Piranha Color Trilinear Camera

PC-30-02K80-00-R
PC-30-02K60-00-R
PC-30-04K80-00-R
PC-30-04K60-00-R

TELEDYNE DALSA
A Teledyne Technologies Company

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Features and Specifications

1.0 Introduction

Camera Features

- 2048 or 4096 trilinear RGB line scan sensor.
- Color spacing: 3 lines, center-to-center.
- Forward and reverse scanning operation.
- Maximum line rates of 22 kHz (2k60) and 32 kHz (2k80), or 12 kHz (4k60) and 17 kHz (4k80).
- Programmable analog gain and offset.
- FPN and PRNU correction.
- White balancing algorithms.
- Optional luminance output.
- Spatial correction.
- Anti-blooming.
- Configurable base or medium Camera Link.
- RoHS and CE compliant.

Applications

- 100% print inspection.
- Electronics manufacturing inspection.
- Postal and parcel sorting.
- High performance document scanning and image lift.
- Narrow and large web inspection.
- High-end industrial inspection.

Models

Model Number	Description
PC-30-02k60-00-R	2k resolution, 3 taps at 60 MHz
PC-30-02k80-00-R	2k resolution, 3 taps at 80 MHz
PC-30-04k60-00-R	4k resolution, 3 taps at 60 MHz
PC-30-04k80-00-R	4k resolution, 3 taps at 80 MHz

1.1 Camera Performance Specifications

2k Model Performance Specifications

Test conditions and notes follow. All numbers measured at 12-bit unless specified otherwise.

Sensor Features	Value
Imager Format	Trilinear CCD
Resolution	2048 pixels

Sensor Features	Value
Pixel Fill Factor	100%
Pixel Size	14 x 14 μm
Antiblooming	10x

Operating Ranges	Value
Minimum Line Rate	3.0 kHz (Operable to 1 Hz from external)
Maximum Line Rate	22.7 kHz (2k60) or 32.3 kHz (2k80)
Pixel RGB Throughput	Up to 80 Mps
Gain	-10 dB to +10 dB

Optical Interface	Value
Back Focal Distance M72 Mount	19.56 mm (M72 x 0.75)
Sensor Alignment x y z Θz	 ± 50 μm ± 50 μm ± 250 μm ±0.2°
Lens Mount	M72 x 0.75, M42x1 and F-mount.

Mechanical Interface	Value
Camera Size	67 x 105 x 76 (l x h x w)
Mass	450 g
Power connector	Single voltage input (+12V to +15V) Hirose 6-pin circular male
Data connector	Camera Link MDR26F

Electrical Interface	
Input Voltage	+12 to +15 volts
Power Dissipation	12 W
Operating Temperature (front plate)	0 to 50 °C
Data Output Format	8 or 12 bits
Output Data Configuration	3 taps 8 bit 3 taps 12 bit 6 taps 8 bit

2k Model Operating Specifications

Test conditions and notes follow. All numbers measured at 12-bit unless specified otherwise.

Operating Specifications	FFC	Unit		Color	-10dB			0dB			+10dB		
					Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Responsivity	Off	DN/(nJ/cm^2)		R		76		228	240	252		758	
				G		127		380	400	420		1264	
				B		63		190	200	210		632	
Responsivity	On	DN/(nJ/cm^2)		R		95		285	300	315		948	
				G		158		475	500	525		1580	
				B		79		238	250	263		790	
Dynamic Range	On	Ratio		RGB		758			240			76	
Random Noise	On	DN rms		RGB		5.4	10		17	30		54	95
DC Offset		DN		RGB		180			180			180	
FPN	Off	DN p-p	K60	RGB			25			55			137
			K80	RG									
			K80	B*			60			140			450
FPN	On	DN p-p		RGB					10				
PRNU global	Off	DN p-p		RGB			760			760			1000
PRNU pixel-to-pixel	Off	DN p-p		RGB			517			517			890
PRNU global	On	DN p-p		RGB					18				
NEE	On	pJ/cm^2		R		56.7			56.7			56.7	
				G		34			34			34	
				B		68			68			68	
SEE	On	nJ/cm^2		R		43.1			13.7			4.3	
				G		25.9			8.2			2.6	
				B		51.8			16.4			5.2	
Saturation Output Amplitude		DN		RGB		4095			4095			4095	

4k Model Performance Specifications

Test conditions and notes follow. All numbers 12 bit unless specified otherwise.

Sensor Features	Value
Imager Format	Trilinear CCD
Resolution	4096 pixels
Pixel Fill Factor	100%
Pixel Size	10 x 10 μm
Antiblooming	100x

Operating Ranges	Value
Minimum Line Rate	3.0 kHz (Operable to 1 Hz)
Maximum Line Rate	12.1 kHz (4k60) or 17.6 kHz (4k80)
Pixel RGB Throughput	up to 80 Mps
Gain	-10 dB to +10 dB

Optical Interface	Value
Back Focal Distance M72 Mount	91.56 mm (M72 x 0.75)
Sensor Alignment x y z Θz	 ±50 μm ±50 μm ±250 μm ±0.2°
Lens Mount	M72 x 0.75, M42x1 and F-mount.

Mechanical Interface	Value
Camera Size	67 x 105 x 76 mm (l x h x w)
Mass	450 g
Power connector	Single voltage input (+12V to +15V) Hirose 6-pin circular male
Data connector	Camera Link MDR26F

Electrical Interface	
Input Voltage	+12 to +15 volts
Power Dissipation	12 W
Operating Temperature (front plate)	0 to 50 °C
Data Output Format	8 or 12 bits
Output Data Configuration	3 taps 8 bit 3 taps 12 bit 6 taps 8 bit

4k Model Operating Specifications

Test conditions and notes follow. All numbers measured at 12-bit unless specified otherwise.

Operating Specifications	FFC	Unit		Color	-10dB			0dB			+10dB		
					Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Responsivity	Off	DN/(nJ/cm²)		R		38		114	120	126		379	
				G		63		190	200	210		632	
				B		32		95	100	105		316	
Responsivity	On	DN/(nJ/cm²)		R		47		143	150	158		474	
				G		79		238	250	263		790	
				B		40		119	125	131		395	
Dynamic Range	On	Ratio		RGB		758			240			76	
Random Noise	On	DN rms		RGB		5.4	10		17	30		54	95
DC Offset		DN		RGB		180			180			180	
FPN	Off	DN p-p	K60	RGB			40			87			275
			K80	RG									
			K80	B*			60			140			450
FPN	On	DN p-p		RGB					10				
PRNU global	Off	DN p-p		RGB			760			760			1000
PRNU pixel-to-pixel	Off	DN p-p		RGB			517			517			890
PRNU global	On	DN p-p		RGB					18				
NEE	On	pJ/cm²		R		113.3			113.3			113.3	
				G		68			68			68	
				B		136			136			136	
SEE	On	nJ/cm²		R		86			27.3			8.6	
				G		51.8			16.4			5.2	
				B		103.5			32.8			10.4	
Saturation Output Amplitude		DN		RGB		4095			4095			4095	

Specification tables test conditions and notes 2k and 4k models:

- Line Rate: 400 Hz.
- Exposure Time (µs):

	2K			4K		
	R	G	B	R	G	B
-10 dB	800	480	960	1600	960	1920
0 dB	253	152	304	506	304	607
+10 dB	80	48	96	160	96	192

- Light Source: Broadband Quartz Halogen, BG-38, with 750nm cutoff filter installed, Correction Color Temperature = 5300°K.
- Ambient Test Temperature: 25°C.
- Output swing (FFC off): 3220 DN includes 180 DN Dark Offset. (Range of 0 to 4095 DN).
- Output swing (FFC on): 3800 DN.
- All numbers are 12-bit unless specified otherwise.
- The responsivity of each color is adjusted to achieve equal output.
- Tested in Camera Link Mode clm 16.
- PRNU specified at 75% of full swing.

General Notes:

- Specifications apply to both 60 MHz and the 80 MHz camera models unless indicated otherwise.
- Specification with "FFC on" apply to the factory calibrated FFC. User calibrated FFC may have a different affect on camera performance.

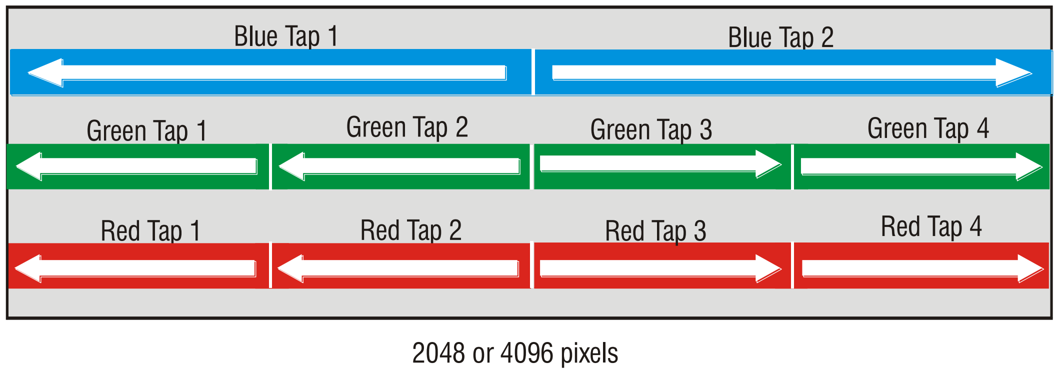
***FPN Notes:**

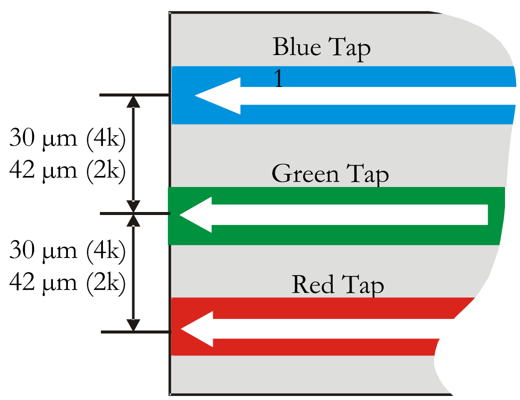
- 2K80 cameras have increased FPN on the blue outputs between pixels 533 - 543 and 1506 - 1516.
- 4K80 cameras have increased FPN on the blue outputs between pixels 1045 - 1055 and 3042 - 3052.
- Outside of this range, FPN meets the same specification as the other colors.

1.2 Image Sensor

The Piranha Color camera uses a trilinear CCD sensor with three lines of pixels: one blue, one red and one green. Depending on your camera model, each line contains either 2048 or 4096 pixels. As illustrated in the diagram below, the blue line has 2 outputs (taps), and the red and green lines have 4 outputs.

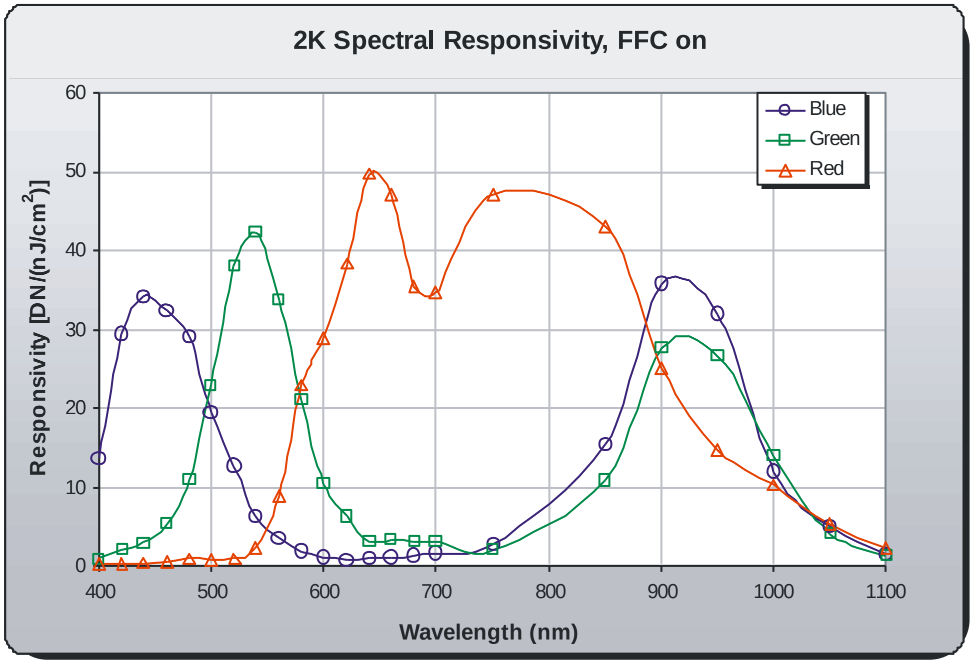
Figure 1: Sensor Block Diagram

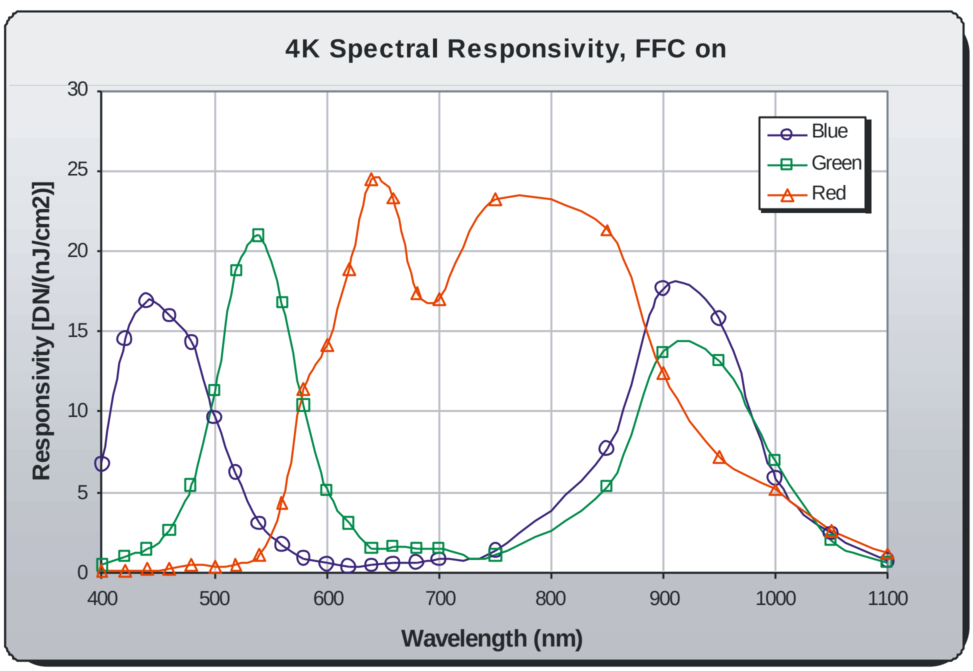




The three color lines are separated 30 µm (4k) or 42 µm (2k) apart center to center.

1.3 Responsivity





Hardware Interface: Connectors and Timing

2.1 Installation Overview

When installing your camera, you should take these steps:

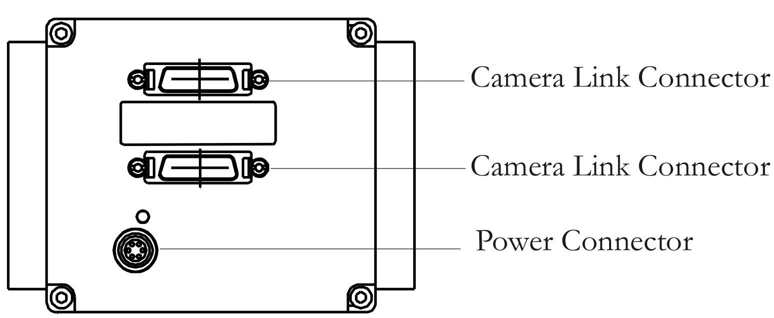
1. Power down all equipment.
2. Following the manufacturer's instructions, install the frame grabber (if applicable). Be sure to observe all static precautions.
3. Install any necessary imaging software.
4. Before connecting power to the camera, test all power supplies. Ensure that all the correct voltages are present at the camera end of the power cable. Power supplies must meet the requirements defined in section 2.2.2 Power Connector.
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. See the LED Status Indicator section below for an LED description.
9. The camera powers on with a baud rate of 9600.

You must also set up the other components of your system, including light sources, camera mounts, host computers, optics, encoders, and so on.

2.2 Input / Output Connectors and LED

The camera uses:

- An LED to display the camera's status.
- High-density 26-pin MDR26 connectors for Camera Link control signals, data signals, and serial communications.
- One 6-pin Hirose connector for power.



Note: Refer to the following sections for details on equipment recommendations and camera connector information.

2.3 Camera LED

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. The fatal error state is accompanied by corresponding messages further describing the problem.

Table 1: Diagnostic LED

Priority	Color of Status LED	Meaning
1	Flashing Red	Fatal Error. For example, camera temperature is too high and camera thermal shutdown has occurred.
2	Flashing Green	Camera initialization or executing a long command (e.g., flat field correction commands `ccp` or `ccf`). During this state, any other sent command is ignored.
3	Solid Green	Camera is operational and functioning correctly and ready to receive commands.

2.4 Power Connector

Figure 2: Hirose 6-pin Circular Male—Power Connector

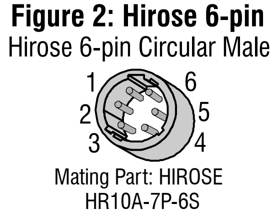


Table 2: Hirose Pin Description

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

The camera requires a single voltage input (+12 V to +15 V). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear supplies provide optimum performance.

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

- Ensure +12 V to +15 V at the camera power input (after the voltage drop across the power cable. This may mean that the power supply will have to provide a voltage greater than the required camera voltage. For example, to achieve +12 V at the camera, the power supply may need to be +12.5 V or greater.
- Protect the camera with a **fast-blow fuse** between power supply and camera.
- Do not use the shield on a multi-conductor cable for ground.
- Keep leads as short as possible to reduce voltage drop.
- Use high-quality **linear** supplies to minimize noise.
- Use an isolated type power supply to prevent LVDS common mode range violation.

Note: Camera performance specifications are not guaranteed if your power supply does not meet these requirements.

2.5 Camera Link Data Connector

Figure 3: Camera Link MDR26 Connector

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

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).

EXSYNC (Triggers Line Readout)

Line rate can be set internally 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 pixel readout.

Direction Control

You control the CCD shift direction through the serial interface. With the software command, `scd`, you determine whether the direction control is set via software control or via the Camera Link control signal on CC3.

Output Signals, Camera Link

IMPORTANT: This camera's data should be sampled on the rising edge of STROBE.

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 Camera Link Roadmap, available from the Knowledge Center on our website here, for the standard location of these signals.

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

- The camera internally digitizes 12 bits and outputs the 8 MSB or all 12 bits depending on the camera's Camera Link operating mode.

2.6 Camera Timing

The Piranha Color camera uses a base or medium Camera Link interface.

Base Configuration

A base configuration uses 1 MDR26 connector and 1 Channel Link chip. The main characteristics of the base configuration are:

- Ports supported: A, B, C.

- Serializer bit width: 28.
- Number of chips: 1.
- Number of MDR26 connectors: 1.

