Enhanced Sensitivity Line Scan/Area Scan CCD Camera

Piranha ES-Sx

Camera User's Manual

ES-S0-12K40 HSLink

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www.teledynedalsa.com

TELEDYNE DALSA
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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.

Support

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

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IMPORTANT: Handling Warning page 47.

Contents

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Introduction to the Piranha ES-Sx Camera

1.1 Camera Highlights

Features

- 12000 x 64 pixels TDI, 5.2 µm x 5.2 µm pixel pitch, 90% fill factor.
- 90 kHz line rate.
- Bidirectional.
- Area Mode operation.

Programmability

- HSLink control interface, 115200 fixed signal baud rate.
- Programmable gain, offset, frame and frame rates, trigger mode, test pattern output, and camera diagnostics.
- Mirroring and forward/reverse control. Mirroring is controlled by Sapera software, not by the camera.
- Selectable Area or TDI Mode of operation. Area Mode facilitates camera alignment and focusing. Area mode can also be used for regular operation.
- Flat-field correction—minimizes lens vignetting, non-uniform lighting, and sensor FPN and PRNU. Flat-field correction is available in TDI mode only; it is not avaliable in Area mode.

Description

The Piranha ES camera family represent Teledyne DALSA's latest generation of enhanced sensitivity, TDI based cameras. The Piranha ES family maximizes system throughput and provides the largest number of pixels available in a TDI camera. All cameras are capable of bi-directionality with 64 stages of integration.

Applications

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

- Flat panel display inspection
- Printed circuit board inspection
- High performance document scanning
- Large web inspection
- Low-light applications
- Postal sorting (flats)

Models

The Piranha ES-Sx cameras are available in these models.

Table 1: Piranha ES-Sx Camera Models Overview

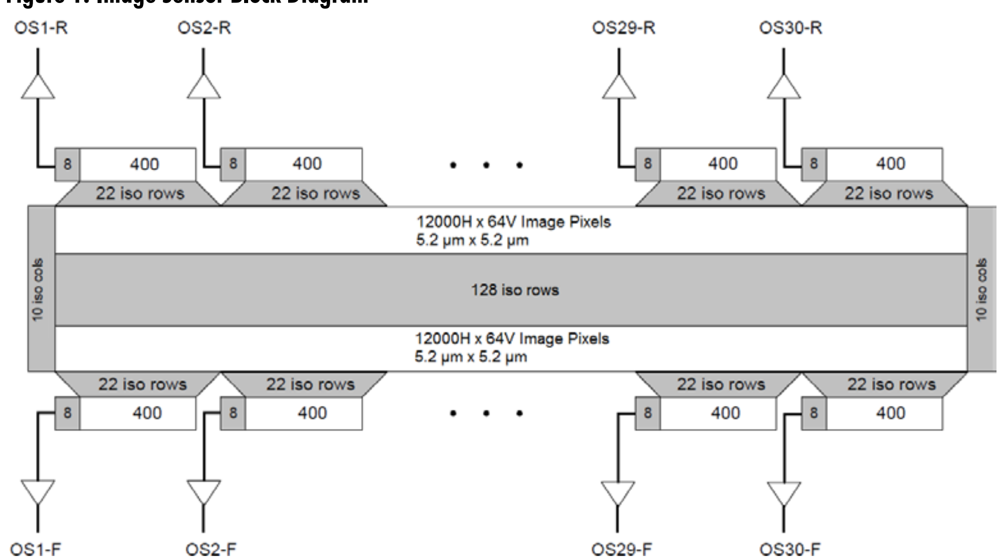
Model Number	Description
ES-S0-12K40	12k resolution, 90 kHz line rate, 1.08 Gpix/s throughput, HSLink interface.

Throughout the manual, the cameras are refered to as the Piranha ES-Sx camera family unless a section is valid to a specific model only where the camera's model number is used.

Sensor

The camera uses a bidirectional TDI sensor. The camera can be configured to read out in either Forward or Reverse CCD shift direction. This is controlled by the software command **scd**.

Figure 1: Image Sensor Block Diagram



1.2 Camera Performance Specifications

Table 2: Camera Performance Specifications

Feature / Specification	
Imager Format	Bidirectional TDI
Resolution	12000 x 64 pixels
Pixel Fill Factor	90 %
Pixel Size	5.2 µm x 5.2 µm
Antiblooming	TBD
CCD Shift Direction Change	0.02 seconds
Optical Interface	
Back Focal Distance	
M72 Mount	6.56±0.25 mm
Sensor Alignment (aligned to sides of camera)	
Flatness	25 µm
Θ y (parallelism)	100 µm
x	±0.175 mm
y	±0.175 mm
z	±0.25 mm
Θ z	±0.6 °
Lens Mount Hole	M72x0.75
Mechanical Interface	
Camera Size (w x h x d)	90 x 180 x 92.1 mm
Mass	< 1500 g
Connectors	
power connector	2-pin Lemo
control / data connector	HSLink
Electrical Interface	
Input Voltage	24 ±10 % Volts DC
Power Dissipation	< 39 W
Operating Temperature[1]	0 °C to 50 °C
Bit Depth	8, 10, or 12 bit selectable
Output Data Configuration	HSLink
Operating Ranges	
Minimum Line Rate	1 Hz
Maximum Line Rate	90 KHz
Throughput	1.08 Gpix/s
Gain	0 to +20 dB

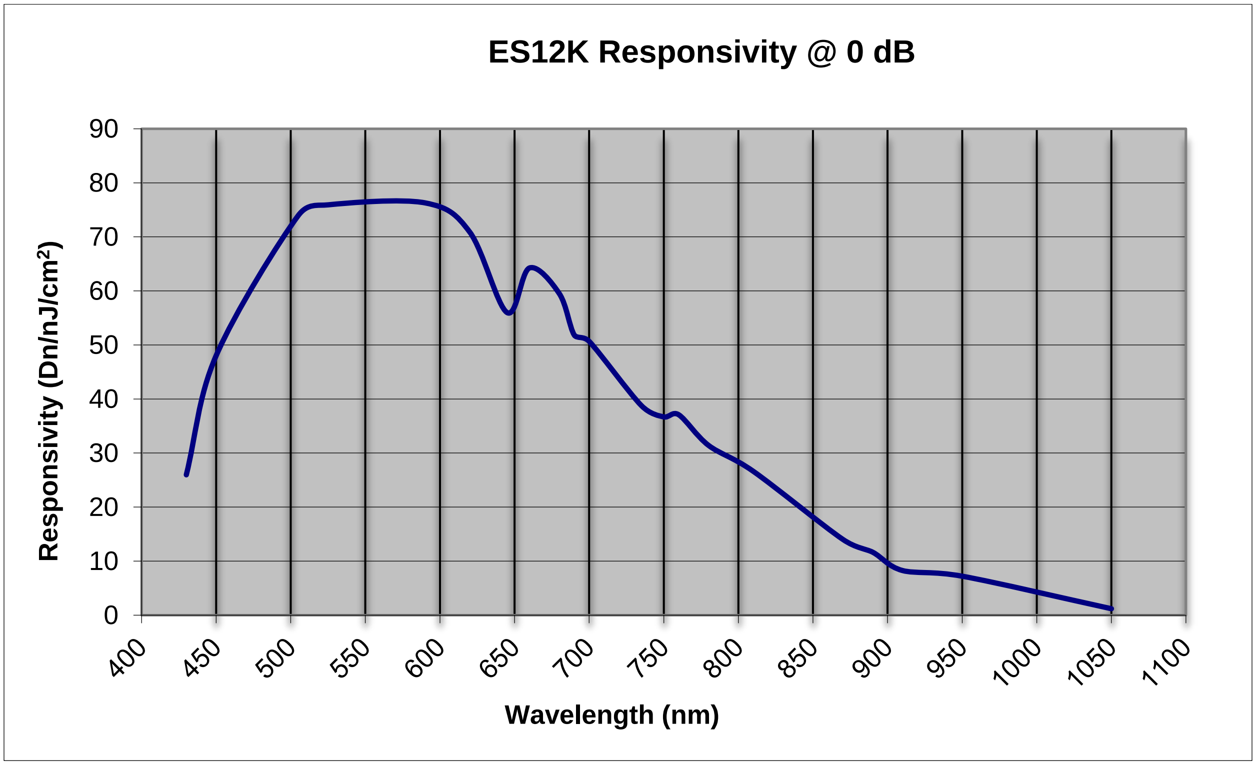
Test conditions unless otherwise noted:

- TDI mode of operation. These specifications are not guaranteed for area mode of operation.
- Line Rate: 10 kHz.
- Nominal Gain setting 0 dB.
- Light Source: Broadband Quartz Halogen, 3250 k, with 700 nm IR cutoff filter installed.
- All specifications are measured at 25 °C (front plate measurement).
- All values are referenced at 8-bit.

1. Measured at the front plate. It is the user's responsibility to insure that the operating temperature does not exceed this range.

Performance	Min Gain 0dB			Min Gain +10dB			Min Gain +20dB		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Dynamic Range	500			160			50		
Random Noise DN rms			0.5			1.5			4.8
SEE nJ/cm^2		3.4			1.1			0.33	
NEE pJ/cm^2		6.4			6.4			6.4	
Corrected Broadband Responsivity (DN/nJ/ cm$^{2)}$		75			237			750	
FPN DN p-p with correction			2						
FPN DN p-p w/o correction			4			13			41
PRNU DN p-p with correction			2						
PRNU % w/o correction			25			25			25
Saturation Output Amplitude DN	255								
DC Offset DN	3			5			7		

1.3 Responsivity



2

Camera Hardware Interface

2.1 Installation Overview

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

When installing your camera, you should take these steps:

1. Power down all equipment.
2. Follow the manufacturer's instructions to install the framegrabber (if applicable). Be sure to observe all static precautions.
3. Install any necessary imaging software.
4. Before connecting power to the camera, test all power supplies. Ensure that all the correct voltages are present at the camera end of the power cable. Power supplies must meet the requirements defined in the Power Connector section below.
5. Inspect all cables and connectors prior to installation. Do not use damaged cables or connectors or the camera may be damaged.
6. Connect data and power cables.
7. After connecting cables, apply power to the camera.
8. Check the diagnostic LED. See LED Status Indicator for an LED description.

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

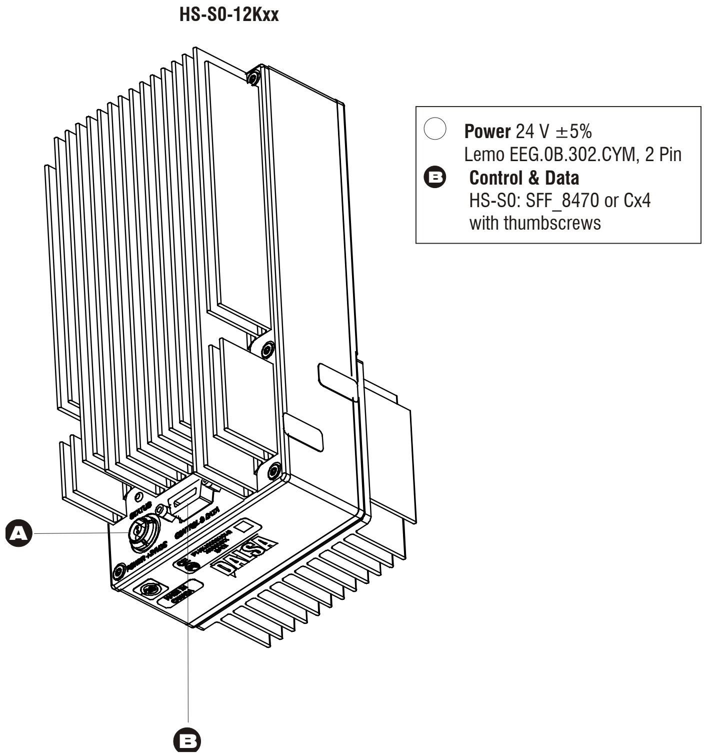
*Please see 4.3 High Temperature and Mounting for more information on camera mounting and heat dispertion.

