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Line Scan CCD Cameras

TELEDYNE DALSA

A Teledyne Technologies Company

PIRANHA 2

P2-2x-xxx40, P2-4x-xxx40, P2-2x-xxx30



Camera User's Manual

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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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1

Introduction to the Piranha 2 Line Scan Camera

1.1 Camera Highlights

Features

- Data rates up to 160MHz
- Resolutions from 1k to 8k for 40MHz model
- Resolutions from 1k to 8k for 30MHz model
- High responsivity
- Exposure control and antiblooming
- Pinned photodiode sensor for low image lag
- Programmable integration time, line rate, gain, offset, bit depth, test pattern, and diagnostics
- Flat-field correction—minimizes sensor FPN and PRNU, lens vignetting and non-uniform lighting
- Camera Link™ interface
- Single 12V to 15V power supply
- Compact design

Performance

- 4x40MHz quad output data rate, 2x40MHz dual output data rate with 40MHz model
- 2x30MHz dual output data rate with 30MHz model
- 8 or 10-bit output from 10-bit digitization
- 1024, 2048, and 4096 pixels, 10µm x 10µm, and 4096, 6144 and 8192 pixels, 7µm x 7µm, 100% fill factor
- Line rates up to 65kHz

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Programmability

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

Usability

- Programmable gains, offsets, and camera controls
- End-of-line sequence and test pattern output for debugging
- Single input supply (+12V to +15V)
- Compliant with CE and MIL-STD-810E (shock and vibration)

Description

Piranha 2 takes performance to a new level. Two and four 8 or 10-bit outputs (selectable) at up to 40MHz deliver up to 160MHz throughput.

Available in 1k to 8k resolutions, Piranha 2 is small, light, and uses a single voltage power supply. Cabling and interface are simplified with the Camera Link high-speed serial standard. The camera is sensitive, but still provides quiet, uniform output thanks to CDS (correlated double sampling) and embedded flat-field correction algorithms. Gain and offset are fully programmable for each output channel, and the camera can output test patterns for cable/ system troubleshooting. All resolutions provide appropriate, readily-available standard lens options (C-mount, F-mount, and M72x0.75 large format photography standards).

All these features combine to make Piranha 2 the most powerful line scan camera in the world. Set it loose on your toughest imaging challenge.

Applications

The Piranha 2 is ideal for applications requiring high speed, superior image quality, and high responsivity.

Applications include:

- Electronics manufacturing inspection
- Postal/ parcel sorting
- High performance document scanning/ image lift
- Narrow and large web inspection
- High-end industrial inspection

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1.2 Image Sensors

The image sensor used in your camera depends on the camera's resolution and number of taps.

1k, 2k, 4k (10 µm), 2 taps: IL-P1 (Figure 1)

2k, 4k (10 µm), 4 taps: IT-P1 (Figure 2)

4k (7 µm), 6k, 8k, 2 taps: IL-P4 (Figure 3)

4k (7 µm), 6k, 8k, 4 taps: IT-P4 (Figure 4)

Figure 1: IL-P1 Image Sensor (1k, 2k, 4k (10 µm), 2 tap models)

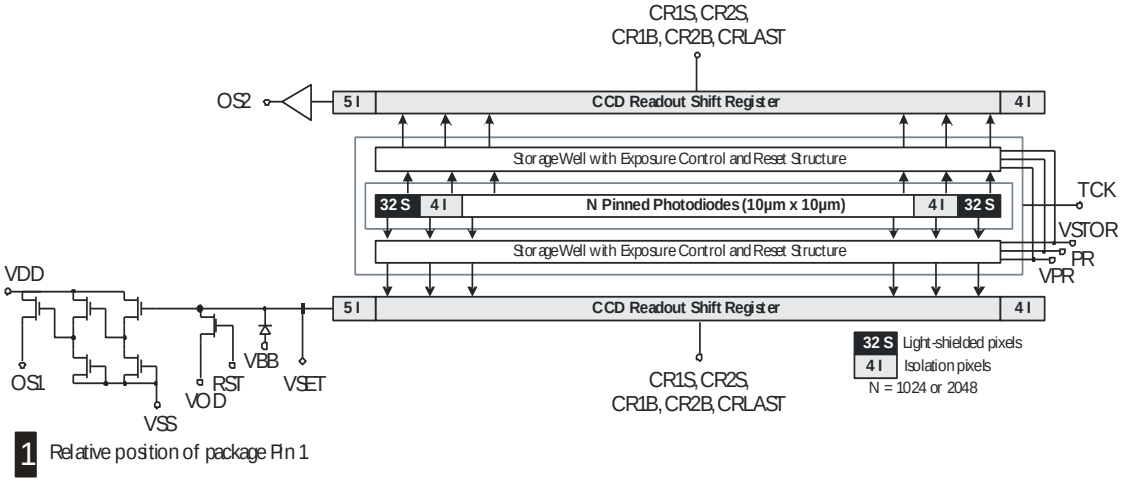
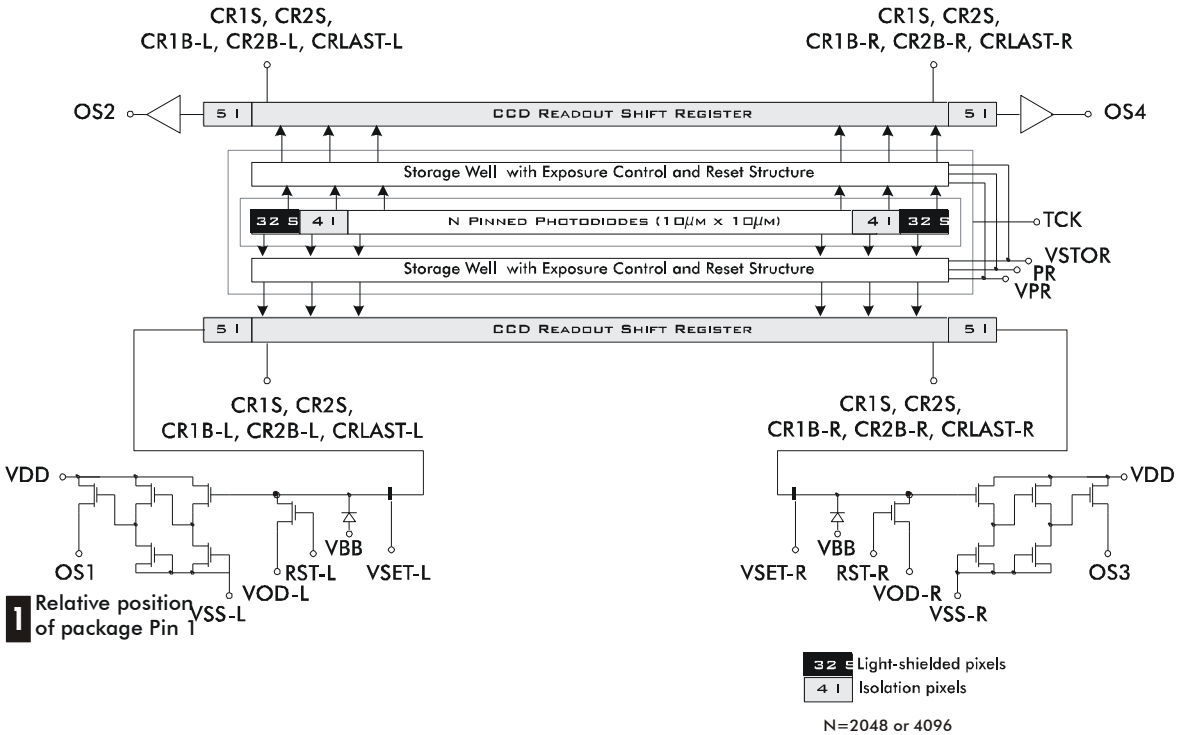


Figure 2: IT-P1 4k Image Sensor (2k, 4k (10 µm), 4 tap models)



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Figure 3: IL-P4 Image Sensor (4k (7µm), 6k, and 8k, 2 tap models)

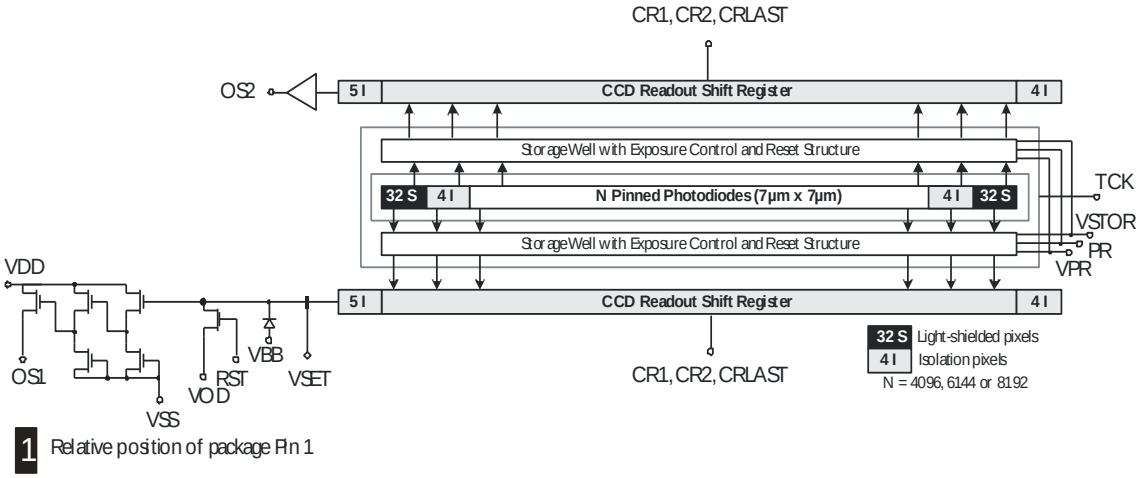
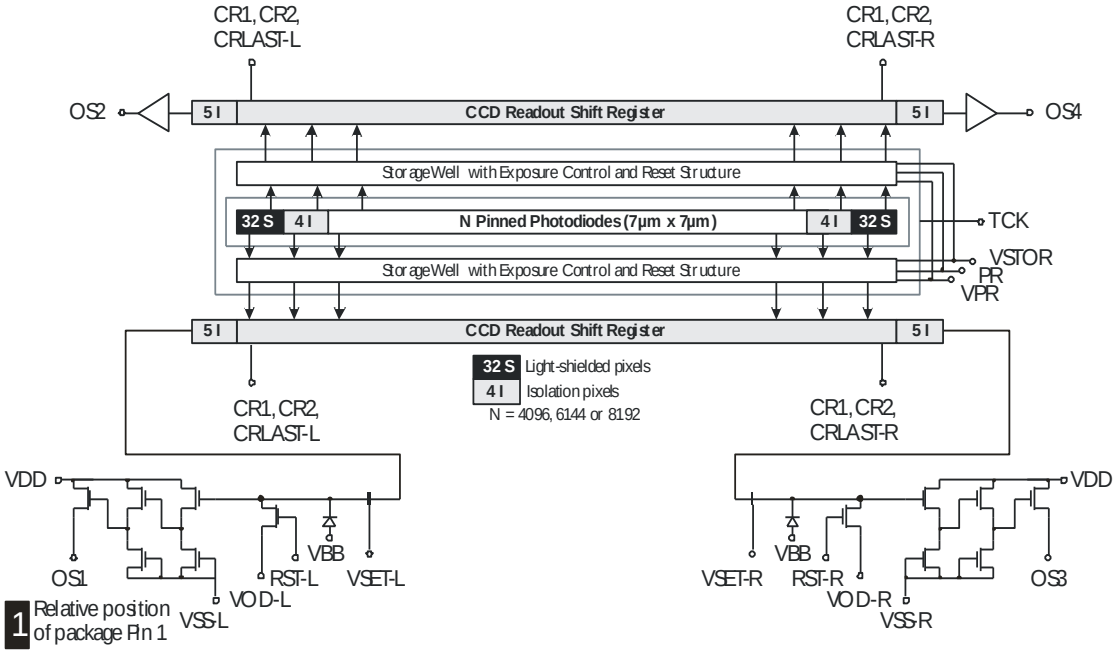


Figure 4. IT-P4 Image Sensor (4k (7µm), 6k, and 8k, 4 tap models)



1.3 Camera Performance Specifications

The following two tables list the camera's performance specifications. The first table lists the operating ranges of the camera, and the second table lists the performance specifications at minimum, nominal and maximum gain levels at 1kHz data rate. Note that as gain levels increase, performance decreases, because your signal to noise decreases.

Also note that the cameras performance specifications were obtained using a line rate of only 1kHz. At low line rates, dark current can become a significant source of noise and appears in specifications such as FPN, PRNU and noise. If you operate the camera at faster line rates, such as 10kHz or greater, the amount of dark current will be reduced by 10x or greater.

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Table 1. Piranha 2 Operating Requirements and Ranges

Operating Requirements	Units	Typical	Notes
Power			
1024—2 o/ p	W	6	
2048—2 / 4 o/ p	W	6 / 8.5	
4096 (7µm)—2 / 4 o/ p	W	6 / 8.5	
4096 (10µm)—2 o/ p	W	7.5	
4096 (10µm)—4 o/ p	W	9.6	
6144—2 / 4 o/ p	W	7.5 / 9.6	
8192 —2 / 4 o/ p	W	7.5 / 10	
Power Supply Current (Vin = +12V)			
1024—2 o/ p	mA	480	
2048—2 / 4 o/ p	mA	500 / 700	
4096—2 / 4 o/ p	mA	500 / 700	
4096 (10µm)—2 o/ p	mA	600	
4096 (10µm)—4 o/ p	mA	800	
6144—2 / 4 o/ p	mA	600 / 800	
8192 —2 / 4 o/ p	mA	620 / 840	
Time to power up, typ	sec.	15	
Time to calibrate (FPN/ PRNU)			
1024	sec.	10	
2048	sec.	19	
4096	sec.	38	
6144	sec.	85	
8192	sec.	115	

Specification	Units	Min	Max	Notes
Data Rate, per tap (40 MHz model)	MHz	40	40	
(30 MHz model)	MHz	30	30	1

Specification	Units	Min	Max 30 MHz	Max 40 MHz	
Line Rate					
1024, 2 o/ p	kHz	1	49.6	65.3	1
2048, 2 o/ p	kHz	1	27	35.4	1
2048, 4 o/ p	kHz	1		68	1
4096, 2 o/ p	kHz	1	14	18.5	1
4096, 4 o/ p	kHz	1		36.2	
6144, 2 o/ p	kHz	1		12.3	
6144, 4 o/ p	kHz	1		24.4	
8192, 2 o/ p	kHz	1	7.15	9.3	
8192, 4 o/ p	kHz	1		18.6	
Temperature					
Front plate Temperature	°C	10	50	2	
Temperature drift before recalibration (recommendation)	°C		10		
Sensor Alignment					

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Specification	Units	Min	Max	Notes
x,y	um		±175	
z	mm		±0.25	
θz	°		±0.6	

Note that the environment conditions represent the state of the environment when the camera was being tested. Typical results are the average values obtained with at a 1kHz line rate and 30°C. Maximum results represent the worst case results from any camera operating at 50°C with a 1kHz line rate.