Base Configuration		
One Channel Link Chip + Camera Control + Serial Communication		
Camera Connector	Right Angle Frame Grabber	Channel Link Signal
1	1	inner shield
14	14	inner shield
2	25	X0-
15	12	X0+
3	24	X1-
16	11	X1+
4	23	X2-
17	10	X2+
5	22	Xclk-
18	9	Xclk+
6	21	X3-
19	8	X3+
7	20	SerTC+
20	7	SerTC-
8	19	SerTFG-
21	6	SerTFG+
9	18	CC1-
22	5	CC1+
10	17	CC2+
23	4	CC2-
11	16	CC3-
24	3	CC3+
12	15	CC4+
25	2	CC4-
13	13	inner shield
26	26	inner shield

Base Configuration Timing

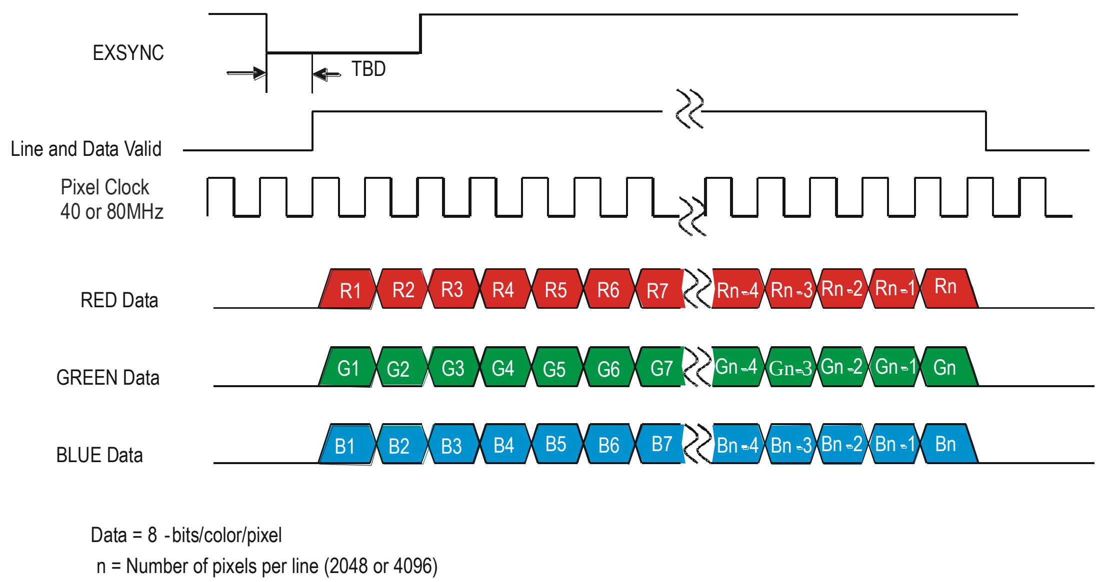
Each pixel output has 8 bits for each of the three colors (red, green, and blue).

Table 3: Base Configuration Video Data

Base Configuration												
					Connector 1				Maximum SSF[8]			
CLM[1]	Bits[2]	Taps[3]	Lum[4]	Time[5]	Port[6] A	Port B	Port C	SOT[7]	2k60	4k60	2k80	4k80
5	8	1	No	NA	R_{0-7}	G_{0-7}	B_{0-7}	30	14.5	7.3	14.5	7.3
								40	19.3	9.7	19.3	9.7
								60	22.7[9]	12.1	28.9[9]	14.6
								80	NA	NA	31.8	17.5
9[10]	8	1	Yes	T_0	R_{0-7}	B_{0-7}	NA	30	14.5	7.3	14.5	7.3
				T_1	G_{0-7}	Y_{7-0}	NA	40	19.3	9.7	19.3	9.7

10[10]	12	1	Yes	T_0	R_{0-7}	$B_{8-11}R_{8-11}$	B_{0-7}	30	14.5	7.3	14.5	7.3
				T_1	G_{0-7}	$Y_{8-11}G_{8-11}$	Y_{0-7}	40	19.3	9.7	19.3	9.7

Figure 4: Base Configuration



Medium Configuration

A medium configuration uses 2 MDR26 connectors and 2 Channel Link chips. The main characteristics of the medium configuration are:

- Ports supported: A, B, C, D, E, F.
- Serializer bit width: 28.
- Number of chips: 2.
- Number of MDR26 connectors: 2.

Medium Configuration (Connector 2)			
2 Channel Link Chips			
Camera Connector	Right Angle Frame Grabber	Channel Link Signal	Cable Name
1	1	inner shield	Inner Shield
14	14	inner shield	Inner Shield
2	25	Y0-	PAIR1-
15	12	Y0+	PAIR1+
3	24	Y1-	PAIR2-
16	11	Y1+	PAIR2+
4	23	Y2-	PAIR3-
17	10	Y2+	PAIR3+
5	22	Yclk-	PAIR4-
18	9	Yclk+	PAIR4+
6	21	Y3-	PAIR5-

Medium Configuration (Connector 2)			
2 Channel Link Chips			
Camera Connector	Right Angle Frame Grabber	Channel Link Signal	Cable Name
19	8	Y3+	PAIR5+
7	20	terminated	PAIR6+
20	7	terminated	PAIR6-
8	19	Z0-	PAIR7-
21	6	Z0+	PAIR7+
9	18	Z1-	PAIR8-
22	5	Z1+	PAIR8+
10	17	Z2-	PAIR9+
23	4	Z2+	PAIR9-
11	16	Zclk-	PAIR10-
24	3	Zclk+	PAIR10+
12	15	Z3-	PAIR11+
25	2	Z3+	PAIR11-
13	13	inner shield	Inner Shield
26	26	inner shield	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.

Medium Configuration Timing

Medium Configuration														
				Connector 1			Connector 2				Maximum SSF8			
CLM[1]	Bits[2]	Taps[3]	Lum[4]	Port[6] A	Port B	Port C	Port D	Port E	Port F	SOT[7]	2k60	4k60	2k80	4k80
14	8	2	No	R^{A}_{0-7}	G^{A}_{0-7}	B^{A}_{0-7}	R^{B}_{0-7}	G^{B}_{0-7}	B^{B}_{0-7}	60	22.7	12.1	28.6	14.5
										80	NA	NA	31.8	17.5
15	8	1	Yes	R_{0-7}	G_{0-7}	B_{0-7}	Y_{0-7}	NA	NA	30	14.5	7.3	14.5	7.3
										40	19.3	9.7	19.3	9.7
										60	22.7	12.1	28.9	14.6
										80	NA	NA	31.8	17.5
16	12	1	Yes	R_{0-7}	B_{8-11} R_{8-11}	B_{0-7}	Y_{0-7}	G_{0-7}	Y_{8-11} G_{8-11}	30	14.5	7.2	14.5	7.3
										40	19.3	9.7	19.3	9.7
										60	22.7	12.1	28.9	14.6
										80	NA	NA	31.8	17.5

CLM 14 Pixels are Interleaved											
Port	Sequence	1	2	3	4	5	6	7	8	9	10
A	Red^{A}	R1	R3	R5	R7	R9	R11	R13	R15	R17	R19
B	$Green^{A}$	G1	G3	G5	G7	G9	G11	G13	G15	G17	G19
C	$Blue^{A}$	B1	B3	B5	B7	B9	B11	B13	B15	B17	B19
D	Red^{B}	R2	R4	R6	R8	R10	R12	R14	R16	R18	R20
E	$Green^{B}$	G2	G4	G6	G8	G10	G12	G14	G16	G18	G20
F	$Blue^{B}$	B2	B4	B6	B8	B10	B12	B14	B16	B18	B20

Figure 5: Medium Configuration (8 Bits/Color/Pixel)

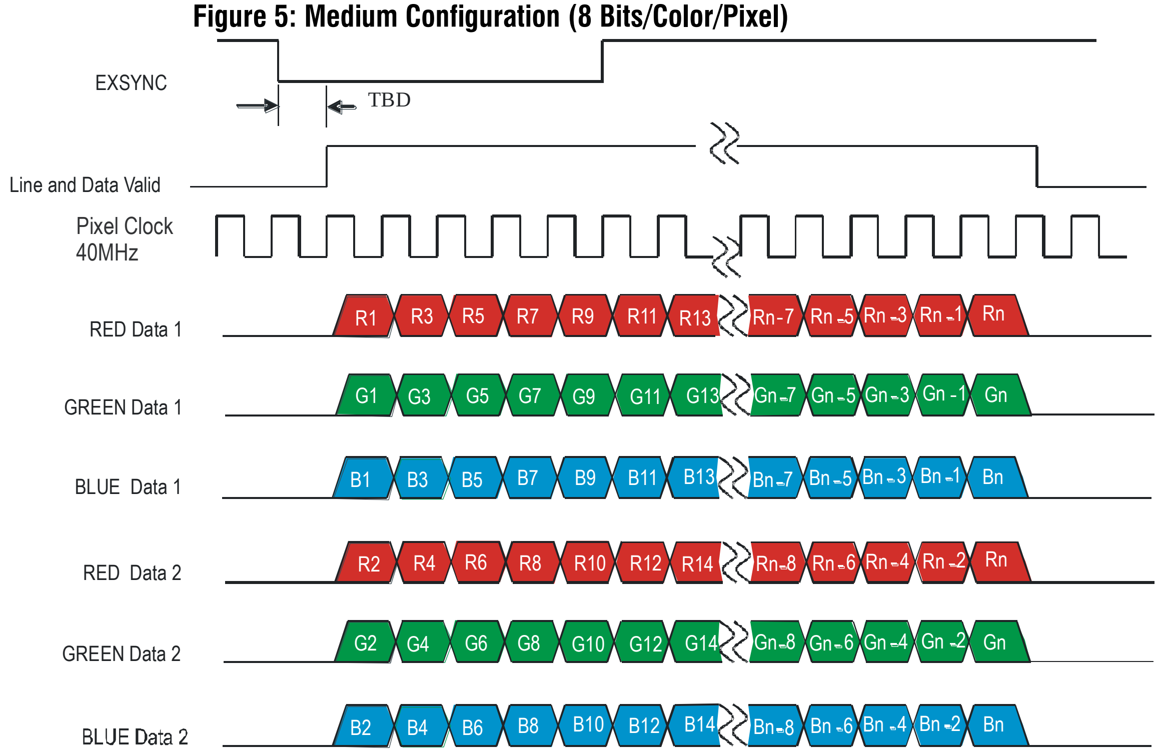
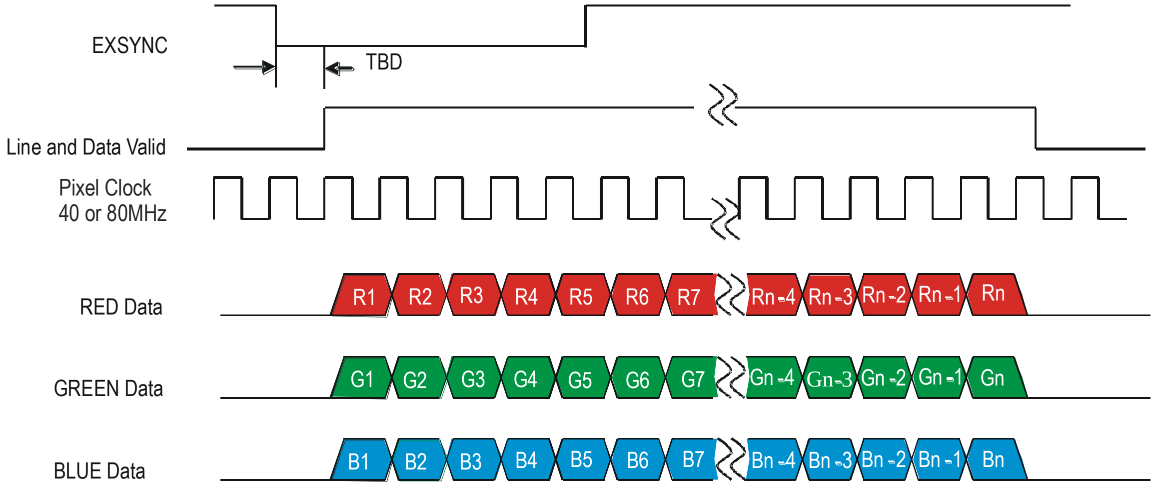


Figure 6: Medium Configuration (12 Bits/Color/Pixel)



Data = 10 or 12 bits/color/pixel
n = Number of pixels per line (2048 or 4096)

Notes for Base and Medium Configuration Timing:

1. CLM: Camera Link Mode.
2. Bits: Number of bits per pixel.
3. Taps: Number of camera link taps per color.
4. Luminance: Indicates if a tap constructed from the RGB using the SCC command is output.
5. Time: Time multiplex interval.
6. Port: Camera Link port.
7. SOT: Output throughput [mega-pixels / second / color].
8. Maximum SSF: Maximum line rate [kHz] possible in this mode (may be reduced by SBH, ELS and SRM).
9. The maximum line rate for SOT 60 for the 80 model is greater than the 60 model as a result of the different readout clocking scheme.
10. Time multiplexing (CLM 9 and 10) is not supported in all frame grabbers.
11. Measurements were made using command settings **els** 0 and **srm** 2.

Software Interface: Configuring the Camera

Using ASCII Commands

All of the camera's functionality is configurable through its serial interface using the three-letter commands. You can use any terminal program (e.g. HyperTerminal) to send serial commands to the camera; however, you must comply with the following serial protocol:

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 9.6 kbps (at power up)
- Camera does not echo characters

Command Format

When entering commands please remember the following:

- A carriage return `<CR>` ends each command.
- The camera will answer each command with either `<CR><LF> OK >` or `<CR><LF>Error xx: Error Message >` or `Warning xx: Warning Message`. The > character is always the last character sent by the camera.
- The following parameter conventions are used in the manual:

i	= integer value
f	= real number
m	= member of a set
s	= string
t	= tap id
x	= pixel column number
y	= pixel row number

Example: to return the current camera settings:

gcp <CR>

3.1 First Power Up Camera Settings

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

- Internal forward color scanning direction.
- Maximum line rate: 32 kHz (2k) or 17 kHz (4k).
- 0 dB calibrated analog gain and offset.
- Factory calibrated FPN and PRNU coefficients enabled.
- 8 bit output.

- 9600 baud rate.
- Exposure mode 2: Internal sync and exposure control.
- RGB color selection.
- Camera Link mode 5: base configuration, RGB, 8 bit output.

Note: The FPN and PRNU coefficients are factory calibrated at 0 dB gain setting 0. The FFC calibration line rate is 400 Hz.

3.2 Rebooting the Camera

The reset command (**rc**) reboots the camera. The camera starts up with the last saved settings and baud rate used before reboot. Previously saved pixel coefficients are also restored.

3.3 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**

3.4 Select Cable

Purpose:	Sets the cable parameters.
Syntax:	**scb m**
Syntax Elements:	*m* Output compare value. Available values are: 0 to 255.
Notes:	In medium configuration, both cables must be the same length. Only one copy of this setting is saved in the camera (rather than with each setting). Using the **lfs** (load factory settings) command, the cable length will be set to the factory default of 100. The cable parameter is a relational value. Increase the value for longer cables, and decrease it for shorter ones. Adjust the value until the test pattern (**svm 1**) is clean.
Example:	**scb 75**

3.5 Help

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

There are two different help screens available. One lists all of the available commands to configure camera operation. The other help screen lists all of the commands available for retrieving camera parameters (these are called “get” commands).

To view the help screen listing all of the camera configuration commands, use the command:

Syntax:	**h**

To view a help screen listing all of the “get” commands, use the command:

Syntax:	**gh**
Notes:	For more information on the camera’s “get” commands, refer to section Returning Camera Settings.

The camera configuration command help screen lists all commands available. Parameter ranges displayed are the extreme ranges available. Depending on the current camera operating conditions, you may not be able to obtain these values. If this occurs, values are clipped and the camera returns a warning message.

Some commands may not be available in your current operating mode. The help screen displays NA in this case.

The following help screen listing is for a 2k camera:

```
ccf   correction calibrate fpn
ccg   calibrate camera gain iti     1-4:0-0:1024-4055
ccp   correction calibrate prnu
cil   calibrate input lut
clm   camera link mode              m     5/9/10/14/15/16/
cpa   calibrate PRNU algorithm      mi    1/2/3/4/:1024-
                                          4055
css   correction set sample         m     1024/2048/4096/
dil   display input lut             taa   0-0:0-1023:0-1023
dpc   display pixel coeffs          xx    1-2048:1-2048
ebc   enable blue correction        i     0-1
eil   enable input lut              i     0-1
els   end of line sequence          i     0-2
epc   enable pixel coefficients     ii    0-1:0-1
gcl   get command log
gcm   get camera model
gcp   get camera parameters
gcs   get camera serial
gcv   get camera version
get   get values                    s
gfc   get fpn coeff                 x     NA
gh    get help
gil   get input lut                 ta    NA
gl    get line                      xx    1-2048:1-2048
gla   get line average              xx    1-2048:1-2048
gpc   get prnu coeff                x     NA
gsf   get signal frequency          i     1-4
h     help
lfc   load fpn coefficients
lfs   load factory settings
lil   load input lut
lpc   load prnu coefficients
lus   load user settings
```

rc	reset camera		
ril	reset input lut		
roi	region of interest	xx	1-2048:1-2048
rpc	reset pixel coeffs		
sab	set add background	ti	0-0:0-4095
sag	set analog gain	tf	0-0:-10.0-+10.0
sah	set averaging horizontal	i	1-2
sao	set analog offset	ti	0-0:0-255
sbr	set baud rate	m	9600/19200/57600/ 115200/
scb	select cable	i	0-255
scc	set colour correction	iiii	0-+4095:-8192- +8191:-8192- +8191:-8192-+8191
scd	set ccd direction	i	0-2
scl	set colour	m	rgb/r/g/b/
sdo	set digital offset	ti	0-0:0-4095
sem	set exposure mode	m	2/3/4/5/6/7/
sfc	set fpn coeff	xi	NA
sfr	set fpn range	xxi	NA
sil	set input lut	tai	NA
slt	set lower threshold	i	0-4095
smm	set mirroring mode	i	0-1
sot	set output throughput	m	30/40/60/80/
spc	set prnu coeff	xi	NA
spr	set prnu range	xxi	NA
srm	set readout mode	i	0-2
ssa	set spatial alignment	i	0-6
ssb	set subtract background	ti	0-0:0-4095
ssf	set sync frequency	f	1-32362
ssg	set system gain	ti	0-0:0-65535
ssn	set set number	i	0-5
sut	set upper threshold	i	0-4095
svm	set video mode	i	0-10
ugr	update gain reference		
vt	verify temperature		
vv	verify voltage		
wfc	write FPN coefficients		
wil	write input lut		
wpc	write PRNU coefficients		
wus	write user settings		

3.6 Sensor Output

Color Scan Direction

Purpose: Selects the forward or reverse color scan direction or external direction control. This accommodates object direction change on a web and allows you to mount the camera “upside down.”

Syntax: **scd *i***

Syntax Elements: ***i***

Shift direction. Allowable values are:

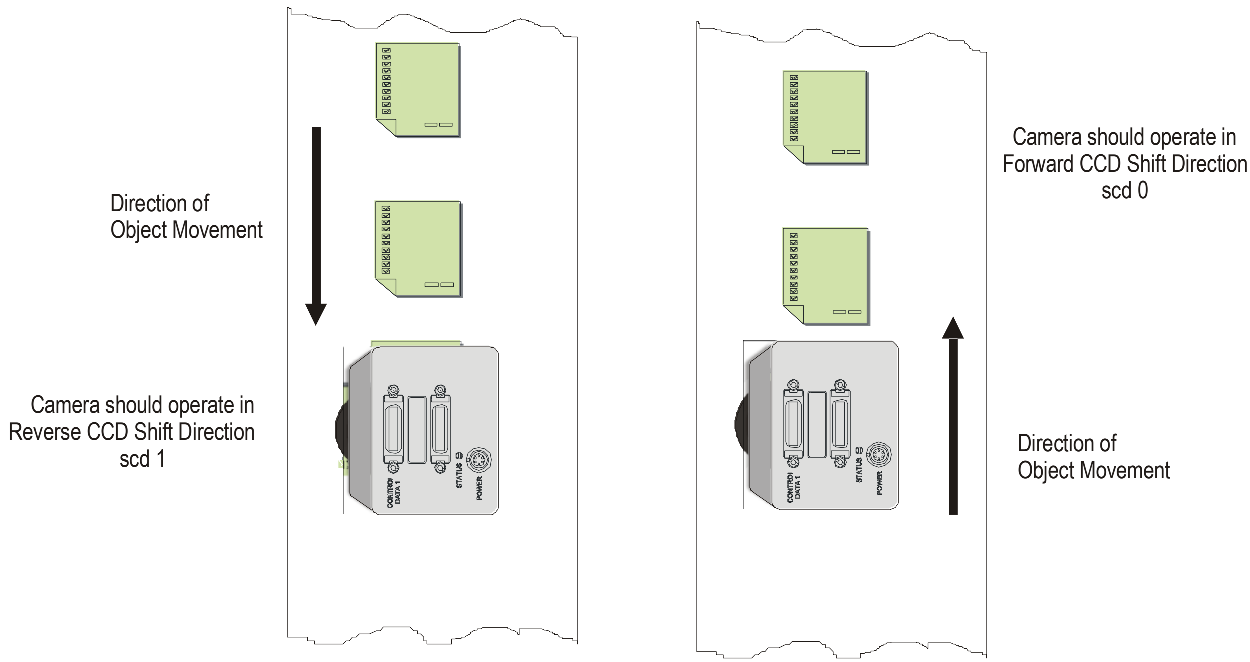
0 = Forward CCD shift direction.

