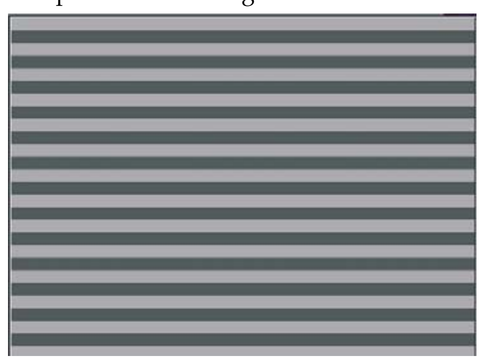
Syntax Elements: **`i`**

0 Video.

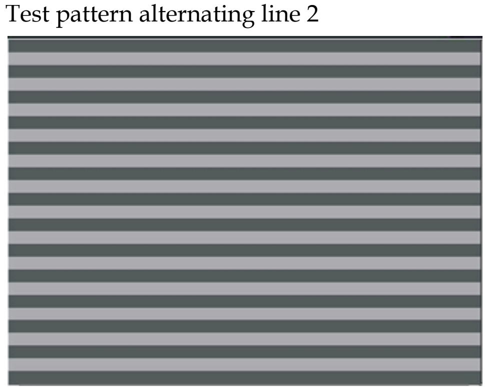
1 Test pattern checkerboard



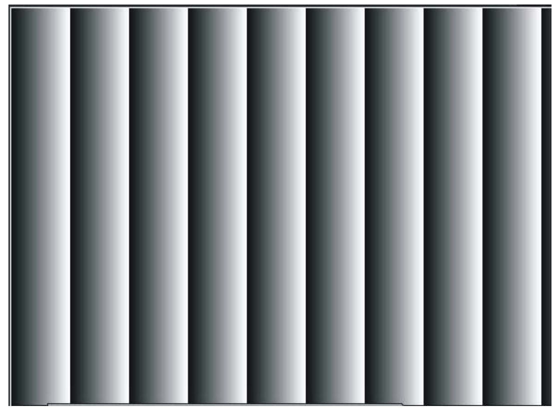
2 Test pattern alternating line 1



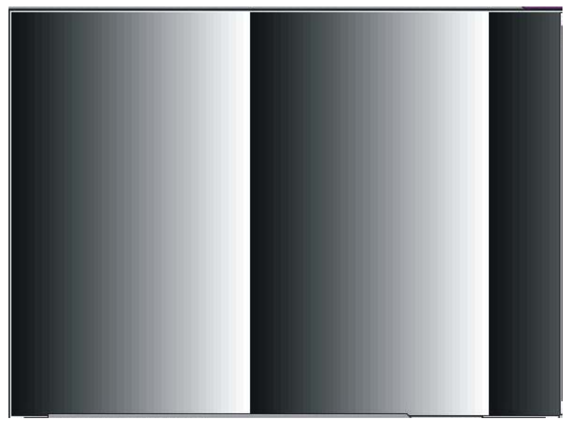
3 Test pattern alternating line 2



4 Test pattern horizontal ramp

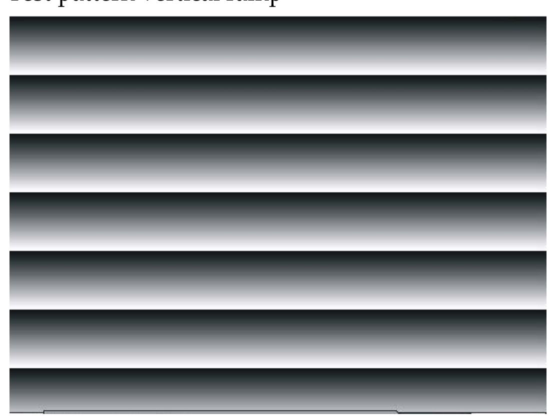


8 bit

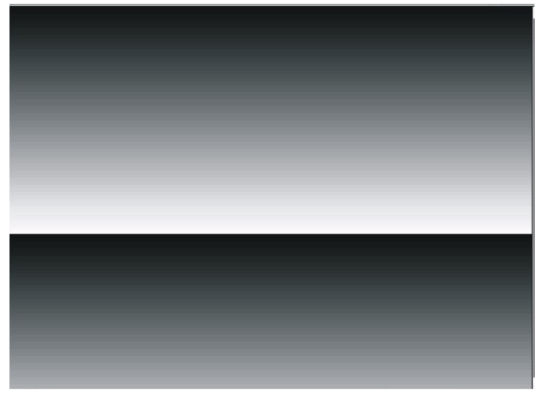


10 bit

5 Test pattern vertical ramp

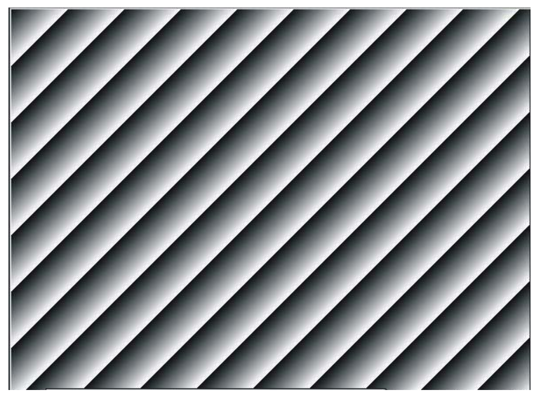


8 bit

