Operation Manual:

SU640CSX

Mil-Rugged, High-Sensitivity, Small SWaP InGaAs SWIR Camera

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1. Introduction

1.1. Foreword

This manual applies to all variants of the SU640CSX camera. These are collectively referred to as the CSX camera. Appendix B to this manual contains configuration information that is specific to your camera variant. It is included as a separate document on the mini-disc that ships with the camera. **The user should become very familiar with the information provided in Appendix B. If you cannot locate Appendix B, please contact SUI for assistance.**

> **Important precautions are located in Section 1.4 Safety Considerations and 1.5 Thermal Management. Refer to these sections prior to powering the camera.**
>
> **Important notes and specific setup steps are indented and in bold.**

1.2. System Description

The CSX camera family offers users a mil-rugged, small size, weight, and power (SWaP) Indium Gallium Arsenide Infrared Camera. This manual documents these model families:

- SU640CSX-12.5B Small SWaP 640 x 512 SWIR
- SU640CSX-12.5B Small SWaP 640 x 512 NIR/SWIR

This manual pertains to both the enclosed and the OEM (open-frame) versions of the CSX. The software commands and optical / electrical interfaces are identical between the enclosed and OEM versions, while the physical dimensions are unique. Some shipping and accounting documents may also refer to the camera similar to GA640CB-12.5B-ENC-FH-STD-[suffix codes]. In this case, the ENC designates enclosed over the alternative of OEM. The camera's optical sensitivity ranges from 0.9 µm. to 1.7 µm for the standard InGaAs camera (designated by STD in the model description above), and from <0.7 µm to 1.7 µm for the NIR/SWIR InGaAs camera (designated by NIR in place of the STD code in the above example).

Designed for laboratory, factory, or military field use, the CSX camera features a high sensitivity imager which includes a single-stage TEC for thermal stabilization at high operating temperature set points, allowing a very stable Non Uniformity Correction (NUC) set to produce high quality imagery.

The focal plane array (FPA) produces a video signal digitized with a resolution of 12 bits or greater using an onboard analog-to-digital converter in each column. The user can select to process the digitized data using non-uniformity corrections (NUCs). The NUCs compensate for exposure time, dark current, and gain tolerances. The digital signal is provided in a base Camera Link compatible format, via industry standard 26-pin SDR connector on the rear panel of the ENC models, or via a board-to-board connector for the OEM models.

Camera Link is a serial communication protocol standard designed for computer vision applications. It was designed for the purpose of standardizing scientific and industrial video products including cameras, cables, and frame grabbers.

Factory non-uniformity corrections are available for a range of preconfigured integration time and FPA sensitivity combinations, which are referred to as OPRs. The OPRs are detailed in Appendix B, which can be found as a separate document on the disc that shipped with the camera. (The file name will start with

4170-xxxx.) Camera operation may be customized using ASCII commands sent through the Camera Link asynchronous serial communication port. These commands are described in section 5 of this manual.

The camera features no moving parts and may be powered indefinitely, as long as it is thermally managed correctly (see Section 1.5 Thermal Management). There is no power switch on the camera. When an AC adapter is used, the best practice is to supply and remove power at the source rather than at the load. Therefore, when using the supplied AC adapter, make the connection at the wall last when powering the camera and disconnect there first when removing power from the camera. Do not make or break the connection at the camera or on the cable while power is being supplied. See Section 2.1.3 for more information about the power interface.

1.3. System Contents

A complete order for an enclosed SU640CSX may include the following:

- SU640CSX camera body
- AC adapter (power supply)
- Storage case
- Assorted cables and adapters.
- Sensors Unlimited mini-disc containing documentation
  - This user manual
  - Appendix B
  - software/freeware SUI-Image Analysis
  - configuration file for compatible National Instruments frame grabber cards (*.ICD file)
- Lens

A complete order for an OEM SU640CSX may include the following:

- SU640CSX-OEM camera chassis
- OEM Accessory Kit, including:
  - AC adapter (power supply)
  - Lens
  - Storage case
  - Assorted cables and adapters.
  - Sensors Unlimited mini-disc containing documentation
    - This user manual
    - Appendix B
    - software/freeware SUI-Image Analysis
    - configuration file for compatible National Instruments frame grabber cards

This break-out allows volume arrangements to eliminate unused parts.

Options include:

- Alternate output connectors available upon request at time of order (e.g. ST4 board-to-board connector).
- Alternate lens mounts and lenses
- Alternate Camera Link Frame grabber cards and cables

1.4. Safety Considerations

The camera can be powered using a DC power supply capable of providing a minimum of 4 Watts of continuous power. The camera is supplied with an appropriate universal mains power supply. Do not exceed the voltage maximum or damage might occur.

If you supply your own power, it is critical that the power connections be made to the proper connector pins. See Section 2.1.3 Power, Trigger, and Sync for details.

The focal plane array is mounted behind a broadband antireflective-coated protective window. When changing lenses or mounting the camera in any optical arrangement, take care not to scratch or touch this window.

To prevent fire, shock hazard or damage to the camera, do not expose to rain or excessive moisture. Do not disassemble camera. Do not remove screws or covers. There are no user serviceable parts inside. Removal of any panel will void the warranty.

When handling the camera, take precautions to avoid electro-static discharge (ESD) to any exposed electrical connector pins.