1 = Reverse CCD shift direction.
2 = External direction control via Camera Link control: CC3 (CC3=1 forward, CC3=0 reverse).

Notes: To obtain the current value of the shift direction, use the command **gcp** or **get scd**.

Related Commands: **smm**

Example: **scd 0**



Sensor Readout Direction (Mirroring Mode)

Purpose:	Selects the camera's horizontal readout direction.
Syntax:	**`smm i`**
Syntax Elements:	***i*** Direction of sensor readout **0 =** Left to right = 1 to n **1 =** Right to left = n to 1
Note:	Pixel readout remains the same after a direction change.
Example:	**`smm 0`**

3.7 Data Output

Setting the Camera Link Mode

Purpose:	Sets the camera's Camera Link configuration, number of Camera Link taps and data bit depth.
Syntax:	**`clm m`**
Syntax Elements:	***m*** **5** = Base configuration, RGB, 8 bit output **9** = Base configuration, RGBY, 8 bit output **10** = Base configuration, RGBY, 12 bit output **14** = Medium configuration, 2xRGB, 8 bit output **15** = Medium configuration, RGBY, 8 bit output **16** = Medium configuration, RGBY, 12 bit output
Note:	• To obtain the current data mode, use the command **`gcp`** or **`get clm`**. • The bit patterns are defined by the Camera Link Roadmap and the Camera Link Standard. Available from the Knowledge Center on the Teledyne DALSA site, here.
Example:	**`clm 5`**

Setting the Camera's Pixel Rate (Throughput)

Purpose:	The **`sot`** command works in conjunction with the **`clm`** command (see previous command) and determines the pixel rate of the camera.
Syntax:	**`sot m`**
Syntax Elements:	***m*** **30 =** outputs pixels RGB (triplet) or RGBY (quad) at 30 Mps **40** = outputs pixels RGB (triplet) or RGBY (quad) at 40 Mps **60 =** outputs pixels RGB (triplet) or RGBY (quad) at 64 Mps **80** = outputs pixels RGB (triplet) or RGBY (quad) at 80 Mps

Note:

- To obtain the current throughput, use the command **`gcp`** or **`get sot`**.
- The bit patterns are defined by the Camera Link Roadmap and the Camera Link Standard. Available from the Knowledge Center on the Teledyne DALSA site, here.
- Changes to the **`clm`** may affect this parameter.

Example: **`sot 80`**

3.8 Set Color Correction

Purpose: Sets the color correction coefficients.

Syntax: **`scc Co C1 C2 C3`**

Syntax Elements:

Co = offset (0 to 4095)
C1 = red multiplier (-8192 to +8191)
C2 = green multiplier (-8192 to +8191)
C3 = blue multiplier (-8192 to +8191)

Note: Set coefficients used to combine three color streams, e.g.
White = C_0 + (C_1 x Red) + (C_2 x Green) + (C_3 x Blue)
C_0 is a DN, whereas:
Coefficient = $C_{1\text{-}3}$ / 4,096
Modified by set color command (SCL):
RGB: White
R|G|B: Red, Green, or Blue
All colors are not necessary because constructing white is different
Factory (initial) values combine the three colors equally:

White = 0 + (0.33 x Red) + (0.33 x Green) + (0.33 x Blue)
C_n = 0.33 x 4,096= 1,365

Red = 0 + (1 x Red) + (0 x Green) + (0 x Blue)
C_1 = 1 x 4,096= 4,096

Range of {-8,192 to +8,191} is equivalent to floating point coefficients of {-2.0 to +1.999}
Step size is 0.000244
Values are saved with camera settings
Values may be viewed with GCP or GET SCC

Example: White = 100 + (0.25 x Red) + (-0.15 x Green) + (0.8 x Blue)
Therefore,
C1 = 0.25 x 4096 = 1024
C2 = (-0.15 x 4096) = -614
C3 = 0.8 x 4096 = 3276

```
OK>scl RGB
OK>scc 100 1024 -614 3276
```

3.9 Camera Selection Variables

There are some camera condition variables that you should determine before adjusting any digital or analog settings like gain or offset, or before changing the camera's exposure time. These variables are:

- The color (or colors) that you want to adjust.
- The set number where you want to save any of these adjustments.
- The region of interest for performing these adjustments.

Setting the Color Variable

Purpose:	Selects the color or colors that you want to adjust with the **ccf**, **ccg**, **ccp**, **cpa**, **dpc**, **gfc**, **gl**, **gla**, **gpc**, **sag**, **sao**, **sdo**, **set**, **sfc**, **spc**, **ssb**, **ssg** commands.
Syntax:	**scl *s***
Syntax Elements:	**s** **rgb** = adjust all colors (red, green, and blue). Power on setting. **r** = adjust red **g** = adjust green **b** = adjust blue
Note:	The camera always powers up using **scl rgb**.
Example:	**scl b**

Color selection limits the taps that can be selected in these commands as follows:

scl	Tap	Notes
rgb	0	All 10 camera taps
r	0	All 4 red taps
	1 to 4	Single red tap
g	0	All green taps
	1 to 4	Single green tap
b	0	All blue taps (2)
	1 to 2	Single blue tap

Selecting the Set Number

Purpose:	When saving and loading camera settings, you have a choice of saving up to four different sets and loading from five different sets (four user and one factory). This command determines the set number from where these values are loaded and saved. The set number is saved along with the camera settings when the **wus** command is issued.
Syntax:	**ssn *i***
Syntax Elements:	**i** **0** = Factory set. Settings can only be loaded from this set. **1** - **4** = User sets. You can save, or load settings with these sets.
Note:	The camera powers up with the last set saved using this command.
Related Commands	**wus, lus, wil, lil, wfc, lfc**

Example:	**`ssn 3`**

Setting a Region of Interest (ROI)

Purpose:	Sets the pixel range used to collect the end-of-line statistics and sets the region of pixels used in the **`ccg`**, **`gl`**, **`gla`**, **`ccf`**, and **`ccp`** commands. In most applications, the field of view exceeds the required object size and these extraneous areas should be ignored. It is recommended that you set the region of interest a few pixels inside the actual useable image.
Syntax:	**`roi x1 x2`**
Syntax Elements:	**`x1`** Column start number. Must be less than the pixel end number in a range from **`1`** to **`sensor resolution`**. **`x2`** Column end. Must be greater than the pixel start number in a range from **`1`** to **`sensor resolution`**.
Notes:	To return the current region of interest, use the commands **`gcp`** or **`get roi`**.
Related Commands	**`ccg`**, **`gl`**, **`gla`**, **`ccf`**, **`ccp`**, **`cpa`**, **`els`**
Example:	roi 10 50

3.10 Exposure Control

Overview

You have a choice of operating in one of six exposure modes. The camera's line rate (synchronization) can be generated internally through the software command **`ssf`** or set externally with an EXSYNC signal, depending on your mode of operation. To select how you want the camera's line rate to be generated:

You must first set the camera exposure mode using the **`sem`** command.
Next, if using mode 2 or 7 use the commands **`ssf`** and **`set`** to set the line rate and exposure time.

Setting the Exposure Mode

Purpose:	Sets the camera's exposure mode allowing you to control your sync, exposure time, and line rate generation.
Syntax:	**`sem`** ***`i`***
Syntax Elements:	***`i`*** Exposure mode to use. Factory setting is **2**.
Notes:	Refer to Table 4: Color 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 or get sem.
Related Commands:	**ssf**, **set**
Example:	**`sem 3`**

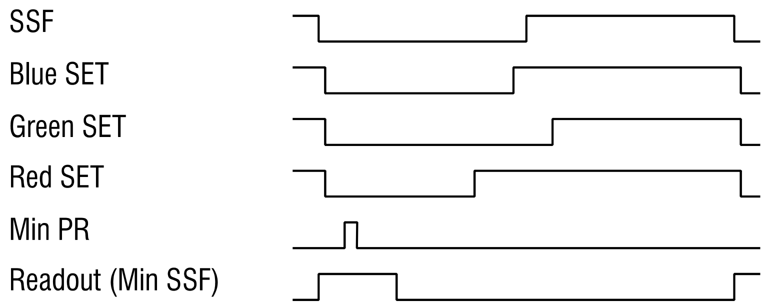
Table 4: Color Exposure Modes

Mode	SYNC	Exposure Control	Description
2	Internal	Internal	Each color may have a different exposure time.
3	External	None	All colors share the same exposure time.
4	External	External	Smart EXSYNC. All colors share same exposure time.
5	External	External	Each color may have a different exposure time.
6	External	Internal	Each color may have a different exposure time.
7	Internal	None	All colors share the same exposure time.

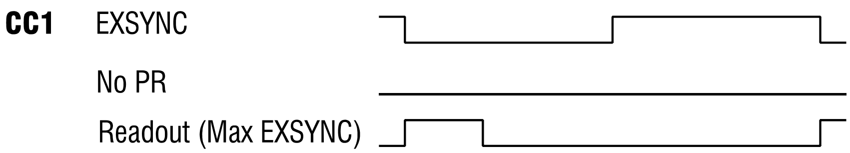
Note: When setting the camera to external signal modes, EXSYNC and/or PRIN must be supplied.

Exposure Modes in Detail

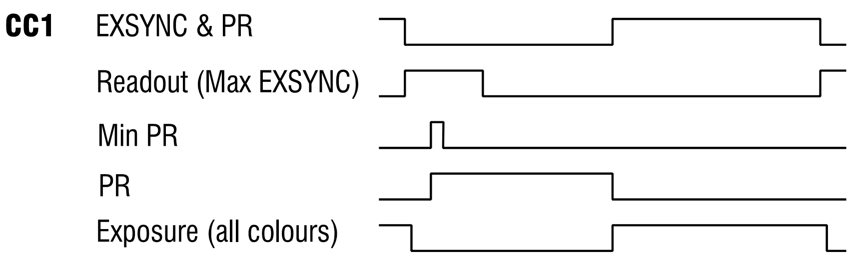
Mode 2: SSF/SET



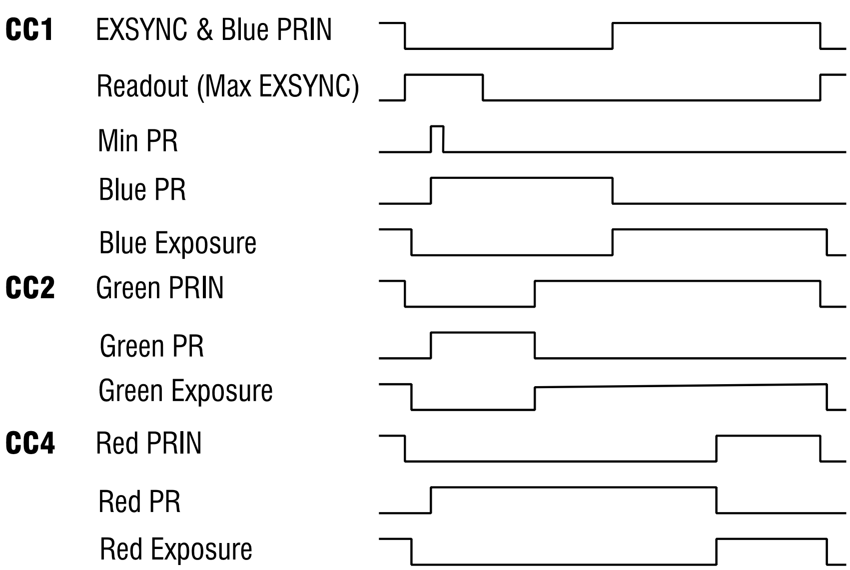
Mode 3: EXSYNC/ECD



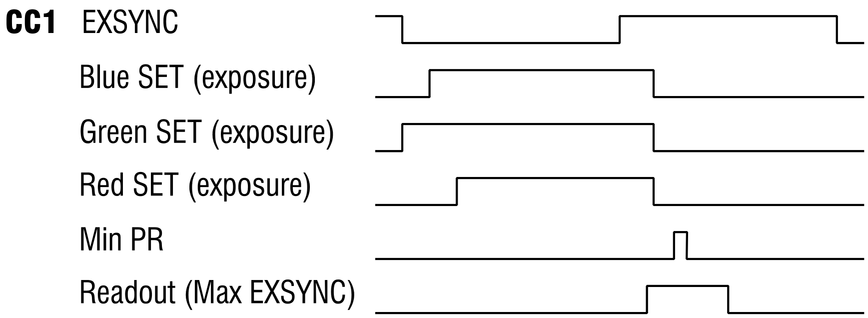
Mode 4: Smart EXSYNC



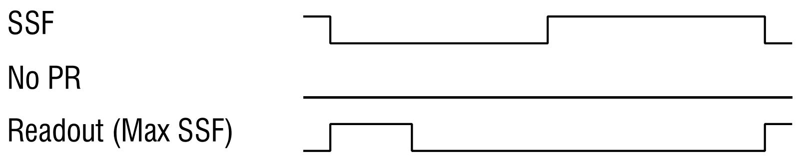
Mode 5: EXSYNC/PRIN



Mode 6: EXSYNC/SET



Mode 7: SSF/ECD



Setting the Line Rate

Applies to Modes 2 and 7

Purpose:	Sets the camera's line rate in Hz. Camera must be operating in exposure mode 2 or 7.
Syntax:	**`ssf f`**
Syntax Elements:	***f*** Desired line rate in Hz. Allowable values are: 2k80: 1 to 32362 Hz 2k60: 1 to 22714 Hz 4k80: 1 to 17699 Hz 4k60: 1 to 12132 Hz
Notes:	To read the current line frequency, use the command **`gcp`** or **`get ssf`**. If you enter an invalid line rate frequency, an error message is returned. Line rate reduces depending on **`clm`**, **`sut`**, **`els`**, and **`sah`** settings. Values less than 5000 Hz will return the warning: "Warning 01: Outside of specification>".
Related Commands:	**`sem`**, **`set`**
Example:	**`ssf 10000`**

Setting the Exposure Time

Applies to Modes 2 and 8

Purpose:	Sets the camera's exposure time in micro seconds. Camera must be operating in mode 2 or 6.
Syntax:	**`set f`**
Syntax Elements:	***f*** Desired exposure time in µs. Allowable range is 5.0 to 9997.000.0 µs.
Notes:	To read the current exposure time, use the command **`gcp`** or **`get set`**. The **`ssf`** and **`set`** commands will "push" each other when set.

Related Commands: **sem**, **ssf**

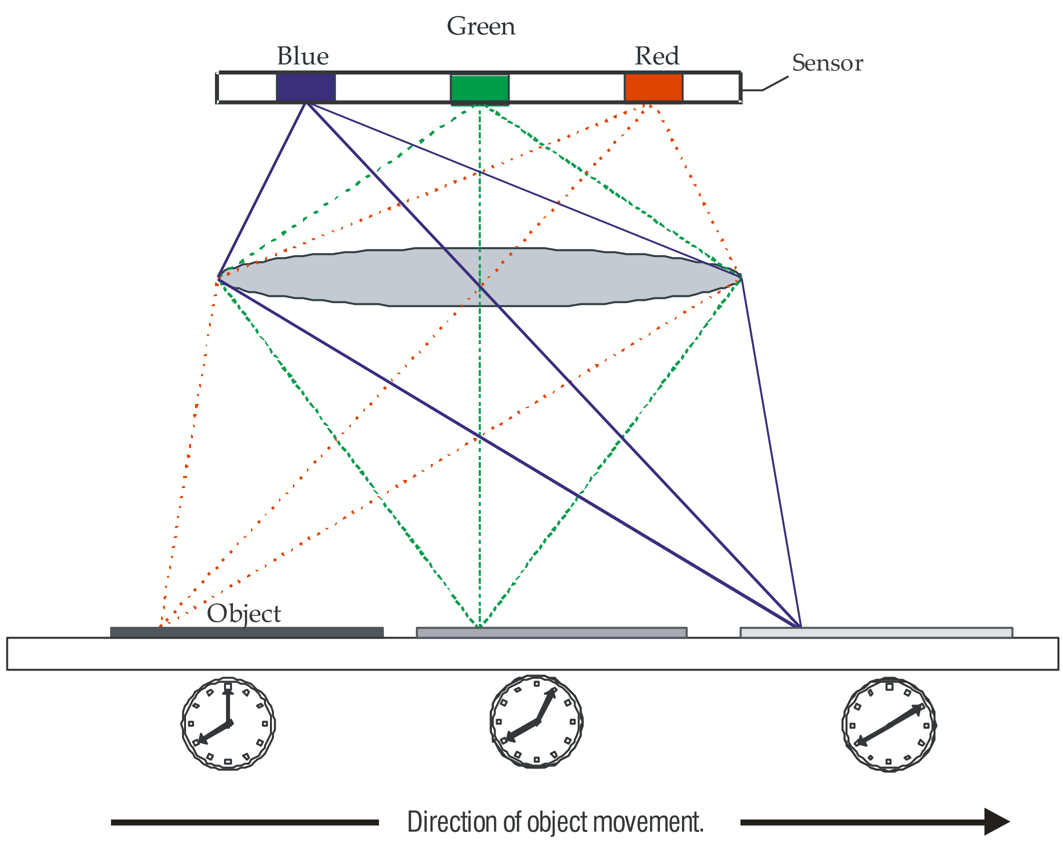
Example: **set 400.5**

3.11 Spatial Correction

Spatial Correction and Trilinear Sensor Design

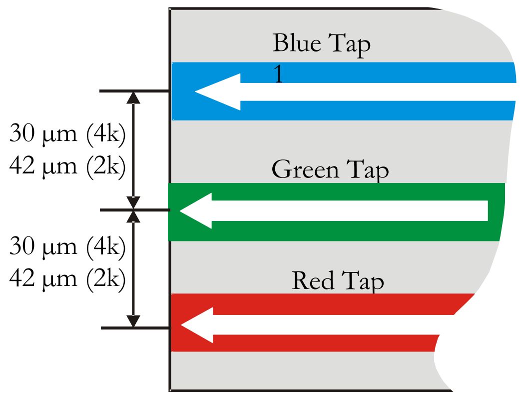
The trilinear sensors three color lines do not share a common optical axis. This results in the three color lines imaging three separate object points.

As a result, the color images need to be stored, delayed and recombined to properly reconstruct the color image. This characteristic is referred to as spatial correction.



As the object travels along the web, the object passes the three color lines at different points in time. As a result, the camera uses spatial correction to reconstruct the image.

The Piranha Color sensor uses proprietary design to minimize the center to center spacing to 30 µm (4k) or 42 µm (2k).



The three color lines are separated 30 µm (4k) or 42 µm (2k) apart center-to-center.