2.2 Input/Output Connectors and LED

The camera uses:

- A diagnostic LED for monitoring the camera. See LED Status Indicator for details.
- ES-S0 model: SFF_8470 / CX4 (with thumbscrews) for control, data and serial communication.
- One 2-pin Lemo connector for power. Refer to the Power Connector section below for details.

Figure 2: Piranha ES-S0 Input and Output Connectors



WARNING: It is extremely important that you supply the appropriate voltages to your camera. Incorrect voltages will damage the camera.

LED Status Indicator

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

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

Table 3: ES-S0 HSLink Diagnostic LED

Color of Status LED	Meaning
Green solid	Camera is operational and functioning correctly.
Green blinking, fast	FG only - LVAL present but not grabbing (20 second time out)

Color of Status LED	Meaning
Green blinking, slow	Waiting for LVAL/Trigger Line Scan – 5 second timeout Area Scan- 20 second timeout
Orange (red and green on together) solid	Running on FPGA/micro backup
Orange blinking, slow	Loss of functionality
Orange one pulse of 0.2 sec	Random Error with HSLINK
Red blinking, fast	Fatal Error- Loss of FPGA code and or micro code
Red blinking, medium	Fatal Error- Loss of other hardware which prevents operation
Red blinking, slow	Over temperature (HSLINK CMD channel still functional)
Red / Green alternating, fast	Link Up, but idle not locked (held in Farend reset)
Red / Green alternating, medium	Incompatilbe HSLINK configuration
Red / Green alternating, slow	Looking for Link

Power Connectors

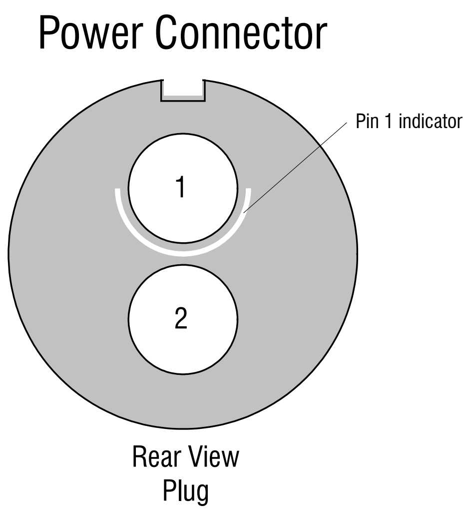


Table 4: Lemo 2-pin Circular Male—Power Connector

Lemo EEG.0B.302.CYM, 2 Pin	
Pin	**Description**
1	Supply voltage, 24 ±10% Volts
2	Ground

The camera requires a single voltage input (24 V). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear supplies provide optimum performance.

Table 5: Power Mating Connectors

FHG.0B.302.CYCD52 (right angle)
FGG.0B.302.CYCD52 (straight)

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

- Apply the appropriate, reliable voltages
- Protect the camera with a **slow-blow fuse** between power supply and camera (2x nominal current).
- Do not use the shield on a multi-conductor cable for ground.
- Keep leads as short as possible to reduce voltage drop.
- Use high-quality **linear** supplies to minimize noise.
- Use an isolated type power supply to prevent LVDS common mode range violation.
- A stable supply of power must be maintained during code upgrades. Camera will fail if power is lost or unstable while updating code. The user can not recover from this failure and the camera will have to be returned to Teledyne DALSA for repair.

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

Data Connectors

HSLink Pinout

SFF_8470 (or CX4) with thumbscrews			
Signal	**Camera**	**Frame Grabber Input**	**Frame Grabber Signal**
DataTx 2+	S16	S1	DataRx 2+
DataTx 2-	S15	S2	DataRx 2-
DataTx 1+	S14	S3	DataRx 1+
DataTx 1-	S13	S4	DataRx 1-
DataTx 0+	S12	S5	DataRx 0+
DataTx 0-	S11	S6	DataRx 0-
Cmd_T+	S10	S7	Cmd R+
Cmd_T-	S9	S8	Cmd R-
Cmd_R-	S8	S9	Cmd_T-
Cmd_R+	S7	S10	Cmd_T+
DataTx 5-	S6	S11	DataRx 5-
DataTx 5+	S5	S12	DataRx 5+
DataTx 4-	S4	S13	DataRx 4-
DataTx 4+	S3	S14	DataRx 4+
DataTx 3-	S2	S15	DataRx 3-
DataTx 3+	S1	S16	DataRx 3+
Signal Ground	G1- G9	G1- G9	Signal Ground
Signal Ground	H1-H2	H1-H2	Signal Ground

Input Signals

The camera accepts control inputs through the HSLink connector.

Table 6: Camera Control Configuration

Signal	Configuration
CC1	EXSYNC
CC3	Forward

The camera ships in internal sync, internal programmed integration (exposure mode 7) TDI Mode.

EXSYNC (Triggers Frame Readout)

Frame rate can be set internally using the serial interface. The external control signal EXSYNC is optional and enabled through the serial interface. This camera uses the **falling edge of EXSYNC** to trigger pixel readout. Section Exposure Mode and Line/Frame Rate for details on how to set frame times, exposure times, and camera modes.

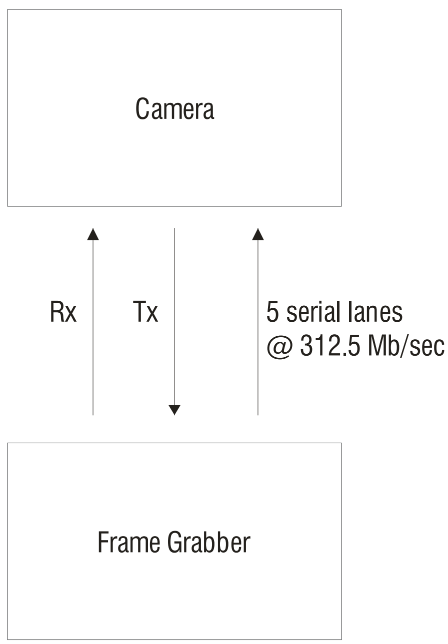
IMPORTANT:
This camera's data should be sampled on the rising edge of STROBE.

Direction Control

You control the CCD shift direction through the serial interface. With the software command, **scd**, you determine whether the direction control is set via software control or via the control signal on CC3. Refer to section Setting the Camera's CCD Shift Direction for details.

Output Signals

Note that LVAL and FVAL are embedded in data lanes. For additional information refer to the HSLink supplementary information below.



Accessories

We can supply HSLink and DC power cables. Contact us and use the following part numbers to order:

Part No.	Description
AC-CA-00405-xx-R	HSLink data cable 5M with screw lock connectors
AC-CA-00410-xx-R	HSLink data cable 10M with screw lock connectors
AC-CA-00415-xx-R	HSLink data cable 15M with screw lock connectors
AC-CA-00115-xx-R	DC power cable. Lemo 2-pin to open-ended cable.

HSLink cables are also available from a number of supplies, including:

www.componentsexpress.com
www.gore.com

Frame Grabbers

The ES-S0 model cameras (HSLink) are compatible with the Xcelera-HS PX8 framegrabber.

HSLINK 12k and Frame Grabber Supplementary Information

Teledyne DALSA designed and pioneered the HSLink as a comprehensive camera-frame grabber communication standard targeted at machine vision industry use. The HSLink 12k and frame grabber product are based on the fundamental capabilities of this new interface.

We are working with industry partners to improve and to broaden the interface's appeal for the machine vision industry and as a result expect that the original specification will change and be improved. Our products delivered during this draft specification phase will be field upgradeable so that customers can gain the benefit from an industry approved interface. The table below summarizes the major functions supported with the alpha product.

HSLINK Function	Alpha (Q4 09)	Comment
Cable Disconnect Recovery	No	Alpha cameras will only properly lock to frame grabber when the camera is turned on before or after starting the data acquisition program. Turn off the camera when exiting a program that uses the Frame grabber.
Data Forwarding	Yes	Customer must identify the Master/Slave Frame grabber during the system configuration step. There is no Master/Slave communication channel support.
Communication Between FG	No	This is the GMII command channel and will enable auto enumeration of slaves and data resend requests from the slaves.
Video Data Resend	No	Master/Slave command channel used for error communication from slave is not available at this time. Can be field upgraded.
LED functions	No	
GeniCam	No	Use the ASCII serial command set for the Alphas.
Trigger/ Direction Control	Yes	
Area/Line Scan Mode	Yes	
12 bit mode	No	Data will be packed on the Link. This will exceed the PCIx 8 Gen 1 bandwidth.
Missed Trigger Flag	No	
DATA CRC Error Flag	Yes	CRC error counters available
Header Error Flag	Yes	Header error counter available
8b/10B Error counter	Yes	Enables BER calculation
Test Patterns	Yes	Good for system debug
Data Lost Flag	No	Indicates missing rows of information
Camera Data buffer overflow	No	
Idle Lock Lost	No	
Far end Reset	No	
Cmd Packet Failure	No	

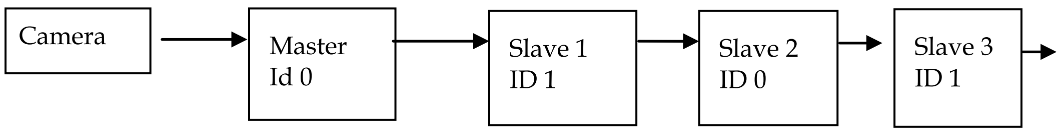
Master/Slave HSLINK reset	No

Camera to Master Frame grabber Power On Discovery Notes

The camera and frame grabber will correctly discover each other if either the camera or the frame grabber are turned on or off, regardless of order.

Master to Slave Power On Discovery Notes

Please Note: The communication channel between master and slave frame grabbers is not functional at this time and therefore must be configured manually, as shown below:



The power on sequence for the Alphas to guarantee function is

1. Camera/Master
2. Slave 1
3. Slave 2
4. Slave 3
5. Slave 4
6. Slave 5

The slave should only be turned on once an image is acquired by the preceding slave.

3

Software Interface: How to Control the Camera

This chapter outlines the more commonly used commands. See A2 Commands for a list of all available commands.

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

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

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

Note: This command set has changes from previous Teledyne DALSA cameras. Do not assume that the Piranha ES commands perform similarly to older cameras.

Serial Protocol Defaults

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 115,200 kbps baud rate
- Camera does not echo characters

Command Format

When entering commands, remember that:

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

- The camera will answer each command with either <CR><LF> OK > or <CR><LF> Error xx: Error Message > or Warning xx: Warning Message >. The > is used exclusively as the last character sent by the camera.