1.5. Thermal Management

WARNING: Do not power the CSX camera until you have considered thermal management. The camera itself does not dissipate heat quickly enough to prevent over-heating under all conditions. Monitoring of the camera case temperature, system temperature, and thermoelectric cooler (TEC) lock are highly recommended to prevent overheating. The case temperature can be monitored by a user-supplied thermocouple or other sensor. System temperature closely tracks case temperature, and can be queried with the SYSTEM:TEMP? command as described in Section 5.15.1 Get System Temperature. The camera can be placed in a higher TEC setpoint to reduce power consumption with the MACRO command as described in Section 5.20.1 Play Macro Command.

WARNING: If the camera temperature is too high, forced convection from an external fan or conduction to an external heat sink is highly recommended. Due to the small size of the camera, the camera may overheat within minutes of applying power if no external cooling or heat sinking is provided.

The CSX camera has been designed to efficiently transfer heat from the focal plane array and other heat-generating components to the chassis. The camera will function properly while the chassis temperature is maintained within the specifications listed in Table 1. The case temperature can be measured anywhere on the camera chasses, the system temperature and TEC lock status can be queried as described in sections 5.15.1 Get System Temperature and 5.15.3 Get TEC Lock Status. The MACRO command changes camera TEC setpoint as described in Section 5.20.1 Play Macro Command. TEC is locked when the thermoelectric cooler is able to maintain the FPA at its setpoint. The camera will lose TEC lock when the low or high case temperature for a given TEC setpoint is exceeded. See Table 1 for the case temperatures that correspond to each TEC setpoint. (*Note: The values in this table are for the standard configuration for the camera, but some customers may have special configurations. Please review the Appendix B file that was supplied in the same media card folder as this manual. The file name will start with the document prefix 4170-xxxx and is specific to the part number of the camera it was shipped with.)*

Table 1. Recommended Case Temperature Range per TEC Setpoint

TEC Setpoint (°C)	MACRO	Low Case Temperature (°C)	High Case Temperature (°C)
18	0	-40	35
32	1	0	55
45	2	20	70

1.6. Camera Cleaning

Power down the camera prior to performing any camera cleaning operation.

Use a soft cloth moistened with a small amount of isopropyl alcohol to clean the outside of the camera enclosure or the power supply housing.

If the protective window of the focal plane array requires cleaning, the following steps are recommended:

1. With the focal plane array mounted in the camera, use clean, dry compressed air to blow loose particles off the window. This step alone is often sufficient to clean the window**. Do not use compressed air gas canisters. They may spray cold fluid that can thermally shock the window.**
2. Moisten a lint free lens cleaning paper with isopropyl alcohol and carefully wipe the surface of the window by dragging the moistened paper from one edge of the window to the other in a single motion. The paper may need to be folded so that it does not contact any surface other than the glass. Use the paper only once and wipe in one direction across the window surface. If the surface is still not clean, repeat this step as necessary, always wiping in the same direction using a new piece of moistened cleaning paper until the window is clean. It is important to use isopropyl alcohol because it acts as a lubricant when wiping the surface of the window.

2. Getting Started Guide

This guide is divided into four sections. The first covers mechanical mounting of the camera, optic, and connecting to the camera inputs and outputs. The second section covers frame grabber options and installation. The third section covers SUI Image Analysis software, and the fourth guides the user in powering on the camera for the first time. Users are strongly advised to review these four sections prior to powering on the camera.

Specific steps necessary to get started are bolded and indented.

2.1. Mechanical Mounts, Optics, and Electrical Connections

The CSX camera comes equipped with mounting provisions on all four sides (left, right, top, bottom). Two threaded holes are present on each side, separated by 19.1mm and set back 3.0mm from the front flange. Refer to Section 2.1.1 Mechanical Mounts for detailed dimensions.

The lens mount is a 1-inch hole with 32 threads/inch, which adheres to the C-mount standard 1-32 UN 2A. However, the camera back focal distance (flange to FPA) is not C-mount compliant and requires the included C-mount spacer to match the C-mount standard. This hybrid mounting plate design permits adapting the camera to a variety of standard lens mount formats, especially those with short back focal distances. See Section 2.1.2 Optical Mounts and Other Optical Considerations for additional details.

There are two electrical connections on the back of the camera, as well as a status indicating LED, which is described in Section 5.15 Thermal Commands and Section 5.13 Trigger Commands. The larger connector is a 26-pin Shrunk Delta Ribbon (SDR) standard connector which carries the Camera Link compatible video signal and LVDS serial communication (serial over Camera Link), as detailed in Section 2.1.4. The smaller 14 pin SDR standard connector carries power, trigger, and sync, which are fully detailed in Section 2.1.3.

2.1.1. Mechanical Mounts

If mounting the camera, refer to the following dimensions:

Dimensions (W x H x D) excluding connectors and lens	Enclosed/OEM	1.25"W x 1.25"H x 1.10"D 31.8W x 31.8H x 28D mm
Weight	Enclosed	≤50 g
	OEM	≤45 g

STEP 1: Mount the camera with the 4-40 tapped mounting holes located on the top, bottom, left, or right side of the camera.

Additional dimensions are provided in the mechanical drawings below (Figure 1, Figure 2 and Figure 3).