The trilinear CCD sensor used in the Piranha Color camera has three linear arrays for Red (R), Green (G) and Blue (B) color channel, respectively. The inter-array spacing between color channels is 3 lines apart centre-to-centre. Because of the spacing between the linear arrays, each array will have a slightly different view of an object that is passing before the camera. Therefore, for each exposure, each color array in the sensor captures an image of a slightly different area on the object.

The spatial correction process is used to properly reconstruct the full color (RGB) image of the object. For example, assuming that the following parameters are used:

The system uses a magnification of 1/10, i.e., an area of 0.1 mm x 0.1 mm on the object will have an image of 10 µm x 10 µm on the sensor;

The encoder is set to have a step of 0.1 mm in the movement of the web; i.e., the image on the sensor will move 10 µm for each step of the encoder;

The image is line captured at each step of the encoder;

The moving object A from the view of line of Red channel to that of Green channel is 3 steps, i.e.:

3 steps x 0.1 mm/step x 1/10 magnification = 30 µm movement of the image on the sensor.

There are 3 more steps to move the image of object A further from the Green channel to the Blue channel.

To properly reconstruct the full RGB image of the object A, the user needs to combine the Red channel data captured at line capture #0 with Green data captured at capture #3 and Blue data captured at capture #6. A parameter *Line Delay* is used to specify which line captures should be combined to properly reconstruct the image. In the above case, the *Line Delay* is 3. In general,

$$\textit{Line Delay} = \frac{\text{Inter-array spacing (30 µm or 42 µm)}}{\text{Step of encoder (µm) x magnification}}$$

The Piranha Color is a bi-directional camera and the direction of the web movement can be arranged in either way. If the object is passing the camera in the other direction, its image will pass over the Blue channel first, then the Green channel, and finally the Red channel. In order to properly construct a full color (RGB) image, the system needs to know the direction of the movement. Another parameter, color scan direction (**`scd`**), is used to specify the direction of web movement.

Setting the Line Delay between Colors

Purpose:	Sets the number of lines of delay between colors that are read out from the sensor.
Syntax:	**`ssa i`**
Syntax Elements:	***i*** Line delay between colors in a range from 0-6.
Notes:	To read the current line delay, use the command `gcp` or get ssa. If your line rate matches the speed of the object, then the value of the line delay will be 3. Adjust the **ssa** value until you remove the red and blue halos above and below a black on white horizontal line in order to set the line delay.
Example:	**`ssa 3`**

3.12 Averaging Horizontal Pixels

Setting the Averaging Horizontal

Purpose:	Averaging reduces the pixel noise and decreases the horizontal resolution. The charge collected in adjacent pixels is averaged together.
Syntax:	**`sah i`**
Syntax Elements:	***i*** The number of horizontal pixels to average. Available values are 1 (factory setting) and 2.

Notes:

- Selecting **`sah 1`** results in no averaging.
- Selecting **`sah 2`** averages pairs of pixels: (P1+P2)/2, (P3+P4)/2, (P5+P6)/2…
- If you are using averaging, the minimum, maximum, and mean statistics generated by the **`gl`** or **`gla`** commands and used by the **`ccg`**, **`cao`**, **`ccf`**, and **`ccp`** commands are for the un-averaged pixels.
- Changing the averaging does not require the recalibration (analog gain, FPN or PRNU) of the camera.
- The current value of horizontal averaging factor can be obtained using the **`gcp`** or **`get sah`** commands.
- Horizontal averaging does not affect the CCD readout time, but it does affect FIFO readout as all the pixels still need to be read out of the CCD, but only the averaged pixels stored in the FIFO (line store).
- ROI will be pushed out to include both averaged pixels at each end (e.g. if the ROI was 4-2048, the start value would be changed to 3, since the first averaged pixel consists of sensor pixels 3 and 4).

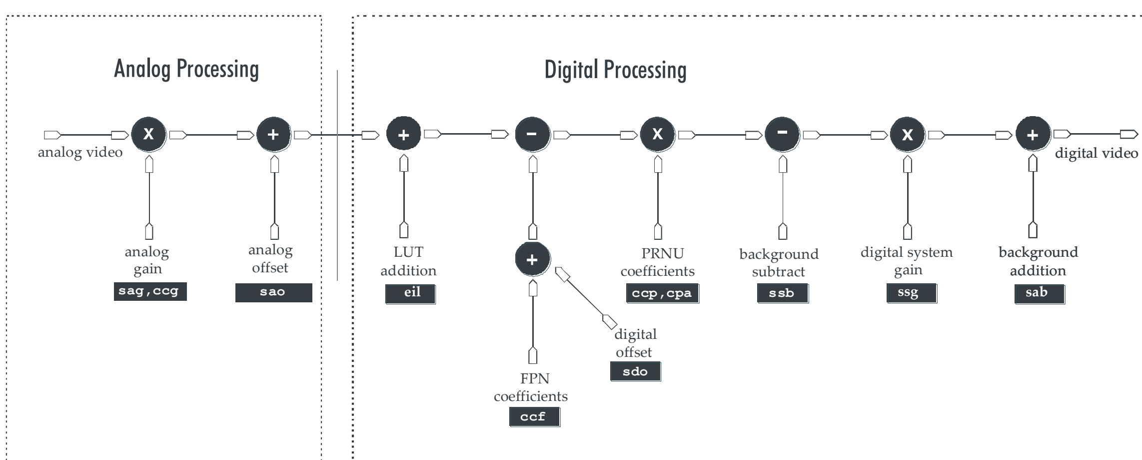
Example: **`sah 2`**

3.13 Processing Chain Overview and Description

The following diagram shows a simplified block diagram of the camera's analog and digital processing chain. The analog processing chain begins with an analog gain adjustment, followed by an analog offset adjustment. These adjustments are applied to the video analog signal prior to its digitization by an A/D converter.

The digital processing chain contains the spatial correction, non-linearity look-up table (LUT) correction, FPN correction, the PRNU correction, the background subtract, the digital gain, and the background add. All of these elements are user programmable.

Figure 7: Signal Processing Chain



Analog Processing

- Optimizing offset performance and gain in the analog domain allows you to achieve a better signal-to-noise ratio and dynamic range use. Perform all analog adjustments prior to any digital adjustments.
- Analog gain (**`sag`** or **`ccg`** command) is multiplied by the analog signal to increase the signal strength before the A/D conversion (and before noise is added to the signal).
- The analog offset (**`sao`** command) or black level is an "artificial" offset introduced into the video path to ensure that the A/D is functioning properly. The analog offset should be set so that it is at least 3 times the RMS noise value at the current gain.

Digital Processing

- To optimize camera performance, complete all analog adjustments before digital signal adjustments.
- Fixed pattern noise (FPN) calibration (calculated using the **`ccf`** command) is used to subtract away individual pixel dark current.
- The digital offset (**`sdo`** command) enables the subtraction of the "artificial" A/D offset (the analog offset) so that application of the PRNU coefficient doesn't result in artifacts at low light levels due to the offset value. You may want to set the **`sdo`** value if you are not using FPN correction but want to perform PRNU correction.
- Photo-Response Non-Uniformity (PRNU) coefficients (calculated using the **`ccp`** or **`cpa`** commands) are used to correct the difference in responsivity of individual pixels (i.e. given the same amount of light different pixels will charge up at different rates) and the difference in light intensity across the image either because of the light source or due to optical aberrations (e.g. there may be more light in the center of the image). PRNU coefficients are multipliers and are defined to be of a value greater than or equal to 1. This ensures that all pixels will saturate together.
- Background subtract (**`ssb`** command) and system (digital) gain (**`ssg`** command) are used to increase image contrast after FPN and PRNU calibration. It is useful for systems that process 8-bit data but want to take advantage of the camera's 12 bit digital processing chain. For example, if you find that your image is consistently between 128 and 255DN(8 bit), you can subtract off 128 (**`ssb 2048`**) and then multiply by 2 (**`ssg 0 8192`**) to get an output range from 0 to 255.
- Background addition (**`sab`** command) is used to ensure a minimum output value, and is added to the digital video after the system gain is applied.

The Effects of the Processing Chain on Calibration

The Processing Chain (as shown in Figure 7):

- Video out = (([video in] x SAG + SAO - SDO - FPN) x PRNU – SSB) x SSG + SSB

Calibration takes place at the output of the parameter being calibrated. If the parameters further down the chain are not zero or unity, then the video out may not be as expected.

For example, if the analog gain is calibrated to an average of 3,000 DN using "CCG 2 0 3000" while SSB is 100, the average video output will be 2,900 DN not 3,000 DN.

This applies to:

- CCG: calibrate analog gain (SAG) or system gain (SSG)

- CCF: calibrate FPN
- CCP: calibrate PRNU
- CPA: calibrate analog gain (SAG) and PRNU

PRNU calibration includes the FPN whether it is enabled or not (as they are linked). If you do not want the PRNU calibration to include the effect of FPN then it should be zeroed first using the RPC command.

CCG 3 (system gain) only includes FPN and PRNU if they are enabled with EPC.

Note: Refer to section 3.9 Camera Selection Variables for details on commands that should be set before performing any analog or digital adjustments.

3.14 Analog Gain and Analog Offset

All analog signal processing chain commands should be performed prior to FPN and PRNU calibration and prior to digital signal processing commands.

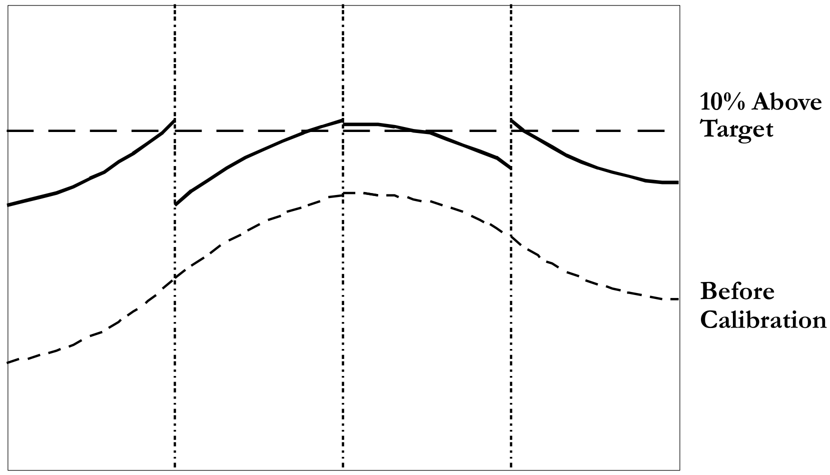
Setting Analog Gain

Purpose:	Sets the camera's analog gain value. Analog gain is multiplied by the analog signal to increase the signal strength before the A/D conversion. It is used to take advantage of the full dynamic range of the A/D converter.
Syntax:	**`sag t f`**
Syntax Elements:	t Tap selection. Use **`0`** for all taps. Color selection limits the taps that may be selected by this command. See **`scl`** for further information. f Gain value in a range from **`-10`** to **`+10`**dB.
Notes:	To return the current analog gain setting, use the command **`gcp`** or **`get sag`**.
Example:	**`sag 0 5.2`**
Related Commands:	**`ccg`**

Calibrating Camera Gain

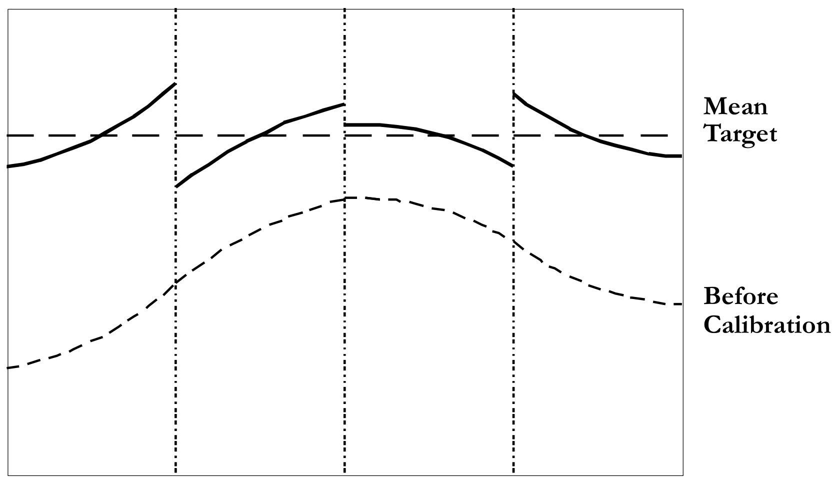
Purpose:	Instead of manually setting the analog gain to a specific value, the camera can determine appropriate gain values. This command calculates and sets the analog gain according to the algorithm determined by the first parameter.
Syntax:	***`ccg i t i`***
Syntax Elements:	***`i`*** Calibration algorithm to use. **`1`** = This algorithm adjusts analog gain so that 8% to 13% of tap region of interest (ROI) pixels are above the specified target value.

Algorithm One



2 = This algorithm adjusts analog gain so that the average pixel value in tap's ROI is equal to the specified target value.

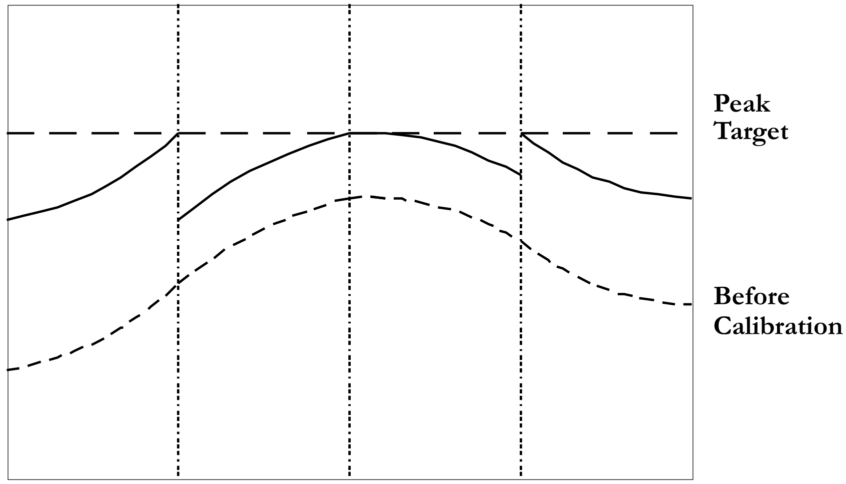
Algorithm Two



3 = This algorithm adjusts digital gain so that the average pixel value in tap's ROI is equal to the specified target.
Note: See Alogrithm Two above for an illustration.

4 = This algorithm adjusts the analog gain so that the peak tap ROI pixels are adjusted to the specified target.

Algorithm Four



t

Tap value. Use **`0`** for all taps. Color selection limits the taps that may be selected by this command. See **scl** for further information.

i

Calculation target value in a range from **`1024`** to **`4055`**DN (12 bit LSB).

Notes: Analog gain calibration requires constant light on a clean, white reference. White plastic or white ceramic is ideal.
If very few tap pixels are within the ROI, gain calculation may not be optimal.
When all taps are selected, taps outside of the ROI are set to the average gain of the taps that are within the ROI.
Perform analog gain algorithms before performing FPN and PRNU calibration.
All digital settings affect the analog gain calibration. If you do not want the digital processing to have any effect on the camera gain calibration, then turn off all digital settings by sending the commands: **`sdo 0 0`**, **`epc 0 0`**, **`ssb 0 0`**, **`ssg 0 4096`**, and **`sab 0 0`**.

Example: **`ccg 2 0 3040`**

Related Commands: **`sag, ssg`**

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 for noise is configured at the maximum specified gain and as a result you should not need to adjust the analog offset.

Syntax: **`sao t i`**

Syntax Elements: **`t`**

Tap selection. Use **`0`** for all taps. Color selection limits the taps that may be selected by this command. See **`scl`** for further information.

i

Offset value in a range from **`0`** to **`255`**DN (12 bit LSB).

Notes: To return the current analog offset value, use the command **`gcp`** or **`get sao`**.

Example: **sao 2 35**
Related Commands: cao

3.15 Flat Field Correction

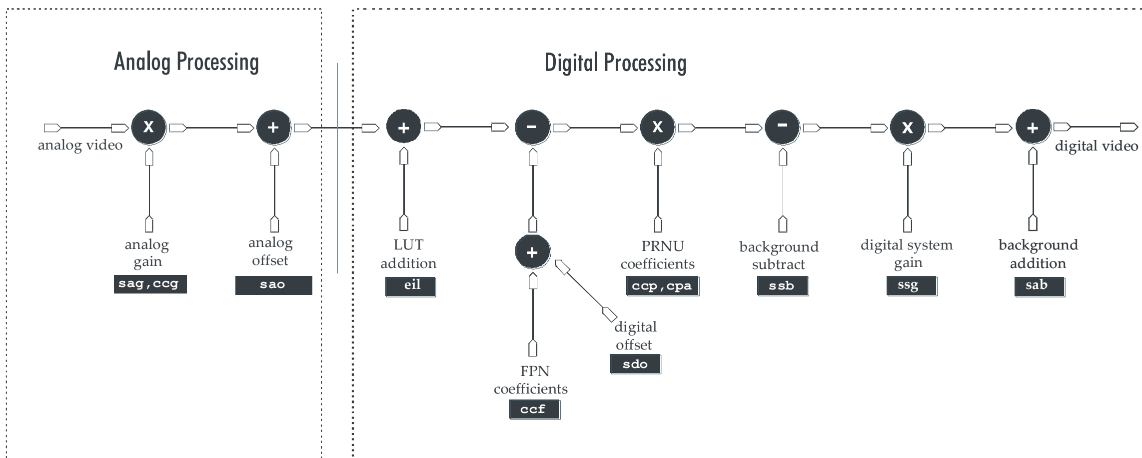
Flat Field Correction Overview

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

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 + Background Addition

where	V_{output}	=	digital output pixel value
	V_{input}	=	digital input pixel value from the CCD
	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
	Background Addition	=	background addition value

The algorithm is performed in two steps. The fixed offset (FPN) is determined first by performing a calibration without any light. This calibration determines exactly how much offset to subtract per pixel in order to obtain flat (zero) output when the CCD is not exposed.

The white light 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).

Flat Field Correction Restrictions

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 analog gain, integration time, line rate, or SRM.

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:

- 50 or 60 Hz ambient light flicker is sufficiently low so as not to affect camera performance and calibration results.
- The analog gain should be adjusted for the expected operating conditions.
- The ratio of the brightest to darkest pixel in a tap should be less than 3 to 1, where:

$$3 > \frac{\text{Brightest Pixel (per tap)}}{\text{Darkest Pixel (per tap)}}$$

- The brightest pixel should be slightly below the target output.

When greater than 6.25% of the pixels from a single row within the region of interest are clipped, then flat field correction results may be inaccurate.

Correction results are valid only for the current analog gain and offset values. If you change these values, it is recommended that you recalculate your coefficients.

Set up the camera operating environment (i.e. line rate, exposure, offset, gain, etc.)

- Signal output should be no higher than 80% of saturation (i.e. When your output is 12-bit data then 80% of 4096 is 3276. For 8 bit output 80% of 256 is 204).
- Your analog offset setting should not be clipping more than 6.25% of the pixels within the region of interest.
- Digital offset and digital system gain, and background subtract and add values should be set to zero (**ssb 0 0**, **sdo 0 0**, **ssg 0 0**, **sab 0 0**)

Set the calibration sample size using the command css. It is recommended that you use the default setting.

Set the region of interest to include all of the image's pixels of importance using the command roi x1 y1 x2 y2. You can use the default if you want to calibrate all pixels.

Perform FPN calculation

FPN calculation removes the fixed pattern noise(dark current) from the video path. It is recommended you repeat the calculation when a temperature change greater than 10°C occurs or when there is a significant change in integration time or analog gain.

