8k to 12k Line Scan CCD Cameras

TELEDYNE DALSA
A Teledyne Technologies Company

Piranha 3

Camera User's Manual

P3-80-12k40-00-R
P3-80-08k40-00-R
P3-87-12k40-00-R
P3-87-08k40-00-R

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www.teledynedalsa.com

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Teledyne DALSA, a Teledyne Technologies company, is an international leader in high performance digital imaging and semiconductors with approximately 1,000 employees worldwide, headquartered in Waterloo, Ontario, Canada. Established in 1980, the company designs, develops, manufactures and markets digital imaging products and solutions, in addition to providing MEMS products and services. For more information, visit Teledyne DALSA's website at www.teledynedalsa.com.

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Contents

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Introduction to the Piranha 3 Camera

1.1 Camera Highlights

Features

- 8k or 12k resolution
- Up to 33.7 kHz line rates
- Selectable 8 or 12 bit output
- 320MHz throughput (8x40 MHz)
- 100x antiblooming
- Selectable Medium or Full Camera Link™ configuration interface
- Automatic tap balancing algorithms
- RoHS, CE and FCC compliant

Key Specifications

Value	Units	8k	12k
		Typ (0dB Gain)	Typ (0dB Gain)
Pixel Pitch	µm	7 x 7	5 x 5
Camera Size	mm	150 H x 42 L x 80 W (P3-80)	
	mm	85 H x 54.2 L x 80 W (P3-87)	
Maximum Line Rate	kHz	33.7	23.5
Broadband Responsivity	DN/ nJ/ cm^2	224	138
Random Noise rms	DN	12.5	10.5
Dynamic Range (8 bit)	ratio	328:1	391:1
FPN Corrected	DN	4	4
PRNU Corrected	DN	18	18

Note: All numbers referenced to 12 bits unless otherwise specified.

Programmability

- Simple ASCII protocol controls gain, offset, line rates, trigger mode, pixel correction, test pattern output, and camera diagnostics

Description

The next generation of Piranha line scan cameras has arrived with more power, more speed and more resolution than ever before. The Piranha 3 camera family takes imaging to a new level with eight outputs running at 40MHz and either 8k or 12k resolutions. The large number of pixels and fast line rates specifically meet the throughput demands of flat panel inspection (Gen7 and Gen8), printed circuit board inspection, and multi-camera web inspection. With this large resolution and high speed, these cameras can inspect more panels in the same amount of time than ever before

Applications

The Piranha 3 family is ideal for applications requiring high speed, superior image quality, and high responsivity. Applications include:

- Flat panel display inspection
- Printed circuit board inspection
- Parcel sorting
- Multi-camera web inspection
- High performance document scanning
- High throughput applications

Models

The Piranha 3 cameras are available in the following models.

Table 1: Piranha 3 Camera Models Overview

Model Number	Description
P3-80-12k40-00-R	12k resolution, 8 taps, 40MHz data rate, Medium or Full Camera Link configuration.
P3-80-08k40-00-R	8k resolution, 8 taps, 40MHz data rate, Medium or Full Camera Link configuration.
P3-87-12k40-00-R	Smaller, square body, 12k resolution, 8 taps, 40MHz data rate, Medium or Full Camera Link configuration.
P3-87-08k40-00-R	Smaller, square body, 8k resolution, 8 taps, 40MHz data rate, Medium or Full Camera Link configuration.

1.2 Camera Performance Specifications

Table 2: Piranha 3 Camera Performance Specifications

Feature / Specification	Units	8k	12k	Notes
Sensor Features				
Imager Format		line scan CCD	line scan CCD	
Resolution	pixels	8192	12288	
Pixel Fill Factor	%	100	100	
Pixel Size	µm	7x7	5x5	
Output Format (# of taps)		8	8	
Antiblooming		100x	100x	

Optical Interface	Units	8k	12k	Notes
Back Focal Distance				
M72 Mount	mm	6.56±0.25	6.56±0.25	
Sensor Alignment				
x	mm	±0.05	±0.05	
y	mm	±0.05	±0.05	
z	mm	±0.25	±0.25	
Θz	°	±0.4	±0.4	
Lens Mount		M72x0.75	M72x0.75	

Mechanical Interface	Units		Notes
Camera Size	mm (h x l x w)	150 x 42 x 80 (P3-80)	
		85 x 54.2 x 80 (P3-87)	
Mass	g	<630 (P3-80) <125 (P3-87)	
Connectors			
power connector		6 pin male Hirose	
data connector		MDR26 female	

Electrical Interface	Units		Notes
Input Voltage	Volts	+12 to +15	Maximum power supply of ±5%
Power Dissipation	W	<15	
Operating Temperature (measured at front plate)	°C	0 to +50	
Data Output Format	Bits	8 or 12 bit user selectable	12 bits available in 4 tap operation only.
Output Data Configuration		Medium or Full Camera Link user selectable	

Specification	Units	8k	12k	Notes
Minimum Line Rate	kHz	2.5	2.5	

Specification	Units	8k	12k	Notes
Maximum Line Rate	kHz	33.7	23.5	
Data Throughput	MHz	320	320	
Gain	dB	-10 to +10	-10 to +10	

Operating Specifications (No Flat Field Correction)		P3-8k									
Specification	Unit	-10 dB			0 dB			+10 dB			
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Notes
Broadband Responsivity	DN/ nJ/ cm^2		71		189	224	236		708		1
Random Noise rms	DN		4.0	5.0		12.5	15.0		40.0	50.0	
Dynamic Range (12 bit)	ratio	820	1036		274	328		82	103		
DC Offset	DN		160			160			160		3
FPN ECD	DN		4	13		10	40		32	128	2
FPN ECE	DN		12	25		58	80		180	260	2
FPN Corrected			3	8		4	8		10	16	4
PRNU ECD	DN		120	330		120	330		140	330	2
PRNU ECE	DN		125	330		140	330		220	330	2
PRNU Pixel to Pixel	DN		80	255		80	255		80	255	
PRNU Corrected											
ECD	DN		16	48		18	64		48	80	2, 5, 6
ECE	DN		16	48		18	64		80	232	
NEE	pJ/ cm^2		56			56			56		
SEE	nJ/ cm^2		58			18			6		

Operating Specifications (No Flat Field Correction)		P3-12k									
Specification	Unit	-10 dB			0 dB			+10 dB			
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Broadband Responsivity	DN/ nJ/ cm^2		43.6		121	138	145		436		1
Random Noise rms	DN		3.3	4.1		10.5	13		33	42	
Dynamic Range (12 bit)	ratio	1000	1242		316	391		100	125		
DC Offset	DN		160			160			160		3
FPN ECD	DN		9	13		16	40		58	128	2
FPN ECE	DN		12	25		40	80		120	255	2
FPN Corrected			3	8		4	8		10	16	4
PRNU ECD	DN		120	330		120	330		140	330	2
PRNU ECE	DN		125	330		130	330		180	330	2

PRNU Pixel to Pixel	DN		80	255		80	255		80	255	
PRNU Corrected											
ECD	DN		16	64		18	64		48	80	2, 5, 6
ECE	DN		16	64		18	64		80	232	
NEE	pJ/ cm^2		76			76			76		
SEE	nJ/ cm^2		95			30			9.5		

Test conditions unless otherwise noted:

- Data Rate: 40MHz
- Line Rate: 2.5kHz
- Light Source: Broadband Quartz Halogen, 3250k, with 750nm cutoff filter installed
- Ambient test temperature 25°C
- All numbers referenced to 12 bits unless otherwise specified
- Specifications are only valid when line rates greater than 2.5kHz and input voltage is between +12V and +15V.

Notes:

1. Halogen 3200K color temperature with 750nm cutoff filter light source, 59 µW/ cm^2 (12k camera) and 71.3 µW/ cm^2 (8k camera) light intensity, line rate 2500 Hz (12k camera) and 5000 Hz (8k camera), ECD, 25 °C ambient temperature.
2. ECE = Exposure control enabled— exposure modes 2, 4, 5 and 6. ECD = Exposure control disabled—exposure modes 3 and 7.
3. Offset is factory-calibrated to 160DN.
4. FPN measurement is performed in dark at 2500 Hz line rate.
5. PRNU corrected is measured at 35% saturation using FPN coefficients calculated at 0% saturation and PRNU coefficients calculated at 70% saturation.
6. The FPN/ PRNU calibration conditions (gain, ECE, ECD, line rated, light) are set before calibration. The residual error is confirmed to be less than the maximum specified.

1.3 Image Sensor

Sensitivity is maximized through our newest IT-P9 and IT-PB sensors that were designed using our state-of-the-art CCD design process.

Figure 1: 12k40 and 08k40 Sensor Block Diagram

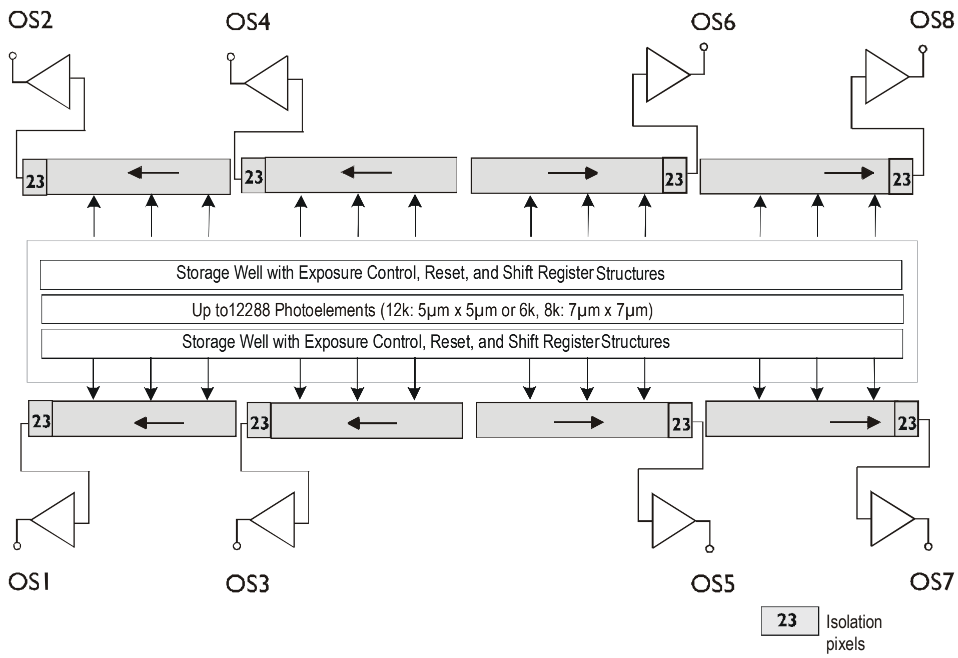


Table 3: 12k40 Pixel Readout

Tap #	First Pixel
1	1-3071 (odd pixels)
2	2-3072 (even pixels)
3	3073-6143 (odd pixels)
4	3074-6144 (even pixels)
5	9215-6145 (odd pixels)
6	9216-6146 (even pixels)
7	12287-9217 (odd pixels)
8	12288-9217 (even pixels)

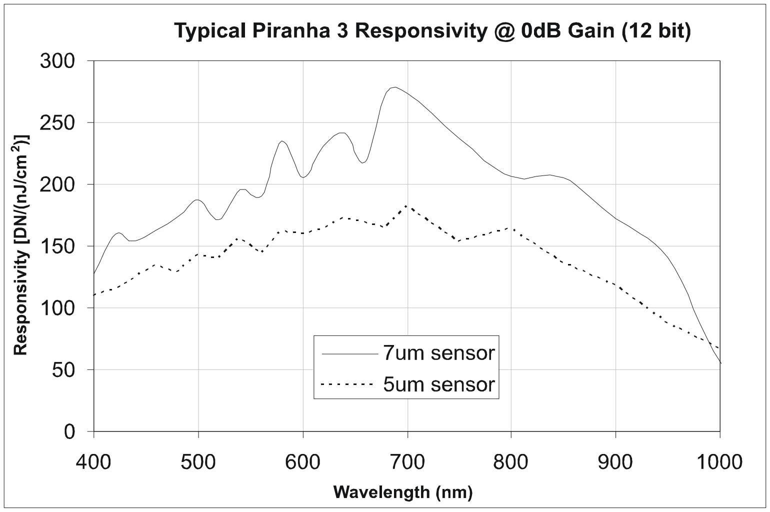
Table 4: 08k40 Pixel Readout

Tap #	First Pixel
1	1-2047 (odd pixels)
2	2-2048 (even pixels)
3	2049-4095 (odd pixels)
4	2050-4096 (even pixels)
5	6143-4097 (odd pixels)
6	6144-4098 (even pixels)

7	8191-6141 (odd pixels)
8	8192-6142 (even pixels)

1.4 Responsivity

Figure 2: Responsivity Graphs



2

Camera Hardware Interface

2.1 Installation Overview

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

When setting up your camera, you should take 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. 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 2.2.1 LED Status Indicator for an LED description.