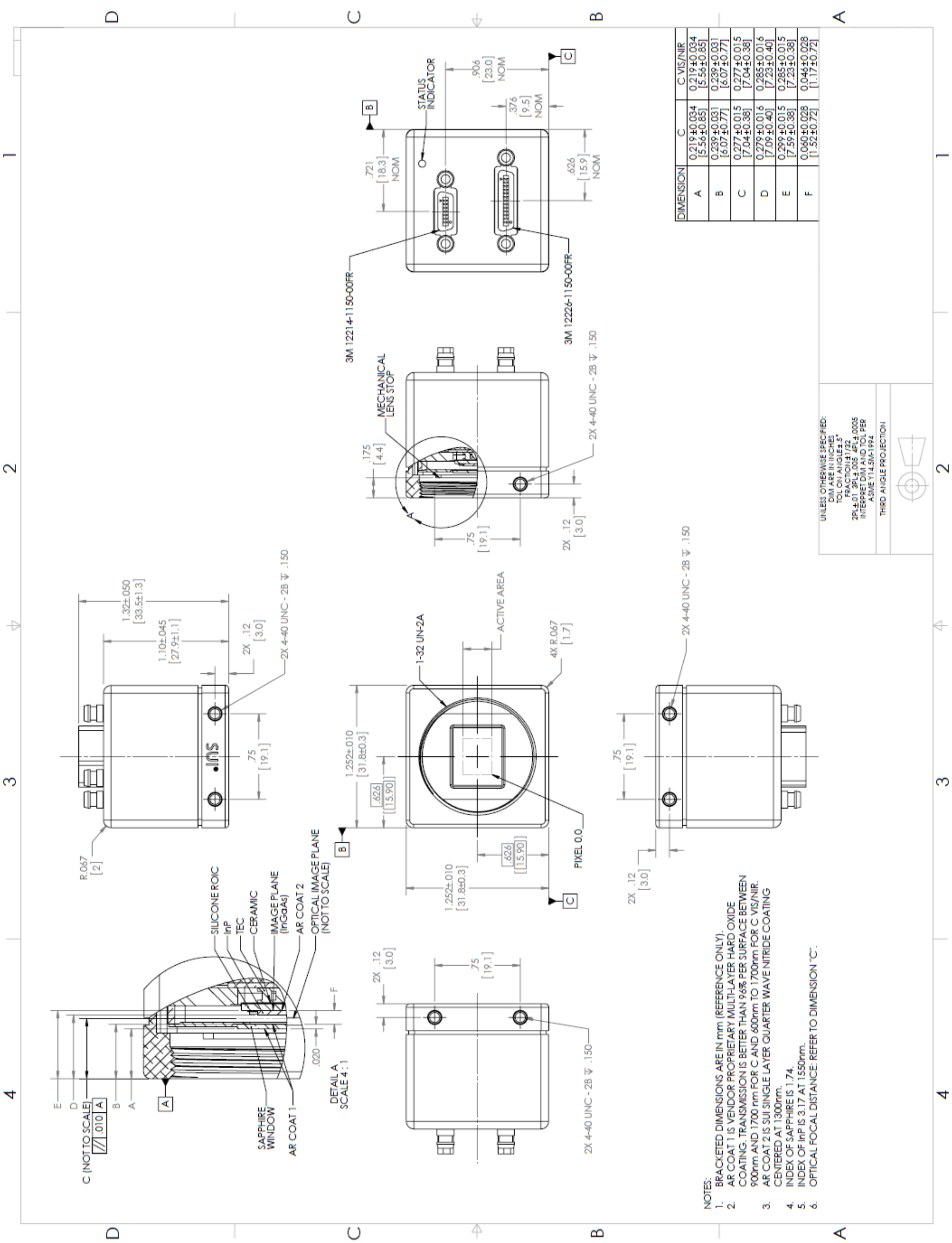
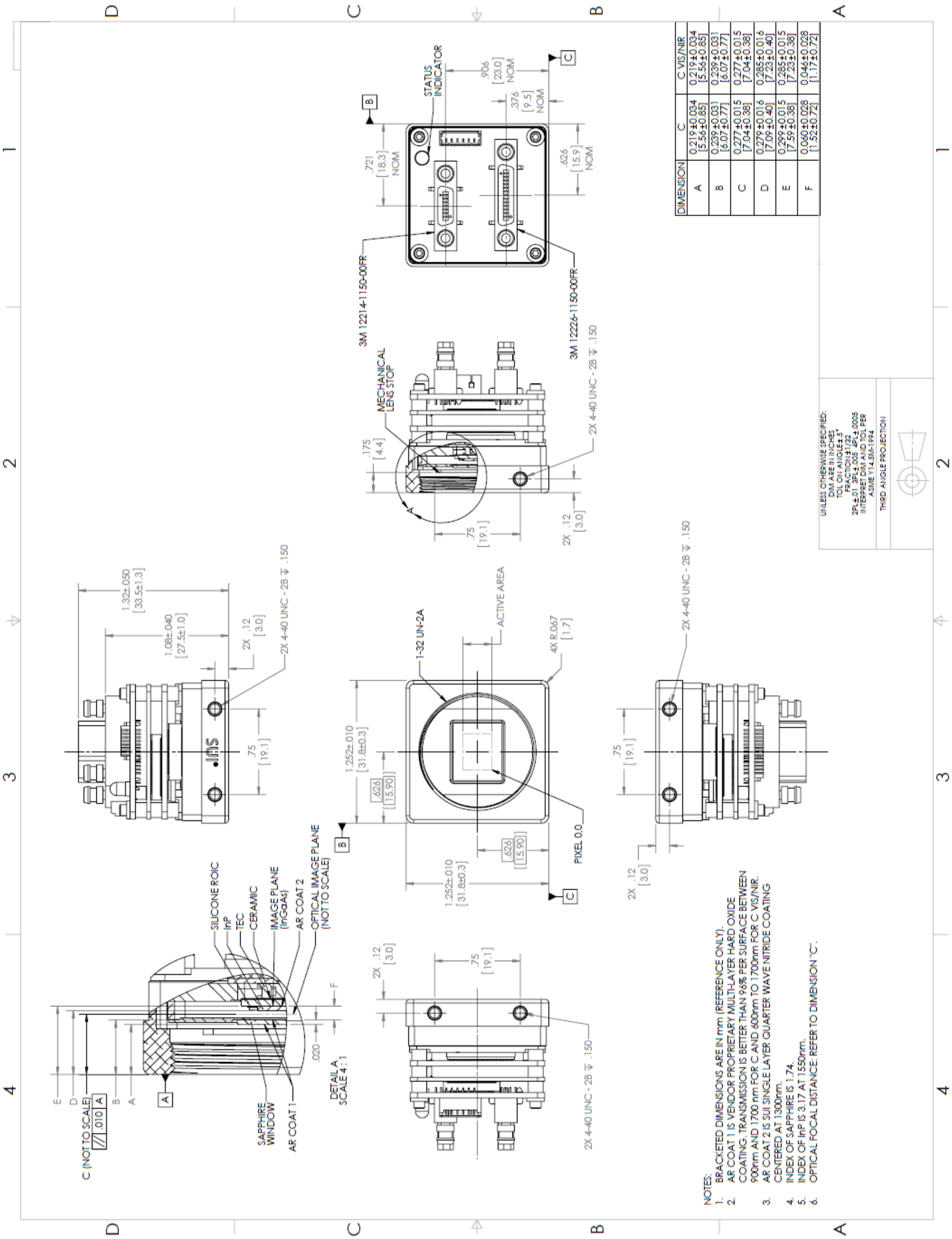