The following parameter conventions are used in the manual:

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

Example: to return the current camera settings

gcp <CR>

Setting Baud Rate

Note on ES-S0 models and baud rate

The ES-S0 cameras employ an 115,200 fixed signal baud rate.

Setting Bit Depth

Set the camera's bit depth using the set data width command. The command is in the form **sdw f**, where the f parameter is 8, 10, or 12—corresponding to 8, 10, or 12-bit outputs, respectively. For example, to set an 8-bit output, use the command **sdw 8**.

Save the selected bit depth using the write user settings command (wus).

Note: For 8 and 10 bit depths, the number of lanes must be set to 5 in Sapera.

For 12 bit depth, the number of lanes must be set to 6 in Sapera.

Camera Help Screen

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

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

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

Syntax:	**h**

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

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

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

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

3.1 First Power Up Camera Settings

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

- TDI mode
- Left to right pixel readout
- Forward CCD shift direction
- 64 integration stages
- ES-S0: 640 throughput
- Exposure mode 7
- 10 kHz line rate
- Factory gain 0 dB
- Factory calibrated FPN and PRNU coefficients.

Note regarding start-up times: This camera requires approximately 20 seconds to power up.

3.2 Sensor Output Format

Selecting TDI or Area Mode Operation

The Piranha ES-Sx cameras have the ability to operate in both TDI and Area Mode.

In Area Mode, the camera operates as an area array camera using a two dimensional array of pixels. Area Mode is useful for aligning the camera to your web direction or when you need a rectangular 2D image and the lighting supports a full frame imager.

In TDI Mode, the camera operates as a TDI enhanced sensitivity line scan camera and combines multiple exposures of an object into one high-resolution result.

The camera stores user settings for Area Mode and TDI Mode separately, allowing you to switch between Area and TDI mode without losing settings specific to each mode. See section 3.4 Saving and Restoring Settings for an explanation on how user settings are stored and retrieved.

In Area Mode use either a strobe or a low frame rate to avoid image smear. TDI operation requires good speed matching between your object and image.

NOTE: Sensor cosmetic specifications for Area Mode of operation are neither tested nor guaranteed.

Purpose:	Selects the camera's operating mode. Area Mode is useful for aligning and focusing your camera.
Syntax:	**`tdi i`**
Syntax Elements:	***i*** **0** Area mode **1** TDI mode
Notes:	• Remember to save your user settings before changing mode. Sending the **`tdi`** command **always** restores your last saved user

settings for the mode of operation requested even if you are already operating in the requested mode. See section 3.4 Saving and Restoring Settings for an explanation on how user settings are stored and retrieved for each mode.

- Flat field correction is not available in Area Mode

Example **`tdi 1`**

Setting the Camera's CCD Shift Direction

Purpose: When in TDI Mode, selects the forward or reverse CCD shift direction or external direction control. This accommodates object direction change on a web and allows you to mount the camera "upside down".

In Area Mode, selects the vertical readout direction. This allows you to mirror the image vertically or mount the camera "upside down".

Syntax: **`scd i`**

Syntax Elements: ***i***

Readout direction. Allowable values are:

0 = Forward CCD shift direction.

1 = Reverse CCD shift direction.

2 = Externally controlled CCD shift direction via HSLink control CC3 (CC3 = 1 forward, CC3 = 0 revese).

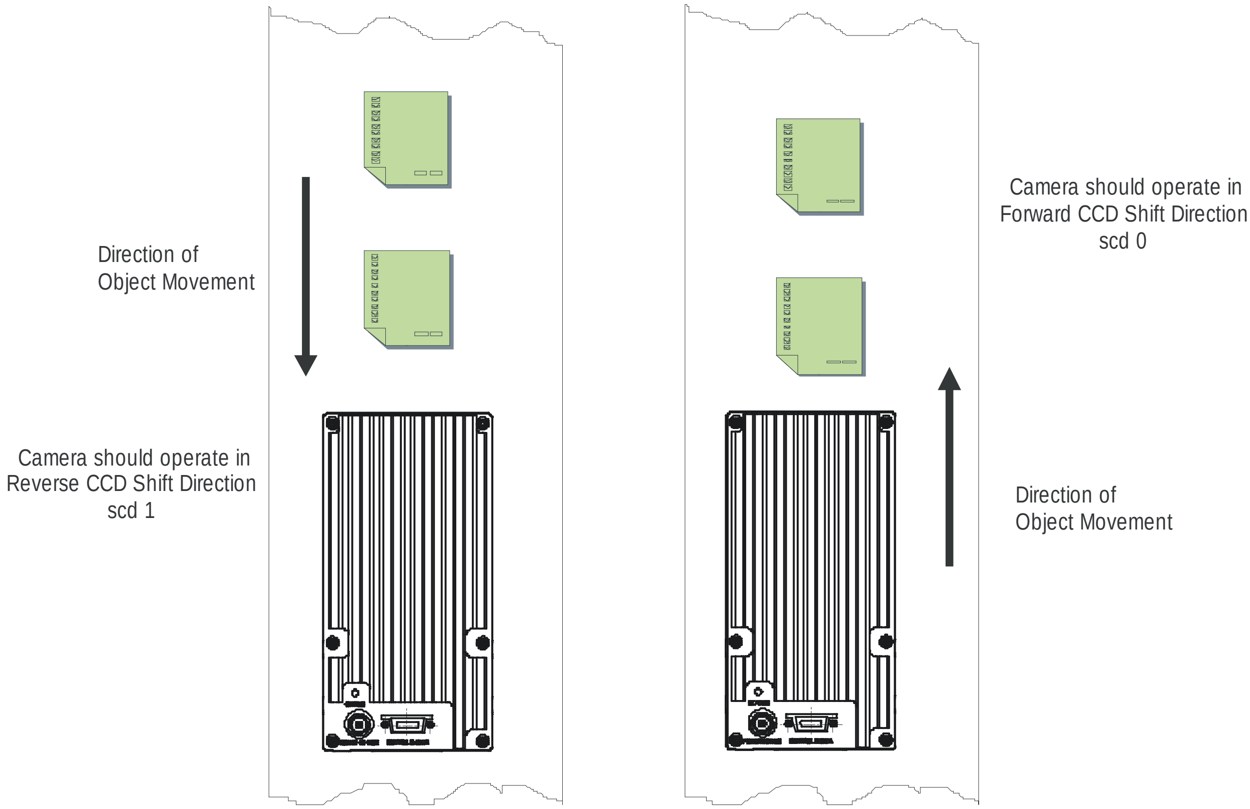
Note: ES-S0: Direction tied to bit 5 GPIO output of HSLink.

Notes:

- The following user settings are stored separately for forward and reverse direction; background add, background subtract, system gain, and pixel coefficients. These settings are automatically loaded when you switch direction. All other settings are common to both directions.
- See the following figures for an illustration of CCD shift direction in relation to object movement.
- Note that some commands that require longer processing time, like **`ccg`**, delay implementation of an external direction change.

Example **`scd 1`**

Figure 3: Object Movement and Camera Direction Example using an Inverting Lens



Exposure Mode and Line/Frame Rate

How to Set Exposure Mode and Line/Frame Rate

You have a choice of operating the camera in one of two exposure modes. Depending on your mode of operation, the camera's line/frame rate (synchronization) can be generated internally through the software command **ssf** or set externally with an EXSYNC signal (CC1). When operating in TDI Mode, it is important that the line rate used matches the web speed. Failure to match the web speed will result in smearing. Refer to the application note, "Line Scan/TDI Line Scan Calculation Worksheet" located on the Knowledge Center page of our website, for a further explanation on how to synchronize your web speed.

To select how you want the camera's line/frame rate to be generated:

1. You must first set the camera's exposure mode using the **sem** command. Refer to section Setting the Exposure Mode below for details.
2. Next, if using mode 7, use the command **ssf** to set the line/frame rate. Refer to section Setting Frame Rate for details.

Setting the Exposure Mode

Purpose:	Sets the camera's exposure mode allowing you to control your sync and line/frame rate generation.
Syntax:	**sem** ***m***
Syntax Elements:	**m** Exposure mode to use. Factory setting is **7**.
Notes:	• Refer to Table 7: Piranha ES Exposure Modes for a quick list of available modes or to the following sections for a more detailed explanation including timing diagrams. • To obtain the current value of the exposure mode, use the command **gcp** or **get sem**. • When setting the camera to external signal modes, EXSYNC must be supplied. • Refer to section **Error! Reference source not found.** for more information on how to operate your camera in TDI or Area Mode. • Exposure Modes are saved separately for TDI Mode and Area Mode. Refer to section 3.4 Saving and Restoring Settings for more information on how to save camera settings.
Related Commands:	**ssf**
Example:	**sem 3**

Table 7: Piranha ES Exposure Modes

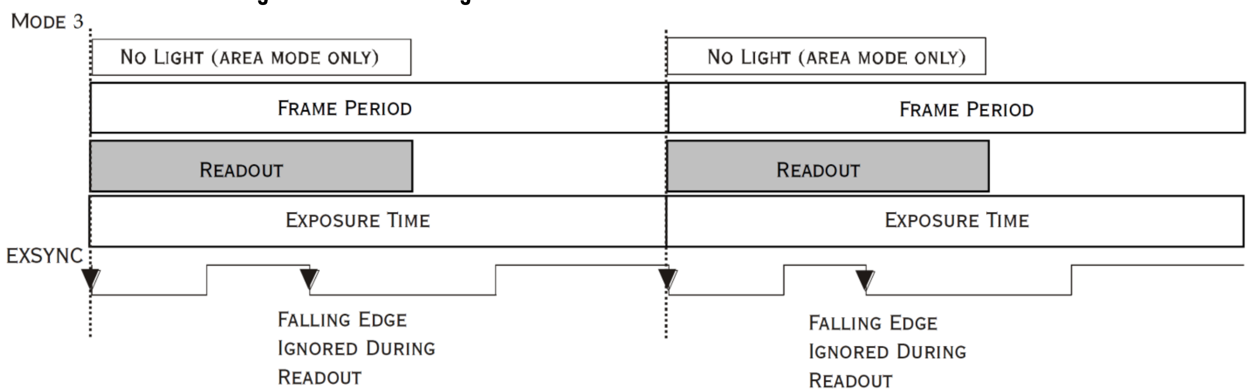
Mode	SYNC	Programmable Frame Rate	Programmable Exposure Time	Description
3	External	No	No	Maximum exposure time with no charge reset.
7	Internal	Yes	No	Internal sync, maximum exposure time with no charge reset.

Exposure Modes in Detail

Frame rate is set by the period of the external trigger pulses. EXSYNC pulses faster than the read out time are ignored. The falling edge of EXSYNC marks the start of readout.

Note: In TDI mode the frame period equals the line period.