1. Stop all light from entering the camera. (Tip: Cover lens with a lens cap.)
2. Verify that the output signal level is within range by issuing the command **gl** or **gla**. If there are too many zeros in the output data (more than 6.25% of output data within the roi) , increase the analog offset (**sao**) or use the automated algorithm **cao 0** ***i***. If the average of the pixels is too high for your application, reduce the analog offset or gain level (**sag**).
3. Issue the command **ccf**. The camera will respond withOK> (if no error occurs). FPN calculation automatically calibrates FPN coefficients and digital offset.
4. After the calibration is complete, you should save these settings to non-volatile memory so they be reusable on reboot. To do so, issue the commands **wfc** and **wus**.
5. To verify output, enable the FPN coefficients using the command **epc 1 0**. You should see close to zero output.

Perform PRNU calculation

Perform PRNU calculation next to determine the multiplication factors required to bring each pixel to the required value (balance target) for flat, white output.

1. Place a white reference in front of the camera.
2. Verify that the output signal level is within range by issuing the command**gl** or **gla**. If the signal level is too low, increase your light level, adjust the analog gain (**sag**) or use the automated algorithm **ccg i 0 i**.
   DALSA recommends a target value of about 80% of saturation. If you change the gain, FPN coefficients should be recalculated.
3. Issue the command **ccp**. The camera will respond with OK>(if no error occurs).
4. After the calculation is complete, you can save these settings to non-volatile memory so they will be remembered after power-down and direction change. To do so, issue the commands **wpc** and **wus.**
5. Enable the coefficients using the command, **epc 1 1**.

FPN Measurement

Performing FPN Measurement

Purpose: Measures fixed pattern noise (FPN).

Syntax: `ccf`

Notes:

- Before sending this command, use the `scl` command to select the color or colors you want to adjust. This allows you to limit the calibration to a single color.
- Perform all analog and digital adjustments before performing FPN correction.
- Perform FPN correction before PRNU correction.

To save FPN coefficients after calibration, use the `wfc` command.

Related Commands: **ccp, wfc**
Example: **ccf**

Setting a Pixel's FPN Coefficient

Purpose: Sets an individual pixel's FPN coefficient.
Syntax **sfc *x i***
Syntax Elements: ***x***
The pixel number from **1** to **sensor pixel count**.
i
Coefficient value in a range from **0** to **4095** (12 bit LSB).
Notes: Before sending this command, use the **scl** command to select the color you want to adjust.
Example: **sfc 10 50**

Setting a Range of FPN Coefficients

Purpose: Sets a range of pixel FPN coefficients.
Syntax **sfr x x i**
Syntax Elements: ***x***

The first pixel number of the range.

x

The last pixel number of the range.

i

Coefficient value in a range from 0-2048.

Notes:
- Before sending this command, use the **scl** command to select the color you want to adjust.

The first pixel of the range must be less than the last.

Example: **sfr 1 100 80**

PRNU Calculation

Performing PRNU to a user entered value

Purpose: Calculate the PRNU coefficients to eliminate the difference in responsivity between the pixels, thereby creating a uniform response to light. Using this command, you must provide a calibration target.
Syntax: **cpa *i1 i2***
Syntax Elements: ***i1***

PRNU calibration algorithm to use:
1 = This algorithm first adjusts each tap's analog gain so that 8-13% of pixels within a tap are above the value specified in the target value parameter. PRNU calibration then occurs using the peak pixel in the region of interest.
This algorithm is recommended for use only when FPN is negligible and FPN coefficients are set to zero. Since this algorithm adjusts the analog gain, it also affects FPN. If FPN is calibrated prior to running this algorithm, FPN will be observable in dark conditions and an incorrect FPN value will be used during PRNU calibration resulting in incorrect PRNU coefficients.
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. Confirm this using the **gla** statistics.

3 = This algorithm includes an analog gain adjustment prior to PRNU calibration. Analog gain is first adjusted so that the peak pixel value in tap's ROI is within 97 to 99% of the specified target value. It then calculates the PRNU coefficients using the 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.

This algorithm is should be used only when FPN is negligible and FPN coefficients are set to zero. Since this algorithm adjusts the analog gain, it also affects FPN. If FPN is calibrated prior to running this algorithm, FPN will be observable in dark conditions and an incorrect FPN value will be used during PRNU calibration resulting in incorrect PRNU coefficients.

This algorithm is more robust and repeatable than algorithm 1 because it uses an average pixel value rather than a number above target. However, this algorithm is slower.

4 = Calculates the PRNU coefficient in the same way as **cpa 2** with the exception that this command only calculates PRNU for pixels within the current Region of Interest (ROI).

i2

Peak target value in a range from 1024 to 4055DN. The target value must be greater than the current peak output value.

Notes:

- Perform all analog adjustments before calibrating PRNU.
- This command performs the same function as the **cpp** command with the exception that you enter a target value.
- 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.

Example: **cpa 1 600**

Performing PRNU Calculation to a Camera Calculated Value

Purpose: Performs PRNU correction and eliminates the difference in responsivity between the most and least sensitive pixel creating a uniform response to light.

Syntax **ccp**

Notes:

- Before sending this command, use the **scl** command to select the color or colors you want to adjust. This allows you to limit the calibration to a single color.
- Perform all analog adjustments before calculating PRNU.
- Perform FPN correction before PRNU correction.
- If FPN cannot be calibrated, use the **`rpc`** command to reset all coefficients to zero, and save them to memory with the **wfc** command. You can then adjust the digital offset (**`sdo`** command) to remove some of the FPN.
- Ensure camera is operating at its expected analog gain, integration time, and temperature.
- To save PRNU coefficients after calibration, use the **`wpc`** command.

Related Commands: **`ccf, cpa`**

Setting a Pixel's PRNU Coefficient

Purpose: Sets an individual pixel's PRNU coefficient.

Syntax: **`spc i1 i2`**

Syntax Elements: ***`i1`***

The pixel number from **`1`** to **`n`**, where n = 2048 or 4096 depending on the resolution.

`i2`

Coefficient value in a range from **`0`** to **`61438`** where:

$$\text{prnu coefficient} = 1 + \frac{i2}{4096}$$

Notes: Before sending this command, use the **scl** command to select the color you want to adjust.

Example: **`spc 1024 10000`**

Setting a range of Pixel PRNU Coefficients

Purpose: Sets a range of pixel PRNU coefficients.

Syntax: ***`spr i1 i2 i3`***

Syntax Elements: ***`i1`***

The first pixel number of the range.

`i2`

The last pixel number of the range.

`i3`

Coefficient value in a range from 0 to 61438 where:

$$\text{prnu coefficient} = 1 + \frac{i3}{4096}$$

Notes: Before sending this command, use the **scl** command to select the color or colors you want to adjust. This allows you to limit the calibration to a single color.

The first pixel of the range must be less than the last.

Example: **spr 4001 4096 0**

Returning Calibration Results and Errors

Returning All Pixel Coefficients

Purpose: Returns all the current pixel coefficients in the order FPN, PRNU, FPN, PRNU… for the range specified by ***x1*** and ***x2***.

Syntax: **dpc *x1 x2***

Syntax Elements: ***x1***

Start pixel to display in a range from **1** to **n**, where n = 2048 or 4096 depending on the resolution.

x2

End pixel to display in a range from **x1** to **n**, where n = 2048 or 4096 depending on the resolution.

Notes: This function returns all the current pixel coefficients in the order FPN, PRNU, FPN, PRNU…
Limited by the **scl** color selection.

Example: **dpc 10 20**

Returning FPN Coefficients

Purpose: Returns a pixel's FPN coefficient value in DN (12 bit LSB)

Syntax: **gfc *i***

Syntax Elements: ***i***

The pixel number to read in a range from **1** to **sensor pixel count**.

Notes: Before sending this command, use the **scl** command to select the color you want to adjust.

Example: **gfc 10**

Returning PRNU Coefficients

Purpose: Returns a pixel's PRNU coefficient value in DN (12 bit LSB)

Syntax: **gpc *i***

Syntax Elements: ***i***

The pixel number to read in a range from **1** to **sensor pixel count**.

Notes: Before sending this command, use the **scl** command to select the color you want to adjust.

Example: **gpc 10**

Enabling and Disabling Pixel Coefficients

Purpose: Enables and disables FPN and PRNU coefficients.

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

Example: **`epc 0 1`**

3.16 Digital Gain and Background Subtract

Setting Digital Offset

Purpose: Sets the digital offset. Digital offset is set to zero when you perform FPN correction (**`ccf`** command). If you are unable to perform FPN correction, you can partially remove FPN by adjusting the digital offset.

Syntax: **`sdo t i`**

Syntax Elements: ***t***

Tap selection. Allowable range is **1** to **4** depending on color selected, or **0** for all taps.

i

Subtracted offset value in a range from **0** to **4095.**

Notes: When subtracting a digital value from the digital video signal, the output can no longer reach its maximum unless you apply digital gain using the **`ssg`** command. See the following section for details on the **`ssg`** command.

Related Commands: **`ssg`**

Example: **`sdo 0 100`**

Subtracting Background

Purpose: Use the background subtract command after performing a flat field correction in order to improve your image in a low contrast scene. This is useful for systems that process 8 bit data but want to take advantage of the camera's 12 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***

Tap selection. Allowable range is **1** to **4** depending on color selected, or **0** for all taps.

i

Subtracted value in a range in DN from **0** to **4095**.

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.

Related Commands: **`ssg`**

Example **`ssb 0 800`**

In 8-bit Camera Link mode: If your scene has a minimum value of 50 DN and a maximum of 200 DN, then to expand it to 0 DN and 255 DN, set the **`ssb`** command to **800** (50 x 16), and the **`ssg`** command to **6990** (4096 / ((200 – 50) x 16)) x 4096).

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***

Tap selection. Allowable range is **1** to **4**, 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:

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

Therefore, the multiplication factor range is 0 to 16.
Use this command in conjunction with the **ssb** command.

Related Commands: **ssb**

Example: **ssg 1 15**

Setting Add Background

Purpose: Use the set add background command to ensure a minimum output value by adding this value to the digital video after system gain is applied.

Syntax: **sab *t i***

Syntax Elements: ***t***

Tap selection. **0** for all taps. Color selection limits the taps that may be selected. See the **scl** command for details.

i

Background add values. The range is from **0** to **4095**.

Related Commands: **ssg, scl**

Example: **sab 1 25**

3.17 Look-Up Tables

The flat field corrections FPN and PRNU assume a linear response to the amount of light by the sensor, output node, analog amplifier, and analog to digital converter. To correct any non-linearity in this system of components a Look-Up Table (LUT) has been implemented in the FPGA for each tap immediately after the ADC. The LUT adds a signed value (-256 to +255) indexed by the 10 MSB of the input value.

Calibrate Input LUT

Purpose: Calibrates the current input look-up table for correcting non-linearity in the analog chain (CCD sense node and analog-to-digital conversion).

Syntax: **`cil`**

Syntax Elements:

Notes: This command calibrates all taps within the ROI for current color (RBG does all).
To calibrate:
Place a white reference in front of the camera. This is similar to a PRNU calibration.
Adjust the light level such that at maximum LUT line rate: 2K60 is equal to 10,501 Hz, and 4K60 is equal to 5,410 Hz. Average output is less than 590 DN (12 bit) and at minimum line rate average output is greater than 3,685 DN (12 bit)
In addition:
Use the **`wil`** command to write the LUT to non-volatile memory.
Use the **`eil`** command to enable use of the LUT.
Use the **`scl`** command to select which colored taps to calibrate.
Use the **`roi`** command to limit the taps calibrated and to limit which pixels are used for calibration. If a tap is not in the region of interest, then it will not be calibrated.
Press spacebar to abort this command.
Rerun this command if the analog gain or operating temperature changes.

Example:

Enable Input LUT

Purpose: Enables or disables the use of the input look-up tables for the correction of the analog chain non-linearity.

Syntax: **`eil`** ***`flag`***

Syntax Elements:

`0`
Disable

`1`
Enable

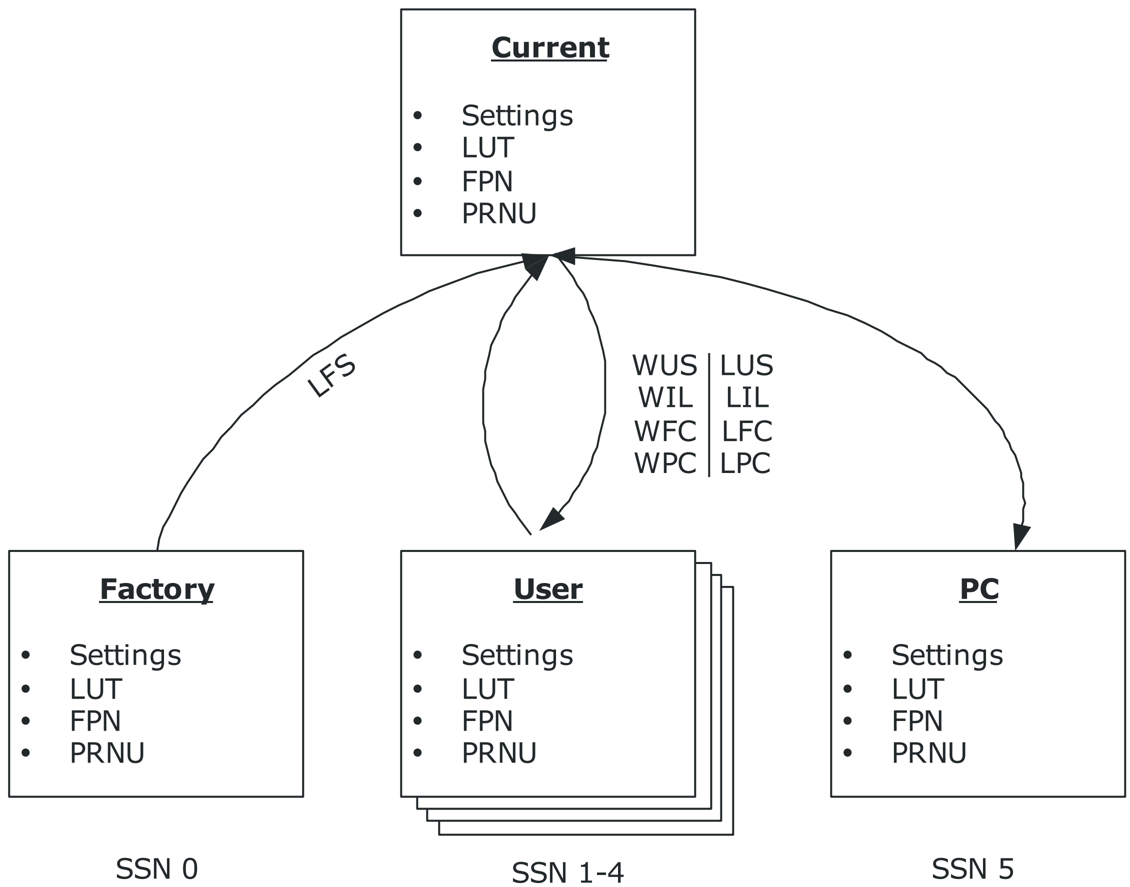
Notes: Coefficients must be created first with the **cil** command.
Setting saved with the **wfs** and **wus** commands.

Example:

3.18 Saving, Loading and Restoring Settings

Saving and Restoring Settings

Figure 8: Saving and Restoring Overview



Factory Settings

On first initialization, the camera operates using user set 1, which has been set equal to the factory settings. You can restore the original factory settings at any time using the command **`lfs`**.

User Settings

You can save or restore your user settings to non-volatile memory using the following commands. Pixel coefficients and LUTS are stored separately from other data.

- To save all current user settings to Flash, use the command **`wus`**. The camera will automatically restore the saved user settings when powered up. **Note:** While settings are being written to nonvolatile memory do not power down the camera or the camera's memory may be corrupted.
- To load the user settings from non-volatile memory, use the command **`lus`**.
- To write and load the LUTs, use the **`wil`** and **`lil`** commands, respectively.

- To write and load the FPN coefficients, use the **wfc** and **lfc** commands, respectively.
- To write and load the PRNU coefficients, use the **wpc** and **lfc** commands, respectively.
- Before issuing the user setting commands, select the set you wish to write using the **`ssn`** command: Sets 1 to 4 are user sets.

Current Session Settings

These are the current operating settings of your camera. To save these settings to non-volatile memory, use the command **`wus`**.

Writing and Loading Setting to Non-Volatile Memory

Write User Settings

Purpose:	Write all the current camera settings to the micro-controller's EEPROM.
Syntax:	**`wus`**
Syntax Elements:	
Example:	**`wus`**
Notes:	Before issuing this command, select the set you wish to write with the **`ssn`** command: Set 1-4 are user sets The settings can be manually restored with using the **`lus`** command. The last saved set (excluding PC sets) of settings will be restored automatically after the power is cycled or after the **`rc`** command – this includes loading the LUT, FPN, and PRNU with the saved set number The format of the file sent to a PC is proprietary.
Related Commands:	

Load User Settings

Purpose:	Load the camera's user settings from non-volatile memory and send values to FPGA.
Syntax:	**`lus`**
Syntax Elements:	
Example:	**`lus`**
Notes:	Before issuing this command, select the set you wish to load with the SSN command **`0`** = Factory set **`1`** to **`4`** = User sets **`5`** = Selects transfer from PC Unlike LFS, LUS only restores the settings and not the FPN, PRNU, and LUT.

Related Commands:

Write Input LUT

Purpose:	Saves current values of input LUT that are in FPGA SDRAM to Flash memory or a PC file.
Syntax:	**`wil`**
Syntax Elements:	
Example:	**`wil`**
Notes:	Before issuing this command, select the set you wish to write with the SSN command: **`0`** = Factory set **`1`** to **`4`** = User sets Input LUT is loaded by LIL, LFS, and automatically at power-up. LUT use is enabled or disabled with the EIL command. Set 0 can only be written from factory mode.
Format of LUT PC File	Provided so that user can generate their own LUT's to send to the camera Binary file ((2 bytes, LSB first) x (1024 values)) x (4 red taps) ((2 bytes, LSB first) x (1024 values)) x (4 green taps) ((2 bytes, LSB first) x (1024 values)) x (2 blue taps) 32 bytes reserved 2 byte CRC-16 of previous bytes e.g. PC-30-02k80 would have 1024 words for red tap 1 + 1024 words for red tap 2 + 1024 words for red tap 3 + 1024 words for red tap 4 + 1024 words for green tap 1 + 1024 words for green tap 2 + 1024 words for green tap 3 + 1024 words for green tap 4 + 1024 words for blue tap 1 + 1024 words for blue tap 2 + 32 unused bytes + 2 byte CRC of the above LUT values are indexed using the most significant 10 bytes of the video signal When LUT's are enabled, an indexed value is added to each value in the video signal e.g. If the value out of the A/D converter was 4007 then the index into the LUT would be 4007 / 4 = 1001.75. If the LUT were enabled, then the value at index 1001 (zero based) in the LUT would be added to the value coming out of the A/D converter.

The LUT values are two's complement signed integers from -256 to +255

e.g. $7_{10} = 11_{12} =$ [0000][0000][0000][0111]
$-12_{10} = 0\text{-}1100_2 =$ [1111][1111][1111][0100]

See WFC for a description of the CRC algorithm.

Load Input LUT

Purpose: Load previously stored LUT for all taps from non-volatile memory to FPGA SDRAM.

Syntax: **lil**

Syntax Elements:

Example: **lil**

Notes: Before issuing this command, select the set you wish to load with the SSN command:

0 = Factory set
1 to **4** = User sets
5 = Selects transfer from PC

LUTs are only loaded from non-volatile memory on: power-up, LIL, and LFS. They are not loaded by LUS.

Related Commands: **wil**

Write FPN Coefficients

Purpose: Saves current values of FPN pixel coefficients that are in FPGA SDRAM to Flash memory or a PC file.

Syntax: **wfc**

Syntax Elements:

Example: **wfc**

Notes: Before issuing this command, select the set you wish to write with the SSN command:

0 = Factory set
1 to **4** = User sets

FPN pixel coefficients are loaded by LFC, LFS, and automatically at power-up.