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

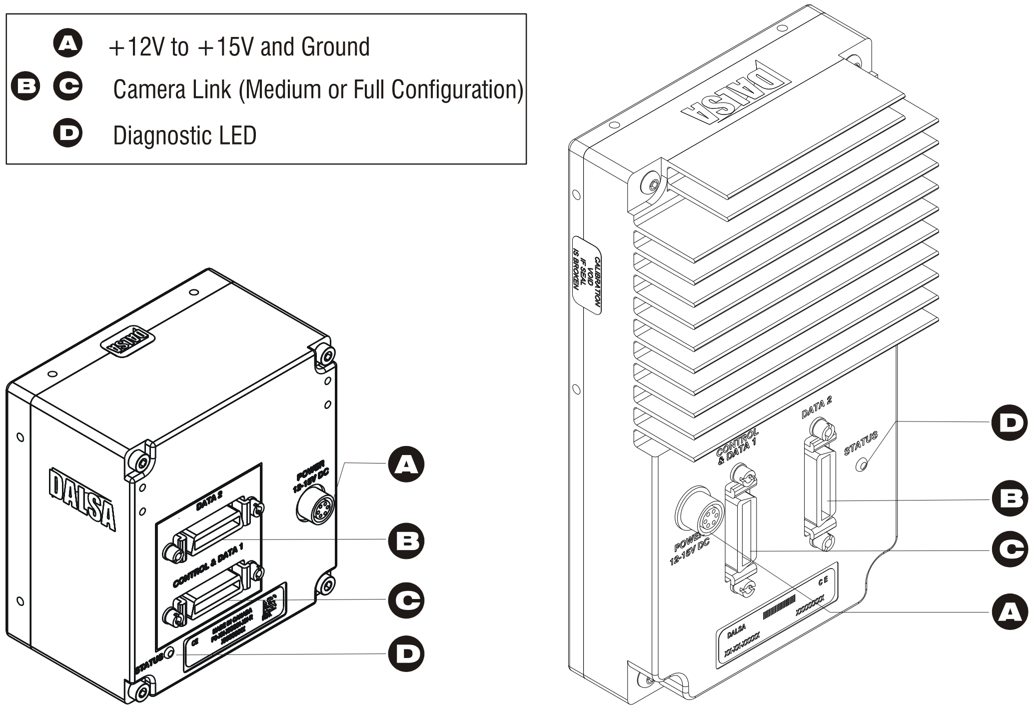
2.2 Input/Output Connectors and LED

The camera uses a:

- Diagnostic LED for monitoring the camera. See LED Status Indicator in section 2.2.1 LED Status Indicator for details.
- 6-pin Hirose connector for power. Refer to section 2.2.2 Power Connector for details.
- High-density 26-pin MDR26 connector for Camera Link control signals, data signals, and serial communications. Refer to section

2.2.3 Camera Link Data Connector for details.

Figure 3: Piranha 3 Input and Output Connectors



P3-87-xxk40-00-R **P3-80-xxk40-00-R**

WARNING: It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage the camera. See section 2.4 for more details.

2.2.1 LED Status Indicator

The camera is equipped with a red/ green LED used to display the operational status of the camera. The table below summarizes the operating states of the camera and the corresponding LED states.

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

Table 5: Diagnostic LED

Color of Status LED	Meaning
Flashing Green	Camera initialization or executing a long command (e.g., flat field correction commands **ccp** or **ccf**)
Solid Green	Camera is operational and functioning correctly
Flashing Red	Fatal Error. Camera temperature is too high and camera thermal shutdown has occurred.
Solid Red	Warning. Loss of functionality (e.g. external SRAM failure)

2.2.2 Power Connector

Figure 4: Hirose 6-pin Circular Male—Power Connector

Table 6: Hirose Pin Description

Pins	Description
1,2,3	+12 to +15V
4, 5, 6	GND

The camera requires a single voltage input with a +12V to +15V operating range (+11V to +16V absolute maximum range). 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:

- 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: Performance specifications are not guaranteed if your power supply does not meet the +12V to +15V requirements.

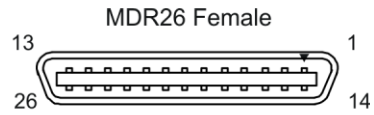
WARNING: It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage the camera. Protect the camera with a fast-blow fuse between power supply and camera.

We offer a power supply with attached 6' power cable that meets the Piranha 3 camera's requirements, but it should not be considered the only choice. Many high quality supplies are available from other vendors. Teledyne DALSA assumes no responsibility for the use of these supplies.

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

2.2.3 Camera Link Data Connector

Figure 5: Camera Link MDR26 Connector



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

**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.

A note concerning the length of the Camera Link cables

The length of the cables over which data can be transmitted without loss depends on the data rate and on the quality of the cables.

The camera is tested using a recognized brand of cable with a length of 5 meters. Data transmission is not guaranteed if you are using a cable greater than 5 meters in length.

Camera Link Configuration

The Camera Link interface is implemented as a Medium or Full Configuration in the Piranha 3 cameras. Refer to section 3.3.1 Setting the Camera Link Mode for details on setting the Camera Link configuration.

Table 7: Camera Link Hardware Configuration Summary

Configuration	8 Bit Ports Supported	Serializer Bit Width	Number of Chips	Number of MDR26 Connectors
Medium	A, B, C, D, E, F	28	2	2
Full	A, B, C, D, E, F, G, H	28	3	2

Table 8: Camera Link Connector Pinout

Medium and Full Configuration			
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-
19	8	Y3+	PAIR5+
7	20	100 ohm	PAIR6+
20	7	terminated	PAIR6-
8	19	Z0-	PAIR7-
21	6	Z0+	PAIR7+

Medium and Full Configuration			
Camera Connector	Right Angle Frame Grabber	Channel Link Signal	Cable Name
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

Table 9: Camera Control Configuration

Signal	Configuration
CC1	EXSYNC
CC2	PRIN
CC3	Spare
CC4	Spare

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 line readout. Section 3.2.1 Exposure Mode, Line Rate and Exposure Time details how to set frame times, exposure times, and camera modes.

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 Implementation Road Map, available here, for the standard location of these signals.

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

- The camera internally digitizes 12 bits and outputs 8 MSB or all 12 bits depending on the camera's Camera Link operating mode. Refer to section 3.3.1 Setting the Camera Link Mode for details on setting the Camera Link configuration.
- For a Camera Link reference refer to Appendix A on page 71.

2.3 Camera Link Video Timing

Figure 6: Piranha 3 Overview Timing Showing Input and Output Relationships

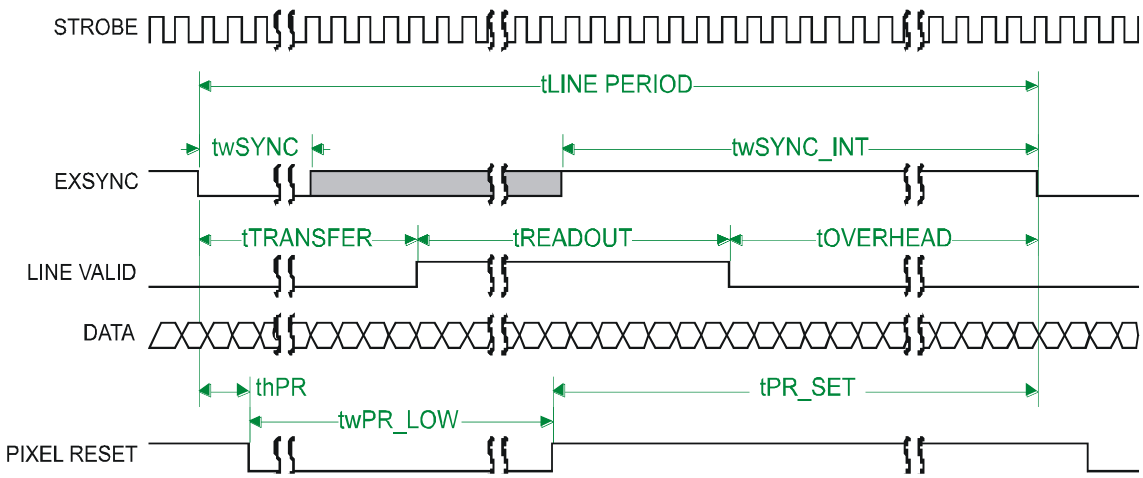


Figure 7: Piranha 3 Fixed (Programmed) Integration Timing with External EXSYNC

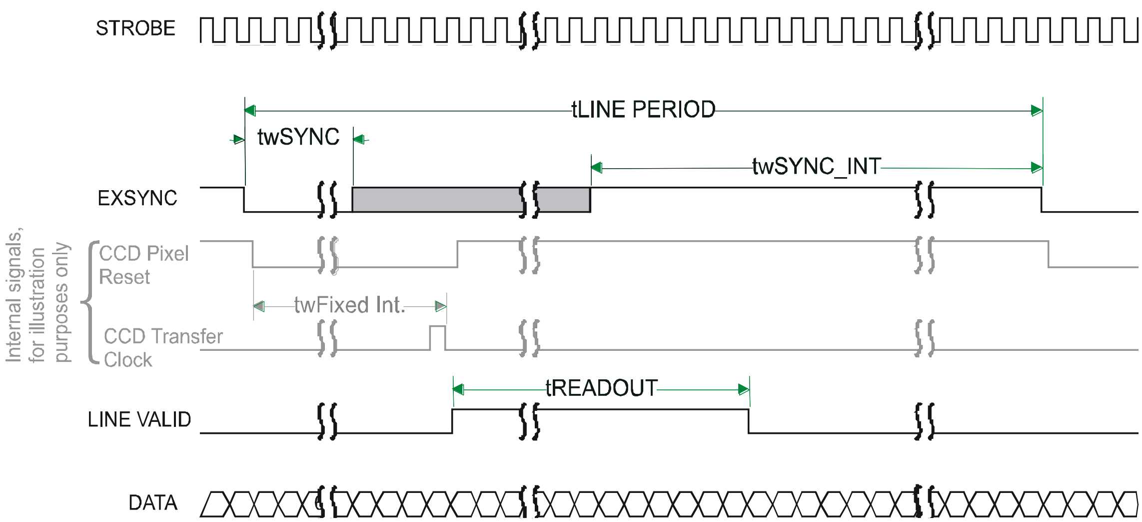


Table 10: Piranha 3 Input and Output

Symbol	Definition	Min (ns)
twSYNC	The minimum low width of the EXSYNC pulse when not in SMART EXSYNC mode.	100
twSYNC$_{(SMART)}$*	The minimum low width of the EXSYNC pulse when in SMART EXSYNC modes to guarantee the photosites are reset.	3,000
twSYNC_INT	The minimum width of the high pulse when the “SMART EXSYNC” feature is turned off	100
twSYNC_INT $_{(SMART)}$ *	Is the integration time when the “SMART EXSYNC” feature is available and turned on. Note that the minimum time is necessary to guarantee proper operation.	3,000

Symbol	Definition	Min (ns)
tLINE PERIOD (t_{LP})	The minimum and maximum line times made up of tTransfer, tREADOUT plus tOVERHEAD to meet specifications.	53,190 (12k) 106,382 (8k)
tTransfer	The time from the reception of the falling edge of EXSYNC to the rising edge of LVAL when pretrigger is set to zero. Pretrigger reduces the number of clocks to the rising edge of LVAL but doesn't change the time to the first valid pixel. If the fixed integration time mode of operation is available and selected then the integration time is added to the specified value.	3,725 ±25
twFixed Int.	Fixed Integration Time mode of operation for variable exsync frequency.	800
tREADOUT	Is the number of pixels per tap times the readout clock period. Pretrigger = 0.	38,400 (12k) 25,600 (8k)
tOVERHEAD	Is the number of pixels that must elapse after the falling edge of LVAL before the EXSYNC signal can be asserted. This time is used to clamp the internal analog electronics	425±25
thPR	Applies when the PRIN exposure control feature is enabled . The PRIN signal must be held a minimum time after the EXSYNC falling edge to avoid losing the integrated charge	Don't care
twPR_LOW	Minimum Low time to assure complete photosite reset	3,000
tPR_SET	The nominal time that the photo sites are integrating. Clock synchronization will lead to integration time jitter, which is shown in the specification as +/ - values. The user should command times greater than these to ensure proper charge transfer from the photosites. Failure to meet this requirement may result in blooming in the Horizontal Shift Register.	3,000

3

Software Interface: How to Control the Camera

All Piranha 3 camera features can be controlled through the serial interface. The camera can also be used without the serial interface after it has been set up correctly. Functions available include:

- Controlling basic camera functions such as gain and sync signal source
- Flat field correction
- Generating a test pattern for debugging

This chapter outlines the more commonly used commands. See section B2 All Available Commands for a list of all available commands.