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Table 2. Piranha2 Performance Specifications, 1kHz line rate, 40MHz Model

		Min. Gain			Nom. Gain			Max. Gain			
Environment Conditions	**Units**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Notes**
Data Rate (40MHz model)	MHz	40	40	40	40	40	40	40	40	40	
Line Rate	kHz		1	1		1	1		1	1	
Gain Setting	dB	-10	-10	-10	0	0	0	+10	+10	+10	
Front Plate Temperature	°C		30	50		30	50		30	50	3

Electro-Optic Specifications	**Units**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Notes**
Broadband Responsivity, 7um pixels	DN/ (nJ/ cm^2)	3	3.4	3.8	9.4	10.7	12	30	34	38	
Broadband Responsivity, 10um pixels	DN/ (nJ/ cm^2)	6	6.8	7.6	18.8	21.4	24	60	68	76	
Dynamic Range	Ratio	496:1			207:1	390:1		62:1	135:1		
Pk-Pk Noise, max	DN		2	3		4	8		15	32	4
RMS Noise, max	DN		0.5	0.5		0.75	1.2		2.2	4	4
FPN uncorrected, max 4K and under	DN		1.1	4		3.5	8		8	27	5
FPN uncorrected, max 6K and over	DN		1.6	4		4	8		14	27	5
FPN corrected, max	DN		0.3	2		1	2		2	8	2
PRNU uncorrected											
1K and 2K, ECD/ ECE	DN		5	18		5	23		8/ 10	39	
4k, ECD/ ECE	DN		9	28		10	28		12/ 20	43	
6K and 8K, ECD/ ECE	DN		15	38		16	38		14/ 27	55	
PRNU corrected ECD/ ECE	DN		1.5 / 2	3 / 3		1.2/ 1.5	3/ 8		2/ 3.5	5/ 27	2
DC Offset	DN										
4k and under			2	3		5	5		7	17	6
6k and over			2	3		5	5		14	17	6

Notes:

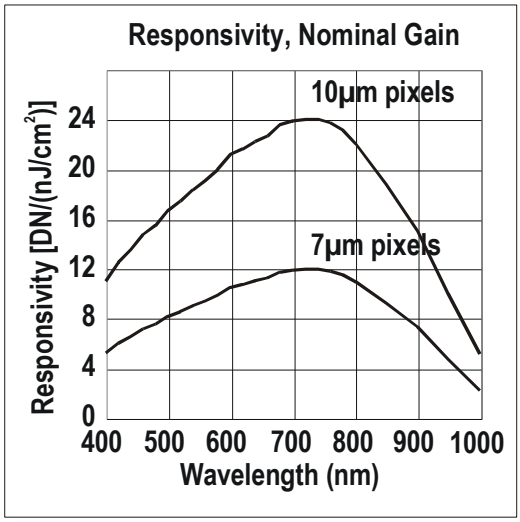
DN = Digital Numbers (0-255); also known as gray levels.
ECE = Exposure Control Enabled
ECD = Exposure Control Disabled

- All measurements taken in 8-bit output mode.
- All measurements are valid for front plate temperatures in still air.
- All measurements used a Tungsten halogen light source, 3200K bulb temp., and 750nm cutoff filter

1. All specifications for the 30MHz model are preliminary.
2. Due to FPN/ PRNU correction calculations, certain digital numbers will be unavailable when outputting 10 bits with FPN/ PRNU correction.
3. Measured at front plate. The corresponding ambient temperature range with still air is 0°C - 37°C.
4. Measurements taken at maximum line rates.
5. Exposure control enabled to set the maximum integration time to 200 microseconds.
6. Refer to Appendix D for DC Offset de-rating curves.

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Figure 5: P2 Responsivity



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2

Camera Hardware Interface

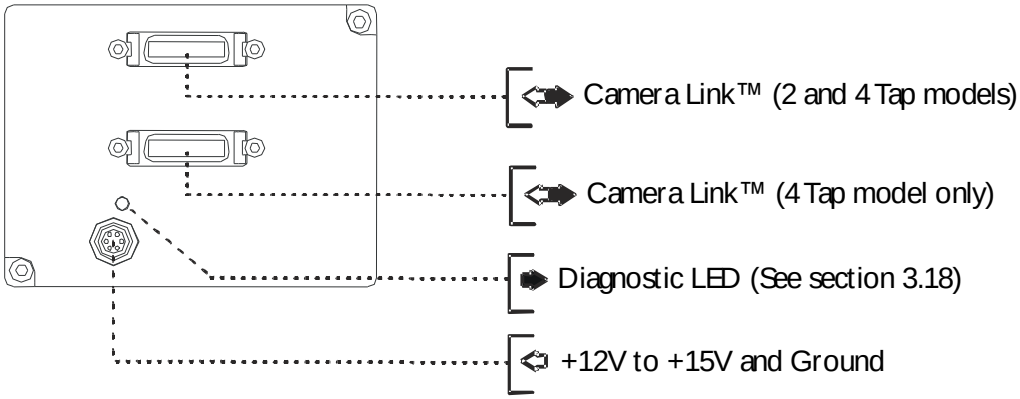
2.1 Installation Overview

In order to set up your camera, you should take these steps:

1. Connect Camera Link™ cables from camera to frame grabber.
2. Connect power.

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

2.2 Input / Output





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.

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2.3 Connectors, Pinouts, and Cables

The camera uses a high-density 26-pin MDR26 connector for Camera Link control signals, data signals, and serial communications, and a 6-pin Hirose connector for power.

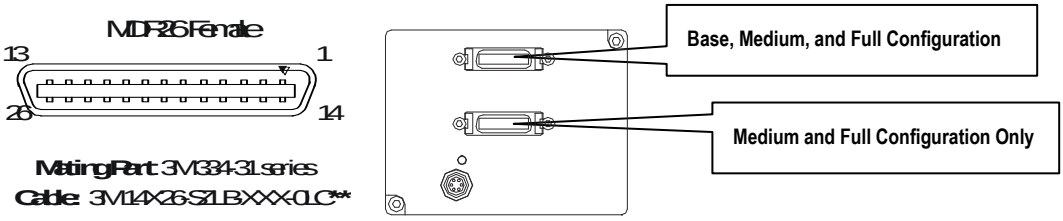


Table 3: Camera Link Medium and Full Configuration

Medium and Full Configurations Up to an additional 2 Channel Link Chips			
Camera Connector	**Right Angle Frame Grabber**	**Channel Link Signal**	**Cable Name**
1	1	inner shield	Inner Shield
14	14	inner shield	Inner Shield
2	25	Y0-	PAIR1-
15	12	Y0+	PAIR1+
3	24	Y1-	PAIR2-
16	11	Y1+	PAIR2+
4	23	Y2-	PAIR3-
17	10	Y2+	PAIR3+
5	22	Yclk-	PAIR4-
18	9	Yclk+	PAIR4+
6	21	Y3-	PAIR5-
19	8	Y3+	PAIR5+
7	20	100 ohm	PAIR6+
20	7	terminated	PAIR6-
8	19	Z0-	PAIR7-
21	6	Z0+	PAIR7+
9	18	Z1-	PAIR8-
22	5	Z1+	PAIR8+
10	17	Z2-	PAIR9+
23	4	Z2+	PAIR9-
11	16	Zclk-	PAIR10-
24	3	Zclk+	PAIR10+
12	15	Z3-	PAIR11+
25	2	Z3+	PAIR11-
13	13	inner shield	Inner Shield
26	26	inner shield	Inner Shield

*Exterior Overshield is connected to the shells of the connectors on both ends.
**3M part 14X26-SZLB-XXX-0LC is a complete cable assembly, including connectors.

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Table 4: Camera Link Base Configuration

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

Unused pairs should be terminated in 100 ohms at both ends of the cable.

Table 5: Camera Control Configuration

Signal	Configuration	Pin
CC1	EXSYNC	9, 22
CC2	PRIN	10, 23
CC3	Spare	11, 24
CC4	Spare	12, 25

See Appendix B for the complete Camera Link configuration table, and refer to the Knowledge Center page on the Teledyne DALSA Web site (www.teledynedalsa.com/ mv/ knowledge/ appnotes.aspx) for the official Camera Link documents.

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

2.4 Power Supplies

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

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.

See section 1.3 for power requirements.



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

Visit http:/ / vfm.dalsa.com 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. Many high quality supplies are available from other vendors. We assume no responsibility for the use of these supplies.

2.5 Control Inputs, Camera Link

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



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

All inputs are optional. The camera ships in exposure mode 2 and with a 5 kHz line rate. All Camera Control (CCx) signals are in a logic HIGH state.

Line rate can be set internally using the serial interface. Power-on rate is always 9600 baud. Data rate for the 40MHz model is always 40MHz. Data rate for the 30MHz model is always 30MHz.

The external control signals, EXSYNC and PRIN, are optional and enabled through the serial interface.

PRIN

PRIN is an optional input signal used for exposure control (PRIN).

PRIN	Indicates
High	Integration
Low	Pixel reset

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EXSYNC (Triggers Line Readout)

EXSYNC is an optional input signal that can be used to trigger the line readout rate. This camera uses the **falling edge of EXSYNC** to trigger line readout.

Note: EXSYNC should not be clocked faster than the camera's specified maximum line rate. The camera ignores the EXSYNC pulse until it has completed reading the last line out.

2.6 Data Bus, Camera Link

These signals indicate when data is valid, allowing you to clock the data from the camera to your acquisition system. These signals are part of the Camera Link configuration and you should refer to the Camera Link Implementation Road Map, available from the Knowledge Center page on the Teledyne DALSA website (www.teledynedalsa.com/ mv/ knowledge/ appnotes.aspx) for the standard location of these signals:

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

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

Digital Data

The camera digitizes internally to 10 bits and outputs either all 10 bits or the most significant 8 bits in LVDS format on the Camera Link connector.

Note: Due to flat-field correction calculations, certain digital numbers will be unavailable when outputting 10 bits with flat-field correction enabled (i.e. you will experience missing codes).

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Test Pattern Pixels and End-of-line Sequence

For information on the test pattern and end of line sequence commands, see section 3.17 Generating Test Patterns.

To facilitate system-level debugging and verification of data path integrity, the camera can generate a test pattern. The test pattern is a ramp from 0 to 255DN, then starts at 0 again. Use the test pattern to verify the proper timing and connections between the camera and the frame grabber.

To alleviate post-processing, Piranha 2 offers an end-of-line sequence that provides basic calculations including "line counter", "line average", "pixels above threshold", "pixels below threshold", and "derivative line sum". These basic calculations are the center of most automatic gain control (AGC) algorithms.

To further aid in debugging and cable/ data path integrity, the first six bits of the output of the end-of-line sequence are "aa", "55", "aa". Refer to the table below.

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	
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 LSB	Use these values to help calculate line average
6	Line sum MID	
7	Line sum MSB	
8	0	
9	Pixels above threshold LSB	Monitor these values (either above or below threshold) and adjust camera gain to keep these values relatively constant. This provides a basis for automatic gain control (AGC)
10	Pixels above threshold MSB	
11	Pixels below threshold LSB	
12	Pixels below threshold MSB	
13	Derivative line sum LSB	Use these values to focus the camera. Generally, the greater the sum the greater the image contrast
14	Derivative line sum Mid	
15	Derivative line sum MSB	
16	0	