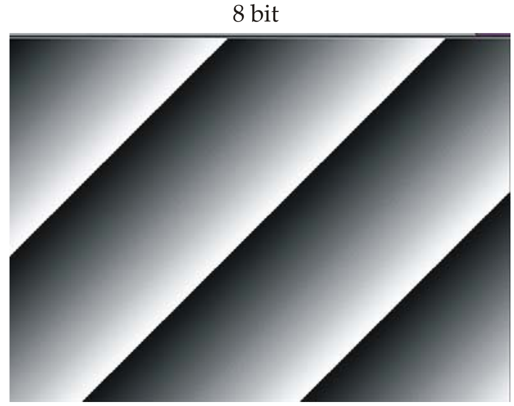


10 bit

6 Test pattern diagonal ramp



8 bit



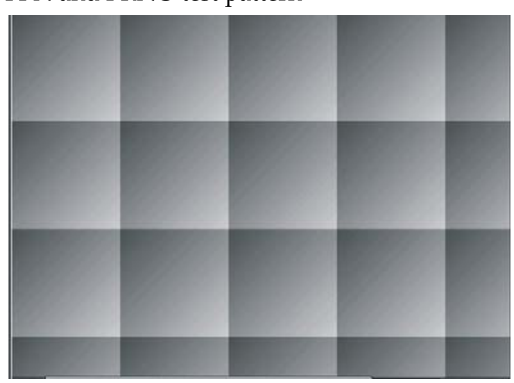
10 bit

7 FPN test pattern

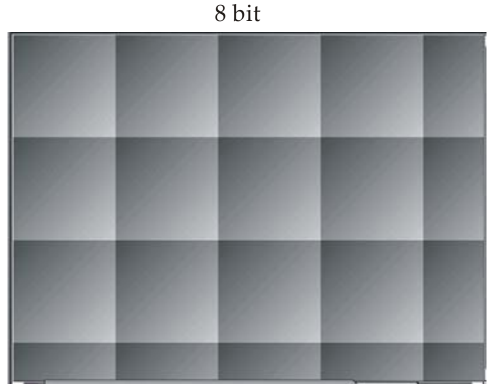
8 bit

10 bit

8 FPN and PRNU test pattern

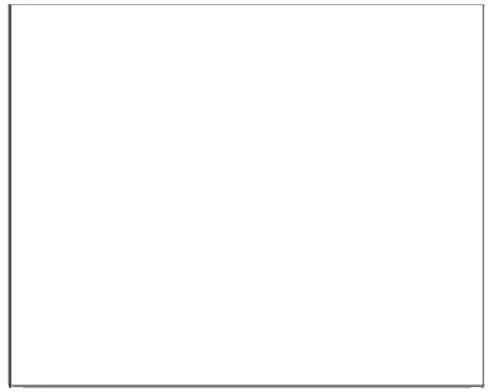


8 bit



10 bit

9 Fixed 1023 test pattern



10 Fixed 255 test pattern

- When switching the camera from video mode (**svm 0**) to one of the test pattern modes (**svm 1** thru **8**), the camera "turns off" 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.