The serial interface uses a simple ASCII-based protocol and the camera does not require any custom software.

Serial Protocol Defaults

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 9.6kbps
- Camera does not echo characters

Command Format

When entering commands, remember that:

- A carriage return <CR> ends each command.
- A space or multiple space characters separate parameters. Tabs or commas are invalid parameter separators.
- Upper and lowercase characters are accepted
- The backspace key is supported

- The camera will answer each command with either <CR><LF> "OK >" or <CR><LF>"Error xx: Error Message >" or "Warning xx: Warning Message". The ">" 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

Setting Baud Rate

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

Camera Help Screen

For quick help, the camera can 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 3.6.6 Returning Camera Settings.

The camera configuration command help screen lists all available commands. Parameter ranges displayed are the absolute maximum 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.

P3 12k Example Help Screen

```
cao  calibrate analog offset      ti      0-8:0-255
ccf  correction calibrate fpn
ccg  calibrate camera gain        iti     1-4:0-8:1024-4055
ccp  correction calibrate prnu
clm  camera link mode             m       15/16/21/
cpa  calibrate PRNU algorithm     ii      1-4:1024-4055
css  correction set sample        m       256/512/1024/
dpc  display pixel coeffs         xx      1-12288:1-12288
els  end of line sequence         i       0-1
epc  enable pixel coefficients    ii      0-1:0-1
gcm  get camera model
gcp  get camera parameters
gcs  get camera serial
gcv  get camera version
get  get values                   s
gfc  get fpn coeff                x       1-12288
gh   get help
gl   get line                     xx      1-12288:1-12288
gla  get line average             xx      1-12288:1-12288
gpc  get prnu coeff               x       1-12288
gsf  get signal frequency         i       1-4
gss  get sensor serial
h    help
lpc  load pixel coefficients      i       0-4
rc   reset camera
rfs  restore factory settings
roi  region of interest           xyxy    1-12288:1-1:1-12288:1-1
rpc  reset pixel coeffs
rus  restore user settings
sag  set analog gain              tf      0-8:-10.0-+10.0
sao  set analog offset            ti      0-8:0-255
sbr  set baud rate                m      9600/19200/57600/115200/
sdo  set digital offset           ti      0-8:0-2048
sem  set exposure mode            m       2/3/4/5/6/7/8/
set  set exposure time            f       3-3330 [uSec]
sfc  set fpn coeff                xi      1-12288:0-2048
sfr  set fpn range                xxi     1-8192:1-8192:0-2048
slt  set lower threshold          i       0-4095
sot  set output throughput        m       320/
spc  set prnu coeff               xi      1-12288:0-28671
spr  set prnu range               xxi     1-8192:1-8192:0-28671
spt  set pretrigger               i       0-16
ssb  set subtract background      ti      0-8:0-4095
ssf  set sync frequency           f       300-23619
ssg  set system gain              ti      0-8:0-65535
sut  set upper threshold          i       0-4095
svm  set video mode               i       0-2
ugr  update gain reference
vt   verify temperature
vv   verify voltage
wfc  write FPN coefficients       i       1-4
wpc  write PRNU coefficients      i       1-4
wus  write user settings
```

3.1 Command Categories

The following diagram categorizes and lists all of the camera's commands. This chapter is organized by command category.

Figure 8: Command Categories

Other

Introduction
Help (**h**)
Set Baud Rate (**sbr**)

Sensor Output Format

Section 3.2
Set Exposure Mode (**sem**)
Set Frame/Line Rate (**ssf**)
Set Exposure Time (**set**)

Camera Output Format

Section 3.3
Camera Link Mode (**clm**)
Camera Throughput (**sot**)
Generate a Test Pattern (**svm**)
Set Upper Threshold (**sut**)
Set Lower Threshold (**slt**)
End of Line Sequence (**els**)
Set Pretrigger (**spt**)

Data Processing

Section 3.4
Region of Interest (**roi**)
Set Analog Gain (**sag** or **ccg**)
Update Gain Reference (**ugr**)
Set Analog Offset (**sao**)
Calibrate Analog Offset (**cao**)
Correction Set Sample (**css**)
Calculate FPN (**ccf**)
Set Digital Offset (**sdo**)
Calculate PRNU (**ccp**)
Enable Pixel Coefficients (**epc**)
Set PRNU Coefficient (**spc**)
Set FPN Coefficient (**sfc**)
Set PRNU Range (**spr**)
Set FPN Range (**sfr**)
Set Background Subtract (**ssb**)
Set Digital System Gain (**ssg**)

Saving and Restoring Settings

Section 3.5
Save Current User Settings (**wus**)
Restore Previously Saved User Settings (**rus**)
Save Current PRNU Coefficients (**wpc**)
Save Current FPN Coefficients (**wfc**)
Load Pixel Coefficients (**lpc**)
Reset Pixel Coefficients (**rpc**)
Restore Factory Settings (**rfs**)
Reboot Camera (**rc**)

Diagnostics

Section 3.6
Get Line of Data (**gl**)
Get an Average of Multiple Lines (**gla**)
Display Pixel Coefficients (**dpc**)
Measure Internal Temperature (**vt**)
Measure Input Voltage (**vv**)
Get Commands

3.2 Sensor Output Format

3.2.1 Exposure Mode, Line Rate and Exposure Time

Overview

You have a choice of operating in one of seven 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:

1. You must first set the camera mode using the **sem** command.
2. Next, if using mode 2, 7 or 8 use the commands **ssf** and/or **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 **7**.
Notes:	• Refer to Table 11: Piranha 3 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 11: Piranha 3 Exposure Modes

Mode	SYNC	PRIN	Programmable Line Rate	Programmable Exposure Time	Description
2	Internal	Internal	Yes	Yes	Internal frame rate and exposure time. Exposure mode enabled (ECE)
3	External	Internal	No	No	Maximum exposure time. Exposure control disabled (ECD)
4	External	Internal	No	No	Smart EXSYNC. ECE.
5	External	External	No	No	External sync, external pixel reset. ECE.
6	External	Internal	No	Yes	Fixed integration time. ECE.
7	Internal	Internal	Yes	No	Internal line rate, maximum exposure time. ECD.

Mode	SYNC	PRIN			Description
8	Internal	Internal	No	Yes	Maximum line rate for exposure time. ECE.

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

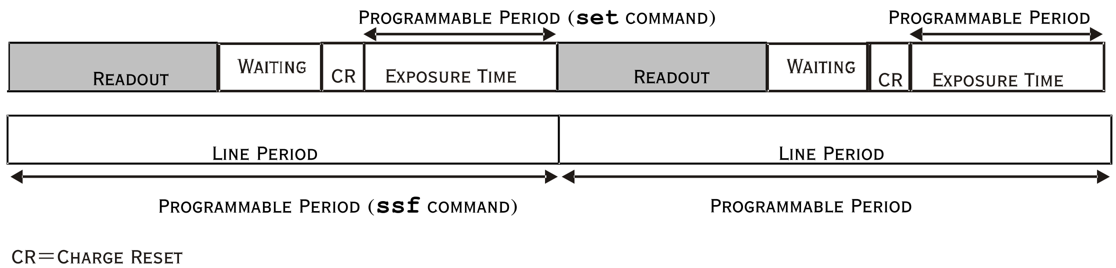
Exposure Modes in Detail

Mode 2: Internally Programmable Line Rate and Exposure Time

Mode 2 operates at a user specified line rate and exposure time.

- When setting the line rate (using the `ssf` command), exposure time will be reduced, if necessary, to accommodate the new line rate. The exposure time will always be set to the maximum time (line period – line transfer time – pixel reset time) for that line rate when a new line rate requiring reduced exposure time is entered.
- When setting the exposure time (using the `set` command), line time will be increased, if necessary, to accommodate the exposure time. Under this condition, the line time will equal the exposure time + line transfer time.

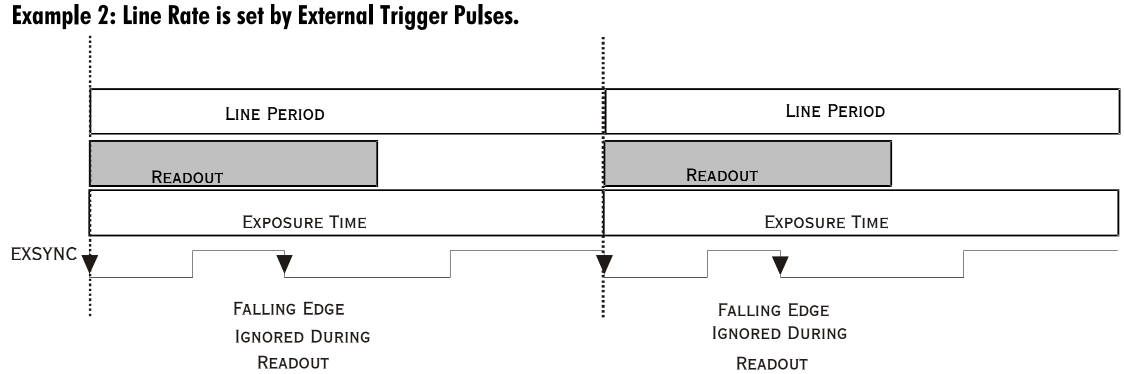
Example 1: Exposure Time less than Line Period



Mode 3: External Trigger with Maximum Exposure

Line rate is set by the period of the external trigger pulses. The falling edge of the external trigger marks the beginning of the exposure.

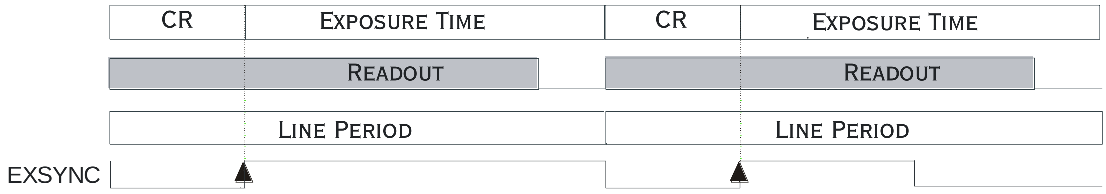
Example 2: Line Rate is set by External Trigger Pulses.



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

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

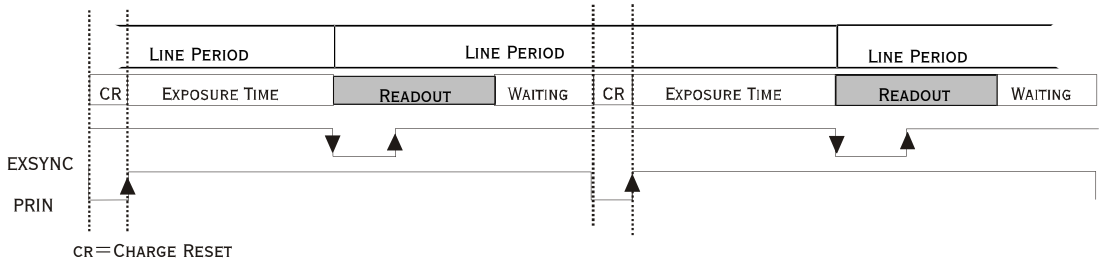
Example 3: Trigger Period is Repetitive and Greater than Read Out Time.



Mode 5: External Line Rate (EXSYNC) and External Pixel Reset (PRIN)

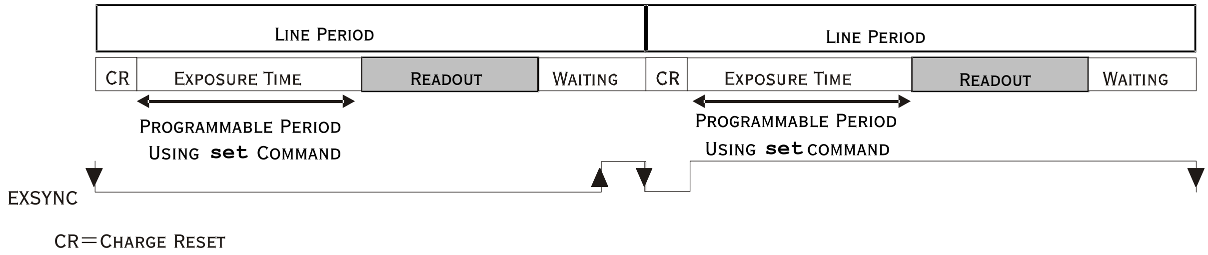
In this mode, the falling edge of EXSYNC sets the line period and the rising edge of PRIN sets the start of exposure time.