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2.7 Timing

Figure 6. Piranha 2 Overview Timing Showing Input and Output Relationships

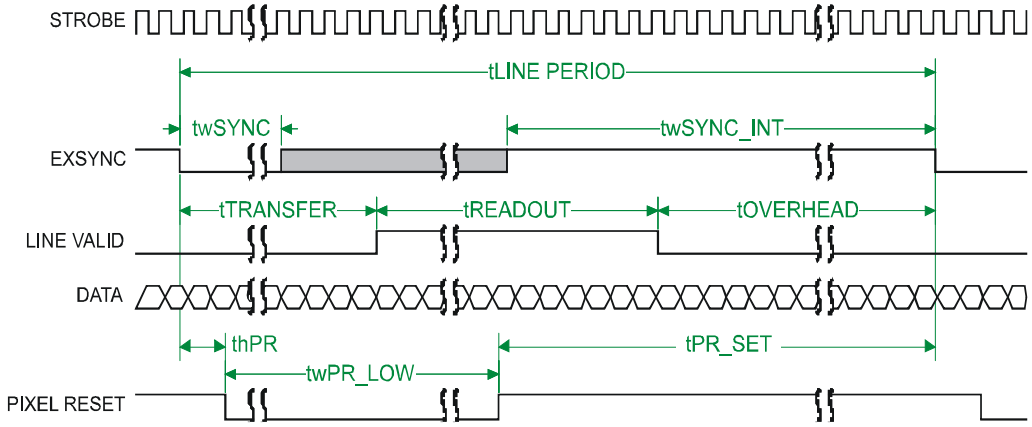
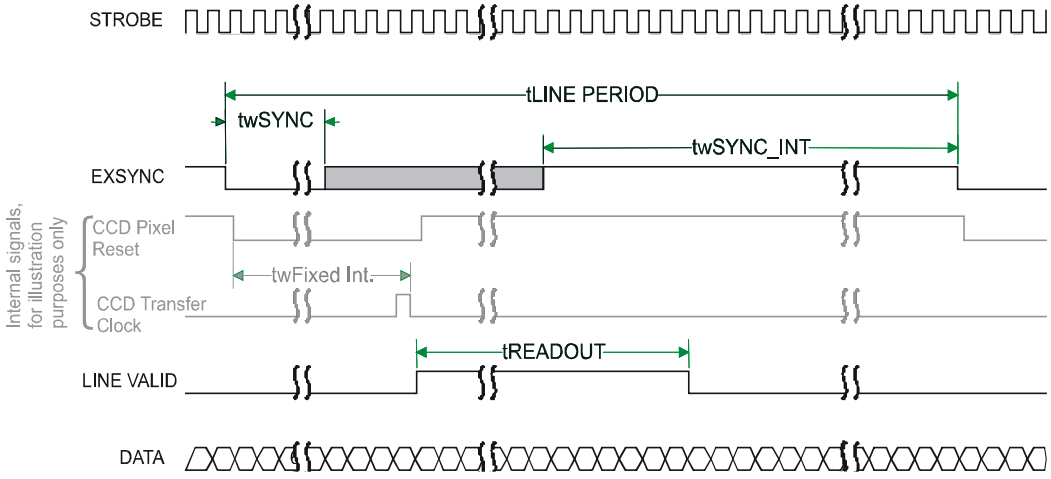


Figure 7. Piranha 2 Fixed (Programmed) Integration Timing with External EXSYNC



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Table 6: Piranha 2 40MHz Timing (Fixed Integration Mode)

Symbol	Definition	Min (ns)	Typ (ns)	Max (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.	2,000		
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.	2,000		
tLINE PERIOD (t_{LP})	The minimum and maximum line times made up of tTransfer, tREADOUT plus tOVERHEAD to meet specifications.	53,190 (8K4T) 106,382 (8K2T) 40,485 (6K4T) 80,645 (6K2T) 27,624 (4K4T) 54,054 (4K2T) 28,248 (2K2T) 15,313 (1K2T)		10^6
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.	1,420 +/ -50		
twFixed Int.	Fixed Integration Time mode of operation for variable exsync frequency.	800		t_{LP} – 2,000
tREADOUT	Is the number of pixels per tap times the readout clock period. Pretrigger = 0.	51,200 (8K4T) 102,400 (8K2T) 38,400 (6K4T) 76,800 (6K2T) 25, 600 (4K4T) 51,200 (4K2T) 25,600 (2K2T) 12,800 (1K2T)		
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	540+/ -50		
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	0		
twPR_LOW	Minimum Low time to assure complete	2,000 +/ - 200		

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Symbol	Definition	Min (ns)	Typ (ns)	Max (ns)
	photosite reset			
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.	2,000+/ -200		

*SMART EXSYNC refers to exposure mode 4. Refer to section 3.9 Setting Line Rate and Exposure Mode for further information on exposure modes.

Table 7: Piranha 2 30MHz Timing (Fixed Integration Mode)

Note: All values are preliminary for the Piranha 2 30MHz

Symbol	Definition	Min (ns)	Typ (ns)	Max (ns)
twSYNC	The minimum low width of the EXSYNC pulse when not in SMART EXSYNC mode.	132		
$twSYNC_{(SMART)}$*	The minimum low width of the EXSYNC pulse when in SMART EXSYNC modes to guarantee the photosites are reset.	2,640		
twSYNC_INT	The minimum width of the high pulse when the "SMART EXSYNC" feature is turned off	132		
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.	2,000		
tLINE PERIOD (t_{LP})	The minimum and maximum line times made up of tTransfer, tREADOUT plus tOVERHEAD to meet specifications.	140487 (8K2T) 70,170 (4K2T) 36,378 (2K2T) 19,483 (1K2T)		10^6
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.	1,874 +/ -66		
twFixed Int.	Fixed Integration Time mode of operation for variable exsync frequency.	800		t_{LP} – 2,000
tREADOUT	Is the number of pixels per tap times the readout clock period. Pretrigger = 0.	138033 (8K2T) 33, 792 (4K4T) 67,584 (4K2T) 33,792 (2K2T) 16,896 (1K2T)		

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Symbol	Definition	Min (ns)	Typ (ns)	Max (ns)
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	712+/ -66		
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	0		
twPR_LOW	Minimum Low time to assure complete photosite reset	2,640 +/ - 264		
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.	2,640+/ -264		

2.8 Camera Link Serial Communication

Camera features can be controlled through the Camera Link™ serial communication (LVDS, 9600 baud). The serial interface uses simple ASCII-based protocol. The following chapter describes how to configure the camera using the serial interface.

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3

Software Interface: How to Control the Camera

3.1 Overview



This chapter details the most commonly used commands. See Appendix C for the complete syntax and command reference for the camera's serial interface.

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

- Controlling basic camera functions such as gain and sync signal source
- Camera calibration
- Measuring internal temperature and voltages
- Capturing video
- Generating a test pattern for debugging

The serial interface uses a simple ASCII-based protocol. The complete protocol is described in Appendix C, Communications Protocol.

Online Help

For quick help, the camera can return all available commands and parameters through the serial interface. To generate this list, send the command **h** to the camera.

Retrieving Camera Settings

To read current camera settings, send the command **gcp**. For an explanation of the camera parameter screen, see section C6 Camera Parameter Screen on page 70.

3.2 Command Format

- A carriage return (CR) ends each command.
- Values in square brackets are optional.

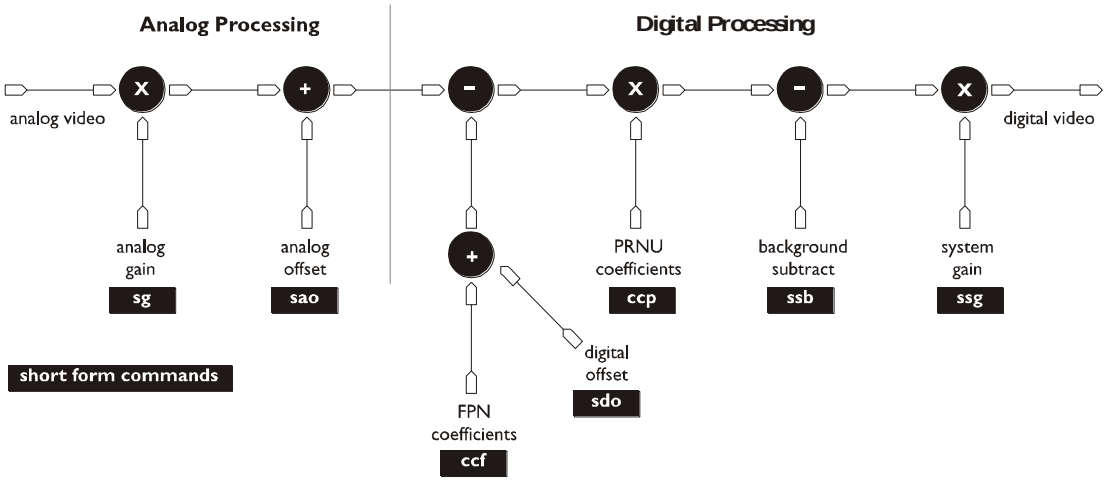
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- There are two methods for entering the commands: In long form each command is written in its entirety. In short form, only a predefined abbreviation is required. The manual uses the short form.
- The camera will answer each command with either "OK >" or "Error x: Error Message >". The ">" is always the last character sent by the camera.
- The following parameters are used in the manual:

  `i` = integer
  `f` = float
  `s` = string
  `t` = tap
  `x1`, **`x2`** = pixel start and stop values

3.3 Processing Chain

The figure below is a simplified block diagram of the camera's processing chain. The analog processing chain contains two elements–a gain stage and an offset stage. The digital processing chain contains the FPN correction, PRNU correction, background subtract, and a system gain stage. The software commands allow you to set and change all the elements of the processing chain. This enables maximum processing flexibility depending on your requirements.



In addition, the two elements of the analog processing chain, analog gain and analog offset, can be adjusted to separate values in the calibrated and uncalibrated modes. For example, the analog gain value can be set to –5db in calibrated mode and 6dB in uncalibrated mode. When switching between calibrated and uncalibrated modes, the camera automatically uses the corresponding value.

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3.4 Startup

When the camera is first started, it must perform several actions before it is ready for imaging. This startup routine takes approximately 15 seconds, and follows this sequence:

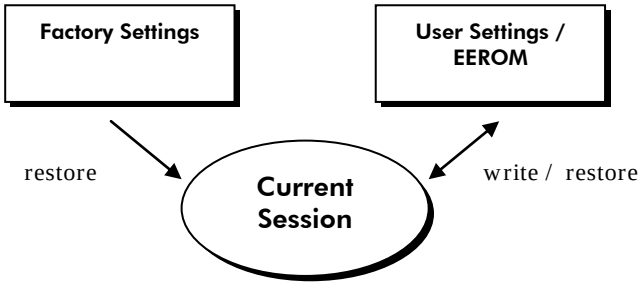
1. Initializes the camera and all internal hardware.
2. Loads the last settings saved to non-volatile memory, including the last set of video correction coefficients, if previously saved.
3. Restores user settings if previously saved, otherwise factory settings.
4. Performs a memory test and voltage test and reports an error if any occurred.

After this startup sequence is complete, the camera will return either the prompt "OK>" if no error occurred, or an error code if a problem has been discovered.

3.5 Saving and Restoring Settings

The camera provides a number of commands for restoring, storing, and saving settings.

- To restore the original factory settings, use the command **`rfs`**. The FPN and PRNU coefficients are reset to 0.
- To save all current settings to EEROM, 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 save all current pixel coefficients to EEROM, use the command **`wpc`**.
- To restore the last saved user settings and the FPN and PRNU coefficients, use the command **`rus`**.



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3.6 Setting Baud Rate

To set the speed of the camera serial communication port, use the command:

Syntax: **sbr *i***

Syntax Elements: ***i***

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.

Example: **sbr 57600**

3.7 Setting the Data Mode

To select the camera output mode, use the command:

Syntax: **sdm *i***

Syntax Elements: ***i***

See Table 8: Mode Selection Values below for allowable parameter values.

Notes: To obtain the current data mode, use the command **gcp**.

Example: **sdm 0**

In the table below, ports A-F refer to ports in the Camera Link specification.

Table 8: Mode Selection Values

Mode	Description
0	8-bit, using A/ B/ C/ D ports for single processor configuration
1	10-bit, using A/ B/ C and D/ E/ F for single processor configuration
2	8-bit using ports A/ B and D/ E for dual processor configuration
3	10-bit, using A/ B/ C and D/ E/ F for dual processor configuration

To obtain the current data mode, use the command **gcp**.

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3.8 Setting the Video Mode

The video mode sets whether the camera is running in calibrated or uncalibrated mode, or if it is generating a test pattern.

To set the video mode, use the command:

Syntax: **svm *i***

Syntax Elements: ***i***

Video mode to use. Allowable values are:

- **0** Uncalibrated video, deactivated video correction
- **1** Calibrated video, activated video correction
- **2** Test pattern right

Notes: To obtain the current video mode, use the command **gcp**.

3.9 Setting Line Rate and Exposure Mode

The camera's line rate (synchronization) is generated internally or input from a frame grabber/ host system. With six different exposure mode settings, the Piranha 2 delivers many possibilities for flexible camera timing. Table 9 outlines each of these six exposure modes, and is followed by a full explanation on how to set the camera's frame rate and exposure time.

Table 9: Piranha 2 Exposure Modes

			Programmable Line Rate ↓	Programmable Exposure Time ↓	
Mode	**SYNC**	**PRIN**			**Description**
1	Internal	Internal	No	No	Maximum line rate and exposure time (factory setting)
2	Internal	Internal	Yes	Yes	Exposure control OFF until a set command is sent
3	External	Internal	No	No	Maximum exposure time
4	External	Internal	No	No	Smart EXSYNC
5	External	External	No	No	
6	External	Internal	No	Yes	Fixed integration time

To obtain the current value of the exposure mode, use the command **gcp**.

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

Overview: Setting Line Rate and Exposure Time

The camera's line rate (synchronization) can be generated internally through software commands or input externally from a frame grabber/ host system. 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. Refer to Setting the Exposure Mode on the following page for details.
2. Then, when applicable, use the commands **ssf** (mode 2 only) to set the line rate and/ or **set** (mode 2 or 6), to set the exposure time. Refer to Setting Line Rate and Setting Exposure Time below for details.

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Setting the Exposure Mode

To select an exposure mode, use the command:

Syntax:	**sem *i***
Syntax Elements:	***i***
	Exposure mode to use. Factory setting is 1. Refer to Table 9 on page 27 for a list of available modes.
Notes:	To obtain the current value of the exposure mode, use the command **gcp**.
Related Commands:	**ssf, set**
Example:	**sem 3**

Setting Line Rate

Camera must be operating in exposure mode 2.

To set the line rate, use the command:

Syntax:	**ssf *i***
Syntax Elements:	***i***
	Desired line rate in Hz. Allowable range is 1000Hz to the camera's maximum line rate. See Table 1. Piranha 2 Operating Requirements and Ranges for maximum line rates.
Notes:	• To read the current line rate frequency, use the command **gcp**. • If you enter an invalid line rate frequency, the valid range of values will be displayed.
Related Commands:	**sem, set**
Example:	**ssf 3000**

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Setting Exposure Time

Camera must be operating in exposure mode 2 or 6.