Figure 1. Mechanical drawing of enclosed CSX.



DIMENSION	C	C VIS/NIR
A	0.219±0.034 [5.56±0.85]	0.219±0.034 [5.56±0.85]
B	0.239±0.031 [6.07±0.77]	0.239±0.031 [6.07±0.77]
C	0.277±0.015 [7.04±0.38]	0.277±0.015 [7.04±0.38]
D	0.279±0.016 [7.09±0.40]	0.285±0.016 [7.23±0.40]
E	0.299±0.015 [7.59±0.38]	0.285±0.015 [7.23±0.38]
F	0.060±0.028 [1.52±0.72]	0.046±0.028 [1.17±0.72]

Figure 2. Mechanical drawing of OEM CSX.

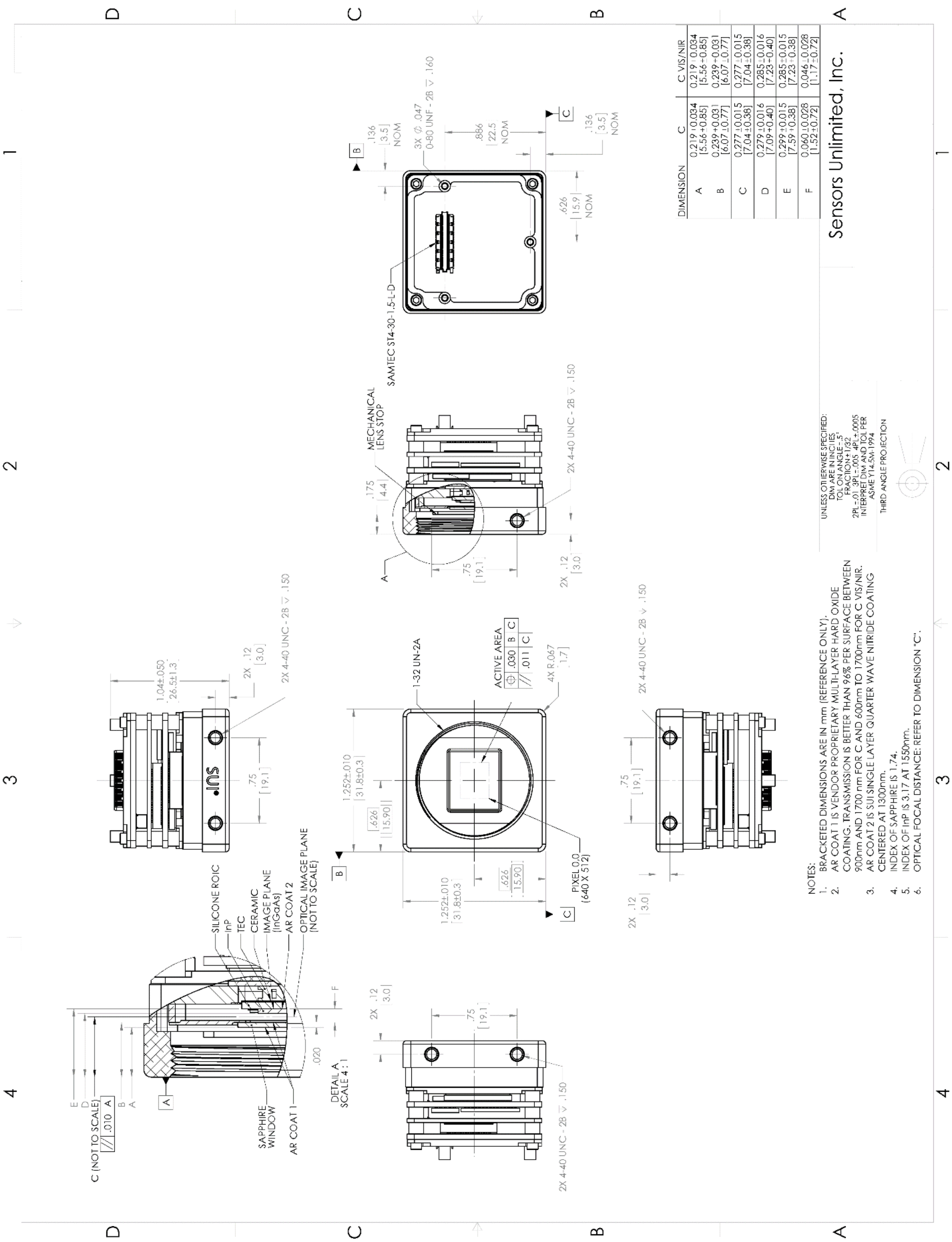


Figure 3. Mechanical drawing of OEM CSX with optional ST4 board-to-board connector

2.1.2. Optical Mount and Other Optical Considerations

The lens mount is a 1-inch hole with 32 threads/inch, which adheres to the C-mount standard 1-32 UN 2A. However, the camera back focal distance (flange to FPA) is not C-mount compliant and requires the included C-mount spacer to match the C-mount standard. This hybrid mounting plate design permits adapting the camera to a variety of standard lens mount formats, especially those with short back focal distances.

> **STEP 2: Screw the lens into the lens mount.** *Note: If using a SUI supplied SOLO lens with its CSX specific adapter, no spacer is needed. Other C-mount lenses require the C-mount spacer between the lens and the camera lens mount.*

The C-mount standard back focal distance is 0.69 inch / 17.5mm. The camera back focal distance is shown in Figure 1 and Figure 2 as dimension E and is dependent on the spectral response of the camera. The back focal distance dimension for SWIR-only cameras is listed in the middle column labeled “C” and the back focal distance dimension for NIR/VIS cameras is listed in the column labeled “C VIS/NIR”.

The optical image plane (dimension C on Figure 1, Figure 2 and Figure 3) takes the index of refraction at 1550 nm and thickness of the sapphire window and InP layer into account.

The spectral response of the CSX camera is broad and beyond the range for which visible consumer and commercial lenses have been designed. The use of SWIR-optimized lenses is strongly recommended. Contact Sensors Unlimited, Inc. for lens options and recommendations. Commercially available visible (non-SWIR optimized) optics are suitable for some SWIR imaging applications, particularly in bright lighting conditions.