Figure 4: Mode 3 Timing

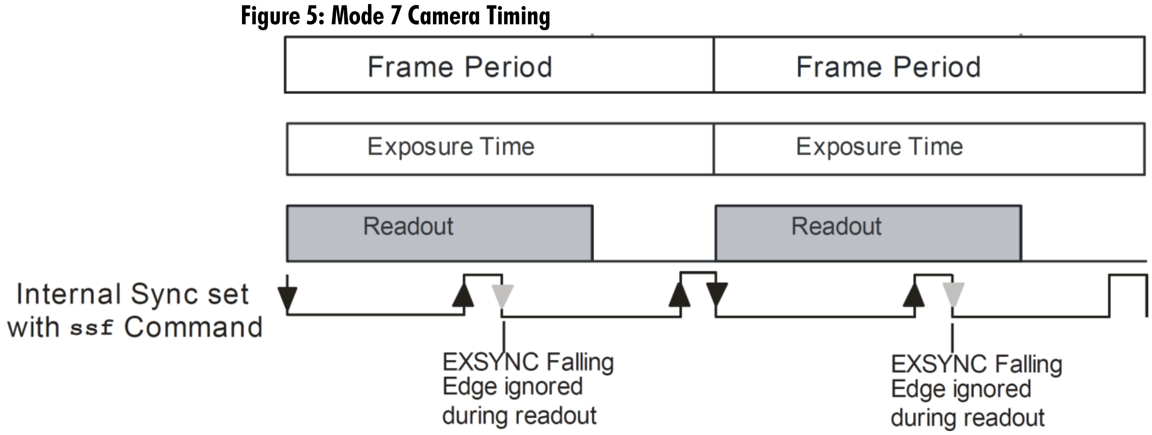


Mode 7: Internal Frame Rate, Maximum Exposure Time

In this mode, the frame rate is set internally using the **ssf** command with a maximum exposure time.

Note: In TDI mode the frame period equals the line period.

Figure 5: Mode 7 Camera Timing



Setting Frame Rate and Exposure Time

Purpose: Sets the camera's frame rate in Hz. Camera must be operating in exposure mode 7.

Syntax: **ssf *f***

Syntax Elements: **f**

Set the frame rate to a value from:

TDI

ES-S0: 1to 90,822

Area

ES-S0: 1 to 350

Value rounded up/down as required. The maximum line/frame rate is affected by throughput setting.

Notes:

- If you enter an invalid frame rate frequency the value, the camera clips the frame rate to be within the current operating range and a warning message is returned.
- If you enter a frame rate frequency out of the range displayed on the help screen, an error message is returned and the frame rate remains unchanged.
- To return the camera's frame rate, use the commad **gcp** or **get ssf**.

Related Commands: **sem**

Example: **ssf 10000**

3.3 Data Processing

Setting a Region of Interest

Purpose: Sets the pixel range used to collect the end-of-line statistics and sets the region of pixels used in the **ccg**, **cpa**, **gl**, **gla**, and **ccf** commands.

In most applications, the field of view exceeds the required object size and these extraneous areas should be ignored. It is recommended that you set the region of interest a few pixels inside the actual useable image.

Syntax: **roi x1 y1 x2 y2**

Syntax Elements: **x1**

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

y1

Row start number. Must be less than or equal to the row end number in a range from **1** to (row end number – 1) except in TDI Mode where ***y1*** must be **1**.

x2

Column end number. Must be greater than or equal to the column start number in a range from **2** to column resolution.

y2

Row end number. Must be greater than or equal to the row start number in a range from **2** to 64 except in TDI Mode where ***y2*** must be **1**.

Related Commands	**ccg**, **cpa**, **gl**, **gla**, **ccf**, **els**
Example:	**roi 10 1 50 1** (TDI Mode)

Digital Signal Processing Chain

Processing Chain Overview and Description

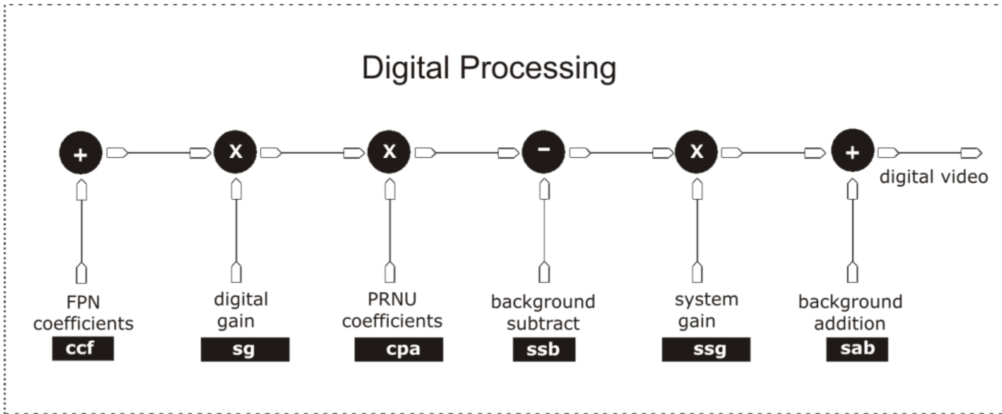
The following diagram shows a simplified block diagram of the camera's digital processing chain.

The digital processing chain contains the digital gain, FPN correction, the PRNU correction, the background subtract, and the system gain and offset. All of these elements are user programmable.

Notes:

- FPN and PRNU correction is not available when operating the camera in Area Mode.
- The following user settings are stored separately for forward and reverse direction; digital gain, system gain, and background subtract. They are saved using the **wus** command. For details on changing camera shift direction, refer to the Setting the Camera's CCD Shift Direction section.
- FPN and PRNU coefficients are stored separately for forward and reverse direction. To save the current PRNU coefficients, use the command **wpc**. To save the current FPN coefficients, use the command **wfc**. Settings are saved for the current direction only.

Figure 6: Signal Processing Chain



Digital Processing

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

1. Fixed pattern noise (FPN) calibration (calculated using the **`ccf`** command) is used to subtract away individual pixel dark current.
2. Photo-Response Non-Uniformity (PRNU) coefficients are used to correct the difference in responsivity of individual pixels (i.e. given the same amount of light different pixels will charge up at different rates) and the change in light intensity across the image either because of the light source or due to optical aberrations (e.g. there many be more light in the center of the image). PRNU coefficients are multipliers and are defined to be of a value greater than or equal to 1. This ensures that all pixels will saturate together. When using PRNU correction, it is important that the A/D offset and Fixed Pattern Noise (FPN) or per pixel offsets are subtracted prior to the multiplication by the PRNU coefficient. The subtraction of these 2 components ensure that the video supplied to the PRNU multiplier is nominally zero and zero multiplied by anything is still zero resulting in no PRNU coefficient induced FPN. If the offset is not subtracted from the video then there will be artifacts in the video at low light caused by the multiplication of the offset value by the PRNU coefficients.
3. Background subtract (**`ssb`** command), system gain (**`ssg`** command), and background addition (**`sab`**) are used to increase image contrast after FPN and PRNU calibration. It is useful for systems that process 8-bit data but want to take advantage of the camera's 12-bit digital processing chain. For example, if you find that your image is consistently between 128 and 255 DN (8-bit), you can subtract off 128 (**`ssb 2048`**) and then multiply by 2 (**`ssg 8192`**) to get an output range from 0 to 255.

The following sections are organized as follows:

1. Setting the Gain.
2. Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction) provides an overview of how to perform flat field calibration.
3. Digital Signal Processing provides a detailed description of all digital processing chain commands.

The algorithm calculates the gain of the 16th tap to set the tap mean to the user target. For adjacent tap 15, the mean of the last 16 pixels are gained to match the mean of the first 16 pixels of tap 16. This seam matching continues to tap 1.

For adjacent tap 17, the mean of the first 16 pixels are gained to match the mean of the last 16 pixels of tap 16. This seam matching continues to tap 30.

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

Flat Field Correction Overview

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

- Fixed Pattern Noise (FPN)
- Photo Response Non Uniformity (PRNU)

Lens and light source non-uniformity Correction is implemented such that for each pixel:

$$V_{output} = [(V_{input} - \text{dark offset} - FPN(\text{pixel})) * \text{digital gain} * PRNU(\text{pixel})]$$

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

The white light calibration is performed next to determine the multiplication factors required to bring each pixel to the required value (target) for flat, white output. Video output is set slightly above the brightest pixel (depending on offset subtracted).

Flat Field Correction Restrictions

It is important to do the FPN correction first. Results of the FPN correction are used in the PRNU procedure. We recommend that you repeat the correction when a temperature change greater than 10°C occurs or if you change the integration time.

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

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

For best results, ensure that:

1. 60 Hz ambient light flicker is sufficiently low not to affect camera performance and calibration results.
2. The brightest pixel should be slightly below the target output.
3. When 6.25% (or more) of pixels from a single row within the region of interest are clipped, flat field correction results may be inaccurate.

How to Perform Flat Field Correction

1

Setup the camera operating environment (ie. Line rate, CCD Shift Direction, exposure, offset, gain, etc)

Select the User Set ("ssn" 1,2,3 or 4)

Digital Offset and gain. Background subtract values should be set to zero. ("ssb 0"," sab 0"," ssg 0")

NOTE:

Items highlighted in GREY are not necessary to perform, unless you require doing so.

Steps 1, 4 and 5 are usually only needed to be performed.

2

Set the calibration sample size using the command "css". (Optional, since the camera defaults to 4096)

3

Set the region of interest (roi) to include all of the images pixels of importance using the command "roi x1 y1 x2 y2".

4

Perform FPN correction. FPN correction should be performed before PRNU correction.

Repeat FPN correction when a temperature change greater then 10C occurs OR when there is a significant change in integration time or gain.

1. Stop all light from entering the camera. (Tip: cover lens with a lens cap)
2. Verify the output signal level is at dark by issuing the command "gl" or "gla (or by viewing a line profile/histogram of the output.)
3. Issue the command "ccf". The camera will respond with OK> if no errors occur. FPN correction automatically calibrates the FPN coefficients.
4. After the correction is complete, save the settings by issuing a "wfc" command. (Note that Forward and Reverse direction settings are stored separately and coefficients must be saved before switching directions)

5

Perform PRNU correction

Perform PRNU correction next to determine the multiplication factors (and automatic gain settings for each tap) required to bring each pixel to the required value (balance target) for a flat white output.

1. Place a white reference in front of the camera. (remove lens cap if needed)
2. Issue the command "cpa 2 i" (or "cpa 4 i" if using roi), where I is equal to or greater than the maximum pixel value in the image. The camera will respond with OK> if no errors occur.
3. After the correction is complete, save the settings by issuing a "wpc" command. (Note that Forward and Reverse direction settings are stored separately and coefficients must be saved before switching directions)
4. Enable the coefficients using the command "epc 1 1". You should now see a flat line. (It may be necessary to average many lines to see the residual FPN and PRNU.)
5. Issue the command "wus" to save all User Settings.

A few notes:

A. Repeat the above steps 3-5 for any CCD shift direction change. (ie, if the above was performed in FORWARD direction, repeat for REVERSE direction.
B. Always ensure what User Set (ssn 1, ssn 2, ssn 3, ssn 4) you are in when performing calibration. When the wfc, wpc and wus commands are performed, this saves all FPN and PRNU coefficients and User settings into that set.
    a. The last User Set (ssn) used in the camera will be the same set loaded into the camera during a power cycle.
    b. You can view what User Set you are in via the GCP screen.
    c. Set 0, "ssn 0" is the factory calibration set. It cannot be overwritten by the User.
C. Remember that the cpa integer "I" is in 14 bit format. (To set an 8 bit value, multiply this by 64 to get the proper 14 bit value.) (For example if the camera is in 8 bit mode and you want a target value of 200DN, the "I" integer for CPA would be 200x64=12800. So, sending "cpa 2 12800" would give you a target value of 200DN.)
D. The CPA command will automatically adjust all tap gain values. The new gains will be displayed in the GCP screen. (ie. If you selected a gain of 5, "sg 0 5" before performing the CPA 2 command, depending on the automatic gain adjustment, this value may now be different.)