To set the camera exposure time, use the command:

Syntax:	**set *f***
Syntax Elements:	***f*** Floating point number in µsecs.
Notes:	• To read the current exposure time, use the command **gcp**. • If you enter an invalid exposure time, the valid range of values will be displayed.
Related Commands:	**sem, ssf**
Example:	**set 2100**

3.10 Setting a Region of Interest

The **roi** command sets the pixel range used to collect the end of line statistic and sets the region of pixels used in the **cag**, **cao**, **gl**, **gla**, **ccf**, and **ccp** commands.

To define a region of interest, use the command:

Syntax:	**roi *x1 x2***
Syntax Elements:	***x1*** Pixel start number. Must be an odd number and less than the pixel end number. ***x2*** Pixel end number. Must be an even number and greater than the pixel start number.
Related Commands	**cag**, **cao**, **gl**, **gla**, **ccf**, **ccp**
Example:	**roi 10 50**

3.11 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.

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Returning a Single Line of Video

The **gl** command returns a complete line of video (without digital processing or test pattern) displaying one pixel value after another. It also displays the minimum, maximum, and mean value of the line sampled. If a region of interest has been set, the statistics are generated for the region of interest only.

Use this command, or the following **gla** command, to ensure the proper video input range into the processing chain before executing any pixel calibration commands.

To return a single line of video, use the command:

Syntax: **gl [*x1*] [*x2*]**

Syntax Elements:

[*x1*]

Optional parameter. This sets the start pixel to display on screen. Allowable range is 1 to sensor pixel count. This parameter does not affect the Min, Max, and Mean statistics generated at the end of the line output.

[*x2*]

Optional parameter. This sets the end pixel to display on screen. Allowable range is 1 to sensor pixel count. This parameter does not affect the Min, Max, and Mean statistics generated at the end of the line output.

Notes:

- If you do not specify a pixel range to display, the line output will display all sensor pixels on screen.
- If a region of interest has been set using the **roi** command, the Min, Max, and Mean statistics at the end of the line output include statistics for the region of interest only.
- If you are using the 4 tap model, and your region of interest is in one half of the sensor only (taps 1 and 2, or taps 3 and 4), the values displayed on screen for the taps outside the ROI are a mean of the ROI line statistics.
- Values returned are in DN.

Example: **gl 10 20**

Returning Multiple Lines of Video

You can also return the average for multiple lines of video data. The number of lines to sample is set and adjusted by the **css** command. The camera displays the Min., Max., and Mean statistics. If you are using a region of interest, the camera displays the statistics for the region of interest only.

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To set the number of lines to sample, use the command:

Syntax:	**css *i***
Syntax Elements:	***i***
	Number of lines to sample. Allowable values are 16, 32, or 64 (factory setting).
Notes:	To return the current setting, use the **gcp** command.
Example:	**css 32**

To return the average of multiple lines of video, use the command:

Syntax:	**gla [*x1*] [*x2*]**
Syntax Elements:	**[*x1*]**
	Optional parameter. This sets the start pixel to display on screen. Allowable range is 1 to sensor pixel count. This value does not affect the Min, Max, and Mean statistics generated at the end of the line output.
	[*x2*]
	Optional parameter. This sets the end pixel to display on screen. Allowable range is 1 to sensor pixel count. This value does not affect the Min, Max, and Mean statistics generated at the end of the line output.
Notes:	• If you do not specify a pixel range to display, the line output will display all sensor pixels on screen. • If a region of interest has been set using the **roi** command, the Min, Max, and Mean statistics at the end of the line output include statistics for the region of interest only. • If you are using the 4 tap model, and your region of interest is in one half of the sensor only (taps 1 and 2, or taps 3 and 4), the values displayed on screen for the taps outside the ROI are a mean of the ROI line statistics. • Values returned are in DN.
Example:	**gl 10 20**

3.12 Optimizing Offset Performance

Optimizing offset performance in the analog domain allows you to achieve a better signal-to-noise ratio (dynamic range) than you would achieve by trying to optimize the offset in the digital domain.

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Setting Analog Offset

To set the analog offset of the camera, use the command:

Syntax: **sao *t i***

Syntax Elements:

t

Tap selection. Allowable range is 1 to 4, or 0 for all taps.

i

Analog offset value. Allowable range is 0 to 1023.

Notes:

- The offset increases linearly with higher values. A value of 100 does **not** equal an offset of 100DN.
- The resulting analog offset value depends on other camera parameters such as temperature, line rate, and gain.
- The offset for calibrated and uncalibrated video is set and saved separately.

Example: **sao 0 200**

Subtracting Offset or Background

To subtract the video scene offset or any other background from the output video signal, use the command:

Syntax: **ssb *t i***

Syntax Elements:

t

Tap selection. Allowable range is 1 to 4, or 0 for all taps.

i

Subtracted value in a range from 0 to 511.

Notes: When subtracting a digital value from the digital video signal the output can no longer reach its maximum. Use the **ssg** command to correct for this. See section 3.13 Setting Gains for details on the **ssg** command.

Example: **ssb 0 20**

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Subtracting Offset in Calibrated Mode

To subtract the A/ D offset from the video signal in calibrated mode only (**svm 1**), prior to the PRNU correction, use the command:

Syntax: **sdo *t i***

Syntax Elements:

t

Tap selection. Allowable range is 1 to 4, or 0 for all taps.

i

Subtracted offset value in a range from 0 to 511.

Notes:

- When subtracting a digital value from the digital video signal, the output can no longer reach its maximum. Use the **ssg** command to correct for this. See section 3.13 Setting Gains for details on the **ssg** command.
- Available in calibrated mode only (**svm 1**).

Example: **sdo 0 100**

Calibrating Offset

To calibrate the analog offset, use the command:

Syntax: **cao *t i***

Syntax Elements:

t

Tap selection. Allowable range is 1 to 4, or 0 for all taps.

i

The line average in a range dependent on the current camera data mode setting.

8 bit: 1 to 100DN

10 bit: 4 to 400DN

See section 3.11 Returning Video Information for more information on line averages

Notes: This command sets offset in **uncalibrated** mode (**svm 0**).

Example: **cao 0 100**

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3.13 Setting Gains

Optimizing gain in the analog domain allows you to achieve a better signal-to-noise ratio (dynamic range) than you would achieve by trying to optimize the gain in the digital domain.

To set the analog gain mode, use the command:

Syntax: **sg *t f***

Syntax Elements:

t

Tap selection. Allowable range is 1 to 4, or 0 for all taps.

f

Gain setting. A gain value of 0 sets the camera to its nominal gain (0dB). The specified gain value range is from –10 to 10dB.

Example: **sg 0 5.2**

To set the digital gain, following a background subtraction, use the command:

Syntax: **ssg *t i***

Syntax Elements:

t

Tap selection. Allowable range is 1 to 4, or 0 for all taps.

i

Gain setting. The gain ranges are 0 to 511 (equal to a gain from 1 to 1.999). Use this command in conjunction with the **ssb** command.

Related Commands: **ssb**

Example: **ssg 1 15**

Calibrating Gains

Instead of setting the analog gain to a specific value, you can have the camera determine the gain value by providing the camera with an average output level to use.

Note: This function requires a constant light input while it executes. This feature is beneficial for achieving a common output level for multiple cameras in a system.

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To calibrate the analog gain:

Syntax:	**cag *t i***
Syntax Elements:	***t***
	Tap selection. Allowable range is 1 to 4, or 0 for all taps.
	i
	Line average in a range dependent on the current camera data mode setting: 8-bit: 64 to 251 DN 10 bit: 256 to 1007 DN See section 3.11 Returning Video Information for more information on line averages
Notes:	• This function requires constant light input while executing. • This command sets gain in **uncalibrated** mode.
Related Commands:	**gla, gl**
Example:	**cag 1 156**

3.14 How to Calibrate the Camera

Calibration Overview

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

Fixed Pattern Noise (FPN)

Photo Response Non Uniformity (PRNU)

Lens and light source non-uniformity

The two point correction is implemented such that for each pixel:

$V_{output} = (V_{input} - FPN(pixel) - digital\ offset) * PRNU(pixel)$

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

The calibration 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 (balance target) for flat, white output. Video output is set slightly above the brightest pixel (depending on offset subtracted).

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For FPN (dark light) the value of all pixels must be between 1DN and 127DN. For PRNU (white light) the value must be between 128DN and 254DN. Use the **gl** command to ensure the proper input to the digital processing, V_{input}.

White light calibration will gain up to maximum white light pixel plus the maximum FPN subtract pixel.

When performing any camera calibration, random noise is minimized by averaging out up to 64 lines of valid data. To adjust the sample line size, use the **css *i*** command, where ***i*** is 16, 32, 64 (factory setting). A lower value reduces the camera's calibration time, at the expense of increased coefficient error.

Calibration time	Typical
1024	10 sec.
2048	19 sec.
4096	38 sec.
6144	85 sec.
8192	115 sec.

LED blinks green while calibrating. **IMPORTANT: While camera is blinking green, do not power down camera or memory may be corrupted.**

Calibration Steps Overview

1. Change camera video mode to calibrated using the command **svm 1**
2. Set up the camera operating environment (i.e. line rate, exposure, gain, etc.)
3. Make sure there are suitable calibration targets. The target to calibrate should be a flat field, e.g. plastic or ceramic for white calibration.
4. Set the calibration sample size using the command **css** (see Returning Multiple Lines of Video page 30).
5. Perform Dark (FPN) calibration (see Dark Calibration on page 36).
6. Perform White (PRNU) calibration (see White Light Calibration on page 37).
7. Save settings and pixel coefficients using the commands **wus** and **wpc**.

Note: It is important to do the FPN calibration first. Results of the FPN calibration are used in the PRNU procedure. We recommend that you repeat the calibration when a temperature change greater than 10°C occurs.

Dark Calibration

Dark calibration is used to remove the fixed analog offset from the video path. It is recommended you repeat the calibration when a temperature change greater than 10°C occurs.

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To perform dark calibration:

1.	Stop all light from entering the camera. (Tip: cover lens with a lens cap.)
2.	Verify that output signal level is within range by issuing the command **gl** or **gla** (a valid range is 1-127). If the signal level is too low, adjust the analog offset (**sao**) . If the signal level is too high, ensure that no light is entering the camera, reduce the analog offset or reduce the gain level (**sg**) .
3.	Issue the command **ccf**. The camera will respond with OK> if no error occurs. Dark calibration automatically calibrates FPN coefficients and digital offset. **To perform a dark calibration with an analog offset value:** Use the **ccf [*i*]** command, where ***i*** is the analog offset DN. When the optional parameter is provided, this command sets the analog offset first to ***i*** before calculating the FPN coefficients range from 1 to 100DN for 8-bit data mode, and 4 to 400DN for 10-bit data mode for the specified region of interest. If value is left blank, current offset values are used.
4.	After the calibration is complete, you can save these settings, and the PRNU coefficients, to non-volatile memory so they will be remembered after power-down. To do so, issue the command **wpc**.

White Light Calibration

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

White light calibration is more complex than dark calibration because the camera attempts to create a flat white image. This calibration corrects PRNU effects as well as non-uniform lighting and lens vignetting affects.

White light calibration 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.

There are several restrictions that must be met in order for the calibration to succeed:

1. The camera is sufficiently sensitive to detect 60 Hz ambient light flicker which may affect camera performance and calibration results.
2. The light level must be set so that all pixels are between 64DN and 254DN, otherwise a warning will be sent stating that the camera could not calibrate all pixels to the same level. Use the **gl** command to determine input level. If the signal level is too low or too high, adjust analog gain using the command **sg**.

These restrictions are all tested within the calibration algorithm and the camera will report an informal message code if any of these conditions could not be met.

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To perform a white light calibration:

1.	Place a white reference in front of the camera.
2.	Verify that output signal level is within range by issuing the command **gl** or **gla** (valid range is 128-254). If signal level is too low or too high, adjust the gain using the command **sg**.
3.	Instruct the camera to perform a white light calibration using the command **ccp**. The camera will respond with OK> if no error occurs. **To perform a white light calibration with an analog gain value:** Use the **ccp [*i*]** command. When the optional parameter is provided the analog gain is adjusted to produce an average white pixel level that is equivalent to the parameter. This command sets the analog gain first to ***i*** before calculating the PRNU coefficients range from 64 to 251DN for 8-bit data mode, and 256 to 1007DN for 10-bit data mode. If value is left blank, current gain values are used.
4.	After the calibration is complete, you can save these settings to non-volatile memory so they will be remembered after power-down. To do so, issue the command **wpc**.

Returning Calibration Results and Errors

After calibration, you can retrieve the results using the command **dpc.** This function returns all the pixel coefficients in the order FPN, PRNU, FPN, PRNU… The camera also returns the pixel number with each coefficient.

To set a range for the returned coefficients provide an optional pixel start and end value:

Example: display pixel coefficient from pixel 10 to 20

```
dpc 10 20
```

The command **gcp** returns all other settings.

3.15 Setting and Reading FPN Coefficients

You can set or read an individual pixel's FPN coefficient.

To set the FPN coefficient, use the command:

Syntax: **sfc *i* *i***

Syntax Elements: ***i***

The pixel number from 1 to the pixel count.

i

Coefficient value in a range from 0 to 127.

Example: **sfc 10 50**

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To read the FPN coefficient, use the command:

Syntax: **gfc *i***

Syntax Elements: ***i***

The pixel number to read.

Example: **gfc 10**

3.16 Setting and Reading PRNU Coefficients

You can set or read an individual pixel's PRNU coefficient.

To set the PRNU coefficient, use the command:

Syntax: **spc *i i***

Syntax Elements: ***i***

The pixel number from 1 to the pixel count.

i

Coefficient value in a range from 0 to 511 where:

$$PixelPRNU = 1 + \frac{i}{512}$$

Example: **spc 10 50**

To read the PRNU coefficient, use the command:

Syntax: **gpc *i***

Syntax Elements: ***i***

The pixel number to read.

Example: **gpc 10**

3.17 Generating Test Patterns

The camera can generate a test pattern to aid in system debugging. Use the command **svm 2** to activate the test pattern. The test pattern is a ramp from 0 to 255DN, then starts at 0 again. Use the test pattern to verify the proper timing and connections between the camera and the frame grabber.