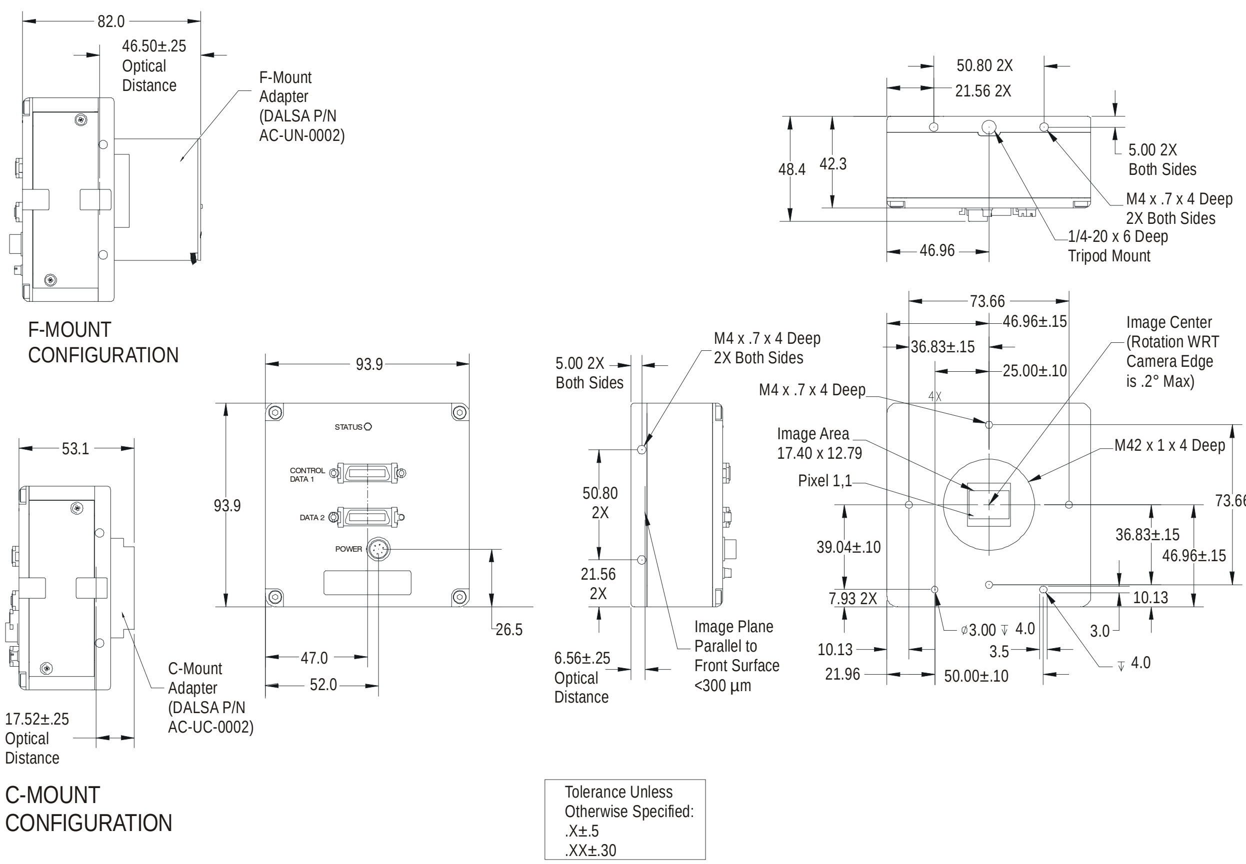
Example: **svm 2**

4

Optical and Mechanical Considerations

4.1 Mechanical Interface

Figure 20: Camera Mechanical Dimensions



For optimal camera performance, the camera should be cooled by applying forced air flow or by attaching the camera to a heatsink. If attaching a heatsink, 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

M42	6.56±0.25mm
F-Mount	46.50 ±0.25mm
C-Mount	17.52±0.25mm

Note that the use of a C-Mount lens will 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://vfm.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 1ms just the same as exposing an intensity of 5W/cm^2 for 1μs.

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

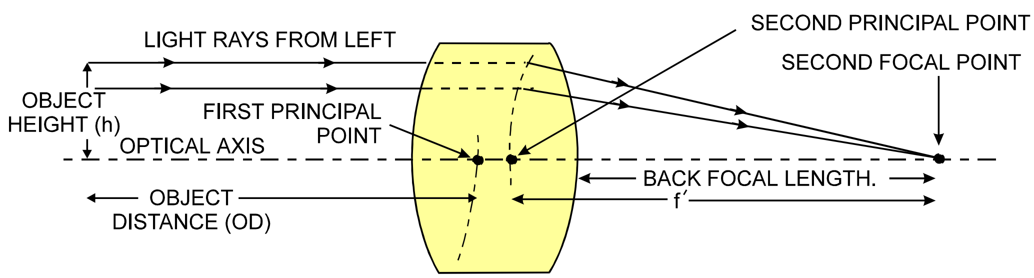
750, which does not include a mounting ring, and the CORION™ HR-750 series hot mirror.