Coefficient use is enabled or disabled with the EPC command
Set 0 can only be written from factory mode.

Format of FPN PC File: Provided so that user can generate their own coefficients to send to the camera
Binary file

((2 bytes, LSB first) x (number of pixels)) x (3 colors – red, green, blue)
32 bytes reserved
2 byte CRC-16 of previous bytes

e.g. PC-30-02k80 would have:

2048 words of red +
2048 words of green +
2048 words of blue +
32 unused bytes +
2 byte CRC of the above

2 byte FPN = [IIII][IIII][IIII][FFFF]
I – Integer portion {0-4095}
F – Binary fraction portion
e.g. $6.5_{10} = 110.1_{2}$ = [0000][0000][0110][1000]

CRC-16 Algorithm

```
// Fast CRC16 Algorithm
// (X^16 + X^12 + X^5 + 1).
//  "unsigned int" is two bytes

unsigned int CRC_table16[256] =
{
   0x0000, 0x1021, 0x2042, 0x3063, 0x4084, 0x50a5, 0x60c6, 0x70e7, 0x8108,
   0x9129, 0xa14a, 0xb16b, 0xc18c, 0xd1ad, 0xe1ce, 0xf1ef, 0x1231, 0x0210,
   0x3273, 0x2252, 0x52b5, 0x4294, 0x72f7, 0x62d6, 0x9339, 0x8318, 0xb37b,
   0xa35a, 0xd3bd, 0xc39c, 0xf3ff, 0xe3de, 0x2462, 0x3443, 0x0420, 0x1401,
   0x64e6, 0x74c7, 0x44a4, 0x5485, 0xa56a, 0xb54b, 0x8528, 0x9509, 0xe5ee,
   0xf5cf, 0xc5ac, 0xd58d, 0x3653, 0x2672, 0x1611, 0x0630, 0x76d7, 0x66f6,
   0x5695, 0x46b4, 0xb75b, 0xa77a, 0x9719, 0x8738, 0xf7df, 0xe7fe, 0xd79d,
   0xc7bc, 0x48c4, 0x58e5, 0x6886, 0x78a7, 0x0840, 0x1861, 0x2802, 0x3823,
   0xc9cc, 0xd9ed, 0xe98e, 0xf9af, 0x8948, 0x9969, 0xa90a, 0xb92b, 0x5af5,
   0x4ad4, 0x7ab7, 0x6a96, 0x1a71, 0x0a50, 0x3a33, 0x2a12, 0xdbfd, 0xcbdc,
   0xfbbf, 0xeb9e, 0x9b79, 0x8b58, 0xbb3b, 0xab1a, 0x6ca6, 0x7c87, 0x4ce4,
   0x5cc5, 0x2c22, 0x3c03, 0x0c60, 0x1c41, 0xedae, 0xfd8f, 0xcdec, 0xddcd,
   0xad2a, 0xbd0b, 0x8d68, 0x9d49, 0x7e97, 0x6eb6, 0x5ed5, 0x4ef4, 0x3e13,
   0x2e32, 0x1e51, 0x0e70, 0xff9f, 0xefbe, 0xdfdd, 0xcffc, 0xbf1b, 0xaf3a,
   0x9f59, 0x8f78, 0x9188, 0x81a9, 0xb1ca, 0xa1eb, 0xd10c, 0xc12d, 0xf14e,
   0xe16f, 0x1080, 0x00a1, 0x30c2, 0x20e3, 0x5004, 0x4025, 0x7046, 0x6067,
   0x83b9, 0x9398, 0xa3fb, 0xb3da, 0xc33d, 0xd31c, 0xe37f, 0xf35e, 0x02b1,
   0x1290, 0x22f3, 0x32d2, 0x4235, 0x5214, 0x6277, 0x7256, 0xb5ea, 0xa5cb,
   0x95a8, 0x8589, 0xf56e, 0xe54f, 0xd52c, 0xc50d, 0x34e2, 0x24c3, 0x14a0,
   0x0481, 0x7466, 0x6447, 0x5424, 0x4405, 0xa7db, 0xb7fa, 0x8799, 0x97b8,
   0xe75f, 0xf77e, 0xc71d, 0xd73c, 0x26d3, 0x36f2, 0x0691, 0x16b0, 0x6657,
   0x7676, 0x4615, 0x5634, 0xd94c, 0xc96d, 0xf90e, 0xe92f, 0x99c8, 0x89e9,
   0xb98a, 0xa9ab, 0x5844, 0x4865, 0x7806, 0x6827, 0x18c0, 0x08e1, 0x3882,
   0x28a3, 0xcb7d, 0xdb5c, 0xeb3f, 0xfb1e, 0x8bf9, 0x9bd8, 0xabbb, 0xbb9a,
   0x4a75, 0x5a54, 0x6a37, 0x7a16, 0x0af1, 0x1ad0, 0x2ab3, 0x3a92, 0xfd2e,
   0xed0f, 0xdd6c, 0xcd4d, 0xbdaa, 0xad8b, 0x9de8, 0x8dc9, 0x7c26, 0x6c07,
   0x5c64, 0x4c45, 0x3ca2, 0x2c83, 0x1ce0, 0x0cc1, 0xef1f, 0xff3e, 0xcf5d,
   0xdf7c, 0xaf9b, 0xbfba, 0x8fd9, 0x9ff8, 0x6e17, 0x7e36, 0x4e55, 0x5e74,
   0x2e93, 0x3eb2, 0x0ed1, 0x1ef0
};

unsigned int CalcCrc(unsigned char *ptr,    // pointer to buffer to process
                 unsigned int  count)   // number of bytes in buffer
{
```

```
    unsigned int sum = 0;

    while(count--)
    {
        sum = CRC_table16[(sum >> 8) ^ *ptr] ^ (sum << 8);
        ptr++;
    }
    return sum;
}
```

Load FPN Coefficients

Purpose:	Loads previously stored FPN pixel coefficients from non-volatile memory to FPGA SDRAM.
Syntax:	**lfc**
Syntax Elements:	
Example:	**lfc**
Notes:	Before issuing this command, select the set you wish to load with the SSN command: **0** = Factory set **1** to **4** = User sets **5** = Selects transfer from PC FPN coefficients are only loaded from non-volatile memory on: power-up, LFC, and LFS. They are not loaded by LUS.
Related Commands:	**wfc**

Write PRNU Coefficients

Purpose:	Saves current values of PRNU pixel coefficients that are in FPGA SDRAM to Flash memory or a PC file.
Syntax:	**wpc**
Syntax Elements:	
Example:	**wpc**
Notes:	Before issuing this command, select the set you wish to write with the SSN command: **0** = Factory set **1** to **4** = User sets PRNU coefficients will be loaded by LPC, LFS, and automatically at power-up Coefficient use is enabled or disabled with the EPC command Set 0 can only be written from factory mode
Format of PRNU PC File	Provided so that user can generate their own coefficients to send to the camera Binary file ((2 bytes, LSB first) x (number of pixels)) x (3 colors – red, green, blue) 32 bytes reserved

2 byte CRC-16 of previous bytes

e.g. PC-30-02k80 would have
2048 words of red +
2048 words of green +
2048 words of blue +
32 unused bytes +
2 byte CRC of the above

2 byte PRNU is an unsigned integer from 0 to 61,438

This value will be converted to the PRNU coefficient as follows:
PRNU = 1 + value / 4096

Therefore the PRNU range is 1 to 15.9995 and the formula to calculate the value is:
value = 4096 x (PRNU -1)

See WFC for a description of the CRC algorithm

Load PRNU Coefficients

Purpose:	Load previously stored PRNU pixel coefficients from non-volatile memory to FPGA SDRAM.
Syntax:	**`lpc`**
Syntax Elements:	
Example:	**`lpc`**
Notes:	Before issuing this command, select the set you wish to load with the SSN command **0** = Factory set **1** to **4** = User sets **5** = Selects transfer from PC PRNU coefficients are only loaded from non-volatile memory on: power-up, LPC, and LFS. They are not loaded by LUS.
Related Commands:	**`wpc`**

3.19 Diagnostics

End-of-line Sequence

Purpose:	Produces an end-of-line sequence that provides basic calculations including "line counter", "line sum", "pixels above threshold", "pixels below threshold", and "derivative line sum" within the region of interest. To further aid in debugging and cable/data path integrity, the first three pixels after Line Valid are AA_{16}, 55_{16}, AA_{16}. Refer to the following table. These statistics refer only to pixels within the region of interest.
Syntax:	**`els`** ***`i`***

Syntax Elements: ***i***

0 Disable end-of-line sequence
1 Enable end-of-line sequence, LVAL is not high for end-of-line statistics.
2 LVAL high for video and end-of-line statistics

Notes:

Example: **els 1**

Table 5: End-of-Line Sequence Description

Location	Value	Description
1	AA_{16}	By ensuring these values consistently toggle between AA_{16} and 55_{16}, you can verify cabling (i.e. no stuck bits)
2	55_{16}	
3	AA_{16}	
4	4 bit counter LSB justified	Counter increments by 1. Use this value to verify that every line is output
5	Line sum (7…0)	Use these values to help calculate line average and gain
6	Line sum (15…8)	
7	Line sum (23…16)	
8	Line sum (31…24)	
9	Pixels above threshold (7…0)	Monitor these values (either above or below threshold) and adjust camera digital gain and background subtract to maximize scene contrast. This provides a basis for automatic gain control (AGC)
10	Pixels above threshold (15…8)	
11	Pixels below threshold (7…0)	
12	Pixels below threshold (15…8)	
13	Differential line sum (7..0)	Use these values to focus the camera. Generally, the greater the sum the greater the image contrast and better the focus.
14	Differential line sum (15…8)	
15	Differential line sum (23…16)	
16	Differential line sum (31…24)	

Setting Thresholds

Setting an Upper Threshold

Purpose: Sets the upper threshold limit to report in the end-of-line sequence.

Syntax: **sut *i***

Syntax Elements: ***i***

Upper threshold limit in range from **0** to **4095**.

Notes: You must first select the color or colors you want to adjust using the **scl** command.

RGB: all outputs
R: red output
G: green output
B: blue output
To change just the white (luminance) value, first change all

outputs using the **scl** command set to **rgb** to the desired white value, and then change each color back individually.
LVAL is not high during the end-of-line statistics.

Related Commands: **els**, **slt**, **scl**

Example: **sut** 1024

Setting a Lower Threshold

Purpose: Sets the lower threshold limit to report in the end-of-line sequence.

Syntax: **slt *i***

Syntax Elements: ***i***

Upper threshold limit in range from **0** to **4095**.

Notes: You must first select the color or colors you want to adjust using the **scl** command.
RGB: white output
R: single color output
G: single color output
B: single color output
LVAL is not high during the end-of-line statistics.

Related Commands: **els**, **sut**

Example: **slt** 1024

Generating Test Pattern

Purpose: Generates a test pattern to aid in system debugging. The test patterns are useful for verifying camera timing and connections. The following tables show each available test pattern.

Syntax: **svm *i***

Syntax Elements: ***i***

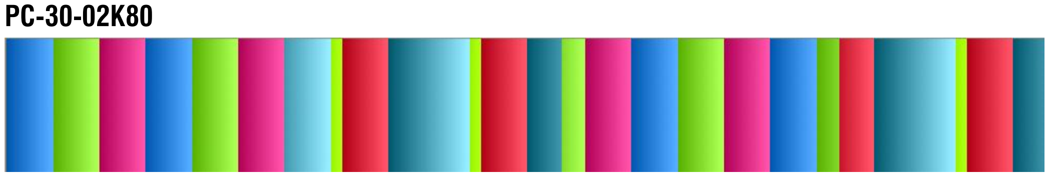
0	Normal video
1	Horizontal ramp
2	Diagonal ramp
3	Vertical ramp
4	0xAA-0x55 alternating pixel pattern per color
5	8 pixels of 0x00 followed by 8 pixels of 0xFF on all colors, repeating
6	DC value
7	FPN demo
8	PRNU demo
9	All 4095 (to get FPN)
10	All 2048 (to get PRNU)

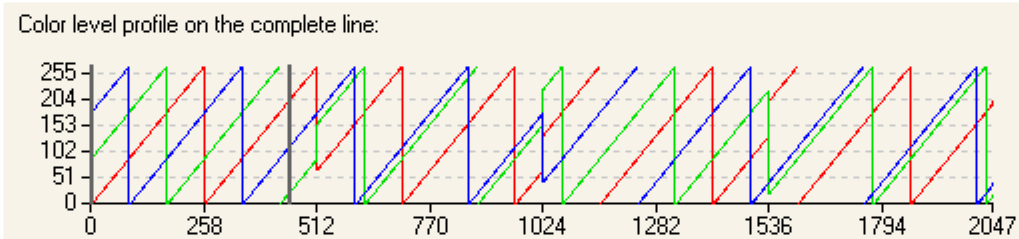
Notes:

Example: **svm 1**

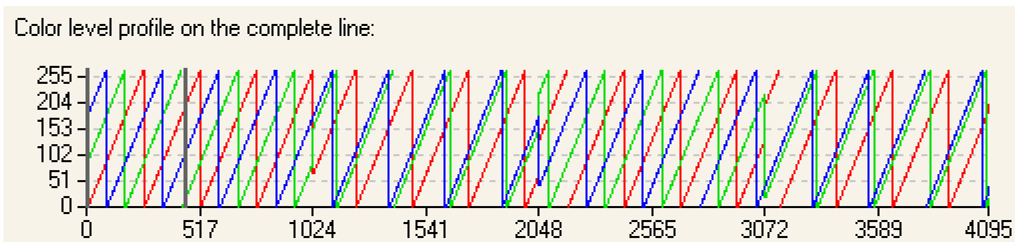
Examples of the horizontal ramp test pattern (**svm 1**):

PC-30-02K80





PC-30-04K80



Returning Video Information

The camera's microcontroller has the ability to read video data. This functionality can be used to verify camera operation and to perform basic testing without having to connect the camera to a frame grabber. This information is also used for collecting line statistics for calibrating the camera.

Returning a Single Line of Video

Purpose: Returns a complete line of video (without pixel coefficients applied) displaying one pixel value after another. After pixel values have been displayed it also displays the minimum, maximum, and mean value of the line sampled within the region of interest (the region of interest command is explained in section Setting a Region of Interest (ROI)).
Use the **`gl`** command, or the following **`gla`** command, to ensure the proper video input range into the processing chain before executing any pixel calibration commands.

Syntax: **`gl`** ***`x1 x2`***

Syntax Elements: ***`x1`***

Pixel start number. Must be less than the pixel end number in a range from **`1`** to **`n`** (sensor resolution), where n = 2048 or 4086.

`x2`

Pixel end number. Must be greater than or equal to the pixel start number in a range from **`1`** to **`n`** (sensor resolution), where n = 2048 or 4086.

Notes: If **`x2`** ≤ **`x1`** then **`x2`** is forced to be **`x1`**.
Values returned are in 12-bit DN.

Related Commands **`roi`**

Example: **`gl 10 20`**

Returning the Average of Multiple Lines of Video

Purpose: Returns the average for multiple lines of video data (without pixel coefficients applied). The number of lines to sample is set and adjusted by the **css** command. The camera displays the Min., Max., and Mean statistics for the pixels in the region of interest (the region of interest command is explained in section Setting a Region of Interest (ROI)).

Syntax: **gla *x1 x2***

Syntax Elements: ***x1***

Pixel start number. Must be less than the column end number in a range from **1** to **n**, where n = 2048 or 4096 depending on the resolution.

x2

Pixel end number. Must be greater than or equal to the column start number in a range from **1** to **n**, where n = 2048 or 4096 depending on the resolution.

Notes: If **x2** ≤ **x1** then **x2** is forced to be **x1**.
Analog gain, analog offset, digital offset, background subtract, and digital system gain are applied to the data. FPN and PRNU coefficients are not included in the data.
Values returned are in 12 bit DN.

Related Commands: **css**, **roi**

Example: **gla 10 20**

Setting the Number of Lines to Sample

Purpose: Sets the number of lines to sample when using the **gla** command or when performing FPN and PRNU calibration.

Syntax: **css *m***

Syntax Elements: ***m***

Number of lines to sample. Allowable values are **1024**, **2048**, or **4096**.

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

Related Commands: **gla**, **ccf**, **ccp**, **cpa**

Temperature Measurement

The temperature of the camera can be determined by using the vt command. This command will return the internal chip case temperature in degrees Celsius. For proper operation, this value should not exceed 75°C.

Note: If the camera reaches 75°C, the camera will shutdown and the LED will flash red. If this occurs, the camera must be rebooted using the command, **rc** or can be powered down manually. You will not be able to restart the camera until the temperature is less than 65°C. You will have to correct the temperature problem or the camera will shutdown again. The camera allows you to send the **vt** (verify temperature) command while it is in this state.

Voltage Measurement

The command `vv` displays the camera's input voltage. Note that the voltage measurement feature of the camera provides only approximate results (typically within 10%). The measurement should not be used to set the applied voltage to the camera but only used as a test to isolate gross problems with the supply voltage.

Camera Frequency Measurement

Purpose:	Returns the frequency for the requested Camera Link control signal
Syntax:	**`gsf i`**
Syntax Elements:	***i*** Camera Link control signal to measure: **1**: CC1 (EXSYNC/Blue PR) **2**: CC2 (Green PR) **3**: CC3 (CCD Direction) **4**: CC4 (Spare/Red PR)
Note:	Accuracy: ±271 ns Reliable up to 40,000 H
Example:	**`gsf 1`**

Returning the LED Status

Purpose:	Returns the status of the camera's LED.
Syntax:	**`gsl`** The camera returns one of the following values: **2** = green (camera is operating correctly) **5** = flashing green (camera is performing a function) **6** = flashing red (fatal error)
Notes:	• Refer to section 2.3 Camera LED for more information on the camera LED.

Returning Camera Settings

Returning All Camera Settings with the Camera Parameter Screen

The camera parameter (gcp) screen returns all of the camera's current settings. The table below lists all of the gcp screen settings.

To read all current camera settings, use the command:

Syntax: **`gcp`**

Example: OK>gcp

C A M E R A S E T T I N G S:

Camera Model No.: PC-30-02K60-00-R
Camera Serial No.: 3
Microcode Version: 03-081-00166-06
CCI Version: 03-110-20014-01
FPGA Version: 03-056-20031-04
UART Baud Rate: 115200

Set Number, Current: 3
Set Number, Last Settings: 3
Set Number, Last LUT: 3
Set Number, Last FPN: 3
Set Number, Last PRNU: 3
Color: RGB
Video Mode: Normal video
Region Of Interest: 1 to 2048
End-Of-Line Sequence: 1
Number Of Line Samples: 1024
Upper Threshold: White: 4095 Red: 4095 Green: 4095 Blue: 4095
Lower Threshold: White: 0 Red: 0 Green: 0 Blue: 0

Readout Mode: Off
Exposure Mode: 7
SYNC Frequency [Hz]: 10498.7
Exposure Time [uSec]: 95.25
CCD Direction: Internal/Forward
Horizontal Averaging: 1
Camera Link Mode: 16, Medium, 1 taps, 12 bits, no time MUX
Cable Parameter: 100
Output Throughput: 80
Spatial Alignment 0
Mirroring Mode: 0, left to right

```
Color Correction Coefficients:      White  0   1365   1365   1365
            Red     0   4096      0      0
            Green   0      0   4096      0
            Blue    0      0      0   4096
Input LUT:        Off
FPN Coefficients:          Off
PRNU Coefficients:         Off
Analog Gain [dB]:          Red     10.0  10.0  10.0  10.0
            Green   10.0  10.0  10.0  10.0
            Blue    10.0  10.0
Analog Reference Gain [dB]:        Red     0.0   0.0   0.0   0.0
            Green    0.0   0.0   0.0   0.0
            Blue     0.0   0.0
Total Analog Gain [dB]:    Red     10.0  10.0  10.0  10.0
            Green   10.0  10.0  10.0  10.0
            Blue    10.0  10.0
Analog Offset:    Red      80    80    80    80
            Green    80    80    80    80
            Blue     80    80
Digital Offset:   Red       0     0     0     0
            Green     0     0     0     0
            Blue      0     0
Background Subtract:       Red      0     0     0     0
            Green     0     0     0     0
            Blue      0     0
System Gain:      Red    4096  4096  4096  4096
            Green   4096  4096  4096  4096
            Blue    4096  4096
Background Add:Red       0     0     0     0
            Green     0     0     0     0
            Blue      0     0
OK>
```

Returning Camera Settings with Get Commands

You can also return individual camera settings by inserting a "**get**" in front of the command that you want to query. If the command has a tap or pixel number parameter, you must also insert the tap number or pixel number that you want to query. This command returns the values without the descriptions found on the **gcp** screen. Refer to Table 6 below for a list of available commands. To view a help screen listing the following get commands, use the command **gh**.