End-of-line Sequence

To further aid debugging, the camera can generate an end-of-line sequence. The end-of-line-sequence outputs "aa", "55", "aa", "line counter", "line average", "pixels above threshold", "pixels below threshold", "derivative line sum". To activate the end-of-line sequence, use the command **els 1**. To disable the end-of-line sequence, use the command **els 0**.

Use the **sut** and **slt** commands to set threshold values between 0 and 255 for 8-bit data modes, or 0 to 1023 for 10-bit data modes.

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3.18 Monitoring the Camera

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

LED state	Priority	Camera Status	Condition
Blinking RED	1	Error	Fatal hardware failure
Steady RED	2	Warning	Monitoring task failure
Blinking GREEN	3	Progress	Lengthy operation in progress. While camera is blinking green, do not power down camera or memory may be corrupted.
Steady GREEN	4	OK	Healthy

Note: 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.

Monitoring Tasks

The camera enters a warning state when any of camera's continuously running monitoring tasks detects a failure. Use the **`wed i i`** command, where the first parameter is the monitoring task and the second parameter is the enable or disable value, to display the status of all the defined monitory tasks (if no parameter is passed) and/ or to enable/ disable specific monitoring tasks.

Note: If you are performing defect detection down to a single pixel, enabling monitoring tasks is not advisable because monitoring can occur during active video and could potentially provide erroneous data.

The following table lists the monitoring tasks:

Monitoring task number	Code	MONITORING TASK	DESCRIPTION
0		All	Enable/ disable all monitoring tasks
1	1	Voltage Monitoring	Monitors all camera voltages
2	2	Temperature Monitoring	Monitors camera temperature
3	4	External SYNC presence	Monitors presence of external SYNC
4	8	External PRIN presence	Monitors presence of external PRIN
5	16	Gain Out Of Spec Monitoring	Monitors current setting of analog gain
6	32	Line Rate Below 1 Khz	Monitors current line rate

Value	Function
0	Disable selected task
1	Enable selected task

Note: by default all monitoring tasks are enabled except voltage monitoring.

Example: enable all monitoring tasks

```
wed 0 1
```


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Example: disable EXSYNC presence

```
wed 3 0
```

Temperature Measurement

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

Voltage Measurement

The command **vv** checks the camera's input voltage and internal voltages during power-up. If they are within the proper range, the camera returns OK>. Otherwise the camera returns an error message. Note that the voltage measurement feature of the camera provides only approximate results (typically within 10%). They should not be used to set the applied voltage to the camera. The purpose of this test is to isolate gross problems with the supply voltages.

3.19 Rebooting the Camera

The command **rc** reboots the camera. The camera starts up with the last saved settings. Previously saved pixel coefficients are also restored.

3.20 Setting the Pre-trigger

A pre-trigger may be required for some frame grabbers.

To set the pre-trigger, use the command:

Syntax:	**sp *i***
Syntax Elements:	***i***
	Pretrigger value from 0 to 15.
Example:	**sp 10**

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4

Optical, Mechanical, and Thermal Considerations

4.1 Mechanical Interface

The camera's electronics are housed in a ruggedized lightweight aluminum case.

Mounting

The camera can be mounted using the M3 holes (metric-threaded) on its base or top, and on its front plate at the corners.

Environment

The camera and cables should be shielded from environmental noise sources for best operation. The camera should also be kept as cool as possible. The specified operating temperature is 10–50°C measured at the front plate, (the corresponding ambient temperature range with still air is 0°C to 37°C). Mounting holes (refer above) allow you to attach heat sinking.

Thermal Management

For any CCD camera optimal performance is achieved by transferring heat away from the sensor. Keeping a sensor "cool" reduces the amount of dark current generated. Dark current is the leading contributor to FPN, PRNU, dark offset, random noise and other performance specifications, especially when a camera is significantly gained (i.e. +10db). Generally, dark current doubles for every 7°C increase in temperature at the sensor and increases linearly with integration time. Further variations in dark current cannot be compensated for with our flat-field correction algorithms. For this reason, at high gains (+10dB), high temperatures (40°C front plate), and low line rates, it is recommended that you recalibrate the flat-field coefficients when the temperature shifts by ±10°C.

Note: Upon initial power-up the front plate camera temperature is near ambient. It is recommended to perform flat-field correction once the camera gets within 10°C of its steady state temperature. For Piranha 2, at an ambient temperature of 25°C and with no airflow, the camera takes 90 minutes to achieve steady state and 20 minutes to reach within 10°C of steady state. If your system cannot perform flat-field correction after warm-up consider the recommended methods of reducing dark current and overall camera temperatures (see below).

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Reducing Dark Current

The Piranha 2 mechanicals have been optimized to transfer heat from the sensor to the front plate. Therefore, to reduce dark current the front plate is the ideal place to mount heat sinks.

The heat fins on Piranha 2 improve conduction and provide a greater surface area for convection (airflow). Mount fans away from the camera to avoid vibration, and direct the airflow on the heat fins to decrease the temperature delta between ambient and front plate temperatures. Convection is the ideal method to minimize camera warm-up times and reduce dark current generation.

Both methods— either conduction through heat sinking, or convection through air flow — greatly reduce dark current and will improve your system performance.

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Figure 8: Piranha 2, 2 tap models

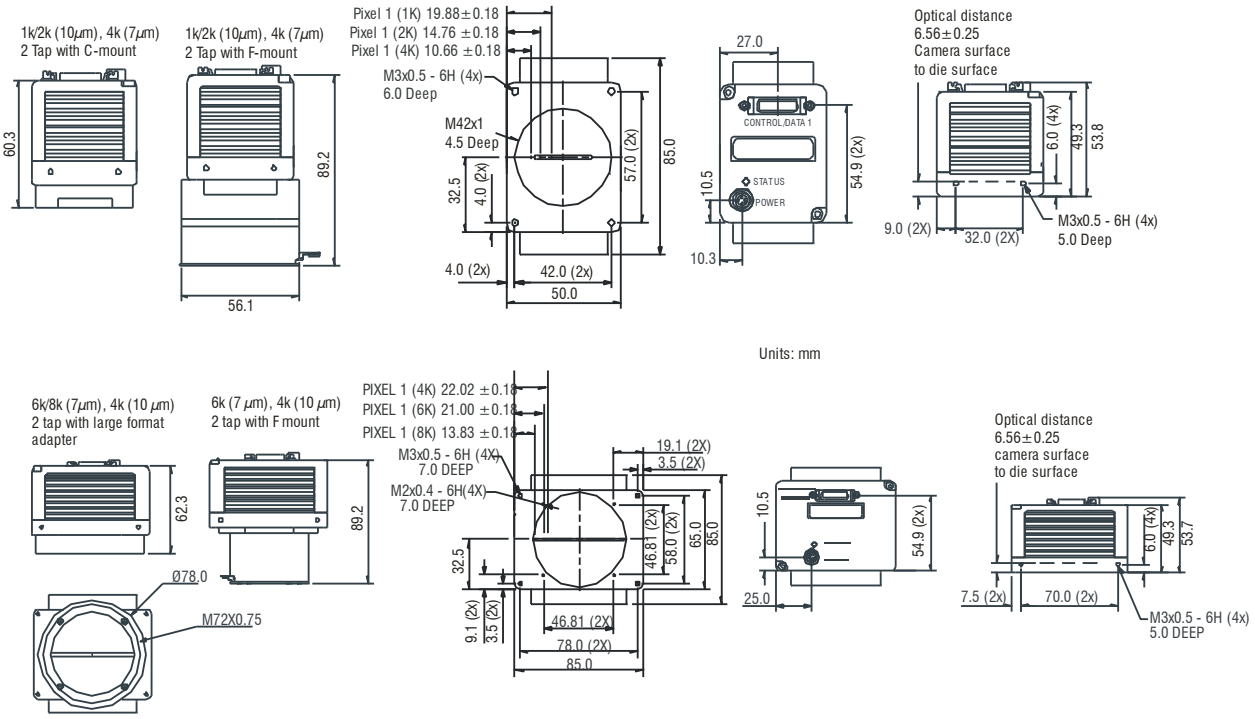
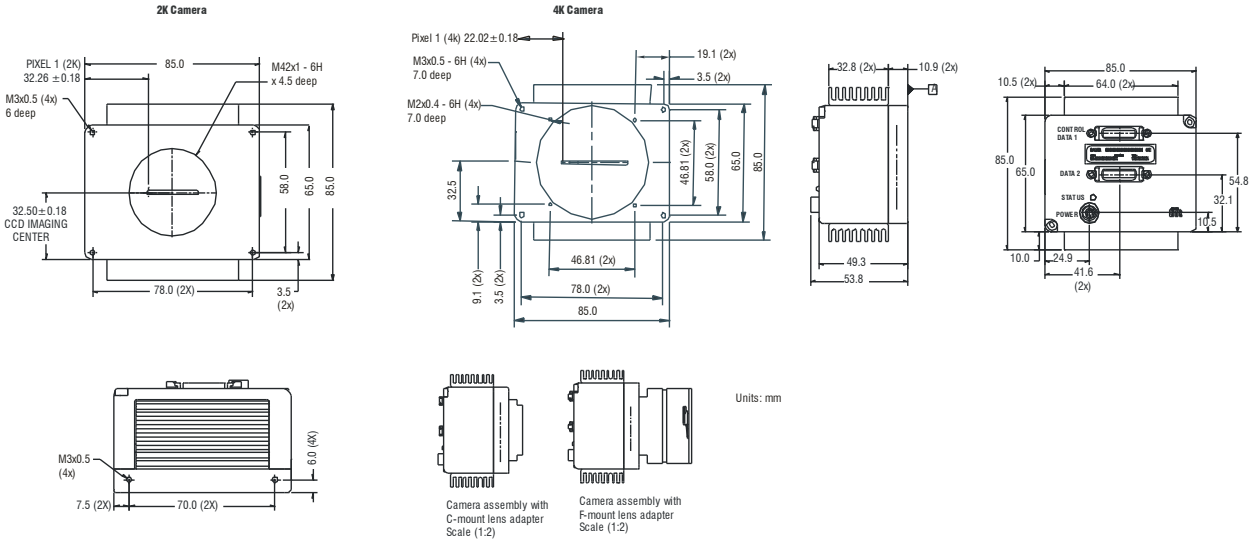
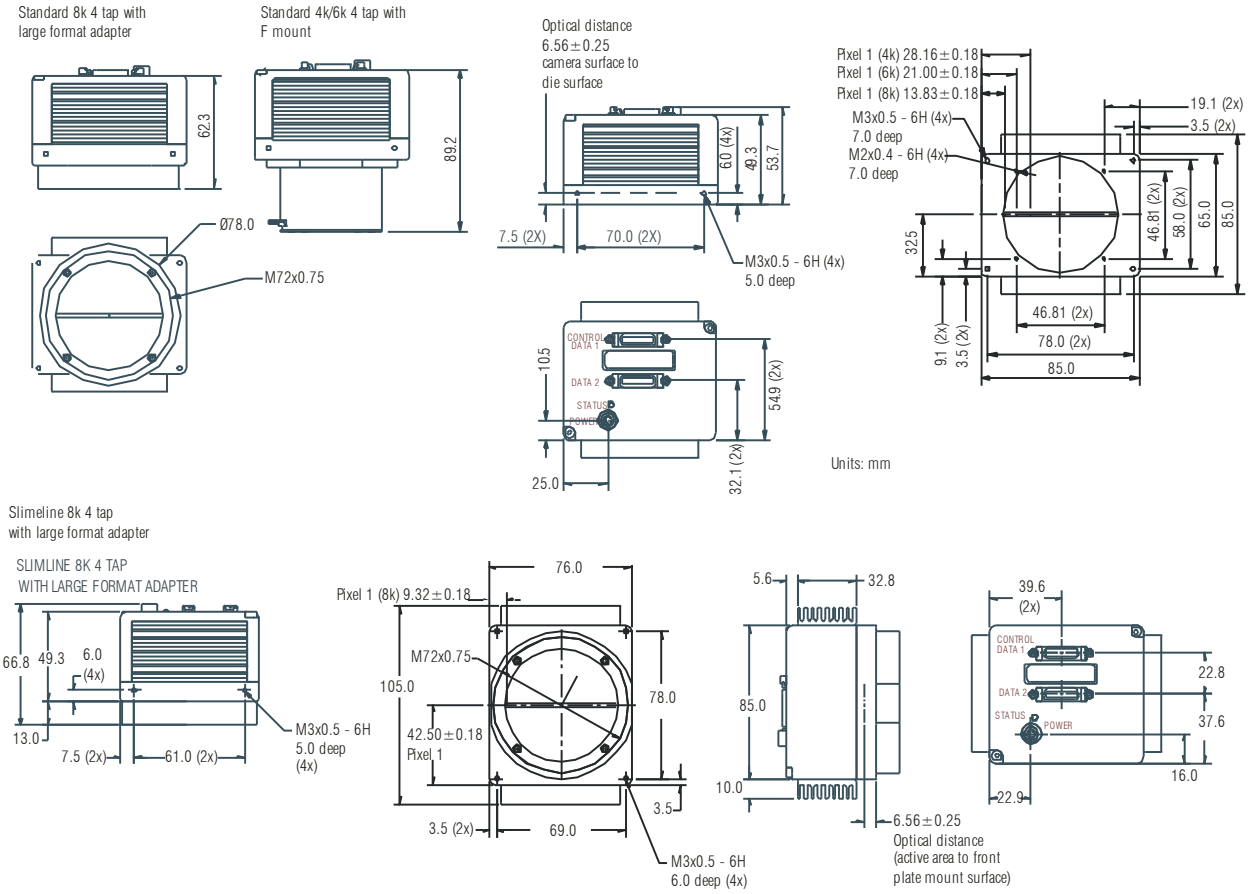


Figure 9: Piranha 2, 4 tap, 10 μm models



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Figure 10: Piranha 2, 4 tap, 7 μm models



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4.2 Optical Interface

Depending upon resolution the cameras can be ordered with different lens mounts. The following table provides this information.