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 21: 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 45mm, and requires that 100µm in the object space correspond to each pixel in the image sensor. Using the preceding equation, the object distance must be 450mm (0.450m).

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

5

Troubleshooting

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

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

Your steps in dealing with a technical problem should be:

1. Try the general and specific solutions listed in sections 5.1, 5.2 and 5.3.
2. 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 3.8 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.

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 a filtered blow bottle or dry, filtered compressed air.
4. Fold a piece of optical lens cleaning tissue (approx. 3" x 5") to make a square pad that is approximately one finger-width
5. Moisten the pad on one edge with 2-3 drops of clean solvent—either alcohol or acetone. Do not saturate the entire pad with solvent.
6. Wipe across the length of the window in one direction with the moistened end first, followed by the rest of the pad. The dry part of the pad should follow the moistened end. The goal is to prevent solvent from evaporating from the window surface, as this will end up leaving residue and streaking behind.
7. Repeat steps 2-4 using a clean tissue until the entire window has been cleaned.
8. 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-40-04M60...)**	
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:

519-886-6000	+49-8142-46770	519-886-6000
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 at http://vfm.dalsa.com/support/appnotes/00450-00_03-32_DALSA_Camera_Link_Road_Map.pdf) 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://vfm.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. The signals are:

• FVAL1—Frame Valid (FVAL1) is defined HIGH for valid lines.

• LVAL1— HIGH indicates Window 1 data.

• 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 vfm.dalsa.com Web site.

Table 15: DALSA Camera Control Configuration

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 programmming 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://vfm.dalsa.com Web site.

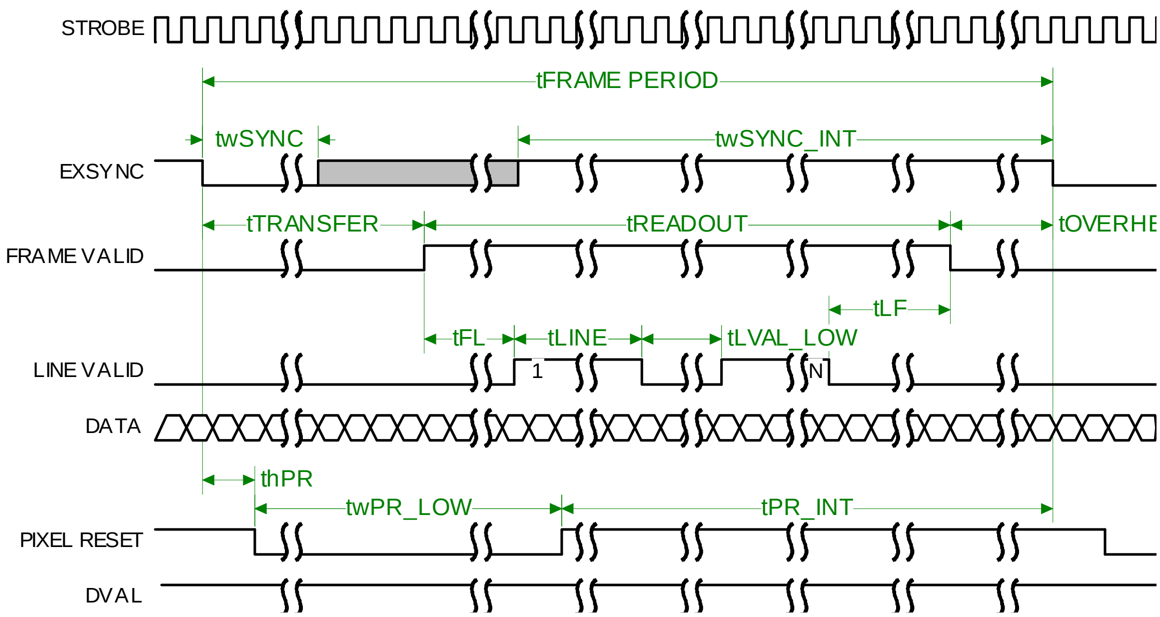
Power

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 22: Pantera SA 4M60 Standard Timing (Input and Output Relationships)



twSYNC	The minimum width of the EXSYNC pulse. When in SMART EXSYNC mode, the minimum width is greater to allow for the photosites to be properly reset.	µs	12		
twSYNC_INT	Is the the integration time when the "SMART EXSYNC" feature is available and turned on. Note that the minimum time is necessary to guarantee proper operation.	µs	10		
t FRAME PERIOD	The minimum frame time made up of tTransfer, tREADOUT plus tOVERHEAD	ms	16.129		1000.0
tTRANSFER	The time from the reception of the falling edge of EXSYNC to the rising edge of FVAL.	µs		58 (`clm 15/16`) 82 (`clm 2/3`)	
tREADOUT	Is the time that frame valid is high	µs		16000 (`clm 15/16`, sot 320) 32000 (`clm 2/3`)	