Digital Signal Processing for Processing

Calibrating Camera Gain

Purpose:	The camera can determine appropriate gain values. This command calculates the gain required to reach the output target with a seam matching algorithm.
Syntax:	**`ccg i`**
Syntax Elements:	**`i`**
	`i` Calculation target value in a range from **`4096`** to **`16064`** DN (14 bit LSB).
Notes:	▪ This function requires constant light input while executing. ▪ To use this command, the CCD shift direction (**`scd`**) should be set to forward (**`0`**) or reverse (**`1`**). ▪ Perform gain algorithms before performing FPN and PRNU calibration.
Example:	**`ccg 13056`**

Updating the Gain Reference

To update the gain reference:

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

FPN Correction

Performing FPN Correction

Syntax:	Performs FPN correction and eliminates FPN noise by subtracting away individual pixel dark current. For a complete description on how to use this command, see the Flat Field Correction Overview on page 29.
Syntax:	**`ccf`**
Notes:	• Before performing this command, stop all light from entering the camera. (Tip: cover lens with a lens cap.) • Perform all analog and digital adjustments before performing FPN correction. • Perform FPN correction before PRNU correction. • Available in TDI Mode only. • Save coefficients before changing directions, changing operating mode, or powering off.
Related Commands:	**`cpa`**
Example:	**`ccf`**

Setting a Pixel's FPN Coefficient

Purpose: Sets an individual pixel's FPN coefficient.

Syntax **`sfc x i`**

Syntax Elements: ***x***

The pixel number from 1 to sensor pixel count.

i

Coefficient value in a range from 0-511 (12-bit LSB).

Notes:
- Available in TDI Mode only.

Example: **`sfc 10 50`**

Returning FPN Coefficients

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

Syntax: **`gfc i`**

Syntax Elements: ***i***

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

Notes:
- Available in TDI Mode only.

Example: **`gfc 10`**

PRNU Correction

Performing PRNU to a user entered value

Purpose: Note: CPA 5/6 should be used. CPA 2/4 is available in the camera but may cause your camera to not meet camera specifications.	Performs PRNU calibration to user entered value and eliminates the difference in responsivity between the most and the least sensitive pixel creating a uniform response to light. Using this command, you must provide a calibration target. Executing these algorithms causes the **ssb** command to be set to 0 (no background subtraction), the **ssg** command to 0 (unity digital gain), and the **sab** command to 0 (no background addition). The pixel coefficients are disabled (epc 0 0) during the algorithm execution but returned to the state they were prior to command execution. Additionally when CPA 5/6 are used, the digital gains will be automatically adjusted for optimal performance when calculating pixel coefficients. It is expected that after using CPA 5/6 that your gains will be set to a new value.
Syntax:	**cpa i i**
Syntax Elements:	***i*** PRNU calibration algorithm to use: **5** = Calculates the PRNU coefficients and Digital gains using the entered target value as shown below: Target value (14 bits) in range from 4096 to 16220DN For example, if the camera is in 8 bit mode and the target is to be 200DN, use (200x64) = 12800 (14 bit equivalent) as target value. The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. It is important to note that the target value (set with the next parameter) does not need to be equal of higher to the highest pixel across all cameras. Since the cpa 5 function now controls gain, negative gain values may also be set automatically. The ideal result of CPA 5 is that the PRNU coefficients and the camera gain are setup automatically. **6** = Calculates the PRNU coefficient and the Digital gains in the same way as **cpa 5** with the exception that this command only calculates PRNU for pixels within the current Region of Interest (ROI). ***i*** Peak target value in a range from 4096 to 16220 DN.
Notes:	• Calibrate FPN before calibrating PRNU. If you are not performing FPN calibration then issue the **rpc** (reset pixel coefficients) command. • CPA 2 and CPA 4 functions are still available for use in the camera, but Teledyne DALSA does not recommend their use and will not guarantee any camera specifications. The improper use of CPA 2/4 may cause the camera to exceed its designed performance criteria. • CPA 2/4 will only calculate a PRNU coefficient and will not

adjust gain.

Example: **cpa 5 13000**

Setting a Pixel's PRNU Coefficient

Purpose: Sets an individual pixel's PRNU coefficient.

Syntax: **`spc i i`**

Syntax Elements: ***i***

The pixel number from 1 to sensor pixel count.

i

Coefficient value in a range from 0 to 28671 where:

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

Returning FPN and PRNU Coefficients

Purpose: Returns all the current pixel coefficients in the order FPN, PRNU, FPN, PRNU… for the range specified by ***x1*** and ***x2***. The camera also returns the pixel number with every fifth coefficient.

Syntax: **`dpc x1 x2`**

Syntax Elements: ***x1***

Start pixel to display in a range from 1 to (sensor pixel count-1).

x2

End pixel to display in a range from **`x1`** +1 to sensor pixel count.

Notes:

- If **`x2<x1`** then **`x2`** is forced to be **`x1`**.

Example: **`dpc 10 20`**

Enabling and Disabling Pixel Coefficients

Purpose: Enables and disables FPN and PRNU coefficients.

Syntax: **`epc i i`**

Syntax Elements: ***i***

FPN coefficients.
`0` = FPN coefficients disabled
`1` = FPN coefficients enabled

i

PRNU coefficients.
`0` = PRNU coefficients disabled
`1` = PRNU coefficients enabled

Example: **`epc 0 1`**

Subtracting Background

Purpose:	Use the background subtract command after performing flat field correction if you want to improve your image in a low contrast scene. You should try to make your darkest pixel in the scene equal to zero.
Sytax	**`ssb i`**
Syntax Elements:	**`i`** Subtracted value in a range in DN from 0 to 4096 (14 bit LSB).
Notes:	• See the following section for details on the **`ssg`** command.
Related Commands	**`ssg`**
Example	**`ssb 500`**

Setting System Gain

Purpose:	Improves signal output swing after a background subtract. When subtracting a digital value from the digital video signal, using the **`ssb`** command, the output can no longer reach its maximum. Use this command to correct for this where: $\text{ssg value} = \frac{\text{max output value}}{\text{max output value - ssb value}}$
Syntax:	**`ssg i`**
Syntax Elements:	**`i`** Gain setting. The gain ranges are 0 to 61439. The digital video values are multiplied by this value where: $\text{System Gain} = 1 + \frac{i}{4096}$
Notes:	• Use this command in conjunction with the **`ssb`** command (described above). • Digital offset is set to zero after sending the **`ccf`** command
Related Commands:	**`ssb, sab`**
Example:	**`ssg 4500`**

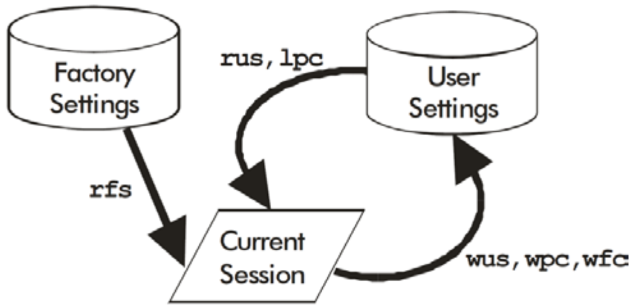
Adding Background

Purpose:	Use the background add command after performing flat field correction if you want to improve your image in a high contrast scene. Use this command to increase the true black above 0 DN.
Sytax	**`sab i`**
Syntax Elements:	**`i`** Add value in a range in DN from 0 to 4096 (14 bit LSB).
Notes:	• See the following section for details on the **`ssg`** command.
Related Commands	**`ssg, ssb`**
Example	**`sab 500`**

3.4 Saving and Restoring Settings

Saving and Restoring Factory and User Settings

Figure 7: Saving and Restoring Overview



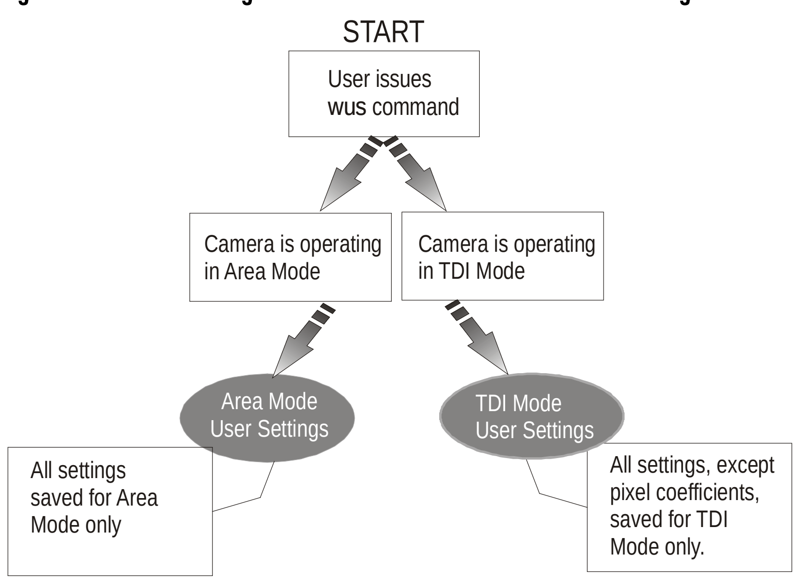
Factory Settings

You can restore the original factory settings, including the factory calibrated pixel coefficient set, at any time using the command **rfs**.

User Settings

There are two main sets of user settings: Area Mode user settings and TDI Mode user settings. After issuing the user settings save command, **wus**, settings are saved depending on which mode the camera is operating in when the command is issued. Also, when operating in TDI Mode, digital gain and offset, and background subtract values are saved as distinct values for Forward and Reverse directions. In other words, you can program the camera to operate with a digital gain value of +5db in Forward direction and an digital gain value of +3db in Reverse direction. Forward and Reverse direction settings are saved simultaneously with the **wus** command. Note that when you switch directions, the settings saved for that direction are automatically loaded.

Figure 8: How User Settings are Stored in the ES-Sx Cameras after issuing the wus Command



You can save or restore your user settings to non-volatile memory using the following commands.

- To save all current user settings to EEPROM for the current mode for both TDI shift directions, use the command **wus**. The camera will automatically restore the saved user settings when powered up.

  WARNING: While settings are being written to nonvolatile memory, do not power down camera or camera memory may be corrupted.

- To restore the last saved user settings, including the last used pixel coefficient set, for the current mode, use the command **rus**.