Lens Mounts

Camera Configuration	Available Lens Mount Options
1K, 2 Tap	No mount and C-mount
2K, 2 Tap, 4 Tap	No mount, C-mount and F-mount
4K, 2 Tap	No mount and F-mount and M72x0.75 (10µm model only)
4K, 4 Tap	No mount, F-mount and M72x0.75
6K, 2 Tap	No mount, F-mount and M72x0.75
6K, 4 Tap	No mount, F-mount and M72x0.75
8K, 2 Tap	No mount, and M72x0.75
8K, 4 Tap	No mount, and M72x0.75

All C-mount and F-mount adapters have the appropriate back focal distance for the lens type being used. Ensure that the image circle diameter of the lens to be used is as great as the length of the imaging region. The following table provides information regarding the lens mount used and the back focal distance. The M72x0.75 lens adapter originated from the high-end photography standard. Distances to its inner flat surface and the outer flat surface are provided.

Mount	Back Focal Distance (sensor die to adapter)
C-Mount	17.52 ±0.25mm
F-Mount	46.5 ±0.25mm
M72x0.75	19.55mm (nominal)—outer flat surface

Detailed mechanicals, including front plate opening sizes, and the distance from the sensor die to the opening, can be found in section 4.1 Mechanical Interface.

Note: Lens manufacturers have readily available lens mounts and lenses to adapt to the M72x0.75 adapter available on the 6K and 8K cameras.

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. The Knowledge Center page on our website, www.teledynedalsa.com/ mv/ knowledge/ appnotes.aspx, has an introduction to this potentially complicated issue posted. See "Radiometry and Photo Responsivity" and "Sensitivities in Photometric Units" in the CCD Technology Primer found under the Application Support link.

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

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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 2 camera.
- 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

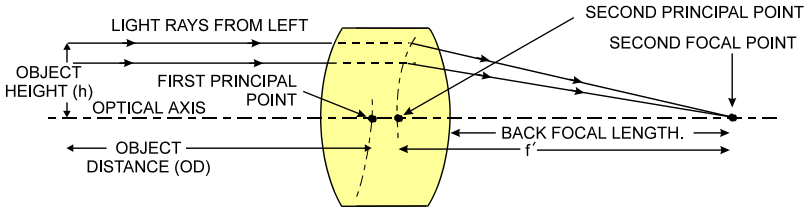
CCD cameras are extremely responsive to infrared (IR) wavelengths of light. To prevent infrared from distorting the images you scan, use a "hot mirror" or IR cutoff filter that transmits visible wavelengths but does not transmit wavelengths over 750nm. Examples are the Schneider Optics™ B+W 489, which 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 11. 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:

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

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

4.3 Compliance

The Piranha 2 cameras have been designed for EMC compliance. The test setup has been verified to the following EMC standards:

CISPR-22:1997

EN 50082-1:1997

EN 61000-4-2; ±6kV CD, ±8kV AD:1995

EN 61000-4-3; 3V/ m:1996

EN 61000-4-4; 500V, 1100V:1995

Follow these specific guidelines to ensure best performance:

- Keep Camera Link cables as short as possible.
- Ensure that all cable shields have 360° electrical connection to the connector.
- Fasten and secure all connectors.

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5

CCD Handling Instructions

5.1 Electrostatic Discharge and the CCD Sensor

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

Electrostatic charge introduced to the sensor window surface can induce charge buildup on the underside of the window that cannot be readily dissipated by the dry nitrogen gas in the sensor package cavity. When charge buildup occurs, surface-gated photodiodes (SGPDs) may exhibit higher image lag. Some SGPD sensors, such as the IL-P4 and the IT-P4 used in the Piranha 2 cameras, may also exhibit a highly non-uniform response when affected by charge buildup, with some pixels displaying a much higher response when the sensor is exposed to uniform illumination. The charge normally dissipates within 24 hours and the sensor returns to normal operation.



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

5.2 Protecting Against Dust, Oil and Scratches

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

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

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

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

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to avoid introducing oily residues, only hold the sensor from the edges of the ceramic package and avoid touching the sensor pins and the window.

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

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

5.3 Cleaning the Sensor Window

1. Use compressed air to blow off loose particles. This step alone is usually sufficient to clean the sensor window.
2. If further cleaning is required, use a lens wiper moistened with alcohol or acetone.
3. We recommend using lint-free ESD-safe cloth wipers that do not contain particles that can scratch the window. The Anticon Gold 9"x 9" wiper made by Milliken is both ESD safe and suitable for class 100 environments. Another ESD acceptable wiper is the TX4025 from Texwipe.
4. An alternative to ESD-safe cloth wipers is Transplex swabs that have desirable ESD properties. There are several varieties available from Texwipe. Do not use regular cotton swabs, since these can introduce charge to the window surface.
5. Wipe the window carefully and slowly.
6. When cleaning long linear sensors, it may be easier to wipe along the width (i.e. as opposed to the length) of the sensor.

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6

Troubleshooting

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

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

Your steps in dealing with a technical problem should be:

1. Try the general and specific solutions listed in sections 6.1, 6.2 and 6.3.
2. If these solutions do not resolve your problem, see section 6.4 on getting product support.

6.1 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.

EXSYNC

When the camera is powered on for the first time, it defaults (no external input required) to exposure mode 2 (5kHz line rate, and internal Sync to trigger readout). After a user has saved settings, the camera powers up with the saved settings. Note, a warning appears when switching to exposure mode requiring external signals if external signals are not present (EXSYNC or PRIN).

PRIN

PRIN is an optional input signal used to control exposure control (PRIN).

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PRIN	Indicates
High	Integration
Low	Pixel reset

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 D11 Generating Test Patterns for further information.

6.2 Troubleshooting Using the Serial Interface

The following commands can aid in debugging. (The complete command protocol is described in Appendix B and C.)

Communications

To quickly verify serial communications send the help command . The **h** command returns the online help menu. If further problems persist, review Appendix C for more information on communications.

Verify Parameters

To verify the camera parameters, send the **gcp** command. See section C6 Camera Parameter Screen for a complete explanation of the camera parameters screen.

Verify Factory Calibrated Settings

To restore the camera's factory settings and reset the FPN and PRNU coefficients to 0, 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. See below.

Generating Test Patterns

The camera can generate a test pattern to aid in system debugging. Use the command **svm 2** to activate the test pattern. The test pattern is a ramp from 0 to 255DN, then starts at 0 again. Use the test pattern to verify the proper timing and connections between the camera and the frame grabber.

- **No test pattern or bad test pattern** — May indicate a problem with the camera (e.g. missing bit) or a system setup problem (e.g. frame grabber or timing). Verify the presence of the LVAL and STROBE signals.
- **Test pattern successful** — Run the **svm 0** command to deactivate video correction. Then run the **gl** command under both dark and light conditions to retrieve a line of raw video (no digital processing). Under dark conditions, with factory settings, the analog offset value should be within the specified range (refer to the user specifications). Adjust the analog offset using the **cao** or **sao** commands. Under light conditions, you should receive a value.

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Verify Voltage

To check the camera's input voltages and internal voltages, use the **vv** command. If they are within the proper range, the camera returns OK>. Otherwise the camera returns an error message.

Verify Temperature

To check the internal temperature of the camera, use the **vt** command. For proper operation, this value should not exceed 75°C.

Verify Pixel Coefficients

To activate video correction, send the command **svm 1**. Then use the **dpc** command to display the pixel coefficients in the order FPN, PRNU, FPN, PRNU… The camera also returns the pixel number with each coefficient.

End-of-line Sequence

To further aid debugging, the camera can generate an end-of-line sequence. The end-of-line-sequence outputs "aa", "55", "line counter", "line average", "pixels above threshold", "pixels below threshold". To activate the end-of-line sequence, use the command **els 1**. To disable the end-of-line sequence, use the command **els 0**.

Use the **sut** and **slt** commands to set threshold values between 0 and 255 for 8-bit data modes, or 0 to 1023 for 10-bit data modes.

LED Status

Located on the back of the camera is a red/ green LED used to display the operational status of the camera. Red lights indicate errors or warnings and green lights indicate progress and OKs. Error and warning states are accompanied by corresponding messages further describing current camera status.

Monitoring Tasks

The camera enters a warning state when any of the camera's continuously running monitoring tasks detects a failure. Use the **wed** command to display the status of all the defined monitory tasks (if no parameter is passed) and/ or to enable/ disable specific monitoring tasks.

6.3 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 or PRIN, if camera is in exposure mode that regulates external signals).

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Line Dropout, Bright Lines, or Incorrect Line Rate

Verify that the frequency of the internal sync is set correctly, or when the camera is set to external sync that the EXSYNC signal supplied to the camera does not exceed the camera's maximum specified line rate.

Noisy Output

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

Dark Patches

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

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

Stuck Bits

If data bits seem to be stuck or do not change, check that the camera is not saturated by preventing light from entering. To verify the data path integrity, check the levels of the 2 test pattern pixels (first 2 pixels following the last End-of-line pixel. You may need to turn the End-of-line sequence "on" by sending the command **`els 1`**). Any deviation from a consistent value of these pixels (170DN/ 85DN) could be an indication of the following:

- shorted bits
- stuck bits
- digital noise pickup on the I/ O cable
- open connection.

To activate the test pattern, use the command **`svm 2`**. Use the test pattern to verify the proper timing and connections between the camera and frame grabber.

To receive a complete line of raw video data (without digital processing or test pattern) through the RS232 port, use the command **`gl`**. The returned data displays one pixel value after another and the minimum, maximum, and mean value of the sampled line. Use this command to ensure the proper video input range.

Probe the output lines with an oscilloscope. Disconnect the digital cable from the camera and check the digital signals at the output of the camera. Ensure that the correct values

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are present. Check all cable connections, especially right at the connector; poor connections or broken wires will cause randomly changing bits or stuck bits.

Horizontal Lines or Patterns in Image

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

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Appendix A

Camera Link™ Reference

Camera Link is a communication interface for vision applications.

For years, the scientific and industrial digital video market has lacked a standard method of communication. Both frame grabbers and camera manufacturers developed products with different connectors, making cable production difficult for manufacturers and very confusing for consumers. A connectivity standard between digital cameras and frame grabbers is long overdue and will become even more necessary as data rates continue to increase.

Increasingly diverse cameras and advanced signal and data transmissions have made a connectivity standard like Camera Link a necessity. The Camera Link interface will reduce support time, as well as the cost of that support. The standard cable will be able to handle the increased signal speeds, and the cable assembly will allow customers to reduce their costs through volume pricing.

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

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image data bit allocations, refer to the official Camera Link specification on the vfm.dalsa.com web site.

Camera Control Signals

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

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

Communication

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

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

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

Power

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

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Appendix B

EMC Declaration of Conformity

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

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

P2-2x-xxx40
P2-4x-xxx40
P2-2x-xxx30

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

EMC: **EN55022 1998**
EN55024 1998
EN61326 2002

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	October 2003
Name and Signature of authorized person	**Hank Helmond** **Quality Manager, Teledyne DALSA Corp.**



This Declaration corresponds to EN 45 014.

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Appendix C

Communications Protocol

C1 Protocol Overview

This protocol defines the method used to control the camera via a serial interface. The communication protocol defines the command format used and error messages provided.

C2 Protocol Features

- ASCII-based

Camera Serial Port Defaults

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

C3 Command Format and Examples

- A carriage return (CR) ends each command.
- Values in square brackets are optional.
- There are two methods for entering the commands: In long form each command is written in its entirety. In short form, only a predefined abbreviation is required. The manual used the short form.
- The following parameters are used in the manual:

  i = integer
  f = float
  s = string
  t = tap
  x1, x2 = pixel start and stop values
- The camera will answer each command with either "OK >" or "Error x: Error Message >". The ">" is always the last character sent by the camera.

Command Format

```
command_long/short_form [parameters…] CR
```

Example: to set the gain to –3.5dB on all taps

```
set_gain 0 -3.5
```

or

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```
sg 0 -3.5
```

Example: to return the camera model number

`get_camera_model`

or

`gcm`

Example: to begin a camera calibration (dark correction)

`correction_calibrate_fpn` or **`correction_calibrate_fpn i`**

or

`ccf` or **`ccf i`**

C4 Networking Mode

The camera's network feature provides the capability to connect and control multiple cameras over a multi-drop RS485 link.

The network feature consists of three commands and a set of definitions describing the behavior of the camera when the commands are sent in network mode.

Command	Short Form	Description
set_camera_ID	sci	Sets camera network ID
get_camera_ID	gci	Reads camera ID
set_netmessage_mode	snm	0: disable, default (messages enabled) 1: enable (messages disabled)

Camera ID

The camera ID is a single, case insensitive ASCII alphanumeric character: A to Z or 0 to 9.

To change the network ID for a camera, use the command **`sci i i`**. Where the first parameter is an ID of A to Z or 0 to 9, and the second, optional, parameter is the camera's serial number.

To read current camera ID, use the **`gcp`** command.

Changing Network ID of a Camera

To change the ID of a networked camera, even if some or all of the cameras share the same camera ID, provide the serial number of the camera as the second parameter when sending the broadcast version of the **`sci`** command.

Example: change network ID of camera with serial number abcd to 1

```
: sci 1 abcd
```

Note: each camera must be polled following use of a broadcast command.

The Network Commands

The network command is an ordinary camera command prefixed by a network prefix. Network prefixes always start with the colon character "**:**" and are followed immediately

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by the camera ID (addressing a single camera on the network), or space (addressing all cameras on the network or a Broadcast command).

The camera replies to the network command only if it is addressed directly. The last line of the camera reply (error or OK message) to the network command is prefixed with the ID of the camera.

Example: return camera ID for camera a

```
:a gci

camera id: a

a OK>
```

Special Case: Empty Network Command

The empty network command is a special case of network commands. If the last command issued was not a Broadcast command, the empty network command will cause the addressed camera to output an "OK" message followed by the ">" prompt and prefixed by the network ID. If the last command issued was a broadcast command, the empty network command is used to query each camera for its READY/ BUSY status.

Example: empty network command issued