Figure 9: EXSYNC controls Line Period and PRIN controls Exposure Time



Mode 6: External Line Rate and Internally Programmable Exposure Time

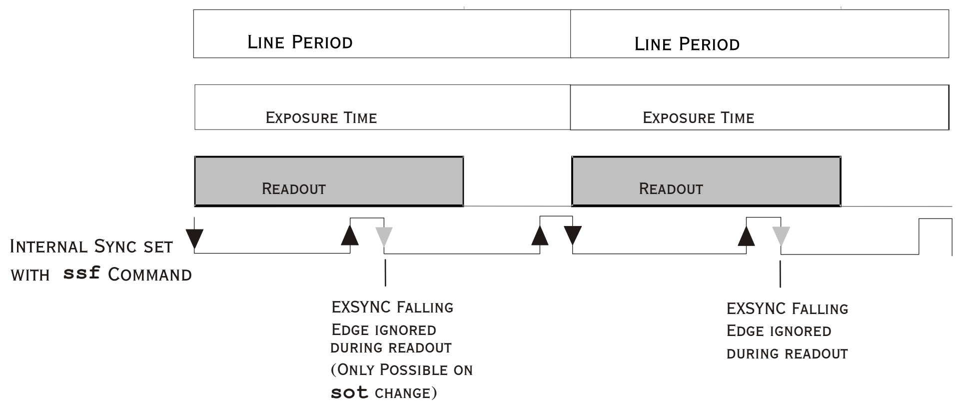
Figure 10: EXSYNC controls Line Period with Internally controlled Exposure Time



Mode 7: Internally Programmable Line Rate, Maximum Exposure Time

In this mode, the line rate is set internally with a maximum exposure time.

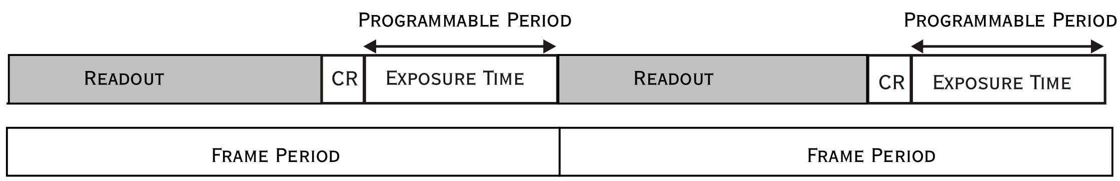
Figure 11: Mode 7 Camera Timing



Mode 8: Maximum Line Rate, Programmable Exposure Time

In this mode, the exposure time is set internally with a maximum line rate.

Figure 12: Mode 8 Timing



CR=CHARGE RESET

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:	***i*** Desired line rate in Hz. Allowable values are: 12k: **2500-23619** Hz 8k: **2500-33855** 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.
Related Commands:	**sem**, **set**
Example:	**ssf 10000**

Setting the Exposure Time

Applies to Modes 2 and 8

Purpose: Sets the camera's exposure time is µs. Camera must be operating in mode 2 or 8.

Syntax: **set *f***

Syntax Elements: ***i***

Desired exposure time in µs. Allowable values are **3** to **3330**µs.

Notes:

- To read the current line frequency, use the command **gcp** or **get set**.
- If you enter an invalid line rate frequency, an error message is returned.

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

Example: **set 400.5**

3.3 Camera Output Format

3.3.1 Setting the Camera Link Mode

Purpose: Sets the camera's Camera Link configuration, number of Camera Link taps and data bit depth. Refer to Table 12 for a description of each Camera Link mode.

Syntax: **clm *m***

Syntax Elements: ***m***

Output mode to use:

15: Medium configuration, 4 taps, 8 bit output
16: Medium configuration, 4 taps, 12 bit output
21: Full configuration, 8 taps, 8 bit output

Notes:

- 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.

Example: **clm 15**

Table 12: Piranha 3 Data Readout Configurations

Camera Link Mode Configuration (Controlled by clm command)				
Command	**Camera Link Configuration**	**Camera Link Taps**	**Camera Link Data Rate**	**Bit Depth**
`clm 15`	Medium	4 Camera Link taps where: 1 = CCD tap 1+2 2 = CCD tap 3+4 3 = CCD tap 5+6 4 = CCD tap 7+8 Note: Concatenated taps are interleaved. Refer to section 1.3 for a sensor readout description.	80MHz	8
`clm 16`	Medium	4 Camera Link taps where: 1 = CCD tap 1+2 2 = CCD tap 3+4 3 = CCD tap 5+6 4 = CCD tap 7+8 Note: Concatenated taps are interleaved. Refer to section 1.3 for a sensor readout description.	80MHz	12
`clm 21`	Full	8 Camera Link taps where: 1 = CCD tap 1 2 = CCD tap 2 3 = CCD tap 3 4 = CCD tap 4 5 = CCD tap 5 6 = CCD tap 6 7 = CCD tap 7 8 = CCD tap 8	40MHz	8

3.3.2 Setting the Camera Throughput

Purpose: In these cameras, the **sot** command works in conjunction with the **clm** command (see above) and determines the throughput of the camera. The Piranha 3 currently only supports a throughput of **320**. This may change in future cameras.

Syntax: **sot *m***

Syntax Elements: ***m***

Output throughput. Allowable value is:

320 = 4 taps at 80MHz or 8 taps at 40MHz

3.3.3 Setting a Pretrigger

Purpose: Some framegrabbers require a small amount of time (several pixels) to acquire data from a camera. Pretrigger allows the framegrabber set up time by sending the LVAL signal high several pixels earlier than valid data.

Syntax: **spt *i***

Syntax Elements: ***i***

Pretrigger in a range from **0** to **16**.

3.4 Data Processing

3.4.1 Setting a Region of Interest (ROI:setting)

Purpose: Sets the pixel range used to collect the end-of-line statistics and sets the region of pixels used in the **ccg**, **cao**, **gl**, **gla**, **ccf**, **ccp**, and **cpa** 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 y1 x2 y2***

Syntax Elements: ***x1***

Pixel start number. Must be less than the pixel end number in a range from **1** to **sensor resolution**.

y1

Column start number. Since the Piranha 3 is a line scan camera, this value must be **1**.

x2

Pixel end number. Must be greater than or equal to the pixel start number in a range from **2** to **sensor resolution**.

y2

Column end number. Since the Piranha 3 is a line scan camera, this value must be **1**.

Notes:
- To return the current region of interest, use the commands **gcp** or **get roi**.

Related Commands **ccg**, **cao**, **gl**, **gla**, **ccf**, **ccp**, **els**

Example: **roi 10 1 50 1**

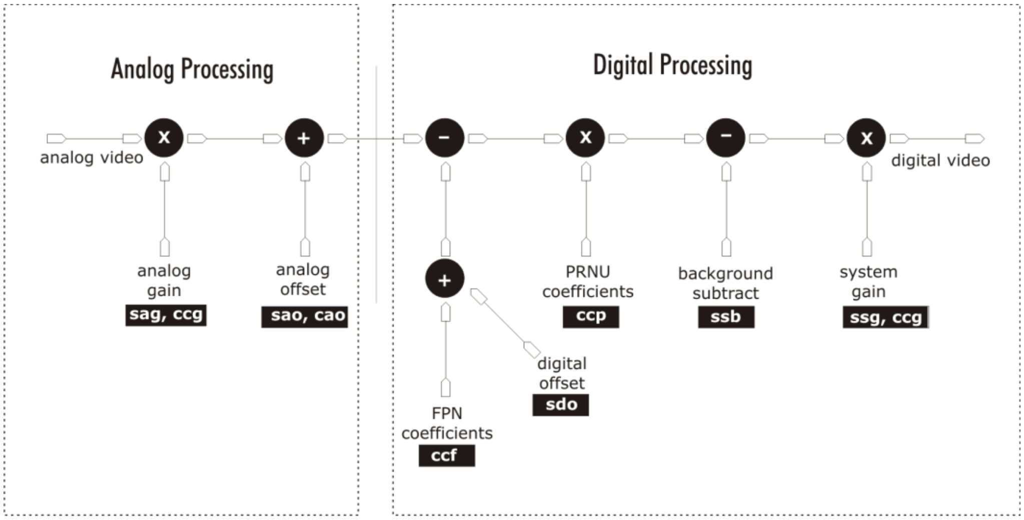
3.4.2 Analog and Digital Signal Processing Chain

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 FPN correction, the PRNU correction, the background subtract, and the digital gain and offset. All of these elements are user programmable.

Figure 13: 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 than you would achieve by trying to optimize the offset in the digital domain. As a result, perform all analog adjustments prior to any digital adjustments.

1. Analog gain (`sag` or `ccg` command) 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. For example, in a low light situation the brightest part of the image may be consistently coming in at only 50% of the DN. An analog gain of 6 dB (2x) will ensure full use of the dynamic range of the A/D converter. Of course the noise is also increased.

2. The analog offset (`sao` or `cao` 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, digital signal processing should be completed after any analog adjustments.

1. Fixed pattern noise (FPN) calibration (calculated using the `ccf` command) is used to subtract away individual pixel dark current.

2. 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.

3. 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 change 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.

4. 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.

Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction)

Flat Field Correction Overview

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:

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

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

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 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, or line rate.

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

PRNU correction requires a clean, white reference. The quality of this reference is important for proper calibration. White paper is often not sufficient because the grain in the white paper will distort the correction. White plastic or white ceramic will lead to better balancing.

For best results, ensure that:

- 50 or 60 Hz ambient light flicker is sufficiently low not to affect camera performance and calibration results.
- For best results, the analog gain should be adjusted for the expected operating conditions and 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 camera is capable of operating under a range of 8 to 1, but will clip values larger than this ratio.
- The brightest pixel should be slightly below the target output.
- When 6.25% of pixels from a single row within the region of interest are clipped, 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 values should be set to zero (**ssb 0 0**, **sdo 0 0**, **ssg 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 with OK> (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 will 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**.

Note: All commands listed above are described in detail in the following sections in the order that they should be performed.

Analog Signal Processing: Setting Analog Gain and Offset

All analog signal processing chain commands should be performed prior to FPN and PRNU calibration and prior to digital signal processing commands. All digital processing (digital offset, pixel coefficients, background subtract and digital gain) should be disabled prior to performing analog processing. To disable digital processing, send the following commands: **sdo 0 0**, **epc 0 0**, **ssb 0 0**, **ssg 0 4096**.

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 or **1** to **8** for individual tap selection. ***f*** Gain value in a range from **−10** to **+10**dB in steps of .035 (typical).
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 (Automatic Tap Matching)

Purpose:	Instead of manually setting the analog gain to a specific value, the camera can determine appropriate gain values for optimal tap matching. 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. **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 gain (**ssg**) 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 maximum pixel per tap within the ROI of the multi-line average (**css** command) is equal to the specified target. **t** Tap value. Use **0** for all taps or **1** to **8** for individual tap selection. **i** Calculation target value in a range from **1024** to **4055**DN (12 bit LSB).
Notes:	• This function requires constant light input while executing. • 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**, and **ssg 0 4096**
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 the 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 or **1** to **8** for individual tap selection. ***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 3 35**
Related Commands:	**cao**