Current Session Settings

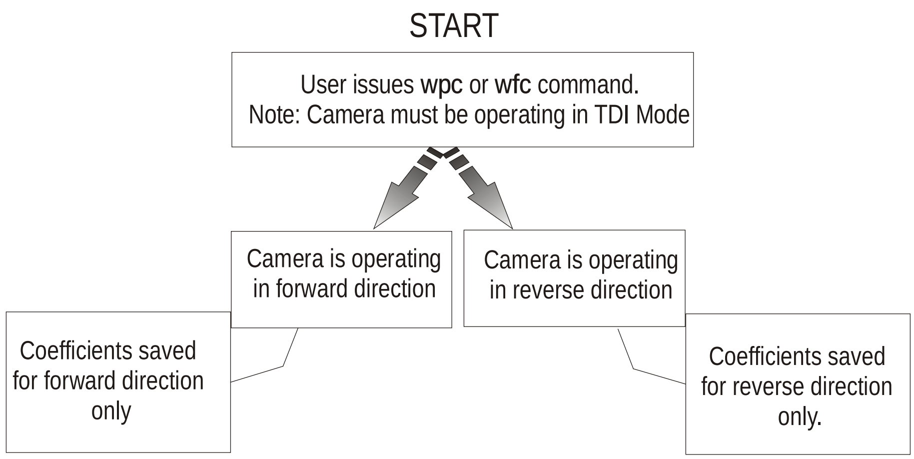
These are the current operating settings of your camera. These settings are stored in the camera's volatile memory and will not be restored once you power down your camera. To save these settings for reuse at power up, use the command **wus**. Settings are saved for the current operating mode (TDI or Area) only.

Saving and Restoring PRNU and FPN Coefficients

Note: Available in TDI Mode only.

Pixel coefficient sets are saved separately for Forward and Reverse direction, depending on which direction the camera is operating in when the **wpc** or **wfc** command is issued. It is important that you save pixel coefficients before switching CCD shift direction or current coefficient values will be lost.

Figure 9: How Pixel Coefficients are saved in the ES-Sx Cameras after issuing the wpc or wfc Command



Selecting the Set Number

Purpose:	When saving and loading camera settings, you have a choice of saving up to four different sets and loading from five different sets (four user and one factory). This command determines the set number from where these values are loaded and saved.
Syntax:	**ssn**
Syntax Elements:	**i** **0** = Factory set. Settings can only be loaded from this set. **1** - **4** = User sets. You can save, or load settings with these sets.

Note:	The camera powers up with the last set saved using this command.
Example:	**`ssn 3`**
Related:	**`rus`**

Saving the Current PRNU Coefficients

Purpose:	Saves the current PRNU coefficients for the current direction for the current set.
Syntax:	**`wpc`**
Notes:	• Available in TDI mode only.

Saving the Current FPN Coefficients

Purpose:	Saves the current FPN coefficients for the current direction for the current set.
Syntax:	**`wfc`**
Notes:	• Available in TDI mode only.

Loading a Saved Set of Coefficients

Purpose:	Loads a saved set of pixel coefficients for the current direction. A factory calibrated set of coefficients is available.
Syntax:	**`lpc`**
Notes:	• Available in TDI mode only.

Resetting the Current Pixel Coefficients

Purpose:	Resets the current pixel coefficients to zero. This command does not reset saved coefficients.
Syntax:	**`rpc`**
Notes:	The digital offset is not reset.

Rebooting the Camera

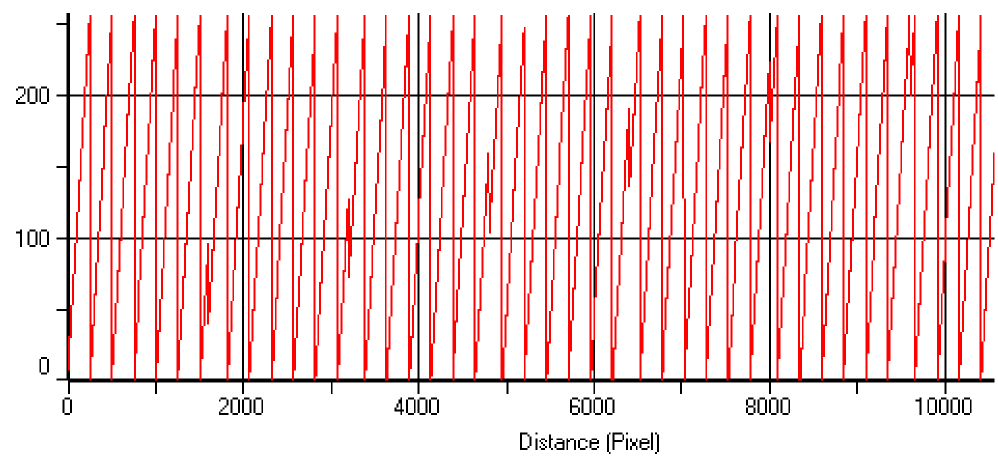
The command **`rc`** reboots the camera. The camera starts up with the last saved settings and the baud rate used before reboot. Previously saved pixel coefficients are also restored.

3.5 Diagnostics

Generating a Test Pattern

Purpose:	Generates a test pattern to aid in system debugging. The test patterns are useful for verifying proper timing and connections between the camera and the frame grabber.
Syntax:	**svm *i***
Syntax Elements:	**i** **0** Video. **1** DCi = Integer ((i – 1) / 400) * 8) + 8 Where i = 1 to 12000 **2** HORi = Modulus (DCi + Modulus (Modulus ((i – 1), 1600), 256), 256) Where i = 1 to 12000 **3** VERi = Row – 1 Where i = 1 to 12000 **4** DIAGi = Modulus ((HORi + VERi), 256) Where i = 1 to 12000
Notes:	•
Example:	**svm 2 horizontal ramp line profile**

Figure 10: Test Pattern



Returning Video Information

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

Returning a Single Line of Video

Purpose:	Returns a complete line of video (without pixel coefficients or test pattern) displaying one pixel value after another. It also displays the minimum, maximum, and mean value of the line sampled within the region of interest (the region of interest command is explained in section Setting a Region of Interest). Use the **gl** command, or the following **gla** command, to ensure the proper video input range into the processing chain before executing any pixel calibration commands.
Syntax:	**gl x1 x2**
Syntax Elements:	***x1*** Column start number. Must be less than the column end number in a range from **1** to (**column resolution – 1**). ***x2*** Column end number. Must be greater than the column start number in a range from **2** to sensor resolution.
Notes:	• If **x2**≤**x1** then **x2** is forced to be **x1**. • Digital offset, background subtract, and digital system gain are applied to the data. FPN and PRNU coefficients are not included in the data. • Values returned are in 12 bit DN. • Available in TDI Mode only.
Related Commands	**roi**
Example:	**gl 10 20**

Returning Averaged Lines of Video

Setting the Number of Lines to Sample

Purpose:	Sets the number of lines to sample when using the **gla** command or for pixel coefficient calculations.
Syntax:	**css *i***
Syntax Elements:	**i** Number of lines to sample. Allowable values are **1024, 2048, or 4096**.
Notes:	• To return the current setting, use the **gcp** command.
Related Commands:	
Example:	**css 1024**

Returning the Average of Multiple Lines of Video

Purpose:	Returns the average for multiple lines of video data (without pixel coefficients or test pattern). The number of lines to sample is set and adjusted by the **css** command. The camera displays the Min., Max., and Mean statistics for the pixels in the region of interest (the region of interest command is explained in section Setting a Region of Interest).
Syntax:	**gla x1 x2**
Syntax Elements:	***x1*** Column start number. Must be less than the column end number in a range from **1** to (**column resolution – 1**). ***x2*** Column end number. Must be greater than the column start number in a range from **2** to column resolution.
Notes:	• If **x2**≤**x1** then **x2** is forced to be **x1**. • Digital offset, background subtract, and digital system gain are applied to the data. FPN and PRNU coefficients are not included in the data. • Values returned are in 12 bit DN. • Available in TDI Mode only.
Related Commands:	**css, roi**
Example:	**gla 10 20**

Temperature Measurement

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

Note: If the camera's internal temperature reaches 75 °C, the camera **will shutdown and the LED will flash red**. If this occurs, the camera **must be rebooted** using the command, **rc** or can be powered down manually. You will have to correct the temperature problem or the camera will shutdown again.

IMPORTANT! Refer to the camera mounting instructions below for more information on managing the camera temperature.

Voltage Measurement

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

Camera Frequency Measurement

Purpose:	Returns the frequency for the requested control signal
Syntax:	**gsf *i***
Syntax Elements:	***i*** Control signal to measure: **1**: CC1 (EXSYNC) **3**: CC3 (Forward)
Example:	**gsf 1**

Returning Camera Settings

Returning All Camera Settings with the Camera Parameter Screen

The camera parameter (GCP) screen returns all of the camera's current settings.

To read all current camera settings, use the command:

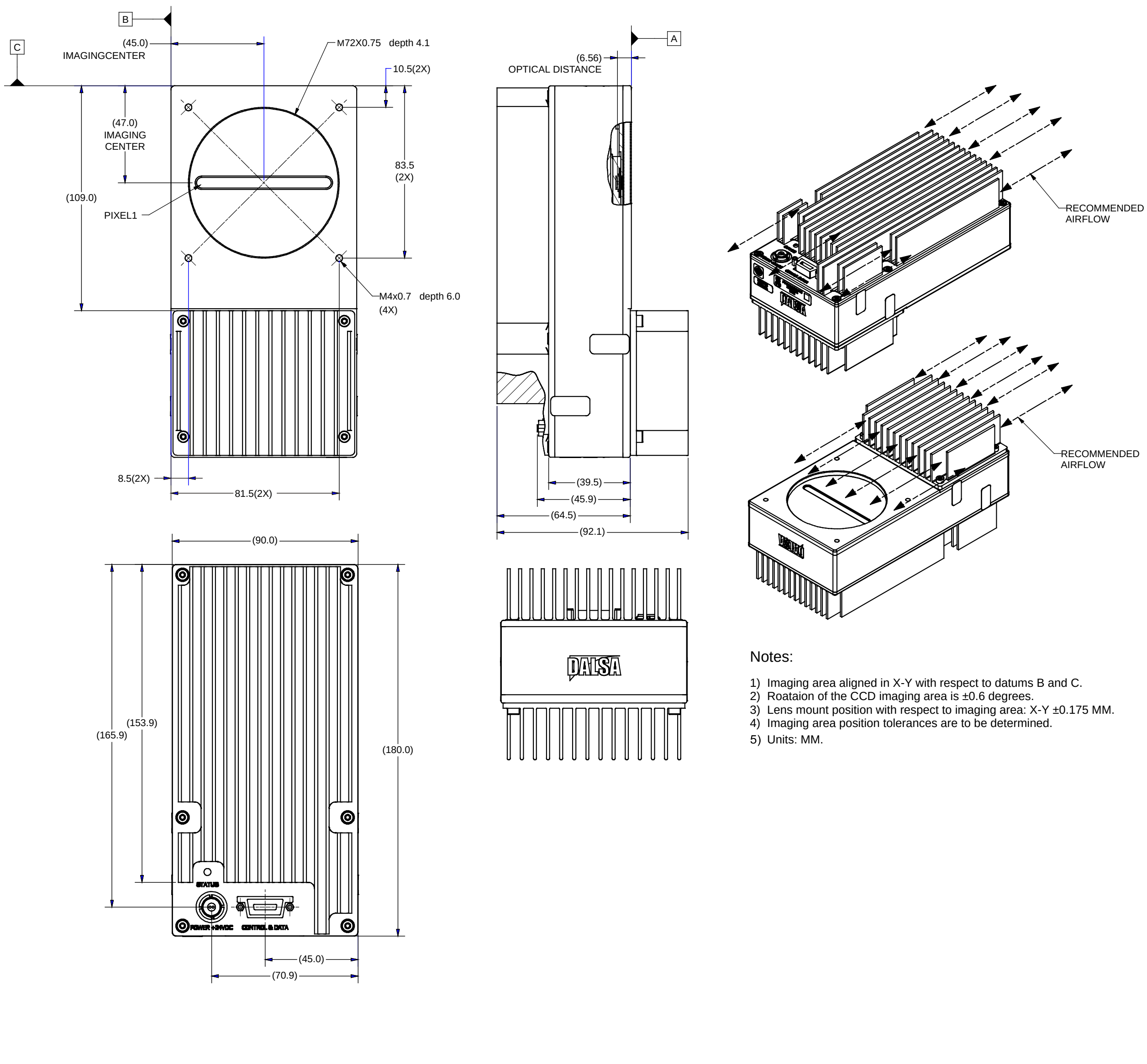
Syntax:	**gcp**

Returning Camera Settings with Get Commands

You can also return individual camera settings by inserting a "**get**" in front of the command that you want to query. If the command has a tap or pixel number parameter, you must also insert the tap number or pixel number that you want to query. Refer to the command section later in this manual for a list of available commands. To view a help screen listing the following get commands, use the command **gh**.