Table 6: Get Commands

Syntax	Parameters	Description
get ccf	x1 x2	Returns the FPN pixel coefficients for the pixel range indicated. **x1** = Pixel start number **x2**= Pixel end number
get ccp	x1 x2	Returns the PRNU pixel coefficients for the pixel range indicated. **x1** = Pixel start number **x2**= Pixel end number
get clm		

Syntax	Parameters	Description
get css		Returns the number of line samples averaged for pixel coefficient calculations or for output of `gla` command.
get dil	t a a	Displays LUT values. t = Tap dependent on scl, 0 for all. a1 = Start LUT address a2 = Stop LUT address, a1 $\leq$ a2
get dpc	x1 x2	Returns pixel coefficients without formatting.
get ebc		Returns blue correction status. **0**: Off **1**: On
get eil		Returns LUTs status. **0**: Off **1**: On
get els		Returns whether the end-of-line statistics are turned off or on. **0**: Off **1**: On
get epc		Returns whether pixel coefficients are enabled or disabled. The first parameter returns the FPN coefficients setting where: **0** = FPN coefficients disabled **1** = FPN coefficients enabled The second parameter returns the PRNU coefficients setting where: **0** = PRNU coefficients disabled **1** = PRNU coefficients enabled
get gcm		Returns the camera's model number
get gcs		Returns the camera's serial number
get gcv		Returns the camera's software version.
get gfc	x	Returns the FPN pixel coefficient for the pixel indicated. Only available when a single color is selected.
get gl	x1 x2	Returns pixel values for the pixel range specified.
get gla	x1 x2	Returns the average of the pixel range indicated.
get gpc	x	Returns the PRNU pixel coefficient for the pixel indicated.
get gsf	i	Returns the frequency of the Camera Link control signal indicated: **1**, **2**, **3**, or **4**.
get gsl		Returns the led status.
get lfc		Returns the current coefficient set number
get lpc		Returns the current coefficient set number.
get lfs		Returns the current coefficient set number.
get lus		Returns the current coefficient set number.
get roi		Returns the current region of interest.
get sab	t	Returns the current background add value. **t** = Tap value. **0** for all taps **1** to **4** for individual tap selection, depending on camera model.
get sag	t	Returns the analog gain in dB for the tap indicated **t** = Tap value. **0** for all taps or **1** to **4** for individual tap selection.
get sah		Returns the horizontal averaging factor.

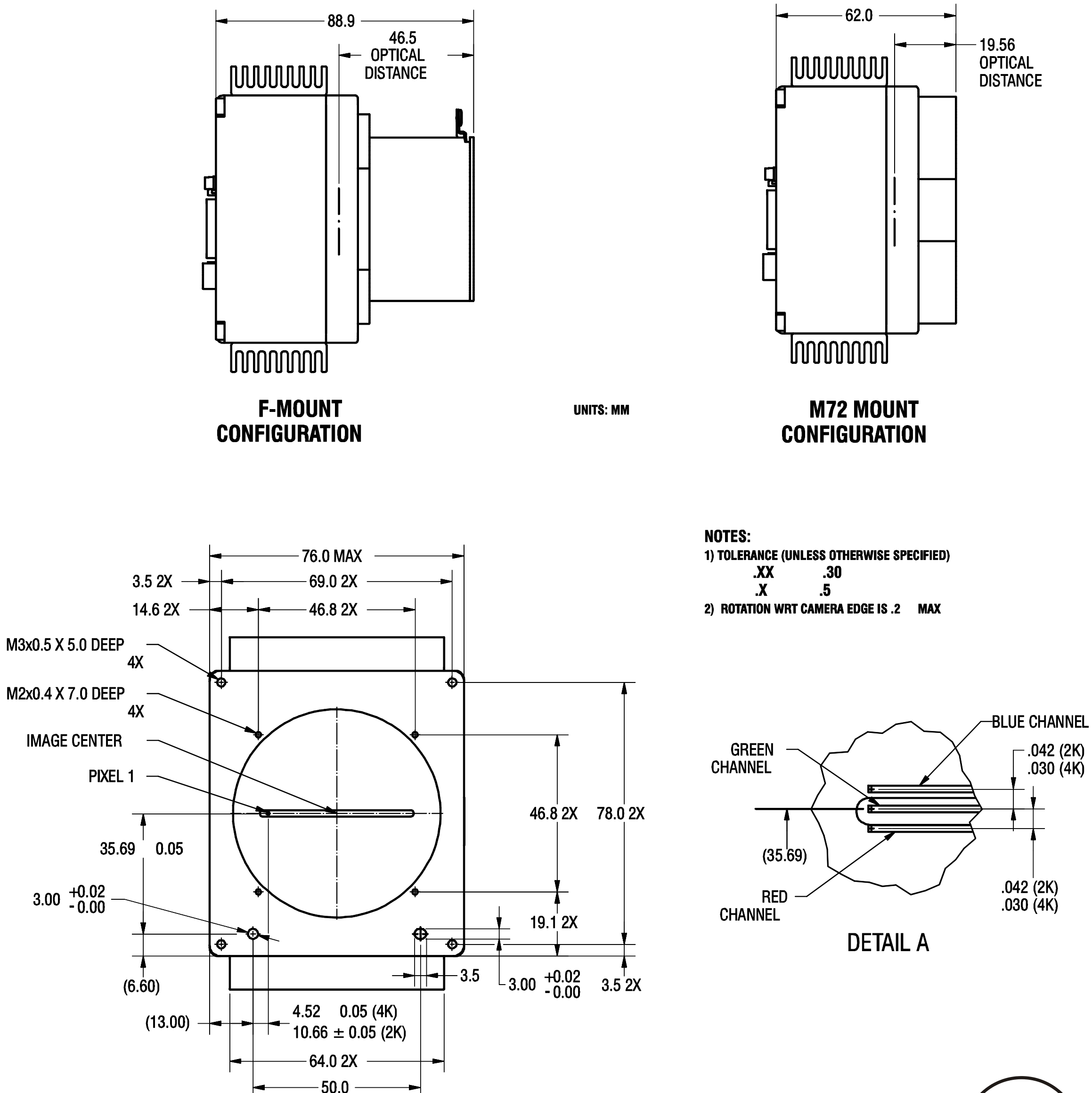
Syntax	Parameters	Description
get sao	t	Returns the analog offset for the tap indicated. **t = 0** for all taps or **1** to **4** for individual tap selection.
get sbr		Returns the speed of camera serial communication port.
get scb		Returns cable parameter.
get scc		Returns current color correction coefficients.
get scd		Returns the CCD shift direction selection where: **0 =** Forward CCD shift direction. **1 =** Reverse CCD shift direction. **2** = Externally controlled direction control via CC3.
get scl		Return current color selection (**rgb**, **r**, **g**, or **b**)
get sdo	t	Returns the digital offset value in DN for the tap indicated. **t** = Tap value. **0** for all taps or **1** to **2** for individual tap selection.
get sem		Returns the current exposure mode: **2 =** Internal SYNC, internal PRIN, programmable line rate and exposure time using commands **ssf** and **set** **3 =** External SYNC, maximum exposure time **4** = Smart EXSYNC **5** = External SYNC and PRIN **6** = External SYNC, internal PRIN, programmable exposure time **7 =** Internal programmable SYNC, maximum exposure time.
get set		Returns the current exposure time in µs.
get sfc	x	Returns the FPN coefficient for the pixel number indicated. **x** =pixel number within the range **1** to **n**, where n = 2048 or 4096 depending on the resolution.
get sfr	x1 x2	Returns pixel range of FPN coefficients. $x1 \leq x2$.
get sil	t a	Returns single LUT entry. Only available when a single color is selected. **t** = tap: 1 to 4 **a** = LUT address
get slt		Returns the current lower threshold value. This command depends on the color selected previously using the **scl** command.
get smm		Returns mirroring mode: **0**: Off **1**: On
get sot		Returns output throughput in mega pixels per second (mps) per color.
get spc	x	Returns the PRNU coefficient for the specified pixel number. This command is only available when a single color is selected. **x**=pixel number within the range **1** to **n**, where n = 2048 or 4096 depending on the resolution.
get spr	x1 x2	Returns the pixel range of PRNU coefficients. $x1 \leq x2$.
get ssb	t	Returns the current background subtract value. **t** = Tap value. **0** for all taps or **1** to **4** for individual tap selection depending on camera model.
get ssf		Returns the current line rate in Hz. Only available while

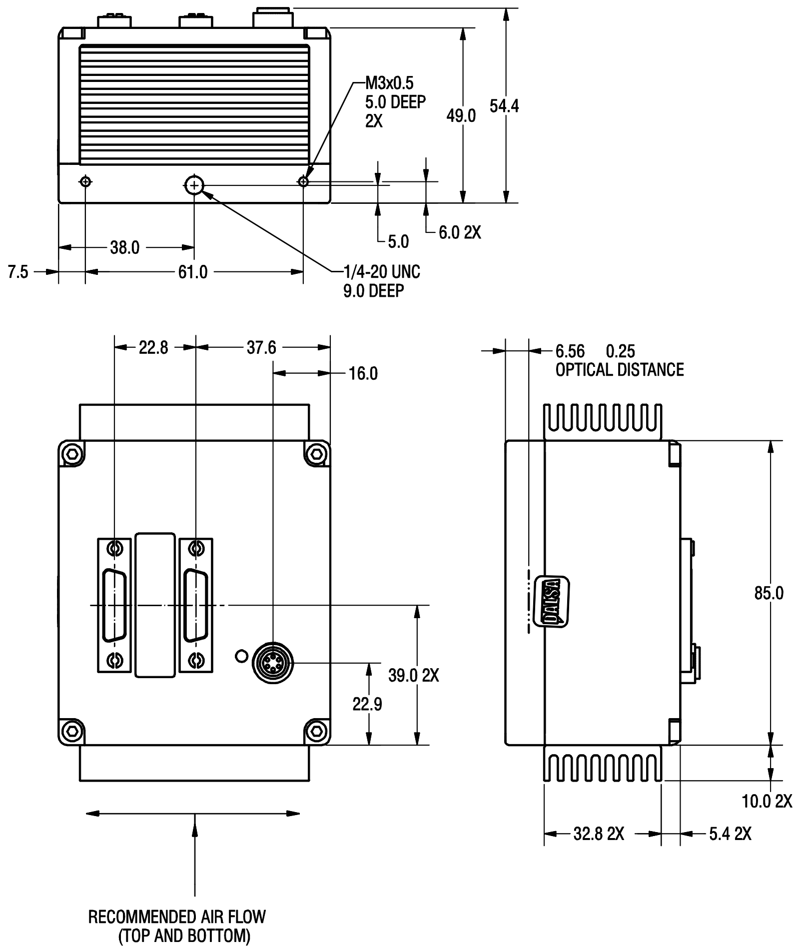
Syntax	Parameters	Description
		in internal exposure modes.
get ssg	t	Returns the current digital gain setting. **t** = tap selection, either **1** to **4** depending on camera model, or **0** for all taps
get ssn		Returns current set number.
get sut		Returns the current upper threshold value.
get svm		Returns the current video mode. **0**: Normal video **1**: Horizontal ramp **2**: Diagonal ramp **3**: Vertical ramp **4**: n/a **5**: n/a **6**: DC value **7**: FPN demo **8**: PRNU demo **9**: All 4095 (to get FPN) **10**: All 2048 (to get PRNU) **11**: Power toggle **12**: All 320 to FPN offset **13**: All zeros **14**: All ones
get ugr	t	Returns the gain reference value. **t** = tap selection: **1** to **4** depending on camera model, or **0** for all taps.
get vt		Returns the camera's internal chip temperature in degrees Celsius.
get vv		Returns the camera's supply voltage.
get wfc		Returns the current coefficient set number.
get wil		Returns the current coefficient set number.
get wpc		Returns the current coefficient set number.
get wus		Returns the current coefficient set number.

Optical and Mechanical Considerations

4.1 Mechanical Interface

Figure 9: Piranha Color Camera Mechanical Dimensions





4.2 Lens Mounts

Model Number	Lens Mount Options
All models	M72 x 0.75, M42x1 and F-mount.

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.

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, $5\mu J/cm^2$ can be achieved by exposing $5mW/cm^2$ for 1ms just the same as exposing an intensity of $5W/cm^2$ for $1\mu s$.

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 infrared light (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

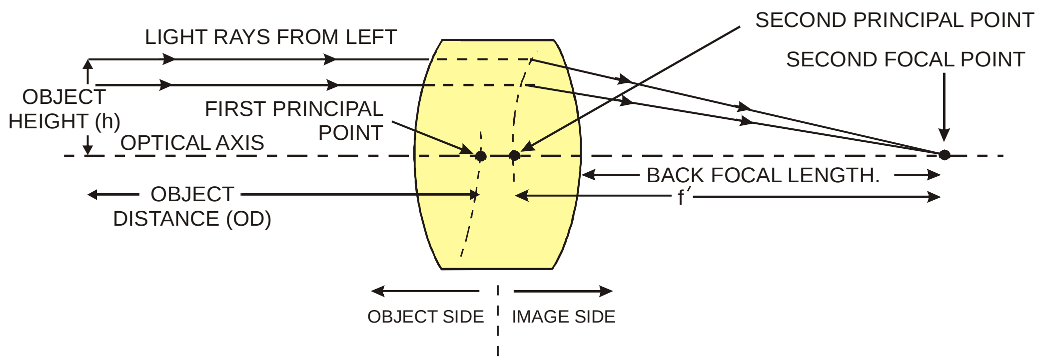
CCD cameras are extremely responsive to infrared (IR) wavelengths of light. To prevent infrared from distorting the images you scan, use a “hot mirror” or IR cutoff filter that transmits visible wavelengths but does not transmit wavelengths over 750nm. Examples are the Schneider Optics™ B+W 489, which 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 10: 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 (0.450m).

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

CCD Handling Instructions

5.1 Electrostatic Discharge and the CCD Sensor

Cameras contain charge-coupled device (CCD) image sensors, which are metal oxide semiconductor (MOS) devices and are susceptible to damage from electrostatic discharge (ESD).

Electrostatic charge introduced to the sensor window surface can induce charge buildup on the underside of the window that cannot be readily dissipated by the dry nitrogen gas in the sensor package cavity. When charge buildup occurs, surface-gated photodiodes (SGPDs) may exhibit higher image lag. Some SGPD sensors, such as the IL-P4 and the IT-P4 used in the Piranha Color cameras, may also exhibit a highly non-uniform response when affected by charge buildup, with some pixels displaying a much higher response when the sensor is exposed to uniform illumination. The charge normally dissipates within 24 hours and the sensor returns to normal operation.

WARNING: Charge buildup will affect the camera's flat-field correction calibration. To avoid an erroneous calibration, ensure that you perform flat-field correction only after a charge buildup has dissipated over 24 hours.

5.2 Protecting Against Dust, Oil and Scratches

The CCD window is part of the optical path and should be handled like other optical components, with extreme care.

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

Dust can normally be removed by blowing the window surface using a compressed air blower, unless the dust particles are being held by an electrostatic charge, in which case either an ionized air blower or wet cleaning is necessary.

Oil is usually introduced during handling. Touching the surface of the window barehanded will leave oily residues. Using rubber fingercots and rubber gloves can prevent oil contamination. However, the friction between the rubber and the window may produce electrostatic charge that may damage the sensor. To avoid ESD damage and to avoid introducing oily residues, only hold the sensor from the edges of the ceramic package and avoid touching the sensor pins and the window.

Scratches can be caused by improper handling, cleaning or storage of the sensor. Vacuum picking tools should not come in contact with the window surface. CCDs should not be stored in containers where they are not properly secured and can slide against the container.

Scratches diffract incident illumination. When exposed to uniform illumination, a sensor with a scratched window will normally have brighter pixels adjacent to darker pixels. The location of these pixels changes with the angle of illumination.

5.3 Cleaning the Sensor Window

Use compressed air to blow off loose particles. This step alone is usually sufficient to clean the sensor window.

If further cleaning is required, use a lens wiper moistened with alcohol or acetone.

We recommend using lint-free ESD-safe cloth wipers that do not contain particles that can scratch the window. The Anticon Gold 9"x 9" wiper made by Milliken is both ESD safe and suitable for class 100 environments. Another ESD acceptable wiper is the TX4025 from Texwipe.

An alternative to ESD-safe cloth wipers is Transplex swabs that have desirable ESD properties. There are several varieties available from Texwipe. Do not use regular cotton swabs, since these can introduce charge to the window surface.

Wipe the window carefully and slowly.

When cleaning long linear sensors, it may be easier to wipe along the width (i.e. as opposed to the length) of the sensor.

Troubleshooting

6.1 Common Issues

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
- software
- light sources
- operating environment
- cabling
- host computer
- optics
- encoder

LED

When the camera is first powered up, the LED will glow on the back of the camera. Refer to section 2.3 for information on the LED.

Connections

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

Cable Length/Type

Ensure that cable lengths are no longer than 10m. Use the **`scb`** command to select the correct cable parameter for the cable length.

Equipment Requirements

Ensure that you are using compatible equipment.

Power Supply Voltages

Check for the presence of all voltages at the camera power connector. Verify that all grounds are connected.

EXSYNC

When the camera is received from the factory, it defaults (no external input required) to exposure mode 7 (5000 Hz line rate, internal Sync to trigger readout). After a user has saved settings, the camera powers up with the saved settings.

If you change to an exposure mode that requires an external sync, ensure that you are providing an external sync

Communications and Verify Parameters

TBD.

Verify Voltage

To check the camera's input voltage, use the **`vv`** command. The supplied voltage must be within specification. Erratic behavior may occur at low voltages. Voltages will be reduced through the use of lengthy power supple cables.

Verify Temperature

To check the internal temperature of the camera, use the **`vt`** command.

6.2 Specific Solutions

Camera Does Not Respond to Serial Commands

Verify that the baud rate of the communications software matches that of the camera. The camera always powers up at 9,600 bps.

Flashing Red LED on Power-up

This indicates a serious error. There will be no camera output and the serial interface will only respond to a limit set of commands. An error message is sent in response to all commands. Refer to Appendix A5 for a description of these errors and the action to take.

Erratic Behavior

Use the **vv** command in order to verify that the supplied voltage is within specification.

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 in exposure mode that requires external signals).

Line Dropout, Bright Lines, or Incorrect Line Rate

Verify that the frequency of the internal sync is set correctly, or when the camera is set to external sync that the EXSYNC signal supplied to the camera does not exceed the camera’s useable line rate under the current operating conditions and that it is free from noise.

Horizontal Lines or Patterns in Image

A faulty or irregular encoder signal may result in horizontal lines due to exposure time fluctuations; ensure that your exposure time is regular. If you have verified that your exposure time is consistent and patterns of low frequency intensity variations still occur, ensure that you are using a DC or high frequency light source.

Noisy Output

Check your power supply voltage outputs for noise. Noise present on these lines can result in poor video quality.

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.

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.