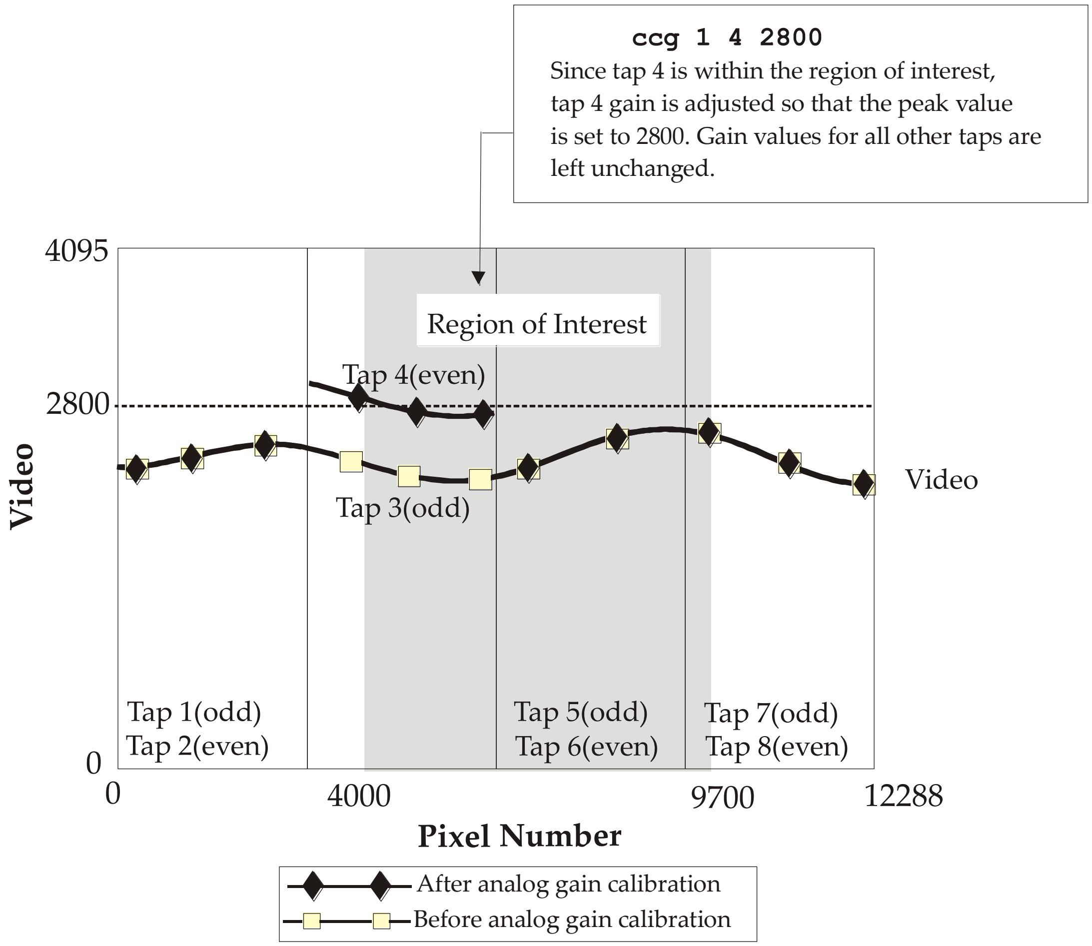
Calibrating Analog Offset

Purpose:	Instead of manually setting the analog offset to a specific value, the camera can determine appropriate offset values. This command calculates and averages each tap's pixels within the region of interest and sets the offset to achieve the specified average target value.
Syntax:	**cao *t i***
Syntax Elements:	***t*** Tap selection. Use **0** for all taps or **1** to **8** for individual tap selection. ***i*** Average target value in a range from **0** to **255**DN (12 bit LSB).
Notes:	• Perform analog offset calibration before performing FPN and PRNU coefficients. • To return the current analog offset values, use the command **gcp** or **get cao**.
Example:	**cao 1 50**
Related Commands:	**sao**

The following diagrams summarize and provide an example of how analog gain is calibrated when using a region of interest.

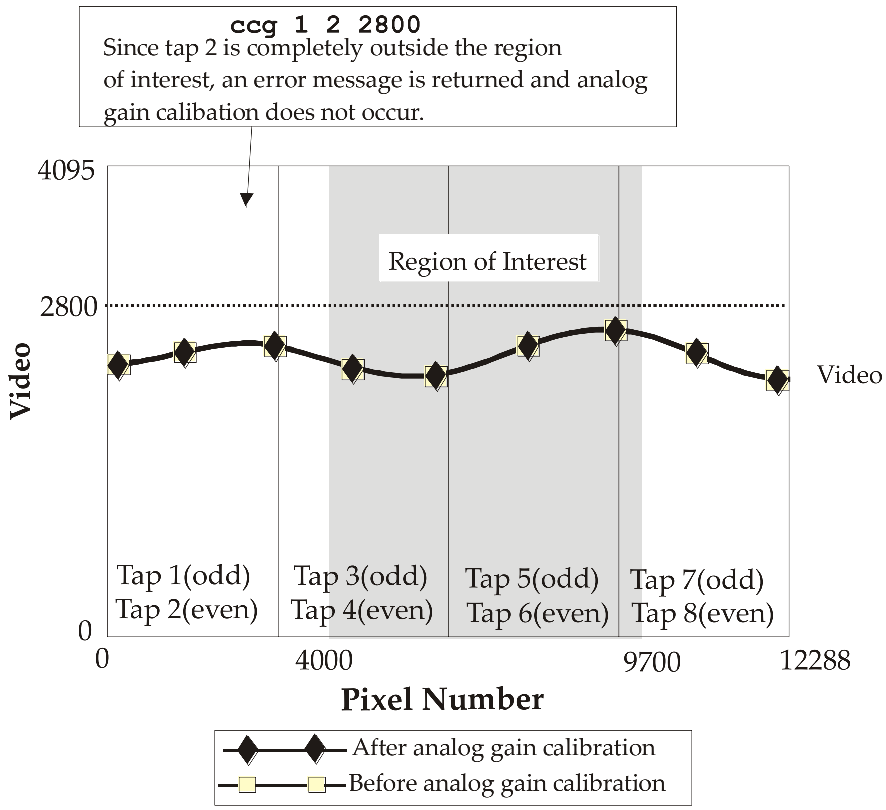
In the following example, analog gain is being set for a single tap inside the region of interest. The peak value of the tap is calibrated to the specified target value and all other taps remain unchanged.

Figure 14: Calibrating Analog Gain for a Tap outside of the Region of Interest



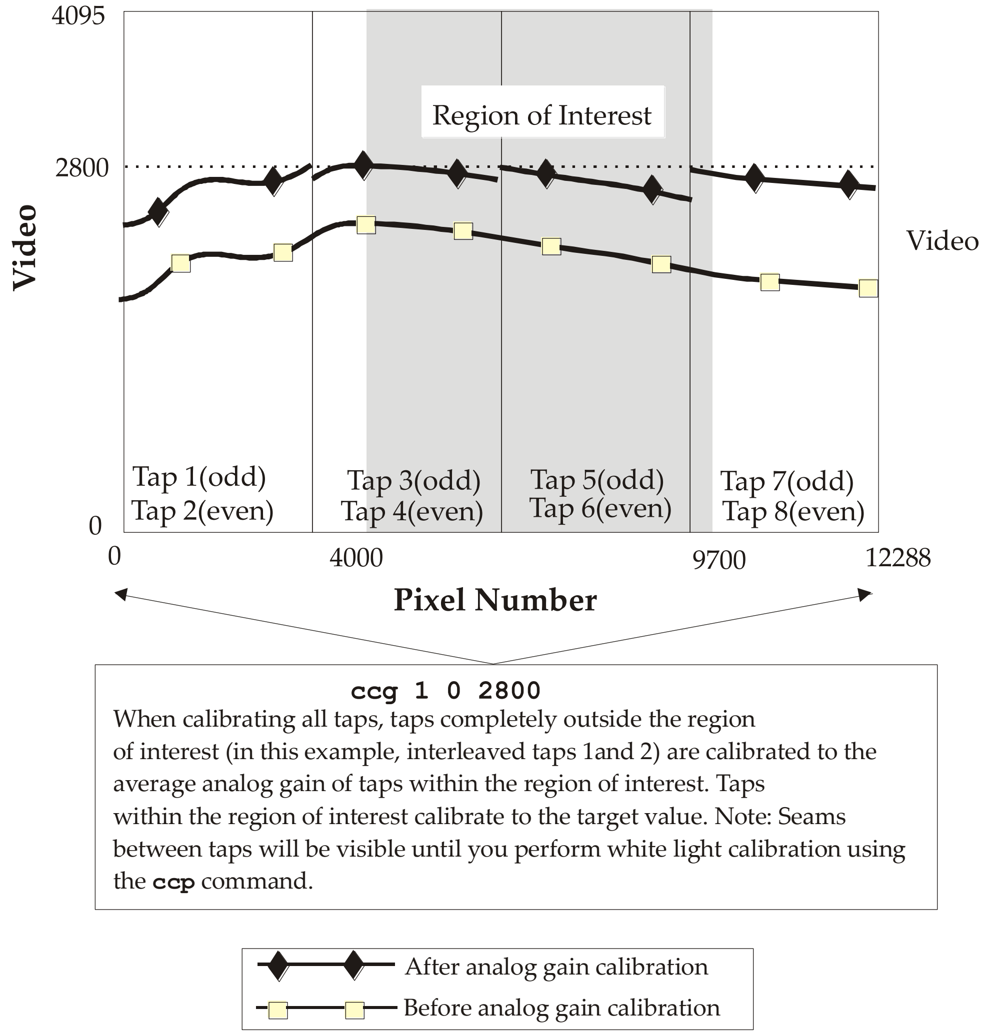
In the following example, analog gain is being set for a tap outside the region of interest. Since analog gain cannot be set for taps outside the region of interest, an error message is returned and calibration does not occur.

Figure 15: Calibrating Analog Gain for a Tap inside the Region of Interest



In the following example, analog gain is being set for all taps. The peak value of each tap within the region of interest is calibrated to the specified target value. All taps completely outside the region of interest are calibrated to the average analog gain value of the taps inside the region of interest.

Figure 16: Calibrating Analog Gain for all Taps



Updating the Gain Reference

To update the analog gain reference:

Purpose:	Sets the current analog gain setting to be the 0dB point. This is useful after tap gain matching allowing you to change the gain on all taps by the same amount.
Syntax:	**`ugr`**

Digital Signal Processing

To optimize camera performance, digital signal processing should be completed after any analog adjustments.

FPN Correction

Performing FPN Correction

Syntax:	Performs FPN correction and eliminates FPN noise by subtracting away individual pixel dark current.
Syntax:	**`ccf`**
Notes:	• Perform all analog and digital adjustments before performing FPN correction. • Perform FPN correction before PRNU correction. • Refer to Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction)on page 35 for a procedural overview on performing flat field correction.
Related Commands:	**`ccp`**
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 **2048** (12 bit LSB).
Example:	**`sfc 10 50`**

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 **8**, or **0** for all taps. ***i*** Subtracted offset value in a range from **0** to **2048** where FPN Coefficient= *i* (12 bit LSB Justified)
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 previous section for details on the `ssg` command.
Related Commands:	`ssg`
Example:	**`sdo 0 100`**

PRNU Correction

Performing PRNU Correction 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:	• 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. • Refer to Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction)on page 35 for a procedural overview on performing flat field correction.
Related Commands:	`ccf`

Performing PRNU to a User Entered Value

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

Syntax: **cpa i i**

Syntax Elements: ***i***

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 (ROI).

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. Recommended peak video output before PRNU calibration is 5-20% lower than target. The target value must be greater than the current peak output value.

This command performs the same function as the **cpp** command but requires that you enter a target value.

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.

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).

i

Peak target value in a range from 1024 to 40554DN.

Notes:

- Perform all analog adjustments before calibrating PRNU.
- Calibrate FPN before calibrating PRNU. 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.
- Note: Refer to Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction)on page 35 for a procedural

overview on performing flat field correction.

Example: **`cpa 1 600`**

Setting a Pixel's PRNU Coefficient

Purpose: Sets an individual pixel's PRNU coefficient.

Syntax: **`spc i i`**

Syntax Elements: ***i***

The pixel number from **1** to **sensor pixel count**.

i

Coefficient value in a range from **0** to **28671** where:

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

Example: **`spc 1024 10000`**

Setting a range of Pixel PRNU Coefficients

Purpose: Sets a range of pixel PRNU coefficients.

Syntax: **`spr i i x`**

Syntax Elements: ***i***

The first pixel number of the range.

i

The last pixel number of the range.

x

Coefficient value in a range from 0 to 28671 where:

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

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

Example: **`spr 4001 4096 0`**

Subtracting Background

Purpose: Use the background subtract command after performing flat field correction if you want to improve your image in a low contrast scene. It is useful for systems that process 8-bit data but want to take advantage of the camera's 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 **8**, 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 25**

Setting Digital System Gain

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

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

Syntax: **ssg *t i***

Syntax Elements: ***t***

Tap selection. Allowable range is **1** to **8**, 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:

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

Use this command in conjunction with the **ssb** command.

Related Commands: **ssb**

Example: **ssg 1 15**

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***. The camera also returns the pixel number with every fifth coefficient.

Syntax: **`dpc`** ***`x1 x2`***

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

Start pixel to display in a range from **`1`** to **`sensor pixel count`**.

`x2`

End pixel to display in a range from **`1`** to **`sensor pixel count`**.

Notes:

- This function returns all the current pixel coefficients in the order FPN, PRNU, FPN, PRNU… The camera also returns the pixel number with each coefficient.

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`**.

Example: **`gfc 10`**

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:

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

Example: **`sfr 1 100 80`**

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**.

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**

3.4.3 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. These basic calculations are used to calibrate analog offset (**cao**) and calibrate analog gain (**ccg**).

To further aid in debugging and cable/ data path integrity, the first three pixels after Line Valid are "aa", "55", "aa". 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

Notes:

- LVAL is not high during the end-of-line statistics.