4

Optical and Mechanical



4.1 Lens Mounts

Model Number	Lens Mount Options
ES-S0	M72x0.75 thread.

4.2 Optical Interface

Illumination

The amount and wavelengths of light required to capture useful images depend on the particular application. Factors include the nature, speed, and spectral characteristics of objects being imaged, exposure times, light source characteristics, environmental and acquisition system specifics, and more. The Knowledge Center on our Web site, provides an introduction to this potentially complicated issue. See “Radiometry and Photo Responsivity” and "Sensitivities in Photometric Units" in the CCD Technology Primer found under the Application Support link.

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

Light Sources

Keep these guidelines in mind when setting up your light source:

- LED light sources are relatively inexpensive, provide a uniform field, and longer life span compared to other light sources. However, they also require a camera with enhanced sensitivity, such as the ES-Sx camera.
- Halogen light sources generally provide very little blue relative to infrared light (IR).
- Fiber-optic light distribution systems generally transmit very little blue relative to IR.
- Some light sources age; over their life span they produce less light. This aging may not be uniform—a light source may produce progressively less light in some areas of the spectrum but not others.

Filters

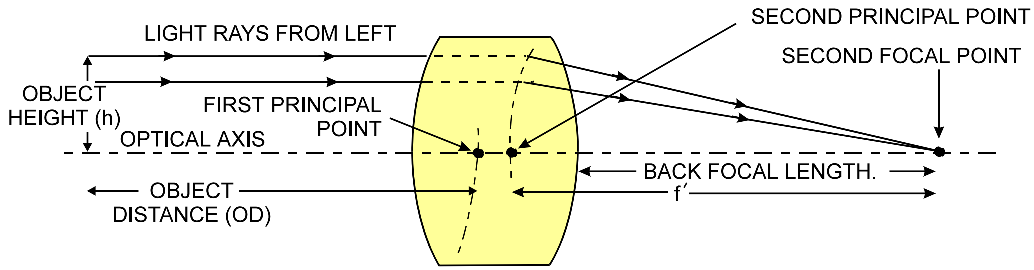
CCD cameras are extremely responsive to infrared (IR) wavelengths of light. To prevent infrared from distorting the images you scan, use a “hot mirror” or IR cutoff filter that transmits visible wavelengths but does not transmit wavelengths over 750nm. Examples are the Schneider Optics™ B+W 489, which includes a mounting ring, the CORION™ LS-750, which does not include a mounting ring, and the CORION™ HR-750 series hot mirror.

Lens Modeling

Any lens surrounded by air can be modeled for camera purposes using three primary points: the first and second principal points and the second focal point. The primary points for a lens should be available from the lens data sheet or from the lens manufacturer. Primed quantities denote characteristics of the image side of the lens. That is, h is the object height and h' is the image height.

The *focal point* is the point at which the image of an infinitely distant object is brought to focus. The *effective focal length (f′)* is the distance from the second principal point to the second focal point. The *back focal length (BFL)* is the distance from the image side of the lens surface to the second focal point. The *object distance (OD)* is the distance from the first principal point to the object.

Figure 11: Primary Points in a Lens System



4.3 High Temperature and Mounting

Warning! Depending on the mounting design and the operating conditions the camera body could become hot. You must take precautions to ensure your safety and avoid touching the camera directly during operation.

Mounting Instructions and Recommendations

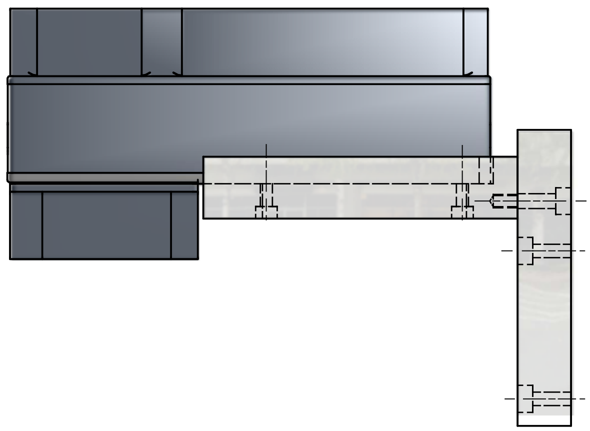
Proper camera mounting ensures that the heat generated by the camera dissipates properly and that the camera maintains a safe temperature.

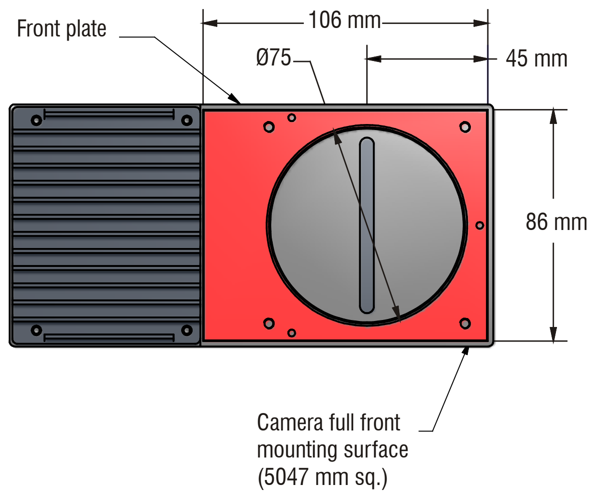
1. The camera should be bolted tightly to a mounting plate made of thermally conductive material (e.g. Aluminum).
2. Keep contact area between the camera's front surface and the mounting plate surface as large as possible. Do not use "stand-off" style mounting.
3. Design the camera mounting plate so that there is enough surface area to dissipate heat. An example of a properly mounted camera is illustrated on the following page.
4. Forced air flow to the fins is the most effective way to cool the camera. If forced air flow is not available, then leave enough space around the fins so that heat can easily dissipate into the air by natural convection.
5. The mount setup plus the airflow must dissipate 40 Watts or more of heat.
6. Proper thermal mounting of the camera should result in an internal camera temperature < 65 °C (verify using command vt) and a front plate temperature < 50 °C.

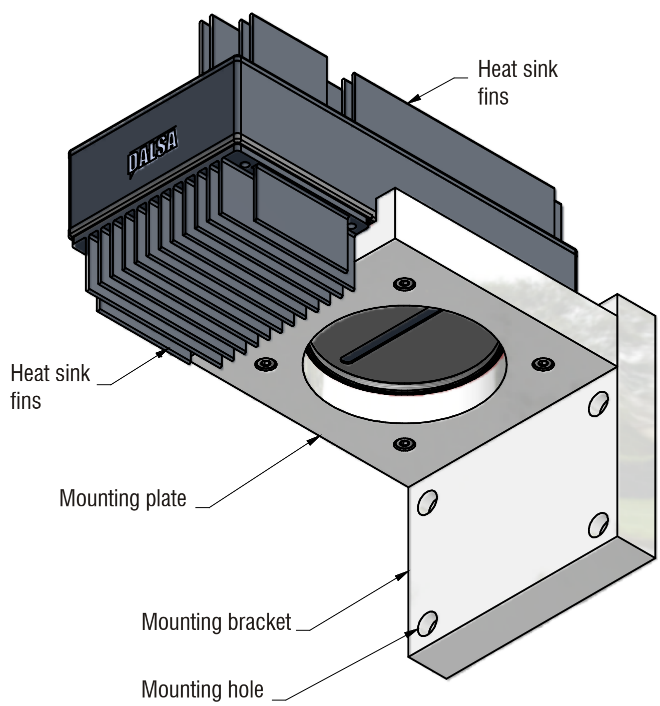
Note: To avoid internal damage the camera automatically shuts down when the internal temperature reaches 75 °C.

The recommendations assume the following conditions:

- The camera mounting plate has at least 5,047 mm sq. contact surface (equal to the full camera mounting surface, as shown) and approximately 3,000 mm sq. of natural convection surface.
- No impediments to the natural convection space around the surface of the mounting plate and the surface of the camera.
- An environment temperature of approximately 25 °C.
- Good contact between the mounting plate and the camera surface.




Front plate
106 mm
Ø75
45 mm
86 mm
Camera full front
mounting surface
(5047 mm sq.)


Heat sink
fins
Heat sink
fins
Mounting plate
Mounting bracket
Mounting hole

6

Troubleshooting

6.1 Common Solutions

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

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

Your steps in dealing with a technical problem should be:

1. Try the general and specific solutions listed in sections 6.1, 6.2 and 6.3.0.
2. If these solutions do not resolve your problem, contact support@teledynedalsa.com for product support.

LED

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

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. Issue the command, **vv**, to confirm correct voltages.

EXSYNC

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

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 Generating a Test Pattern 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.

Verify Factory Calibrated Settings

To restore the camera's factory settings and disable the FPN and PRNU coefficients, 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 test patterns to aid in system debugging. Use the command svm 1 (or up to svm 4) to activate a test pattern. A description of available test patterns is in section 3.5 Diagnostics. Use the test pattern to verify the proper timing and connections between the camera and the frame grabber.

Verify Voltage

To check the camera's input voltage, use the **vv** command. If it is within the proper range, the camera returns OK> and the voltage value. 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.

Note: If the camera reaches 75°C, the camera **will shutdown and the LED will flash red**. If this occurs, the camera **must be rebooted** using the command, **rc** or can be powered down manually. You will have to correct the temperature problem or the camera will shutdown again. If you enter any command other than **vt** or **rc**, the camera responds with:

```
Error 09: The camera's temperature exceeds the specified operating
range>
```

Verify Pixel Coefficients

Use the **dpc** command to display the pixel coefficients in the order FPN, PRNU, FPN, PRNU… The camera also returns the pixel number for each fifth pixel.

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 if camera is in exposure mode that requires external signals). Unused signals in the cable should be termintated in 100Ω.

Line Dropout, Bright Lines, or Incorrect Frame Rate

Verify that the frequency of the internal sync is set correctly, or when the camera is set to external sync that the EXSYNC signal supplied to the camera does not exceed the camera's useable frame rate under the current operating conditions.