```
:a CR

a OK>
```

Broadcast Commands and READY/BUSY Status

Broadcast commands are commands sent to all cameras on the network at the same time. After a broadcast command is sent, and before issuing the next command, *each* camera on the link must be polled until a READY status is returned. A BUSY status indicates that the camera is not ready to receive the next command.

To poll the status of a networked camera, send an empty network command to each camera until they each return the READY reply.

Both the READY and BUSY reply consist of six characters: Carriage Return (CR), Line Feed (LF), and the network ID of the queried camera, followed by a space and either the BUSY code "0", or the READY code "1" and the prompt character ">".

Example: query command followed by a BUSY reply

```
:a CR

<CR><LF>a 0>
```

Example: query command followed by a READY reply

```
:a CR

<CR><LF>a 1>
```

After all cameras return the READY status, use the **gps** to poll each camera for the return codes of the sent broadcast command.

Note, the QUERY BUSY mode is active only after a broadcast command, normally the camera does not support this mode of operation. The controlling software must wait for a reply from the camera before sending the next command.

Camera will not reply to the Broadcast command.

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To read the status of the last command executed (major error code + coded value of informal messages) and coded value for all pending monitoring task warnings poll each camera by using network version of the **gps** command.

Example: reading status from camera ID "a"

```
:a gps
```

Enabling/Disabling Non-Command Messages in the Network Environment

To enable/ disable camera messages unrelated to the executed command, such as initialization and monitoring task messages, use the command **snm *i***.

Value	Function
0	Enable messages, default
1	Disable messages

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C5 Error Handling

Use the **gps** command to read the status of the last command executed. Return values come in the following order:

- Decimal number representing the code of the last command.
- Decimal number representing the error code for last command executed.
- Decimal value representing sum of all informal message codes caused by last command executed.
- Decimal number representing sum of all pending warning values from all monitoring tasks.

Example: value returned following a ccf command