Example: **els 1**

Table 13: End-of-Line Sequence Description

Location	Value	Description
1	A's	By ensuring these values consistently toggle between "aa" and "55", you can verify cabling (i.e. no stuck bits)
2	5's	

Location	Value	Description
3	A's	
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

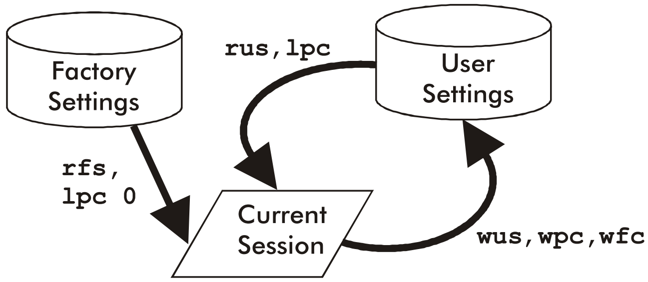
Purpose:	Sets the upper threshold limit to report in the end-of-line sequence.
Syntax:	**sut *i***
Syntax Elements:	***i*** Upper threshold limit in range from **0** to **4095**.
Notes:	• LVAL is not high during the end-of-line statistics.
Related Commands:	• **els**, **slt**
Example:	**sut 1024**

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:	• LVAL is not high during the end-of-line statistics.
Related Commands:	• **els**, **sut**
Example:	**slt 1024**

3.5 Saving and Restoring Settings

Figure 17: Saving and Restoring Overview



Factory Settings

On first initialization, the camera operates using the factory settings. You can restore the original factory settings at any time using the command **rfs**.

User Settings

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

- To save all current user settings to EEPROM, 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 camera or camera memory may be corrupted.
- To restore the last saved user settings, use the command **rus**.
- To save the current pixel coefficients, use the command **wpc *i*** and **wfc *i***.
- To restore saved pixel coefficients, use the command **lpc *i***.

Current Session Settings

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

3.5.1 Saving and Restoring PRNU and FPN Coefficients

Saving the Current PRNU Coefficients

Purpose:	Saves the current PRNU coefficients. You can save up to four sets of pixel coefficients
Syntax:	`wpc i`
Syntax Elements:	*i* PRNU coefficients set to save. **1** = Coefficient set one **2** = Coefficient set two **3** = Coefficient set three **4** = Coefficient set four
Example:	`wpc 2`

Saving the Current FPN Coefficients

Purpose:	Saves the current FPN coefficients. You can save up to four sets of pixel coefficients
Syntax:	`wfc i`
Syntax Elements:	*i* FPN coefficients set to save. **1** = Coefficient set one **2** = Coefficient set two **3** = Coefficient set three **4** = Coefficient set four
Example:	`wfc 2`

Loading a Saved Set of Coefficients

Purpose:	Loads a saved set of pixel coefficients. A factory calibrated set of coefficients is available.
Syntax:	`lpc i`
Syntax Elements:	*i* FPN coefficients set to save. **0 =** Factory calibrated pixel coefficients. **1** = Coefficient set one **2** = Coefficient set two **3** = Coefficient set three **4** = Coefficient set four
Example:	`lpc 0`

Resetting the Current Pixel Coefficients

Purpose:	Resets the current pixel coefficients to zero. This command does not reset saved coefficients.
Syntax:	`rpc`

Notes: The digital offset is not reset.

3.5.2 Rebooting the Camera

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

3.6 Diagnostics

3.6.1 Generating a Test Pattern

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

Syntax: **svm *i***

Syntax Elements: ***i***

0 Video.

1 12 bit ramp test pattern.

2 8 bit step test pattern.

Example: **svm 1**

3.6.2 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 or test pattern) 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 3.4.1 Setting a Region of Interest (ROI:setting)).

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 or equal to the pixel end number in a range from **1** to **sensor resolution**.

x2

Pixel end number. Must be greater than or equal to the pixel start number in a range from **1** to **sensor resolution**.

Notes:
- Values returned are in 12 bit DN.

Related Commands: `roi`

Example: `gl 10 20`

Returning Averaged Lines of Video

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 i`

Syntax Elements:

i

Number of lines to sample. Allowable values are **256**, **512**, or **1024** (factory setting).

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

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

Example: `css 1024`

Returning the Average of Multiple Lines of Video

Purpose: Returns the average for multiple lines of video data (without pixel coefficients or test pattern). 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 3.4.1 Setting a Region of Interest (ROI:setting)).

Syntax: `gla x1 x2`

Syntax Elements:

x1

Column start number. Must be less than or equal to the column end number in a range from **1** to **column resolution**.

x2

Column end number. Must be greater than or equal to the column start number in a range from **1** to column resolution.

Notes:
- 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`

3.6.3 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.

3.6.4 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.

3.6.5 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) **2**: CC2 (PRIN) **3**: CC3 (Spare) **4**: CC4 (Spare)
Example:	**gsf 1**

3.6.6 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`

GCP Screen		Desctiption
GENERAL CAMERA SETTINGS		
Camera Model No.:	**P3-xx-xxxxx**	Camera model number.
Camera Serial No.:	**xxxxxxxxx**	Camera serial number.
Firmware Design Rev.:	**xx-xx-xxxxx-xx**	Firmware design revision number.
CGI Version:	**03-81-xxxxx-xx**	CGI version. Part of FPGA firmware.
FPGA Design Rev.:	**xxx.xx**	DSP design revision number.
UART Baud Rate:	**9600**	Serial communication connection speed set with the **sbr** command. See Setting Baud Rate on page 24 for details.
Exposure Mode:	**2**	Current exposure mode value set with the **sem** command. See section 3.2.1 Exposure Mode, Line Rate and Exposure Time for details.
SYNC Frequency:	**5000 Hz**	Current line rate. Value is set with the **ssf** command. See section 3.2.1 Exposure Mode, Line Rate and Exposure Time for details.
Internal Exposure Time:	**50 uSec**	Current exposure time setting. Value is set with the **set** command. See section 3.2.1 Exposure Mode, Line Rate and Exposure Time for details.
Video Mode:	**video**	Current video mode value set with the **svm** command. See section 3.6.1 Generating a Test Pattern for details.

Region of Interest:	**(1,1) to (12288, 1)**	Region of interest size set with the **roi** command. See section 3.4.1 Setting a Region of Interest (ROI:setting) for details.
End-Of-Line Sequence:	**on**	States whether an end of line sequence is turned on or off. Set using the **els** command. See section 3.4.3 End-of-line Sequence for details.
FFC Coefficient Set:	**0**	Current pixel coefficient set loaded. Refer to section 3.5.1 Saving and Restoring PRNU and FPN Coefficients for details.
FPN Coefficients:	**off**	States whether FPN coefficients are on or off. Set with the **epc** command. Refer to section 3.4.2 Analog and Digital Signal Processing Chain for details.
PRNU Coefficients:	**off**	States whether PRNU coefficients are on or off. Set with the **epc** command. Refer to section 3.4.2 Analog and Digital Signal Processing Chain for details.
Number of Line Samples:	**256**	Number of lines samples set with the **css** command. See section 3.6.2 Returning Video Information for details.
Upper Threshold	**0**	Upper threshold value set with the **sut** command. See section 3.4.3 End-of-line Sequence for details.
Lower Threshold	**4095**	Lower threshold value set with the **slt** command. See section 3.4.3 End-of-line Sequence for details.
Camera Link Mode:	**21, Full, 8 taps, 8 bits, no time MUX**	Camera Link mode set with the **clm** command. See section 3.3.1 Setting the Camera Link Mode for details.

Output Throughput:	320	Camera throughput value set with the **sot** command. Throughput is set to 320 and is not configurable in the Piranha 3 camera. See section 3.3.2 Setting the Camera Throughput for details.
Pretrigger	0	Pretrigger set with the **spt** command. See section 3.3.3 Setting a Pretrigger.
Analog Gain (dB):	3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0	Analog gain settings set with the **sag** command. See section 3.4.2 Analog and Digital Signal Processing Chain for details.
Analog Reference Gain (dB):	3.0 3.0 3.0 3.0	Analog reference gain set with the **ugr** command. See section Analog Signal Processing for details.
Total Analog Gain (dB):	6.0 6.0 6.0 6.0	This is the sum of the analog gain and analog gain reference values and is the total analog gain being used by the camera.
Analog Offset:	100 100 100 100 100 100 100 100	Analog offset settings set with the **sao** command. See section 3.4.2 Analog and Digital Signal Processing Chain for details.
Digital Offset:	50 50 50 50 50 50 50 50	Digital offset settings set with the **sdo** command. See section 3.4.2 Analog and Digital Signal Processing Chain for details.
Background Subtract:	150 150 150 150 150 150 150 150	Background subtract settings set with the **ssb** command. See section 3.4.2 Analog and Digital Signal Processing Chain for details.
System Gain:	125 125 125 125 125 125 125 125	Digital gain settings set with the **ssg** command. See section 3.4.2 Analog and Digital Signal Processing Chain for details.

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. Refer to Table 14 below for a list of available commands. To view a help screen listing the following get commands, use the command **gh**.

Table 14: Get Commands

Syntax	Parameters	Description
`get cao`	`t`	Returns the analog offset for the tap indicated **t** = tap selection, either **1** to **8**, or **0** for all taps
`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`		Returns the current Camera Link mode.
`get css`		Returns the number of line samples averaged for pixel coefficient calculations or for output of **gla** command.
`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.
`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 gsf`	`i`	Returns the frequency of the Camera Link control signal indicated, either **1**, **2**, **3**, or **4**.
`get lpc`		Returns the current coefficient set number.

Syntax	Parameters	Description
get rfs		Returns whether factory settings have been saved. The camera always returns **1** (factory settings have been saved).
get roi		Returns the current region of interest.
get rus		Returns whether user settings have been saved. **0** = No user settings saved **1** = User settings have been saved
get sag	**t**	Returns the analog gain in dB for the tap indicated **t** = Tap value. **0** for all taps or **1** to **8** for individual tap selection.
get sao	**t**	Returns the analog offset for the tap indicated. **t = 0** for all taps or **1** to **8** for individual tap selection.
get sbr		Returns the speed of camera serial communication port.
get sdo	**t**	Returns the digital offset value in DN for the tap indicated. **t** = Tap value. **0** for all taps or **1** to **8** for individual tap selection.
get sem		Returns the current exposure mode: **3 =** External SYNC, maximum exposure time **7 =** Internal programmable SYNC, maximum exposure time. Factory setting.
get sfc	**x**	Returns the FPN coefficient for the pixel number idicated. **x** =pixel number within the range **1** to **sensor pixel count**.
get sgr		Returns the current analog gain reference value in dB.
get slt		Returns the current lower threshold value.
get sot		Returns the Camera Link strobe rate.
get spc	**x**	Returns the PRNU coefficient for the specified pixel number. **x**=pixel number within the range **1** to **sensor pixel count**.
get spt		Returns the current pretrigger value.
get ssb	**t**	Returns the current background subtract value. **t** = Tap value. **0** for all taps or **1** to **8** for individual tap selection.
get ssf		Returns the current line/ frame rate in Hz.
get ssg	**t**	Returns the current digital gain setting. **t** = tap selection, either **1** to **8**, or **0** for all taps
get sut		Returns the current uppder threshold value.
get svm		Returns the current video mode. **0**: Normal video mode **1**: Test pattern **2**: Test pattern **3**: Test pattern
get ugr		Returns the gain reference value

Syntax	Parameters	Description
`get vt`		Returns the camera's internal chip temperature in degrees Celsius.
`get vv`		Returns the camera's supply voltage.
`get wfc`		Returns whether FPN coefficients have been saved. `0` = No FPN coefficients saved `1` = Pixel coefficients have been saved
`get wpc`		Returns whether PRNU coefficients have been saved. `0` = No PRNU coefficients saved `1` = Pixel coefficients have been saved
`get wus`		Returns whether user settings have been saved. `0` = No user settings saved `1` = User settings have been saved