In cases where a visible lens is used, it should be noted that the lens focus markings will be miss-calibrated due to the wavelength dependence of the refraction properties of the glass. Additionally, the CSX camera does not include controls for auto iris or auto focus. Auto iris lenses that permit manual control of the aperture in “stop-down aperture” or “depth of field” preview mode may be adapted to work with the CSX camera.

Some lenses default their default iris position to full open. If the lens does not default to full aperture, locate and disable the mechanical metering lever that controls the aperture via a stop or other mechanical means to hold the lever in a desired f/stop position.

If necessary, contact Sensors Unlimited, Inc. for lens options and recommendations.

2.1.3. Power, Trigger, and Sync Interface

The CSX requires an adapter cable to mate the power, trigger, and sync connectors to the chassis. Attach the supplied Power, Sync, Trigger cable (PN 8030-0020) to the camera chassis POWER/AUX connection by following these steps:

> **STEP 3: WITH ALL COMPONENTS DEENERGIZED: Connect the provided 14 pin SDR Power, Sync, Trigger cable (PN 8030-0020) to the camera, inserting the connector until it is fully seated and the shell is parallel to the mating panel surface. Snug (do not overtighten) the cable retention screws.**
>
> **WARNING: Do not make or break this connection while power is being supplied.**

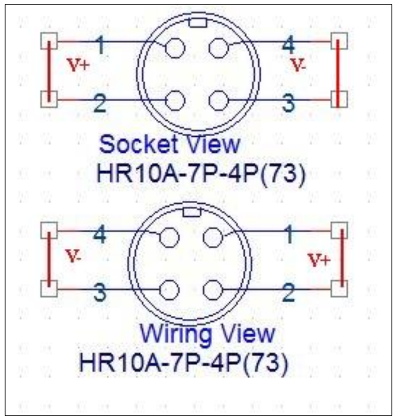


Figure 4. Hirose Power Connector Diagram

An AC adapter is provided with a cable that connects to the back panel of the camera via a supplied hybrid adapter cable. The adapter cable mates with the connector labeled POWER/AUX, and provides a snap-fit connector of the Hirose HR10A-7P-4P(73) series on the fly end, as well as supplies SMA connectors for the Sync and Trigger logic connections. The mating Hirose connector is on the auto-selecting AC adapter which plugs into 100-240 VAC (47 Hz - 63 Hz) mains; international mains adapter blades are available.