Repeat steps 3-5 using a clean tissue until the entire window has been cleaned.

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

6.3 Product Support

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

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

Customer name	
Organization name	
Customer phone number fax number email	
Complete Product Model Number (e.g. PC-30-04K80-00-R.)	
Complete Serial Number	
Your Agent or Dealer	
Acquisition System hardware (frame grabber, host computer, light sources, etc.)	
Power supply setting and current draw	
Data rate used	
Control signals used in your application, and their frequency or state (if applicable)	☐ EXSYNC ☐ Camera Link ☐ Other _______
Voltage reported by the **`vv`** command and voltage range reported by the **`? vvRange`** command.	
gcp screen	Please attach text received from the camera when the gcp command is run.
gcl log	Please attach text received from the camera in response to the gcl command. (This is a log of the last 50 commands and the camera's response to them.)
Detailed description of problem encountered.	Please attach description with as much detail as appropriate.

In addition to your local Teledyne DALSA representative, you may need to call 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
Email:	support@teledynedalsa.com		

Appendix A: ASCII Command Reference

The following table lists and describes all of the camera's available ASCII commands.

Parameters:
t = tap id
i = integer value
f = float
m = member of a set
s = string
x = pixel column number
y = pixel row number

Table 7: Command Quick Reference

Mnemonic	Syntax	Parameters	Description
correction calibrate fpn	ccf		Performs FPN calibration and eliminates FPN noise by subtracting away individual pixel dark current. Measures FPN (dark current). Use the **epc** command to enable subtracting these values from the video. Use **wfc** to write these values to non-volatile memory.
calculate camera gain	ccg	**i t i**	Calculates the camera gain according to the selected algorithm. **i** = Calibration algorithm to use. **1** = This algorithm adjusts analog gain so that 8% to 13% of tap ROI pixels are above the specified target value. **2** = This algorithm adjusts analog gain so that the average pixel value in tap's ROI is equal to the specified target value. **3** = This algorithm adjusts digital (system) gain so that the average pixel value in tap's ROI is equal to the specified target. **4=** This algorithm adjusts the analog gain so that the peak tap ROI pixels are adjusted to the specified target. **t =** Tap value. Use **0** for all taps or **1** or **4** for individual tap selection depending on the color selected using the **scl** command. **i** = Calibration target value in a range from **1024** to **4055**DN (12 bit LSB).
correction calibrate prnu	ccp		Performs PRNU calibration in order to eliminate the difference in responsivity between the pixels to create a uniform response to light.
calibrate input LUT	cil		Calibrates the input lookup table (LUT). The LUTs are used to remove nonlinearity from the analog chain.
camera link mode	clm		Selects the CameraLink mode.
calculate PRNU algorithm	cpa	i1 i2	Performs PRNU calibration according to the selected algorithm. **i1** = The calibration algorithm:

Mnemonic	Syntax	Parameters	Description
			1 = The algorithm first adjusts each tap's analog gain so that 8-13% of pixels within a tap are above the value specified in the target value parameter. PRNU calibration then occurs using the peak pixel in the region of interest. (Identical to **ccp**) **2** = Calculates the PRNU coefficients using the entered target value as shown below: $\text{PRNU Coefficient} = \frac{\text{Target}}{(\text{AVG Pixel Value}) - (\text{FPN}+\textbf{sdo}\ \text{value})}$ The calculation is performed for all sensor pixels but warnings only apply to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. **3** = This algorithm includes an analog gain adjustment prior to PRNU calibration. Analog gain is first adjusted so that the peak pixel value in tap's ROI is within 97 to 99% of the specified target value. It then calculates the PRNU coefficients using the 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 only apply to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. **4** = This algorithm is the same as 2 with the exception that it only calculates PRNU for the pixels within the current Region of Interest (ROI). The second parameter is the target value to use in a range from **1024** to **4055** DN. **i2** = Output target.
correction set sample	css	m	Sets the number of lines to sample when using the **gla** command or when performing FPN and PRNU calibration where m is **1024**, **2048**, or **4096**.
display input LUT	dil	t a1 a2	Displays the range of input LUT values, where: **t** = Tap number: 0 for all. The range is modified by the color selected. **a1** = Range start address: 0 to 1023. **a2** = Range stop address: 0 to 1023.

Mnemonic	Syntax	Parameters	Description
			a1 ≤ a2
display pixel coeffs	dpc	x1 x2	Displays the pixel coefficients in the order FPN, PRNU, FPN, PRNU, … **x1** = Pixel start number **x2**= Pixel end number in a range from **1** to **n**. Where n = **2048** or **4096.**
enable blue correction	ebc	i	Enable blue correction, where: **0**: Disable/Off **1**: Enable/On
enable input LUT	eil	i	Enable input LUT, where: **0**: Off **1**: On
end of line sequence	els	i	Sets the end-of-line sequence: **0**: Off **1**: On **2**: LVAL (video and statistics)
enable pixel coefficients	epc	i1 i2	Sets whether pixel coefficients are enabled or disabled. The first parameter sets the FPN coefficients where **i1** is: **0** = FPN coefficients disabled **1** = FPN coefficients enabled The second parameter sets the PRNU coefficients where **i2** is: **0** = PRNU coefficients disabled **1** = PRNU coefficients enabled
get command log	gcl		Displays the last 50 commands and the camera's response to them.
get camera model	gcm		Displays the camera model number.
get camera parameters	gcp		Displays all of the camera parameters.
get camera serial	gcs		Displays the camera serial number.
get camera version	gcv		Displays the camera's firmware versions.
get values	get	s	Displays the current value of the parameter(s) set by the command **s**.
get fpn coefficient	gfc	x	Read the FPN coefficient **x** = pixel number to read in a range from **1** to **n**. Where n = **2048** or **4096**.
get help	gh		Returns all of the available “get” commands.
get input LUT	gil	t a	Display a single LUT value. Must select a color with SCL first. **t =** Tap number; 0 for all; range modified by color selected **a =** LUT address; 0 to 1023
get line	gl	x1 x2	Gets a line of video (without pixel coefficients applied) displaying one pixel value after another and the minimum, maximum, and mean value of the sampled line.

Mnemonic	Syntax	Parameters	Description
			x1 = Pixel start number **x2** = Pixel end number in a range from **1** to **n**. Where n = **2048** or **4096**.
get line average	gla	x1 x2	Read the average of line samples. **x1** = Pixel start number **x2** = Pixel end number in a range from **1** to **n**. Where n = **2048** or **4096**.
get prnu coeff	gpc	x	Displays a PRNU coefficient. **x** = pixel number to read in a range from **1** to **n**. Where n = **2048** or **4096**.
get signal frequency	gsf	i	Reads the requested Camera Link control frequency. **1** = EXSYNC frequency **2** = CC2 **3** = Direction **4** = CC4
help	h		Display the online help.
load FPN coefficients	lfc		Loads the FPN coefficients from non-volatile memory to current. This command is modified by the **ssn** command.
load factory settings	lfs		Loads the camera's factory settings LUT, FPN and PRNU coefficients. Also used to clear a fatal error if the user settings are corrupt at power up.
load input LUT	lil		Load input LUT's from non-volatile memory to current. Modified by the **ssn** command.
load pixel coefficients	lpc		Load the previously saved PRNU coefficients from non-volatile memory. Modified by the **ssn** command.
load user settings	lus		Load the camera user settings from non-volatile memory. Modified by the **ssn** command.
reset camera	rc		Resets the entire camera (reboot). Baud rate is not reset and reboots with the value last used.
reset input LUT	ril		Set all values in all current LUT's to zero.
region of interest	roi	x1 x2	Sets the pixel range affected by the **ccg**, **gl**, **gla**, **cil, ccf, ccp**, and **cpa** commands. The parameters are the pixel start and end values (**x**).
reset pixel coeffs	rpc		Resets the FPN and PRNU coefficients to 0.
set add background	sab	ti	Set 12 bit value to add at end of digital chain. **t =** Tap; 0 to 4 depending on color selected; 0 for all taps **i =** Value to add

Mnemonic	Syntax	Parameters	Description
set analog gain	sag	t f	Sets the analog gain in dB. **t** = tap selection, either **1** or **4** depending on the color selected, or **0** for all taps. **f**= gain value specified from **-10** to **+10 dB**
set analog offset	sao	t i	Sets the analog offset. **t =** tap selection, **1** to **4** depending on color selected, or **0** for all taps. **i**= Offset value in a range from **0** to **255** (12-bit LSB). Set to three time RMS noise at high gain.
set averaging horizontal	sah	i	Sets the number of horizontal pixels to average. Available values are **1** (factory settings) and **2**.
set baud rate	sbr	i	Set the speed of camera serial communication port. Baud rates: **9600**, **19200**, **57600**, and **115200**. Power on default: 9600.
select cable	scb	i	Sets the cable parameter. Increase this value for longer cables and decrease the value for shorter cables.
set color correction	scc	i1 i2 i3 i4	Set how three video streams from the CCD are combined to provide the four (red, green, blue, and luminance) output streams. Use SCL to select the color, RGB for luminance, to modify. i1 = Offset (0 to 4095) i2 = Red multiplier (-8192 to 8191) i3 = Green multiplier (-8192 to 8191) i4 = Blue multiplier (-8192 to 8191) Multipliers are divided by 4096 to get the actual factor.
set ccd direction	scd	i	Sets the CCD shift direction where: **0 =** Forward CCD shift direction. **1 =** Reverse CCD shift direction. **2** = Externally controlled direction control via CC3.
set color	scl	s	rgb/r/g/b
set digital offset	sdo	t i	Subtracts this value from the video signal prior to FPN correction. **t** = tap selection, **1** to 4 depending on color selected, or **0** for all taps. **i** = Offset in a range from **0** to **4095**.
set exposure mode	sem	m	Sets the exposure mode: **2 =** Internal line rate and exposure time set using commands **ssf** and **set** **3 =** External SYNC, maximum exposure time **4** = Smart EXSYNC **5** = External SYNC and PRIN

Mnemonic	Syntax	Parameters	Description
			6 = External SYNC, internal exposure time set using SET command **7 =** Internal line rate, maximum exposure time. Factory setting.
set exposure time	set	f	Sets the exposure time. Refer to the camera help screen (**h** command) for allowable range.
set fpn coeff	sfc	x i	Set the FPN coefficient. First must select a single color with SCL. **x** =pixel number within the range **1** to **n**. Where n = **2048** or **4096**. **i**= FPN value within the range **0** to **4095** (12-bit LSB).
set fpn range	sfr	x x i	Set a range of pixel FPN coefficients. First must select a single color with SCL. **x1**=first pixel number of the range. **x2**=last pixel number of the range **i**=coefficient value in a range from **0** to **4095**.
set input LUT	sil	t a i	Set a single value in a LUT. First must select a single color with SCL. **t =** Tap; 1 to 4 depending on color **a =** Address within LUT; 0 to 1023 **i =** Value; -256 to 255
set lower threshold	slt	i	The pixels below the lower threshold are counted and reported in the end-of-line sequence. **i =** Threshold in a range from **0**-**4095**.
set mirroring mode	smm	i	Set mirroring mode: **0 =** Left to right **1 =** Right to left
set output throughput	sot	m	Sets the camera's total throughput per color. Valid values are: 30, 40, 60, or 80 mega-pixels per second per color.
set prnu coeff	spc	x i	Set a PRNU coefficient. First must select a single color with SCL. **x**=pixel number within the range **1** to **n**. Where n = **2048** or **4096**. **i**= PRNU value within the range **0** to **61438**.
set prnu range	spr	i1 i2 x	Set a range of pixel PRNU coefficients. First must select a single color with SCL. **i1** = first pixel number of the range **i2** = last pixel number of the range **x** = coefficient value in a range from **0** to **61438**.
set readout mode	srm	i	Select vertical transfer dark clear mode. **0 =** Auto, clears dark below approximately 60% of maximum line

Mnemonic	Syntax	Parameters	Description
			rate **1 =** Always clears dark; reduces the maximum line rate **2 =** Off
set spatial alignment	ssa	i	Set line delay between colors. 0 to 6.
set subtract background	ssb	t i	Subtract this value from the output signal. **t** = Tap value. **0** for all taps or **1** to number of camera taps the color selected. **i** = Subtracted value in a range from **0** to **4095**.
set sync frequency	ssf	f	Set internal line rate. 1Hz to **22,714** Hz (2k model) or **12,132** Hz (4k model).
set system gain	ssg	t i	Set the digital gain. **t** = tap selection, **0** for all taps or **1** to number of camera taps for color **i** = Digital gain in a range from **0** to **65,535**. The digital video values are multiplied by this number divided by 4,096.
set select number	ssn	i	Set number for write/load settings commands: **0 =** Factory set (load only) **1-4 =** Internal user sets
set upper threshold	sut	i	The pixels equal to or greater than the upper threshold are counted and reported in the end-of-line sequence. **i =** Threshold **0**-**4095**.
set video mode	svm	i	Switch between normal video mode and camera test patterns: 0: Normal video 1: Horizontal ramp 2: Diagonal ramp 3: Vertical ramp 4: N/A - A5 pattern 5: N/A - Data transmission 6: DC value 7: FPN demo 8: PRNU demo 9: All 4095 (to get FPN) 10: All 2048 (to get PRNU) 11: Power toggle 12: All 320 - FPN offset 13: All zeros 14: All ones
update gain reference	ugr		For all taps, changes 0 dB gain to equal the current analog gain value.
verify temperature	vt		Display the internal temperature of the camera.
verify voltage	vv		Display the voltage supplied to the

Mnemonic	Syntax	Parameters	Description
			camera.
write FPN coefficients	wfc		Write current FPN coefficients to non-volatile memory set previously using the **ssn** command.
write input LUT	wil		Write current LUT's to non-volatile memory set previously using the **ssn** command.
write PRNU coeffs	wpc		Write current PRNU coefficients to non-volatile memory set previously using the **ssn** command.
write user settings	wus		Write current camera settings to non-volatile memory set previously using the **ssn** command.

A5 Error Handling

The following table lists warning and error messages and provides a description and possible cause. Warning messages are returned when the camera cannot meet the full value of the request; error messages are returned when the camera is unable to complete the request.

Table 8: Warning and Error Messages

Message	Description
Warning 01: Outside of specification>	Parameter accepted was outside of specified operating range (e.g. gain greater than ±10 dB of factory setting, or SSF below specification).
Warning 02: Clipped to min>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 03: Clipped to max>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 04: Related parameters adjusted>	Internal operating condition is adjusted to accommodate the entered command. E.g. requesting exposure time longer than line time automatically adjusts the line time to meet the exposure time requirement.
Warning 07: Coefficient may be inaccurate A/D clipping has occurred>	In the region of interest (ROI) greater than 6.251% single or 1% of averaged pixel values were zero or saturated.
Warning 08: Greater than 1% of coefficients have been clipped>	Greater than 1% of FPN or PRNU coefficients have been calculated to be greater than the maximum allowable and so were clipped.
Warning 09: Internal line rate inconsistent with read out time>	Changes to the parameter (e.g. horizontal averaging) have changed read out time and that is greater than the *internal* SYNC.
Error Message	**Description**
Error 01: Internal error xx>	Where xx is a code list below. Only output during power up. Customer should contact customer support.

Message	Description
Error 02: Unrecognized command>	Command is not valid (or not available at the current access level).
Error 03: Incorrect number of parameters>	Too many or too few parameters.
Error 04: Incorrect parameter value>	This error is returned for: - Alpha character received instead of numeric character or visa versa. - Float where integer expected. - Not an element of the set of possible values. E.g., Baud Rate. - Outside the range limit
Error 05: Command unavailable in this mode>	E.g. Set sync frequency (ssf) when in external sync mode 3 (sem).
Error 06: Timeout>	Command not completed in time. E.g. CCF or CCP in SEM 3 when no external EXSYNC is present.
Error 07: Camera settings not saved>	Indicates that user settings have been corrupted by turning off the power while executing the WUS command. Must build up new settings from factory and re-save with WUS. Also present during manufacturing before settings saved for first time.
Error 08: Unable to calibrate - tap outside ROI>	Cannot calibrate a tap that is not part of the end of line statistics.

Appendix B: Blue Correction Command

Note: This command applies to the PC-30-0xK80 cameras only.

The 80 mega-pixel camera models (PC-30-02K80 and PC-30-04K80) show an artifact at the mid-point of the blue taps. This blue correction command enables replacing these pixels with interpolated values.

Affected pixels:

Model	1st Blue Tap	2nd Blue Tap
PC-30-02K80-00-R	534	1515
PC-30-04K80-00-R	1046	3051

The bilinear interpolation equation:

Blue: [B1][B2][B3]

B2 = ½ x (B1 + B3)

This value is saved with the **`wus`** command.

This value may be viewed on the **`gcp`** screen or with the **`get ebc`** command.

Enabling blue correction

Syntax:	**`ebc i`**
Syntax Elements:	***`i`*** **`0`**: disable **`1`**: enable
Notes	This value is saved using the **`wus`** command. This value may be viewed on the **`gcp`** screen or by sending the **`get ebc`** command.

Appendix C: EMC Declaration of Conformity

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

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

	PC-30-02K80-00-R PC-30-02K60-00-R PC-30-04K80-00-R PC-30-04K60-00-R

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

EMC:	CISPR 24:1997, A1:2001, and A2:2002 / EN 55024:1998, A1:2001, and A2:2003 European CISPR 22:2005 / EN 55022:2006

This product complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the CE mark accordingly.

Place of Issue	Waterloo, ON, CANADA
Date of Issue	December 2007
Name and Signature of authorized person	Hank Helmond Quality Manager, Teledyne DALSA Corp.

Appendix D: Revision History

Revision Number	Change Description
00	Preliminary release
01	-"rfs" commands substituted with "lfs" commands (no change to command performance). "i" parameter removed from "wpc," "wfc," and "wil" commands descriptions. These commands use the "ssn" command to indicate the storage set. Parameter 5 (PC set. Selects transfer from PC) removed from command "ssn". This parameter is not in the current cameras. -Extensive updates throughout manual. Manual remains preliminary. -Base and medium configuration timing tables updated. -Product name revised from PC-30-02k40 and 04k40 to PC-30-02k60 and 04k60. -Blue correction enable command and algorithm added. -Revised and added information to the Generating a Test Pattern section, page 60. Example test patterns added. -Set Binning Horizontal (sbh) command replaced with Set Averaging Horizontal (sah) command. Horizontal average replaces horizontal binning. -Added Warning 09: Changing this parameter (e.g. vertical binning) has changed read out time and that is greater than the *internal* SYNC, to table 10: Warnings and Errors.
02	-Revised base and medium configuration tables in section 2.6 Camera timing, page 15. SOT command updated, sot 30 removed. -Lens mount option M42x1 added to specifications and mechanical sections. -Revised FPN values added to the performance specifications table for the 2k80 and 4k80 models, page 5. -RoHS designation added, including camera model numbers.
03	-SOT 30 parameter removed from the Help screen description, page 22, the Data Ouput section, page 26, and from the list of all available commands, page 79. -"Pending" added to declarations of CE compliance in manual.
04	-Mechanical connector dimension revised. -Blue correction affected pixels, revised in Appendix B. -EMC declaration: "pending" stamp removed and fulfilled requirements listed. -Exposure mode 5 revised so that the timing signal for the green exposure starts at the same time as CC2 Green PRIN rising edge. The signal was starting too late. Page 31.
05	-Test conditions and notes for the performance and operating specification, Section 1.1, combined. -Operating specifications tables for both 2k and 4k models revised. -Sensor responsivity graphs revised, Section 1.3.
06	-SOT 30 command added to camera. Base and medium configuration tables updated on pages 19 and 21.
07	"Preliminary" designation removed.
08	Mechanical drawing revised showing sensor alignment measured from tooling holes in the front plate. Teledyne DALSA logo added.

Revision Number	Change Description
	Blue correction algorithm revised, Appendix B.

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