4

Optical and Mechanical Considerations

4.1 Mechanical Interface

Figure 18: P3-80 Mechanical Drawing

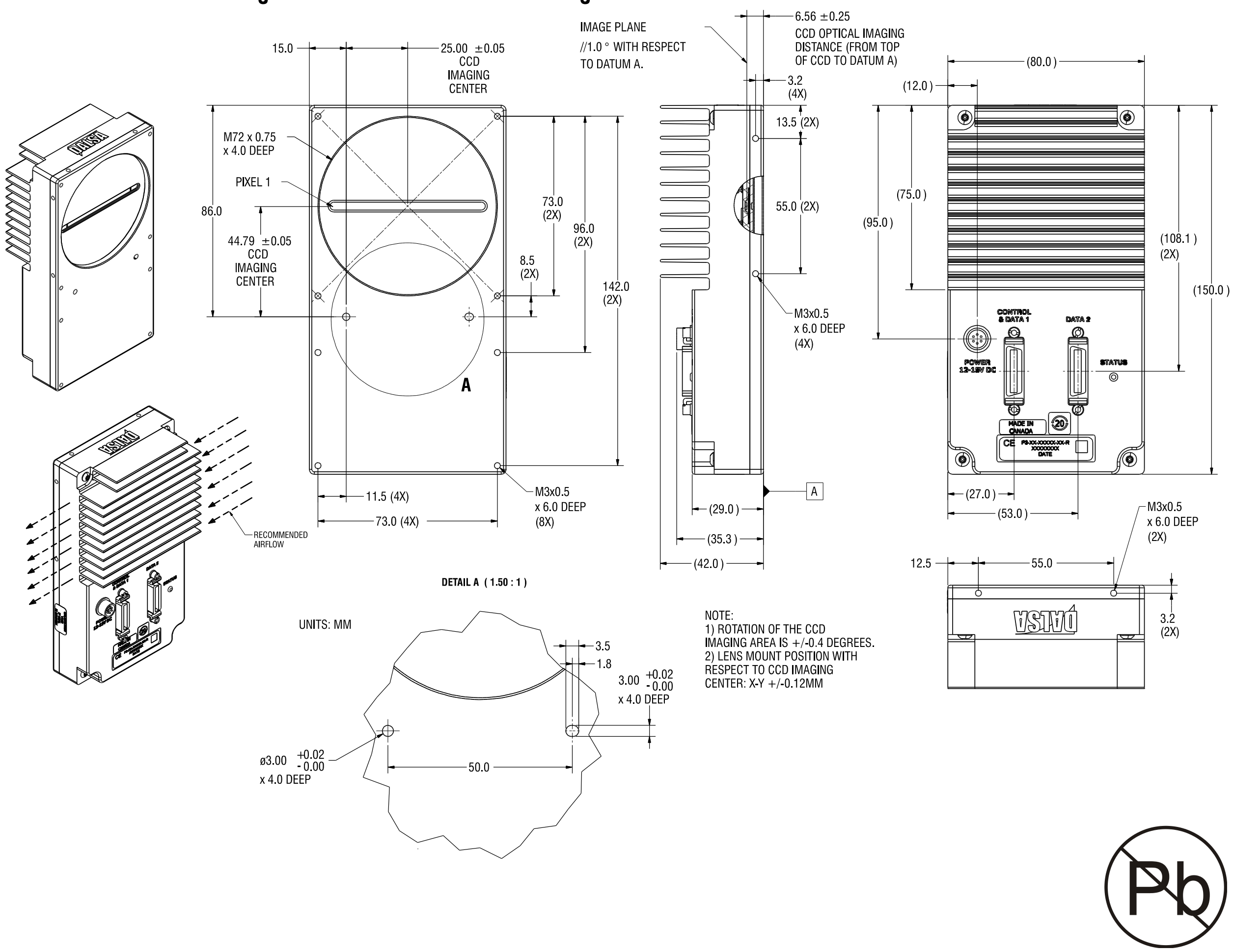
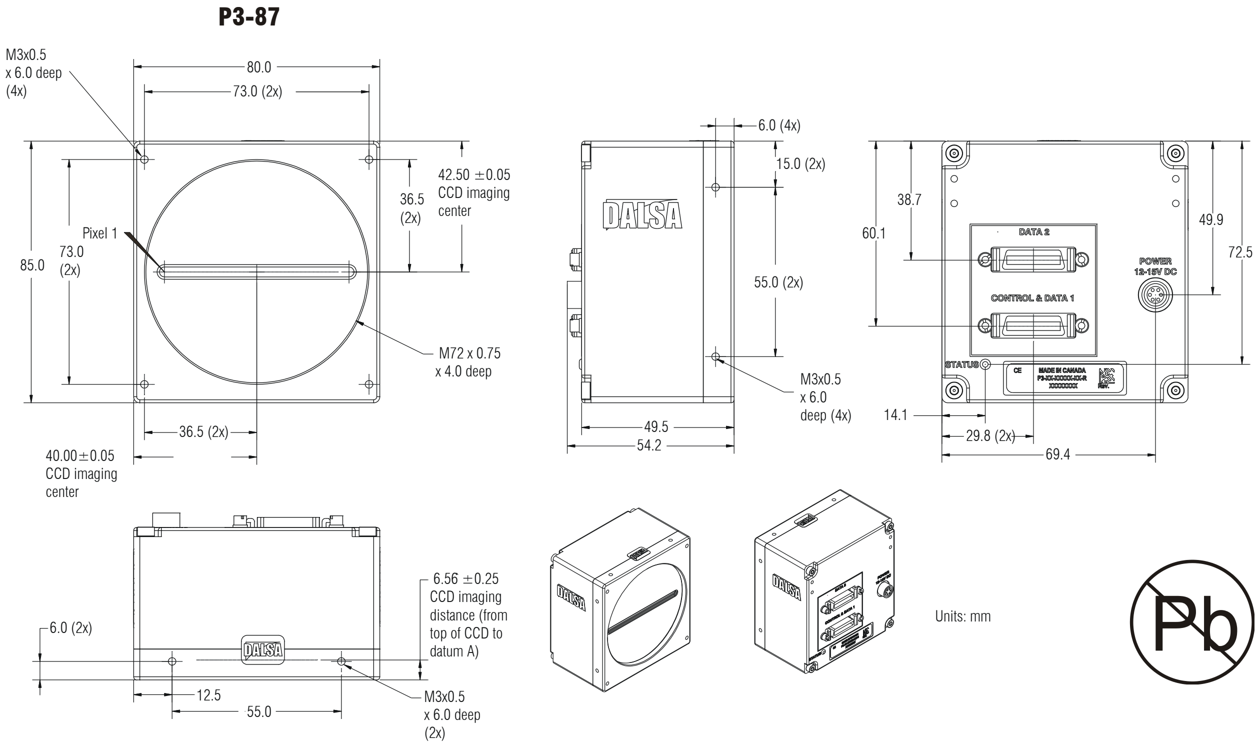


Figure 19: P3-87 Mechanical Drawing



Lens Mounts

Model Number	Lens Mount Options
All models	M72x0.75

Mount	Back Focal Distance (sensor die to adapter)
M72	6.56±0.25mm

4.2 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. Teledyne DALSA's Web site, here, provides an introduction to this potentially complicated issue. See "Radiometry and Photo Responsivity" and "Sensitivities in Photometric Units" in the CCD Technology Primer found under the Application Support link.

It is often more important to consider exposure than illumination. The total amount of energy (which is related to the total number of photons reaching the sensor) is more important than the rate at which it arrives. For example, $5\mu J/cm^2$ 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, such as the Piranha 3 cameras.
- Halogen light sources generally provide very little blue relative to IR.
- Fiber-optic light distribution systems generally transmit very little blue relative to IR.
- Some light sources age; over their life span they produce less light. This aging may not be uniform—a light source may produce progressively less light in some areas of the spectrum but not others.

Filters

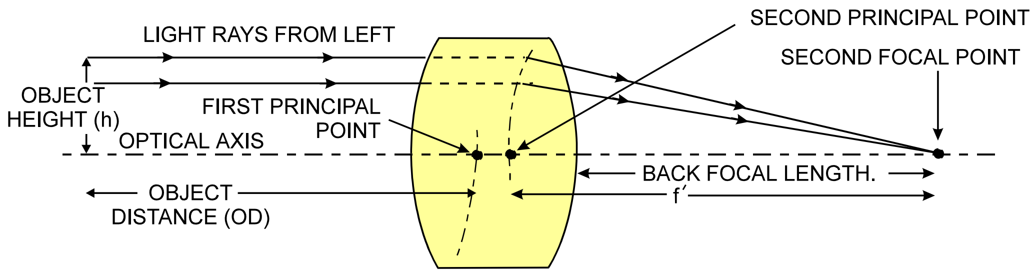
CCD cameras are extremely responsive to infrared (IR) wavelengths of light. To prevent infrared from distorting the images you scan, use a "hot mirror" or IR cutoff filter that transmits visible wavelengths but does not transmit wavelengths over 750nm. Examples are the Schneider Optics™ B+W 489, which 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 20: Primary Points in a Lens System



Magnification and Resolution

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

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

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

By similar triangles, the magnification is alternatively given by:

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

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

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

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

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

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

5

Troubleshooting

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

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

Your steps in dealing with a technical problem should be:

1. Try the general and specific solutions listed in sections 5.1, 5.2 and 5.3.
2. If these solutions do not resolve your problem, see section 5.4 on getting product support.

5.1 Common Solutions

Connections

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

Power Supply Voltages

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

Data Clocking/Output Signals

To validate cable integrity, have the camera send out a test pattern and verify it is being properly received. Refer to section 3.6.1 Generating a Test Pattern for further information on running test patterns.

5.2 Troubleshooting Using the Serial Interface

Communications

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

Verify Parameters

To verify the camera setup, send the **gcp** (get camera parameters) command.

Verify Factory Calibrated Settings

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

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

Verify Timing and Digital Video Path

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

Verify Voltage

To check the camera's input voltages, use the **vv** command. Make sure the voltage is within the proper range (+12V to +15V). If a problem still persists, contact Technical Support. See section **Error! Reference source not found.** for contact information.

5.3 Specific Solutions

No Output or Erratic Behavior

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

Line Dropout, Bright Lines, or Incorrect Line rate

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

Noisy Output

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

Dark Patches

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

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

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

Horizontal Lines or Patterns in Image

A faulty or irregular encoder signal that is applied as the EXSYNC 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 and that no ambient light is affecting your system.

Appendix A

Camera Link™ Reference, Timing, and Configuration Table

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

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

The Camera Link Implementation Road Map (available from the link) details how we standardize the use of the Camera Link interface.

LVDS Technical Description

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

Camera Signal Requirements

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

Video Data

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

- FVAL—Frame Valid (FVAL) is defined HIGH for valid lines.
- LVAL—Line Valid (LVAL) is defined HIGH for valid pixels.
- DVAL—Data Valid (DVAL) is defined HIGH when data is valid.
- Spare— A spare has been defined for future use.

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

Camera Control Signals

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

- Camera Control 1 (CC1)
- Camera Control 2 (CC2)
- Camera Control 3 (CC3)
- Camera Control 4 (CC4)

The Piranha 3 uses the following camera control signals:

Table 15: Camera Control Configuration

C1	EXSYNC, negative edge active
CC2	PRIN
CC3	Not Used
CC4	Not Used

Communication

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

- SerTFG—Differential pair with serial communications to the frame grabber.
- SerTC—Differential pair with serial communications to the camera.

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

Power

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

Appendix B

Error Handling and Command List

B1 Error Handling

The following table lists warning and error messages and provides a description and possible cause.

Table 16: Warning and Error Messages

Message	Description
OK>	SUCCESS
Warning 01: Outside of specification>	Parameter accepted was outside of specified operating range (e.g. gain greater than ±10 dB of factory setting).
Warning 02: Clipped to min>	Parameter was clipped to the current operating range. Use GCP to see value used.
Warning 03: Clipped to max>	Parameter was clipped to the current operating range. Use GCP to see value used.
Warning 04: Related parameters adjusted>	Parameter was clipped to the current operating range. Use GCP to see value used.
Warning 05: Missing codes – insufficient digital gain>	Output when the digital gain is such that missing codes are to be expected due to not enough digital gain.
Warning 06: Missing codes – too much digital gain>	Output when the digital gain is such that missing codes are to be expected due to too much digital gain.
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	A FPN/ PRNU has been calculated to be greater than the maximum allowable 511 (8).
Message	**Description**
Error 01: Internal error xx>	Output only in “diagnostic mode” or self check at power or reset camera. Where xx is a code.

Message	Description
Error 02: Unrecognized command>	Command is not available in the current access level or it is not a valid command.
Error 03: Incorrect number of parameters>	
Error 04: Incorrect parameter value>	This response returned for ·Alpha received for numeric or vice versa ·Not an element of the set of possible values. E.g., Baud Rate ·Outside the range limit
Error 05: Command unavailable in this mode>	Command is valid at this level of access, but not effective. Eg line rate when in smart Exsync mode
Error 06: Timeout>	Command not completed in time. Eg FPN/ PRNU calculation when no external exsync is present.
Error 07: Camera settings not saved>	Tried saving camera settings (**rfs**/ **rus)** but they cannot be saved.
Error 08: Unable to calibrate - tap outside ROI>	Cannot calibrate a tap that is not part of the end of line statistics.
Error 09: The camera's temperature exceeds the specified operating range>	Indicates that the camera has shut itself down to prevent damage from further overheating.

B2 All Available Commands

Parameters:
i = integer
t = tap id
i = integer value
f = real number
s = string
x1 = horizontal pixel start number
x2 = horizontal pixel end number
y1 = vertical pixel start number
y2 = vertical pixel end number

As a quick reference, the following table lists all of the commands available to the camera user. For detailed information on using these commands, refer to Chapter 3.

Command	Syntax	Parameters	Description
calibrate analog offset	**cao**	**t i**	Calibrates the analog gain and averages each tap's pixels within the ROI to the specified average target value. **t** = tap selection, either **1** to **number of CCD taps**, or **0** for all taps **i** = target value in a range from **0** to **255**DN (12-bit LSB) Refer to Analog Signal Processing: Setting Analog Gain and Offset for details.
correction calibrate fpn	**ccf**		Start FPN coefficient calibration. Refer to section 3.4.2 Analog and Digital Signal Processing Chain for details.