The Hirose connector provides + and - power across the 4 contacts. Pins 1 - 2 are DC + and pins 3-4 are DC -. DC- is isolated from ground by a protection resistor, capacitor, and ferrite slug, yet it is not forbidden to ground the negative supply (review this connection if unusual noise coupling is noticed). If you are wiring to this connector, a handy hint is that commercial connectors will emboss or otherwise label the pin numbers onto the connector to insure there is no confusion as to which side of the indexed connector you are viewing. **WARNING: Insure wiring polarity is correct. Reversed connection is a common cause of damage.**

> **STEP 4: If the supplied AC adapter is being used, insert the power connector on the provided AC adapter (PN 8000-0726) into the camera power adapter cable until snap-locked. Do not make or break this connection while power is being supplied.**

If the supplied AC adapter is not being used, test the power source for proper voltage, polarity, and pin connections before connecting the power cable to the camera. Do not exceed the voltage maximum or damage may occur. The power source used must conform to the power specifications with regard to maximum power and ripple, etc. to ensure proper camera performance.

> **STEP 5: Regardless of the source of power (supplied AC adapter, lab power supply, etc.) the best practice is to supply and remove power at the source rather than at the load. Therefore, when using the supplied AC adapter, make the connection at the wall last when powering the camera and first when removing power from the camera. Do not make or break the connection at the camera or on the cable while power is being supplied.**

If using the trigger input or sync output, connect the appropriate adapter cable to the external device. The Trigger and Sync is compliant to 3.3V CMOS logic in terms of supply voltage, crossover points, and loading. Safety is built in should a compatible trigger be applied while the camera is not powered. The trigger, synch, and video shells are tied to Digital ground through individual inductors. V- is tied to ground through a ferrite inductor as well. The signal source must be compliant with the specifications described in Section 5.13 Trigger Commands.

2.1.4. Electrical Interfaces

Two electrical connector interfaces to the CSX camera are located on the camera back panel, as well as a status indicating LED. The LED behavior is described in Section 5.15 Thermal Commands and in 5.13 Trigger Commands. The larger connector is a 26-pin Shrunk Delta Ribbon (SDR) standard connector which carries the Camera Link compatible video signal and LVDS serial communication (serial over Camera Link). The smaller 14 pin SDR standard connector carries power, trigger in, and sync out.

The digital data interface is through a base Camera Link compatible interfaces using low-voltage differential signaling (LVDS). The CSX can be interfaced to most frame grabbers, and operation has been verified with National Instruments, Imperx frame grabbers and Pleora CL convertors to USB3 or GigE interfaces. Power over Camera Link (PoCL) is not supported and therefore special PoCL cables are compatible but not required.

> **STEP 6: To connect to the digital interface, connect the separately-supplied SDR Camera Link cable to the camera, inserting the connector until it is fully seated and the shell is parallel to the mating panel surface. Snug (do not over tighten) the cable retention screws.**
>
> **WARNING: Ensure that the camera power is off at the AC source when making any connections to the camera or its adapters.**

2.2. Frame Grabber Options and Installation

The digital output allows the user to connect the camera to a computer frame grabber through a Camera Link® cable. This connection provides bi-directional communication. Image data flows from the camera to the computer, and camera control information flows in both directions. A Camera Link® frame grabber card is used to connect the camera link cable to the computer. Sensors Unlimited, Inc. fully supports National Instruments frame grabber cards and provides limited support for Imperx laptop frame grabber cards.

The CSX is designed to communicate with third party fully-compatible Camera Link frame grabber cards, which may require the user to build a configuration file with the assistance of the frame grabber source documentation and software. The CSX camera should work with frame grabbers from Matrox, Pleora Technologies, and other manufacturers. Pleora provides Camera Link to GigE and Camera Link to USB3 converters which have been demonstrated to work with the CSX camera. However, SUI provides only limited support for these and other frame grabbers.

2.2.1. National Instruments Frame Grabbers

Figure 5. National Instruments frame grabber cards for desktop computers

National Instruments (NI) produces a range of Camera Link® frame grabbers for desktop computers. Their product line can be found at their website. Please contact Sensors Unlimited, Inc. for specific recommendations.

A Camera Link® cable is used to connect the Digital port on the back of the camera to the frame grabber. There are two common versions of the cable connection: Mini Delta Ribbon (MDR) and the smaller Shrunk Delta Ribbon (SDR). The CSX camera is fitted with a SDR connector while the NI frame grabber cards are fitted with MDR connectors. Customers using a NI frame grabber should be sure that they are using an MDR-SDR (or SDR-MDR) cable for compatibility with their camera and frame grabber.

2.2.2. Imperx Frame Grabbers

National Instruments does not provide a Camera Link® solution for laptops. However, frame grabbers for laptops can be purchased from other manufacturers. Imperx, for example, produces a FrameLink Express card for laptops equipped with an ExpressCard slot. More information can be found at the Imperx website. SUI provides limited support for Imperx frame grabber cards. However, laptop manufacturers no longer offer models with the ExpressCard slot.