				20000 (**clm 15/16, sot 260**) 40000 (**clm 2/3, sot 130**)	
tOVERHEAD	Is the number of pixels that must elapse after the falling edge of FVAL before the EXSYNC falling edge can occur.	ns		TBD	
tLINE	The line time	µs		(**clm 15/16, sot 320**) 18.475 µs (**clm 15/16, sot 260**) 22.875 µs (**clm 2/3, sot 130**) 45.600 µs	
tFL	Number strobes between FVAL rising and the first LVAL rising edge.	clocks		0	
tLVAL_LOW	Number strobes that LVAL is low during readout	µs		TBD	
tLF	Number of strobes between last LVAL falling and FVAL falling edge.	clocks		0	
thPR	N. A.	ns			
twPR_LOW	N. A.	ns			
tPR_INT	N. A.	ns			

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.

Table 16: All Available Commands

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.

coefficient set number	**csn**	**i**	Selects the coefficient set to use, either: **0** = Factory calibrated set of FPN and PRNU coefficients. These coefficients cannot be erased or modified. **1** = User calibrated set of FPN and PRNU coefficients. These coefficients **can** be deleted or modified.
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**
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.
get camera serial	**gcs**		Read the camera serial number.
get camera version	**gcv**		Read the firmware version and FPGA version.
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 where ***i*** is: **0** = Factory calibrated coefficients **1** = User coefficient set
reset camera	**rc**		Reset the entire camera (reboot).
restore factory settings	**rfs**		Restore the camera's factory settings.
restore user settings	**rus**		Restore the camera's last saved user settings.

set analog offset	**sao**	**t i**	Set the analog gain. **t** = Tap selection. Allowable value is **0** for all taps. **i** = Analog offset value. Allowable range is **0** -**1023**.
set baud rate	**sbr**	**m**	Set the speed of the serial communication port. Baud rates: **9600**, **19200**, **57600**, and **115200**. Default baud: 9600
set exposure mode	**sem**	**m**	Set the exposure mode. Available values are: **2**: Internal SYNC, programmable frame rate and exposure time using commands ssf and set. Exposure control enabled (ECE). **3**: External SYNC, maximum exposure time, exposure control disabled (ECD) **4**: Smart EXSYNC. Exposure control enabled (ECE). **7**: Internal programmable SYNC, maximum exposure time, exposure control disabled (ECD)
set exposure time	**set**	**f**	Sets the exposure time to a floating point number in µs. Allowable range is **10**-**999989** µs in increments described in Table 11: Allowable Exposure Time Increments on page 27.
set sync frequency	**ssf**	**f**	Sets the frame rate in Hz to a value from **1** to **62.1** (4M60 full frame) or **1** to 31 (4M30 half frame).
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.
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 fixed 255

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 **2-1728** and must belong to the following set: 4, 8, 12, …1728
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

Revision History

00	Preliminary release
01	.Added the **sce** and **eec** commands to Table 16: All Available Commands. Updated the **set** command description from allowable steps of 1µs to allowable steps of 18.475 and 37.0µs in 3.4.3 Setting the Exposure Time and in Table 16: All Available Commands.
02	In section 3.6.1, updated Mode 2 timing diagram to show that readout and exposure time can overlap. Added the windowing commands, **wss**, **wts**, and **wse** to section 3.5 Setting a Vertical Window of Interest and Table 16: All Available Commands. Added the **ssg**, and **ssb** commands to section and Table 16: All Available Commands.
03	Updated Figure 20: Camera Mechanical Dimensions On page 6 changed the 'Camera Size' from 94x94x46 to 94x94x48 and the 'Mass' from <500 to <550.
04	Updated mechanical drawing to show tooling holes on the front cover.
05	Updated dynamic range, responsivity, operating temp (to 50° from 40°, measured at front plate)
06	Updated responsivity, dynamic range. Added get command. Added Max Frame Rate vs Sequence Size graph. Removed GSS command. Removed SCG and SFG commands. Added SVM 5 pattern.
07	Added test patterns 6 to 8.
08	Added flat field correction commands.
09	Added sot command to section 3.3.3 Setting the Camera's Pixel Rate. Added section 3.1 First Power Up Camera Settings.

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