```
gps

2 0 192 33
```

The returned value, 2 0 192 33, reads as follows:

Returned value	Description
2	Command code: correction_calibrate_fpn
0	Error code: successful
192	Informal message: code 64 + code 128
33	Monitoring task message: code 1 + code 32

The following tables list the codes for errors, informal messages, and monitoring task messages. (Refer to section E7 for a list of all available commands.)

Error Codes		
Code	**Description**	**Suggested Cause**
0	Command executed successfully	Command executed without major error detected
1	Internal camera error (PIXEL INDEX)	Internal software error trap
2	Internal camera error (RESULT CODE)	Internal software error trap
3	Invalid command	Command not recognized
4	Command parameters incorrect or out of range	Command parameters are invalid or out of range
5	Command not available in current exposure mode	**ssf** and **set** are allowed only in mode 2 (**ssf** and **set**) and in mode 6 (**set**)
6	Command available in CALIBRATED mode only	**ccf**, **ccp**
7	Command available in UNCALIBRATED mode only	**cao**, **cag**
8	Command not available in VIDEO TEST mode	**sao**, **sg**
9	Start value must be an odd number less than the even numbered end value	**roi**: invalid starting or ending pixel index
10	Camera memory check failure	Memory test of external RAM failed

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Error Codes		
Code	**Description**	**Suggested Cause**
11	Unable to configure DSP	DSP (FPGA) configuration failure
12	DSP configuration reset failure	DSP (FPGA) could not be placed in configuration mode
13	Get line process command timed out, check for the presence of external signals	**gl**,**gla**,**cao**,**cag**,**ccf**,**ccp** timed out. Current exposure mode requires external SYNC, however SYNC signal not present
14	DSP echo test error	DISC bus communication test failure
15	Invalid sensor configuration (DSP)	Invalid sensor configuration read from DSP (FPGA)
16	Invalid sensor configuration (ADC)	Invalid sensor configuration encoding on the board
17	Sensor configuration mismatch	Sensor configuration read from DSP is different than one encoded on the board
18	One (or more) of the supply voltages is out of specification	**vv** command result
19	The camera's temperature is outside the specified operating range	**vt** command result
20	Not Used	Not Used
21	Analog offset calibration failure	Analog offset calibration failure (could not tune the analog offset to obtain targeted video level)
22	Analog gain calibration failure	Analog gain calibration failure (could not tune the analog gain to obtain targeted video level)
23	CRC check failure while attempting to restore the camera settings	Camera setting will initialize to default settings, since restore of USER/ FACTORY settings failed (internal micro EE memory failure). Contact your DALSA representative or Product Support if this error code is returned.
24	Camera settings not saved	**rus**, **rfs** attempted but settings were not saved. Contact your sales representative or Product Support if this error code is returned.
25	Pixel coefficients write failure	Failure while writing pixel coefficients to EEROM (I2C EEROM external to micro)
26	I2C communication fault while accessing temperature sensor	Serial communication fault (I2C) while accessing temperature sensor
27	Timeout waiting for DISC SYNC to go LOW	Internal communication protocol error
28	Unable to calibrate gain. Tap number outside ROI.	Analog gain could not be calibrated because tap number specified in **cag** command is outside region of interest.
29	Unable to calibrate offset. Tap number outside ROI.	Analog offset could not be calibrated because tap number specified in **cao** command is outside region of interest.

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Informal Message Codes		
Code	**Description**	**Suggested Cause**
1	INFO: CRC check failure while attempting to restore calibration status	Pixel calibration status will be set to NOT CALIBRATED (internal micro EEROM failure)
2	INFO: CRC check failure while attempting to restore pixel coefficients	All pixel coefficients will be reset to zero (external EEROM (I2C) failure)
4	INFO: Flash memory ID error	Reported from boot process, only if DSP configuration fails (possible cause: communication error with serial flash memory)
8	INFO: DSP configuration file missing or corrupt	Reported from boot process, only if DSP configuration fails (possible cause)
16	INFO: Serial communication failure while accessing external ADC chip	Reported from boot process if communication verification fails with external ADC chip (camera voltage measurement, SPI)
32	INFO: Calibration may be out-of-specification (PRNU coefficient clipped)	**ccp**: several coefficients were clipped during the **ccp** command process
64	INFO: Calibration may be out-of-specification (FPN coefficient clipped)	**ccf**: several coefficients were clipped during the **ccf** command process
128	INFO: Calibration may be out-of-specification (DO+FPN > 511)	**ccf**: at least one pixel -> digital offset + FPN coefficient > 511
256	INFO: Changing analog settings of calibration mode voids pixel calibration	**sao**, **sg** in calibration mode after calibration has been done
512	INFO: For better calibration results, run FPN calibration first	**ccp**: **ccp** called before **ccf**
1024	INFO: Coefficient may be inaccurate. A/ D clipping has occured.	Insufficient analog offset or too much gain for given light.

Monitoring Task Message Codes		
Code	**Description**	**Suggested Cause**
1	WARNING: One or more voltages out of specification	At least one of voltages is out of specification
2	WARNING: Camera temperature exceeds specified limit	Current camera temperature exceeds specification limit
4	WARNING: External SYNC not detected	Exposure Mode 3,4,5,6: external SYNC not detected
8	WARNING: External PRIN not detected	Exposure Mode 2: external PRIN not detected
16	WARNING: Analog gain is over/ under the specification	Current analog gain setting is out of specification

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Monitoring Task Message Codes		
Code	**Description**	**Suggested Cause**
32	WARNING: Line rate is set below 1000 Hz	Exposure mode 2: current line rate is below 1Khz

C6 Camera Parameter Screen

You can read current camera settings with the **gcp** command. The table below lists the settings displayed on the gcp screen with sample values, along with a description of some of these settings:

See the following section for a complete command list.

GCP Screen		Desctiption
GENERAL CAMERA SETTINGS		
Camera Model No.:	P2-xx-xxxxx	Camera model number.
Camera Serial No.:	xxxxxxxxx	Camera serial number.
Camera Network ID:	x	Camera network id set with the **sci** command.
Network Message Mode:	disabled	Displays whether network messages are enabled or disabled. Set with the **snm** command. See C4 Networking Mode for details.
Firmware Design Rev.:	xx-xx-xxxxx-xx	Firmware design revision number.
DSP Design Rev.:	xx.xx	DSP design revision number.
SETTINGS FOR UNCALIBRATED MODE:		
Analog Gain (dB):	+0.0 +0.0 +0.0 +0.0	Analog gain value set with the **sg** and **cao** commands. Available only in uncalibrated mode (**svm 0**). See section 3.13 Setting Gains for details.
Analog Offset:	308 324 304 292	Analog offset value set with the **sao** and **cag** command. The **cag** command is available only in uncalibrated mode (**svm 1**). See section 3.12

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GCP Screen		Desctiption
		Optimizing Offset Performance for details.
SETTINGS FOR CALIBRATED MODE:		
Analog Gain (dB):	+0.0 +0.0 +0.0 +0.0	Analog gain value set with the **sg** or **ccp** command. The **ccp** command is available only in calibrated mode (**svm 1**). See sections 3.13 Setting Gains and White Light Calibration (page 37) for details.
Analog Offset:	0 0 0 0	Analog offset value set with the **sao** or **ccf** command. The **ccf** command is available only in calibrated mode (**svm 1**). See section 3.12 Optimizing Offset Performance and Dark Calibration (page 36) for details.
Digital Offset:	0 0 0 0	Digital offset value set with the **sdo** command. Available only in calibrated mode (**svm 0**). See section 3.12 Optimizing Offset Performance for details.
Calibration Status:	FPN(uncalibrated) PRNU(uncalibrated)	Calibration status will change to calibrated after a **ccf** or **ccp** command has been issued after a power up. Calibration status will return to uncalibrated after camera reboot or a **rpc** or **svm 0** command had been issued.
SETTINGS COMMON TO CALIBRATED AND UNCALIBRATED MODES:		
System Gain:	0 0 0 0	Digital gain value set with the **ssg** command. See section 3.13 Setting Gains for details.

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GCP Screen		Desctiption
Background Subtract:	0 0 0 0	Background subtract value set with the **ssb** command. See section 3.12 Optimizing Offset Performance for details.
Pretrigger:	0	Pretrigger value set with the **sp** command. See section 3.20 Setting the Pre-trigger for details.
Number of Line Samples:	64	Number of lines samples set with the **css** command. See section 3.11 Returning Video Information for details.
Video Mode:	1	Current video mode value set with the **svm** command. See section 3.8 Setting the Video Mode for details.
Data Mode:	0	Current data mode value set with the **sdm** command. See section 3.7 Setting the Data Mode for details.
Exposure Mode:	2	Current exposure mode value set with the **sem** command. See section 3.9 Setting Line Rate and Exposure Mode for details.
SYNC Frequency:	5000 (4998.51) Hz	Current line rate. Value is set with the **ssf** command. See section 3.9 Setting Line Rate and Exposure Mode for details.
Exposure Time:	197.950 uSec	Current exposure time setting. Value is set with the **set** command. See section 3.9 Setting Line Rate and Exposure Mode for details.
End-Of-Line Sequence:	on	States whether an end of line sequence is turned on or off. Set using the **eol** command. See section 3.17 Generating Test Patterns for details.

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GCP Screen		Desctiption
`Upper Threshold:`	`240`	Upper threshold value set with the **`sut`** command.
`Lower Threshold:`	`15`	Lower threshold value set with the **`slt`** command.
`Region of Interest:`	`0001-4096`	Region of interest size set with the **`roi`** command. See section 3.10 Setting a Region of Interest for details.

C7 Commands

The following table lists all of the commands available to the camera user. The first column of the table lists command codes returned as first code from **`gps`**.

Parameters:

`i` = integer
`f` = float
`t` = tap selector
`s` = string
`x1` = pixel start number
`x2` = pixel end number
`[]` = optional parameter

Code	Command	Short Form	Parameters	Description
0	calibrate_analog_gain	**`cag`**	**`t i`**	Calibrates the analog gain. The first parameter is the tap selection 1 to 4, 0 for all taps. The second parameter is a line average in a range from 64 to 251DN for 8-bit mode and 256 to 1007DN for 10-bit. This command requires a constant light input and only works in uncalibrated mode.
1	calibrate_analog_offset	**`cao`**	**`t i`**	Calibrates the analog offset. The first parameter is the tap selection 1 to 4, 0 for all taps. The second parameter is a line average in a range from 1 to 100DN for 8-bit mode and 4 to 400 for 10-bit. This command only works in uncalibrated mode.
2	correction_calibrate_fpn	**`ccf`**	**`[i]`**	Start FPN coefficient calibration. Use **`css`** to set sample size. Values range from 1 to 100DN for 8-bit mode and 4 to 400 for 10-bit.
3	correction_calibrate_prnu	**`ccp`**	**`[i]`**	Start PRNU coefficient calibration. Use **`css`** to set sample size. Values range from 64 to 251DN for 8-bit mode and 256 to 1007DN for 10-bit.
4	correction_set_sample	**`css`**	**`i`**	Set number of line samples averaged for pixel coefficient calculations or for output of

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Parameters:

i = integer
f = float
t = tap selector
s = string
x1 = pixel start number
x2 = pixel end number
[ ] = optional parameter

Code	Command	Short Form	Parameters	Description
				gla command. Values: 16, 32, 64. Factory setting: 64
5	display_pixel_coeffs	**dpc**	**[i] [i]**	Display the pixel coefficients in the order FPN, PRNU, FPN, PRNU, … Optional pixel start and end values in a range from 1 to sensor pixel count.
6	endof_line_sequence	**els**	**i**	Set the end-of-line sequence: **0**: Off **1**: On, default value
7	get_camera_id	**gci**		Read the camera ID.
8	get_camera_model	**gcm**		Read the camera model number.
9	get_camera_parameters	**gcp**		Read camera parameters.
10	get_camera_serial	**gcs**		Read the camera serial number.
11	get_camera_version	**gcv**		Read the firmware version and FPGA version.
12	get_fpn_coeff	**gfc**	**i**	Read the FPN coefficient.
14	get_line	**gl**	**[i] [i]**	Get a line of raw video (no digital processing or test pattern) displaying one pixel value after another and the minimum, maximum, and mean value of the sampled line. Optional pixel start and end values in a range from 1 to sensor pixel count.
15	get_line_average	**gla**	**[i] [i]**	Read the average of line samples. Use **css** to set sample size. Optional pixel start and end values in a range from 1 to sensor pixel count.
13	get_prnu_coeff	**gpc**	**i**	Read the PRNU coefficient.
16	get_processing_status	**gps**		Read the status of last executed command and coded value for all pending monitoring task warnings.
17	get_sensor_serial	**gss**		Read the sensor serial number.
18	help	**h**		Display the online help.
19	region_of_interest	**roi**	**i i**	Set the pixel range for reading end-of-line statistic and for the region of pixels used in the **cag**, **cao**, **gl**, **gla**, **ccf**, and **ccp** commands. Pixel start and end values in a range from 1 to

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Parameters:

i = integer
f = float
t = tap selector
s = string
x1 = pixel start number
x2 = pixel end number
[ ] = optional parameter

Code	Command	Short Form	Parameters	Description
				sensor pixel count.
20	reset_camera	**rc**		Reset the entire camera (reboot).
21	reset_pixel_coeffs	**rpc**		Reset the pixel coefficients to 0.
22	restore_factory_settings	**rfs**		Restore the camera's factory settings. FPN and PRNU coefficients reset to 0.
23	restore_user_settings	**rus**		Restore the camera's last saved user settings and FPN and PRNU coefficients.
24	set_analog_offset	**sao**	**t i**	Set the analog offset. The first parameter is the tap selection 1 to 4, 0 for all taps. The second parameter controls the digital analog convertor (DAC), in a range from 0 to 1023, that sets analog offset. Offset increases with higher values.
25	set_baud_rate	**sbr**	**i**	Set speed of serial communication port. Baud rates: 9600, 19200, 57600, and 115200. Default baud: 9600
26	set_camera_id	**sci**	**s [s]**	Set camera ID. The first parameter is a character A to Z, or 0 to 9. The second optional parameter is the serial number of the addressed camera.
27	set_data_mode	**sdm**	**i**	Set the data mode of camera output to: 0: 8-bit, A/ B/ C/ D ports, single processor 1: 10-bit, A/ B/ C and D/ E/ F ports, single processor 2: 8-bit, A/ B and D/ E ports, dual processor 3: 10-bit, A/ B/ C and D/ E/ F ports, dual processor
28	set_digital_offset	**sdo**	**t i**	Subtracts the input value from the video signal prior to the PRNU correction. The first parameter is the tap selection 1 to 4, 0 for all taps. The second parameter is the offset in a range from 0 to 511. Use in calibrated mode only.

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Parameters:

i = integer
f = float
t = tap selector
s = string
x1 = pixel start number
x2 = pixel end number
[ ] = optional parameter

Code	Command	Short Form	Parameters	Description
29	set_exposure_mode	**sem**	**i**	Set the exposure mode: 1: Internal SYNC and PRIN, max line rate and exposure time, factory setting 2: Internal SYNC and 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
30	set_exposure_time	**set**	**f**	Set the exposure time in exposure mode 2 or 6. Value will be a floating point number in µsecs
31	set_fpn_coeff	**sfc**	**i i**	Set the FPN coefficient. The first parameter is the pixel number within the range 1 to 8192. The second value is a specified value within the range 0 to 127.
32	set_gain	**sg**	**t f**	Set the analog gain. The first parameter is the tap selection 1 to 4, 0 for all taps. The second parameter is a gain value specified from –10 to 10. A gain value of 0 sets the camera to its nominal gain.
33	set_lower_threshold	**slt**	**i**	Set the lower threshold to a value from 0 to 255 for 8-bit data modes, and 0 to 1023 for 10-bit.
34	set_netmessage_mode	**snm**	**i**	Enable/ disable camera messages unrelated to the executed network command: **0**: Enable messages, default **1**: Disable messages
35	set_pretrigger	**sp**	**i**	Set the pretrigger to a value from 0 or 15.
36	set_prnu_coeff	**spc**	**i i**	Set the PRNU coefficient. The first parameter is the pixel number within the range 1 to 8192. The second parameter is a specified value within the range 0 to 511where:

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Parameters:

i = integer
f = float
t = tap selector
s = string
x1 = pixel start number
x2 = pixel end number
[ ] = optional parameter

Code	Command	Short Form	Parameters	Description
				$PixelPRNU = 1 + \frac{i}{512}$
37	set_subtract_background	**ssb**	**t i**	Subtracts the input value from the output signal. The first parameter is the tap selection 1 to 4, or 0 for all taps. The second parameter is the subtracted value range from 0 to 511.
38	set_sync_frequency	**ssf**	**i**	Sets the line rate, in exposure mode 2, to a value from 1000Hz to camera's maximum line rate. Value rounded up/ down as required.
39	set_system_gain	**ssg**	**t i**	Set the digital gain. The first parameter is the tap selection 1 to 4, or 0 for all taps. The second parameter is a gain value is specified from 0 to 511.
40	set_upper_threshold	**sut**	**i**	Set upper threshold to a value from 0 to 255 in 8-bit data modes, and 0 to 1023 in 10-bit.
41	set_video_mode	**svm**	**i**	Switch between calibrated and uncalibrated modes: **0**: Uncalibrated video, deactivate video correction **1**: Calibrated video, activated correction **2**: Test pattern
42	verify_temperature	**vt**		Check the internal temperature of the camera.
43	verify_voltage	**vv**		Check the camera voltages and return OK or fail.
44	warning_enable_disable	**wed**	**[i] [i]**	Read enable/ disable status of all defined monitoring tasks. Optionally, the first parameter selects a monitoring task and the second parameter enables/ disable the selected task.
45	write_pixel_coeffs	**wpc**		Write all current pixel coefficients to EEROM.
46	write_user_settings	**wus**		Write all of the user settings to EEROM except pixel coefficients which are written using the **wpc** command.

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Appendix D

DC Offset De-rating Curve

As of December 2004, all Piranha 2 line scan cameras have been modified. This modification has caused:

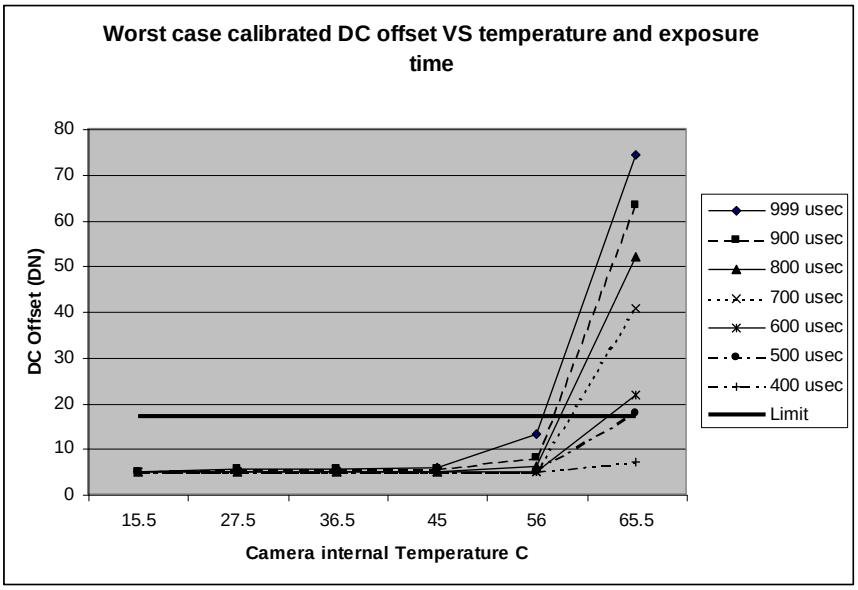
- The Charge Transfer Efficiency (CTE) of the sensor to be improved, and
- An increase in dark current at the minimum line rate and maximum gain.

This increased dark current is only an issue when the camera is using long integration times, at the maximum gain setting, or at high ambient temperatures. Operating the camera at high temperatures or at low line rates with maximum gain, impacts the camera's ability to perform offset calibration. Figure 12 illustrates camera operating conditions and the associated limits for optimal offset calibration. The offset values indicated are the values obtained after issuing the **`cao 0 5`** (calibrate analog offset) command. The plot shows the DC offset over temperature at maximum gain with the optimal offset calibration limit being represented by the Limit line. The area under the Limit line shows the operating conditions where the camera's offset can be calibrated to camera specifications; the area above the Limit line shows the operating conditions where the camera's DC offset is greater than camera specifications. If you are operating the camera in this range, you may want to reduce the effect of the increased dark current by:

- Adjusting the calibration target value higher to enable offset compensation to work. For example, **`cao 0 30`**.
- Adding cooling to reduce temperature. Refer to the Thermal Management section on page 43 for more information.
- Operating the camera at higher line rate and averaging or discarding the extra lines

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Figure 12: Worst Case Calibrated DC Offset vs. Temperature and Exposure Time



Notes:

- Camera ambient temperature is approximately 15°C less than the internal camera temperature.
- Camera gain is 10dB

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Appendix E

Revision History

Revision Number	Change Description
00	Preliminary release
01	Updated pgs 9-10: Added sensor alignment specifications of x,y: ±175um, z: ±0.18mm and ø: 0.6°. Changed FPN uncorrected: Max Gain 27DN. Changed RMS Noise: typ. 1.2DN, max 4DN. Added Notes: All measurements taken in 8-bit output mode; All specifications are valid for the front plate temperature range of 10°C to 50°C, in still air. Added Notes 4 and 5. Page 25,26 Mechanicals drawings: Included specifications on the location of pixel 1 with respect to edges of the front plate. On page 27 removed nominal from C, F-Mount chart and replaced with ±0.18mm
02	1K, 2k, and 4K--2 tap Piranha 2 cameras available.
03	Mostly minor text and spec changes, plus replacing Doody with Helmond on EMC declaration
04	Added note 4 on page 10. Added section 3.10, page 27, Setting a Region of Interest. Added section 3.11, page 27, Returning Video Information. Removed all references of the css command default being 128 and changed it to 64. On page 31, Calibrating Gains, changed allowable ranges from 64 (was 128) to 251 and 256 (was 512) to 1007. Added error message 28 and 29 on page 64. Removed error message 20. Added informal message codes 32 and 64 on page 65. Added section C6 Camera Parameter Screen on page 65. In section C7, command table: cag: range is now 64 (was 128) to 251 or 256 (was 512) to 1007 ccp: range is now 64 (was 128) to 251 or 256 (was 512) to 1007 css: 64 is now the factor setting. 128 was removed. roi: explanation expanded to include the roi influence on the cag, cao, gl, gla, ccf and ccp commands.
05	Added P2x-xxx30 part number to front cover. Added 30MHz info to section 1.1 Camera Highlights. Added 30MHz specs to section 1.3 Camera Performance Specifications Added Note 1 on page 10 Added table 5, page 20, 30MHz timing values Added P2-2x-xxx30 to EMC Declaration of Conformity, page 61.
06	Updated drawing in section 2.2. LED was referenced to section D13 which no longer exists. It is now referenced to section 3.18. In section 3.16, page 39, and Appendix B, All Available Commands table, added equation for determining the PRNU coefficient for the spc command.

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Revision Number	Change Description
07	Added the following note (or similar) to these sections, "While settings are being written to nonvolatile memory, do not power down camera or camera memory may be corrupted." 1. Section 3.5, page 25, second bullet 2. Page 36, middle of page in calibration section 3. Section 3.18 in the LED description table, Blinking Green section Added revision history.
08	Fixed incorrect ± character in mechanical drawings. Updated Colorado Springs address Added Appendix D: De-rating Curves Removed maximum DC Offset specification from Specification table in Chapter 1 and added note 6 to refer to Appendix D for DC Offset de-rating curves.
09	Added 8k 30MHz model to: Table 1: Operating Requirements and Ranges (max line rate) Table 7: Piranha 2 30MHz Timing
10	Added 4k, 10µm model to: Section 1.2 Image Sensors [Figure 2: IT-P1 4k Image Sensor (2k, 4k (10 µm), 4 tap models)] Section 1.3 Camera Performance Specifications (power and power supply current specs)
11	Added 2k, 4 tap model to: Section 1.2 Image Sensors [Figure 2: IT-P1 4k Image Sensor (2k, 4k (10 µm), 4 tap models)] Section 1.3 Camera Performance Specifications (power and power supply current, line rate specs) Added Figure 1: IL-P1 Image Sensor (1k, 2k, 4k (10 µm), 2 tap models) to Chapter 4, Mechanical Interface Updated z tolerance from .18mm to .25mm in table 1 and Lens Mount table (page 47).
12	Table 1. P2 Operating Requirements and Ranges, page 9, revised Typical values under Power Supply Current for the 6144 (2/ 4 o/ p) and 8192 (2/ 4 o/ p) to 580/ 800 and 620/ 830 mA respectively. Section 2.5, page 16, "The camera ships in..." statement revised to read, "The camera ships in exposure mode 2 and with a 5 kHz line rate." GCP screen, page 70, "Sensor Serial No.: XXXXXXX Sensor serial number" row removed from table.
13	-EMC requirements, page 61, revised to: EN55022 1998, EN55024 1998, EN61326 2002. -Page 9: Operating Requirement Typical Power 4096(10um)-2 o/ p 7.5 4096(10um)-4 o/ p 9.6 6144 - 2/ 4 o/ p 7.5/ 9.6 Power Supply Current (Vin = +12V) 4096 - 2/ 4 o/ p 500/ 700 4096(10um) - 2 o/ p 600 4096(10um) - 4 o/ p 800 6144 - 2/ 4 o/ p 600/ 800 8192 - 2/ 4 o/ p 620/ 840

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Revision Number	Change Description
14	The following note was removed from page 37 as this feature is not available for this camera model: "3. The variance in light intensity across the target must not be more than 4 to 1. Because the maximum per-pixel digital gain is 2x, the camera will not be able to compensate for extremely non-uniform light."

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