Figure 6. Imperx FrameLink Express frame grabber for laptops.

SUI recommends that new customers check with their frame grabber supplier for compatibility with their desktop or laptop computer. Each frame grabber is designed to interface with specific hardware ports in the computer. Failure to check with the frame grabber supplier may result in compatibility issues when installing the frame grabber in the computer.

For interfacing Camera Link cameras to laptops, the company Pleora Technologies offers external frame grabber convertors, with versions for interfacing to USB3 with their iPort CL-U3 or to Ethernet networks with their iPort CL-GigE. The convertors are supplied with user software called eBusPlayer for display, control of the camera, and for saving of images or video clips. Ask SUI Support for a setup guide for Pleora eBusPlayer. They also offer a Software Development Toolkit (SDK). *NOTE: SUI Image Analysis software does not work with the Pleora hardware, but saved eBusPlayer images can be viewed with it.*

2.2.3. Frame Grabber Installation

Video acquisition and camera control software is dependent on the frame grabber used. New users are advised to connect to the camera with software provided by the frame grabber manufacturer prior to connecting with SUI Image Analysis. For example, if using a National Instruments frame grabber, it is best to test the connection with NI Measurement and Automation eXplorer (NI MAX) software first. Or, if using an Imperx frame grabber, it is best to first test the connection with Imperx FrameLink Express software.

Once data is successfully grabbed from the camera with NI MAX or Imperx FrameLink Express, users may want to switch to SUI Image Analysis (SUI IA) software for image/video acquisition, camera control, and basic image analysis. SUI IA is compatible with both National Instruments brand Camera Link frame grabber boards and Imperx frame grabber cards. It is not compatible with other frame grabbers or the Pleora convertors. SUI IA may be operated in offline mode, with no connection to the camera for post-processing. See Section 2.3 for more information on SUI Image Analysis software. The latest version of SUI software is posted for download at: http://www.sensorsinc.com/products/software/. Compatibility notes with Windows and NI-IMAQ are also posted there.

2.2.4. National Instruments Frame Grabber Setup

If a National Instruments or Imperx frame grabber is being used, National Instruments IMAQ must be installed. NI-IMAQ Vision is National Instruments library of powerful functions for image processing that is distributed with their imaging frame grabber cards. This software library easily integrates with National Instruments LabVIEW Software, an extensive instrument-programming environment. License to the software is given with ownership of the frame grabber board.

Note: NI-IMAQ Version 19.5, which is included in NI Vision Acquisition Software published August 2019, is the most recent version compatible with SUI Image Analysis 7.x. If necessary, either roll back NI-IMAQ to the 2019 or even to the 2017 version, or contact us for guidance.

Note: NI-IMAQ 19.5 defaults to using IMAQdx protocols for Gen-I-Cam and a registry change is needed for support of the ICD files used by SUI cameras. Follow the guidance on the SUI software page.

STEP 7a: Install NI-IMAQ and other National Instruments software and hardware according to National Instruments' instructions.

The camera configuration file (an .ICD file) is provided on the Sensors Unlimited minidisc shipped with the camera. This configuration file properly configures the frame grabber for the CSX's Camera Link interface timing and allows the selection of camera Operational Modes with pull-down menus. Use NI Measurement and Automation Explorer (NI MAX) to load the .icd file to the default directory.

2.2.5. Imperx FrameLink Express Frame Grabber Setup

A laptop computer equipped with an ExpressCard interface is required to support Imperx FrameLink Express Frame Grabbers. Install the FrameLink Express Application according to the manufacturer's instructions. SUI recommends FrameLink Express Application Version 1.4.0, which can be obtained from Imperx on request. Once the software is installed, follow these steps to ensure proper recognition of the frame grabber card:

1. Shut down the laptop computer.
2. Insert the FrameLink Express Frame Grabber into the ExpressCard interface.
3. With the camera powered down, connect the SDR-SDR Camera Link cable to the camera and to the frame grabber card. Take care to avoid putting undue stress on the frame grabber card. They cannot support the weight of a Camera Link cable and are susceptible to damage.
4. Power up the computer.
5. Power up the camera as described in Section 2.4 Powering the Camera for the First Time.
6. Open FrameLink Express application. If the Camera Link card is not recognized, repeat steps 1 through 4.
7. Use the View pulldown menu to open the Camera Parameters and Terminal dialogs. Use the "Learn" function to set the camera resolution, and change camera bit depth to 12. Click "Apply" and "Grab". You should see a live image on the main window.
8. Switch to the Terminal window and change the Baud rate to 57600 (this is the factory default). You should now be able to send serial commands and receive responses.
9. To use the SUI Image Analysis software, you will also have to install the NI IMAQ software drivers.

2.3. SUI Image Analysis Freeware

Included on the minidisc is the installable freeware sample program SUI Image Analysis. Connecting to the camera with either NI MAX or FrameLink Express Application prior to using SUI Image Analysis is highly recommended.

This freeware is a sample program that works with National Instruments frame grabbers. It is a runtime using the NI base installation and connects only to specific NI and Imperx frame grabbers. Follow these steps to install SUI Image Analysis:

STEP 7b: If applicable, install the National Instruments software and hardware prior to installing SUI-IA. (SUI-IA is only compatible with the NI environment)

STEP 7c: Install SUI-IA from the minidisc, as found in a subdirectory.