Noisy Output

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

Dark Patches

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

1. Take standard ESD precautions.
2. Wear latex gloves or finger cots
3. Blow off dust using a filtered blow bottle or dry, filtered compressed air.
4. Fold a piece of optical lens cleaning tissue (approx. 3" x 5") to make a square pad that is approximately one finger-width
5. Moisten the pad on one edge with 2-3 drops of clean solvent—either alcohol or acetone. Do not saturate the entire pad with solvent.

Appendix A

Error Handling and Command List

A1 Error Handling

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

Table 8: Warning and Error Messages

Warning Messages	
Camera Response	**Comment**
OK>	Camera executed command
Warning 01: Outside of specification>	Parameter accepted was outside of specified operating range (e.g. gain greater than ±10 dB of factory setting, or SSF below specification).
Warning 02: Clipped to min>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 03: Clipped to max>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 04: Related parameters adjusted>	Internal operating condition is adjusted to accommodate the entered command. E.g. requesting exposure time longer than line time automatically adjusts the line time to meet the exposure time requirement.
Warning 07: Coefficient may be inaccurate A/D clipping has occurred>	In the region of interest (ROI) greater than 6.251% single or 1% of averaged pixel values were zero or saturated.
Warning 08: Greater than 1% of coefficients have been clipped	Greater than 1% of FPN or PRNU coefficients have been calculated to be greater than the maximum allowable and so were clipped.
Warning 09: Internal line rate inconsistent with read out time>	Changing this parameter has changed read out time and that is greater than the *internal* SYNC

Error Messages	
Camera Response	**Comment**
Error 01: Internal error xx>	Where xx is a code list below. Only output during power up. Customer should contact Teledyne DALSA customer support.
Error 02: Unrecognized command>	Command is not valid.
Error 03: Incorrect number of parameters>	Too many or too few parameters.
Error 04: Incorrect parameter value>	This response returned for ▪ Alpha received for numeric or visa versa ▪ Float where integer expected ▪ Not an element of the set of possible values. E.g., Baud Rate ▪ Outside the range limit
Error 05: Command unavailable in this mode>	E.g. SSF when in SEM 3
Error 06: Timeout>	Command not completed in time. E.g. CCF in SEM 3 when no external EXSYNC is present.
Error 07: Camera settings not saved>	Indicates that user settings have been corrupted by turning off the power while executing the WUS command. Must build up new settings from factory and re-save with WUS.
Error 08: Unable to calibrate - tap outside ROI>	Cannot calibrate a tap that is not part of the end of line statistics.
Error 09: The camera's temperature exceeds the specified operating range>	Indicates that the camera has shut itself down to prevent damage from further overheating. (flashing red) Shuts down at internal temperature of 75˚C and will not restart until below 65˚C (equivalent to 50˚C at front plate).
Error 10: FPGA Flash Program Failed	FCS failed either because of communication error or a bad file was sent.

A2 Commands: Quick Reference

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

As a quick reference, the following table lists all of the camera configuration commands available to the camera user. For detailed information on using these commands, refer to Chapter 3. Note: This table does not list "get" commands. Refer to section Returning Camera Settings for a list of these commands.

Table 9: Command Quick Reference

Mnemonic	Syntax	Parameters	Description
correction calibrate fpn	**ccf**		Performs FPN calibration and eliminates FPN noise by subtracting away individual pixel dark current. Refer to Digital Signal Processing and Processing Chain Overview and Description for details.
calculate camera gain	**ccg**	**i**	Calculates the camera gain according to the selected algorithm. **i** = Calibration target value in a range from: **4096** to **16064** DN (14 bit LSB).
calculate PRNU algorithm	**cpa**	**i i**	Performs PRNU calibration according to the selected algorithm. The first parameter is the algorithm where **i** is: **2** = Calculates the PRNU coefficients using the entered target value as shown below: $\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - \text{FPN}_i}$ The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. **4** = This algorithm is the same as 2 with the exception that it only calculates PRNU for the pixels within the current Region of Interest (ROI). The second parameter is the target value to use in a range from **4096** to **16220** DN.
correction set sample	**css**	**m**	Set number of line samples averaged for pixel coefficient calculations or for output of **gla** command. Values: **1**, **1024, 2048, 4096**. Refer to Returning Averaged Lines of Video on page 40 for details.
display pixel coeffs	**dpc**	**x1 x2**	Displays the pixel coefficients in the order FPN, PRNU, FPN, PRNU, … **x1** = Pixel start number **x** 2= Pixel end number In a range from **1** to **12000**.

Mnemonic	Syntax	Parameters	Description
enable pixel coefficients	`epc`	`i i`	Sets whether pixel coefficients are enabled or disabled. The first parameter sets the FPN coefficients where `i` is: `0` = FPN coefficients disabled `1` = FPN coefficients enabled The second parameter sets the PRNU coefficients where `i` is: `0` = PRNU coefficients disabled `1` = PRNU coefficients enabled Refer to section Enabling and Disabling Pixel Coefficients on page 34 for details.
get command log	`gcl`		
get camera model	`gcm`		Reads the camera model number.
get camera parameters	`gcp`		Reads all of the camera parameters.
get camera serial	`gcs`		Read the camera serial number.
get camera version	`gcv`		Read the firmware version and FPGA version.
get fpn coeff	`gfc`	`x`	Read the FPN coefficient `x` = pixel number to read in a range from `1` – `sensor pixel count`. Refer to Returning FPN Coefficients on page 31 for details.
get help	`gh`		Returns a help screen listing all of the "get" commands.
get line	`gl`	`x x`	Gets 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. `x` = Pixel start number `x` = Pixel end number In a range from `1` to `12000`. Refer to Returning a Single Line of Video on page 40 for details.
get line average	`gla`	`x x`	Read the average of line samples. `x` = Pixel start number `x` = Pixel end number in a range from `1` to `12000`. Refer to Returning Averaged Lines of Video on page 40 for details.
get prnu coeff	`gpc`	`x`	Read the PRNU coefficient. `x` = pixel number to read in a range from `1` – `sensor pixel count`.
get signal frequency	`gsf`		

Mnemonic	Syntax	Parameters	Description
help	`h`		Display the online help. Refer to section 3.1 Camerea Help Screen for details.
help, single command	`?`	`s`	
load pixel coefficients	`lpc`		Loads the previously saved pixel coefficients from non-volatile memory where ***i*** is: **0** = Factory calibrated coefficients **1** = Coefficient set one **2** = Coefficient set two **3** = Coefficient set three **4** = Coefficient set four
read bit error counter	`rbc`		
reset camera	`rc`		Reset the entire camera (reboot). Baud rate is not reset and reboots with the value last used.
restore factory settings	`rfs`		Restore the camera's factory settings. FPN and PRNU coefficients reset to 0. Refer to section 3.4 Saving and Restoring Settings for details.
region of interest	`roi`	`x y x y`	Sets the pixel range affected by the **cag**, **gl**, **gla**, **ccf**, **cpa** and commands. The parameters are the pixel start and end values (**x**) and the column start and end values (**y**) in a range from **1** to **4096**. Refer to section Setting a Region of Interest for details.
reset pixel coeffs	`rpc`		Reset the pixel coefficients to 0. Refer to section Enabling and Disabling Pixel Coefficients on page 34 for details.
reset stats counter	`rsc`		
restore user settings	`rus`		Restore the camera's last saved user settings and FPN and PRNU coefficients. Refer to section 3.4 Saving and Restoring Settings for details.
set add background	`sab`	`i`	0 - 4096
set ccd direction	`scd`	`i`	Sets the CCD shift direction where: **0 =** Forward TDI shift direction. **1 =** Reverse TDI shift direction. **2 =** Externally controlled direction.
set data width	`sdw`	`i`	Selects the bit depth, where: sdw 8 = 8-bit output sdw 10 = 10-bit output sdw 12 = 12-bit output

Mnemonic	Syntax	Parameters	Description
set exposure mode	**sem**	**m**	Set the exposure mode: **3 =** External SYNC, maximum exposure time **7 =** Internal programmable SYNC, maximum exposure time. Factory setting.
set fpn coeff	**sfc**	**x i**	Set the FPN coefficient. **x** =pixel number within the range **1** to **12000**. **i**= FPN value within the range **0** to **8191** (12-bit LSB). Refer to Performing FPN Correctionon page 31 for details.
set gain	**sg**	**tf**	0-30 : -20 to +20
set prnu coeff	**spc**	**x i**	Set the PRNU coefficient. **x**=pixel number within the range **1** to **12000**. **i**= PRNU value within the range **0** to **65535**
set subtract background	**ssb**	**i**	Subtract the input value from the output signal. **i** = Subtracted value in a range from **0** to **4096**
set sync frequency	**ssf**	**i**	Set the frame rate to a value from: TDI ES-S0: **1 to 90,822** Area ES-S0: **1 to 320** Value rounded up/down as required. Refer to Setting Frame Rate on page 26 for details.
set system gain	**ssg**	**i**	Set the digital gain. **i** = Digital gain in a range from **0** to **61438**. The digital video values are multiplied by this number. Refer to Setting System Gain on page 35 for details.
set set number	**ssn**	**i**	0 - 4
set video mode	**svm**	**i**	Switch between normal video mode and test patterns: **0**: Normal video mode **1**: Test pattern **2**: Test pattern **3**: Test pattern **4**: Test pattern Refer to section Generating a Test Pattern for details.

Mnemonic	Syntax	Parameters	Description
set TDI mode	`tdi`	`i`	Set the camera's operating mode. **0**: Area Mode **1**: TDI Mode Refer to section **Error! Reference source not found.** for details.
update gain reference	`ugr`		Changes 0 dB gain to equal the current gain value.
verify temperature	`vt`		Check the internal temperature of the camera
verify voltage	`vv`		Check the camera's input voltages and return OK or fail
write FPN coefficients	`wfc`	`i`	Write all current FPN coefficients to EEROM. Refer to section Saving and Restoring PRNU and FPN Coefficients for details.
write PRNU coeffs	`wpc`	`i`	Write all current PRNU coefficients to EEROM. Refer to section Saving and Restoring PRNU and FPN Coefficients for details.
write user settings	`wus`		Write all of the user settings to EEROM. Refer to section Saving and Restoring Factory and User Settings for details.

Appendix B

EMC Declaration

Teledyne DALSA's ES-12K cameras meet the requirements outlined below which satisfy the EMC requirements for CE marking, the FCC Part 15 requirements, and the Industry Canada ICES-003 evaluation.

Model ES-12K
Evalutation Date: February 18, 2010
The CE Mark Evaluation of the Teledyne DALSA ES-12K Camera, which is manufactured by Dalsa Inc., meets the following requirements:
EN 55022, EN 55011 , CISPR 22, CISPR 11, FCC Part 15, and ICES-003 Class A. EN 61326-1 and EN 55024 Immunity to Disturbances.

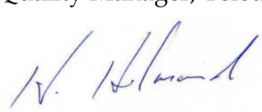
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment.

This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at the user's own expense.

Changes or modifications not expressly approved by Teledyne DALSA could void the user's authority to operate the equipment.

Name and Signature of authorized person

Hank Helmond
Quality Manager, Teledyne DALSA Corp.



Appendix C

Revision History

Revision	Change Description	Date
00	Preliminary release.	June 20, 2012

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