Command	Syntax	Parameters	Description
calculate camera gain	`ccg`	`i t i`	Calculates the camera gain and optimizes tap matching 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 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 all tap ROI pixels are within 98% of the specified target value and then performs a PRNU correction. `t =` Tap value. Use `0` for all taps or `1` to `8` for individual tap selection. `i` = Calibration target value in a range from `1024` to `4055`DN (12 bit LSB).
correction calibrate prnu	`ccp`		Start PRNU coefficient calibration. Refer to section 3.4.2 Analog and Digital Signal Processing Chain for details.
camera link mode	`clm`	`i`	Sets the Camera Link configuration, number of Camera Link taps, and data bit depth. `15`: Medium configuration, 4 taps, 8 bit output `16`: Medium configuration, 4 taps, 12 bit output `21`: Full configuration, 8 taps, 8 bit output Refer to section 3.3.1 Setting the Camera Link Mode for details.

Command	Syntax	Parameters	Description
calculate PRNU algorithm	`cpa`	**i i**	Performs PRNU calibration according to the selected algorithm. The first parameter is the algorithm where **i** is: **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. (Identical to **ccp i**) **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 are only applied 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 are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. The second parameter is the target value to use in a range from **1024** to **4055**DN. section 3.4.2 Analog and Digital Signal Processing Chain **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.
correction set sample	`css`	**m**	Set number of line samples averaged for pixel coefficient calculations or for output of **gla** command. Values: **256**, **512**, **1024**. Refer to Returning Averaged Lines of Video on page 55 for details.

Command	Syntax	Parameters	Description
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 **sensor pixel count**. Refer to Returning Calibration Results and Errors on page 49 for details.
end of line sequence	els	i	Sets the end-of-line sequence: **0**: Off **1**: On Refer to section 3.4.3 End-of-line Sequence for details.
enable pixel coefficients	epc	i i	Sets whether pixel coefficients are enabled or disabled. The first parameter sets the FPN coefficients where **i** is: **0** = FPN coefficients disabled **1** = FPN coefficients enabled The second parameter sets the PRNU coefficients where **i** is: **0** = PRNU coefficients disabled **1** = PRNU coefficients enabled Refer to section Enabling and Disabling Pixel Coefficients on page 49 for details.
get camera model	gcm		Reads the camera model number.
get camera parameters	gcp		Reads all of the camera parameters.
get camera serial	gcs		Read the camera serial number.
get camera version	gcv		Read the firmware version and FPGA version.
get commands	get		Retrieves camera settings for the command name specified. Refer to Returning Camera Settings with Get Commands on page 60 for details.
get fpn coeff	gfc	x	Read the FPN coefficient **i** = pixel number to read in a range from **1** – **sensor pixel count**. Refer to Returning Calibration Results and Errors on page 49 for details.
get help	gh		Lists all of the available get commands.
get line	gl	x1 x2	Get a line of video (not including FPN and PRNU coefficients) displaying one pixel value after another and the minimum, maximum, and mean value of the sampled line. **x1** = Pixel start number **x2** = Pixel end number in a range from 1 to sensor pixel count. Refer to Returning a Single Line of Video on page 54 for details.

Command	Syntax	Parameters	Description
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 **sensor pixel count**. Refer to Returning Averaged Lines of Video on page 45 for details.
get prnu coeff	`gpc`	**i**	Read the PRNU coefficient. **i** = pixel number to read in a range from 1 to sensor pixel count. Refer to Returning Calibration Results and Errors on page 49 for details.
get signal frequency	`gsf`	**i**	Read the current sync frequency. **1**: CC1 (EXSYNC) **2**: CC2 (PRIN) **3**: CC3 (Spare) **4**: CC4 (Spare) Refer to section 3.6.5 Camera Frequency Measurement for details.
get sensor serial	`gss`		Read the sensor serial number
help	`h`		Display the online help. Refer to on page 24 for details.
load pixel coefficients	`lpc`	**i**	Loads the previously saved pixel coefficients from non-volatile memory where ***i*** is: **0** = Factory calibrated coefficients **1** = Coefficient set one **2** = Coefficient set two **3** = Coefficient set three **4** = Coefficient set four Refer to 3.5.1 Saving and Restoring PRNU and FPN Coefficients for details.
reset camera	`rc`		Reset the entire camera (reboot).
restore factory settings	`rfs`		Restore the camera's factory settings. FPN and PRNU coefficients reset to 0. Refer to section 3.5 Saving and Restoring Settings for details.
region of interest	`roi`	**x1 y1 x2 y2**	Sets the pixel range affected by the cag, cao, gl, gla, ccf, and ccp commands. The parameters are the pixel start and end values (x) and the column start and end values (y) in a range from 1 to sensor pixel count. Refer to section 3.4.1 Setting a Region of Interest (ROI:setting) for details.
reset pixel coeffs	`rpc`		Reset the pixel coefficients to 0. Refer to Resetting the Current Pixel Coefficients on page 53 for details.

Command	Syntax	Parameters	Description
restore user settings	**rus**		Restore the camera's last saved user settings and FPN and PRNU coefficients. Refer to section 3.5 Saving and Restoring Settings for details.
set analog gain	**sag**	**t f**	Sets the analog offset. **t** = Tap value. **0** for all taps or **1-8** for individual tap selection. **f**= gain value specified from **−10** to **+10** Refer to Analog Signal Processing: Setting Analog Gain and Offset on page 38 for details.
set analog offset	**sao**	**t i**	Sets the analog offset. **t** = Tap value. **0** for all taps or **1-8** for individual tap selection. **i**= Offset value in a range from 0 to 255. Offset increases with higher values. Refer to Analog Signal Processing: Setting Analog Gain and Offset on page 38 for details.
set baud rate	**sbr**	**i**	Set the speed of camera serial communication port. Baud rates: **9600**, **19200**, **57600**, and **115200**. Default: 9600. Refer to section Setting Baud Rate on page 24 for details.
set digital offset	**sdo**	**t i**	Subtracts the input value from the video signal prior to FPN correction. **t** = Tap value. **0** for all taps or **1** to **8** for individual tap selection. **i** = Offset in a range from **0** to **2048**DN. Refer to Setting Digital Offset on page45 for details.
set exposure mode	**sem**	m	Set the exposure mode: **2 =** Internal SYNC, internal PRIN, programmable line rate and exposure time using commands **ssf** and **set** **3 =** External SYNC, internal PRIN, 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. Factory setting. **8** = Internal SYNC, internal PRIN, programmable exposure time. Maximum line rate for exposure time.
set exposure time	**set**	**f**	Sets the exposure time. Refer to the camera help screen (**h** command) for allowable range.

Command	Syntax	Parameters	Description
set fpn coeff	`sfc`	`x i`	Set the FPN coefficient. `x` =pixel number within the range `1` to `sensor pixel count`. `i`= FPN value within the range `0` to `2048`. Refer to Setting a Pixel's FPN Coefficient on page 44 for details.
set fpn range	`sfr`	`x x i`	Set a range of pixel FPN coefficients `x`=first pixel number of the range. `x` =last pixel number of the range `i` =coefficient value in a range from `0` to `2048`. Refer to Setting a Range of FPN Coefficients on page 49 for details.
set lower threshold	`slt`	`i`	Sets the lower threshold that is checked for and reported in the end-of-line sequence in a value from `0-4095`. Refer to section 3.4.3 End-of-line Sequence for details.
set output throughput	`sot`	`m`	This command works in conjunction with the `clm` command and determines the pixel rate of the camera. `320` = 4 taps at 80MHz or 8 taps at 40MHz This command is currently not configurable in the Piranha 3 camera.
set prnu coeff	`spc`	`x i`	Set the PRNU coefficient. `x` =pixel number within the range `1` to `sensor pixel count`. `i`= PRNU value within the range `0` to `28671`. Refer to on page 46 for details.
set prnu range	`spr`	`i i x`	Set a range of pixel PRNU coefficients `i`=first pixel number of the range `i`=last pixel number of the range `x`=coefficient value in a range from `0` to `28671`. Refer to Setting a Range of PRNU Coefficients on page 47 for details.
set pretrigger	`spt`	`i`	Set the pretrigger to a value from `0` to `16`.
set subtract background	`ssb`	`t i`	Subtract the input value from the output signal. `t` = Tap value. `0` for all taps or `1` to `8` for individual tap selection. `i` = Subtracted value in a range from `0` to `4095`. Refer to on page 44 for details.

Command	Syntax	Parameters	Description
set sync frequency	`ssf`	`i`	Set the frame rate to a value from: 12k: **300-23619**Hz 8k: **300-33855**Hz Value rounded up/ down as required. Refer to section 3.2.1 Exposure Mode, Line Rate and Exposure Time for details.
set system gain	`ssg`	`t i`	Set the digital gain. **t** = Tap value. **0** for all taps or **1** to **8** for individual tap selection. **i** = Gain value is specified from **0** to **65535**. The digital video values are multiplied by this number. Refer to Setting Digital System Gain on page 48 for details.
set upper threshold	`sut`	`i`	Set upper threshold that is check for and reported in the end-of-line sequence to a value from **0-4095**. Refer to section 3.4.3 End-of-line Sequence for details.
set video mode	`svm`	`i`	Switch between normal video mode and test patterns: **0**: Normal video mode **1**: 12 bit ramp test pattern **2**: 8 bit step test pattern Refer to section 3.6.1 Generating a Test Pattern for details.
update gain reference	`ugr`		Changes the 0dB gain to equal the current analog gain value set with the **sag** command.
verify temperature	`vt`		Get the internal temperature of the camera
verify voltage	`vv`		Get the camera input voltage
write FPN coefficients	`wfc`	`i`	Write all current FPN coefficients to EEROM where ***i*** is: **1** = FPN coefficient set one **2** = FPN coefficient set two **3** = FPN coefficient set three **4** = FPN coefficient set four Refer to section 3.5.1 Saving and Restoring PRNU and FPN Coefficients for details.
write pixel coeffs	`wpc`	`i`	Write all current PRNU coefficients to EEROM where ***i*** is: **1** = PRNU coefficient set one **2** = PRNU coefficient set two **3** = PRNU coefficient set three **4** = PRNU coefficient set four Refer to section 3.5.1 Saving and Restoring PRNU and FPN Coefficients for details.

Command	Syntax	Parameters	Description
write user settings	wus		Write all of the user settings to EEROM. Refer to section 3.5 Saving and Restoring Settings for details.

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):

P3-80-08k40-00-R
P3-80-12k40-00-R
P3-87-08k40-00-R
P3-87-12k40-00-R

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

EMC:	CISPR 11:2004 / EN 55011:2003, CLASS A, GROUP1 IEC/EN 61000-3-2:2001 IEC/EN 61000-3-3:2001 EN 61326:2001 / IEC 61326:2002 IEC/EN 61000-4-2:2001 IEC/EN 61000-4-3:2002/ENV 50204 IEC/EN 61000-4-4:2004 IEC/EN 61000-4-5:2001 IEC/EN 61000-4-6:2004 IEC/EN 61000-4-11:2004
	FCC PART 15, SUBPART B, CLASS A
	EUROPEAN CISPR 11:2004/EN 55011:2003

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	April 2005
Name and Signature of authorized person	**Hank Helmond** **Quality Manager, Teledyne DALSA Corp.**

This Declaration corresponds to EN 45 014.

Appendix D

Revision History

Revision Number	Change Description
00	RoHS camera preliminary release.
01	CE and no-Pb stamps added to front cover. New parameter (4) added to command Correction Calibrate PRNU (cpa), pages 25, 46, and 79. Two new commands added: Set FPN Range (sfr), and Set PRNU Range (spr), pages 47, 49, and 83.
02	Tooling hole dimensions added to mechanical drawing, section 4.1 page 63. Piranha 3 square option added to mechanicals section, section 4.1 page 63. Also added to the Models table, page 8, and to the EMC declaration, page 85.
03	-Labels for power and control/ data connectors updated on the mechanicals. New labels read: "Power 12 - 15V DC" and "Control & Data 1." -Revised allowable line rate values, page 30. 12k: 2500-23619Hz and 8k: 2500-33855Hz. - Reference to the camera with square body and heat sink (P3-87-12k40-01-00-R) removed.
04	-Camera model names on cover revised to include all models. -Input and output connectors figure, page 16, revised to include both camera body models, slim and square. -Revised model numbers added to mechanical interface diagrams, page 63. -Measurement units (mm) added to mechanical diagrams.
05	Note added to section 2.2.3 recommending a Camera Link cable no longer than 5 meters for lossless data transmission.
06	Camera mechanicals revised so that the sensor alignment is done based on the tooling holes in the camera's front plate. Mechanical illustration in the manuals and datasheets revised to show the new alignment. Teledyne DALSA logo and information also added.

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