If using a different brand frame grabber, SUI-IA can be used in an Off-line mode only, relying on the frame grabber's supplied software for data acquisition and storage, and importing the data as desired.

In addition to SUI Image Analysis, Camera Link Terminal, a dedicated terminal for serial communications, is provided on the minidisc. This software provides advanced serial communication functionality, such as the ability to send script files and to send command sequences repeatedly (loop test). This software can be used alongside SUI Image Analysis, NI MAX, or FrameLink Express Application.

2.4. Powering the Camera for the First Time

The CSX camera factory default configuration has the camera power on to free running (not triggered) operation with Auto Gain Control (AGC), corrections, enhancements, and other functions enabled. The exact configuration is located in Appendix B, which is included as a separate document and includes default factory settings and calibration information. It is highly recommended that the user become familiar with this document.

It is recommended that the user become familiar with toggling AGC and enhancements on/off, manually setting OPRs, and cross-referencing with the OPR tables on Appendix B. The power-up operating mode can be user-customized and saved so the camera boots to desired operating conditions, as described in Section 5.5 Configuration Commands.

The user can send serial commands directly through a terminal, or can use the GUIs provided in NI MAX and SUI Image Analysis. If using NI MAX or SUI IA, be aware that the contents of the .ICD file, including camera configuration settings, will be sent to the camera each time "Snap" or "Grab" buttons are clicked. This occurs in the background and is not obvious. This functionality can be disabled by unclicking the "Serial Commands Enabled" checkbox in NI MAX and saving the .ICD file.

The most basic user commands are shown in Table 2. Basic User Commands:

Table 2. Basic User Commands

Command	Description	Full Description
AGC:ENABLE [ON/OFF]	Toggles automatic gain control. AGC allows the camera to automatically select the most appropriate OPR for a given scene. The OPR is an operational configuration that controls TEC setpoint, integration time, frame time, and nominal FPA gain.	Section 5.9.1
AGC:ENABLE?	Returns the state of the AGC.	Section 5.9.2
OPR x	Loads an operational configuration. This includes integration time, frame time, and nominal FPA gain. See the separate Appendix B document for descriptions of individual OPRs. **If AGC is on, the OPR x command will immediately be over-ridden by the AGC. Turn AGC:ENABLE OFF prior to using OPR x.**	Section 5.5.3
OPR?	Returns the current OPR.	Section 5.5.4
ENH:ENABLE [ON/OFF]	Toggles the in-camera image enhancements. These should be turned off for radiometric, machine-vision, and similar applications.	Section 5.10.1
ENH:ENABLE?	Returns the state of in-camera enhancements.	Section 5.10.2

3. Camera Link Data Interface

The digital data interface to the camera is through a base Camera Link compatible interface using low-voltage differential signaling (LVDS). Sensors Unlimited cameras can be interfaced to most frame grabbers, and they have verified operation with National Instruments cards.

PoCL 'Power over Camera Link' is not employed and special PoCL cables are not required. However, PoCL cables are compatible.

Table 3. Digital output 26-pin connector (3M 12226-1150-00FR) signal assignment. (Standard Camera Link protocol)

1	Inner shield (camera GND)	20	SerTC-
14	Inner shield (camera GND)	8	SerTFG-
2	X0-	21	SerTFG+
15	X0+	9	CC1-
3	X1-	22	CC1+
16	X1+	10	No connect
4	X2-	23	No connect
17	X2+	11	No connect
5	Xclk-	24	No connect
18	Xclk+	12	No connect
6	X3-	25	No connect
19	X3+	13	Inner shield (camera GND)
7	SerTC+	26	Inner shield (camera GND)

Table 4. Digital output ST4 board-to-board connector variant (ST4-30-1-1.50-L-D) signal assignment.

2	XCLK_N	1	X0_N
4	XCLK_P	3	X0_P
6	GND	5	GND
8	X2_N	7	X1_N
10	X2_P	9	X1_P
12	GND	11	GND
14	X3_N	13	CC1_N
16	X3_P	15	CC1_P
18	GND	17	GND
20	SER_TC_N	19	SER_TFG_N
22	SER_TC_P	21	SER_TFG_P
24	GND	23	GND
26	NC	25	NC
28	Trig_In	27	Sync_Out
30	Trig_In_RTN	29	Sync_Out_RTN
32	NC	31	NC
34	NC	33	NC
36	NC	35	NC
38	NC	37	NC
40	NC	39	NC
42	NC	41	NC
44	NC	43	NC
46	Reserved, Do not use	45	Reserved, Do not use
48	Reserved, Do not use	47	Reserved, Do not use
50	Reserved, Do not use	49	Reserved, Do not use
52	NC	51	NC
54	PWR_RTN	53	PWR_IN
56	PWR_RTN	55	PWR_IN
58	PWR_RTN	57	PWR_IN
60	PWR_RTN	59	PWR_IN

Table 5. AUX/IO 14-pin connector (3M 12214-1150-00FR) signal assignment.

1	V-	8	SYNC-RTN
2	V-	9	SYNC-OUT
3	V-	10	TRIG-IN-RTN
4	V+	11	TRIG-IN
5	V+	12	RS232-RTN
6	V+	13	RS232-TX
7	V+	14	RS232-RX

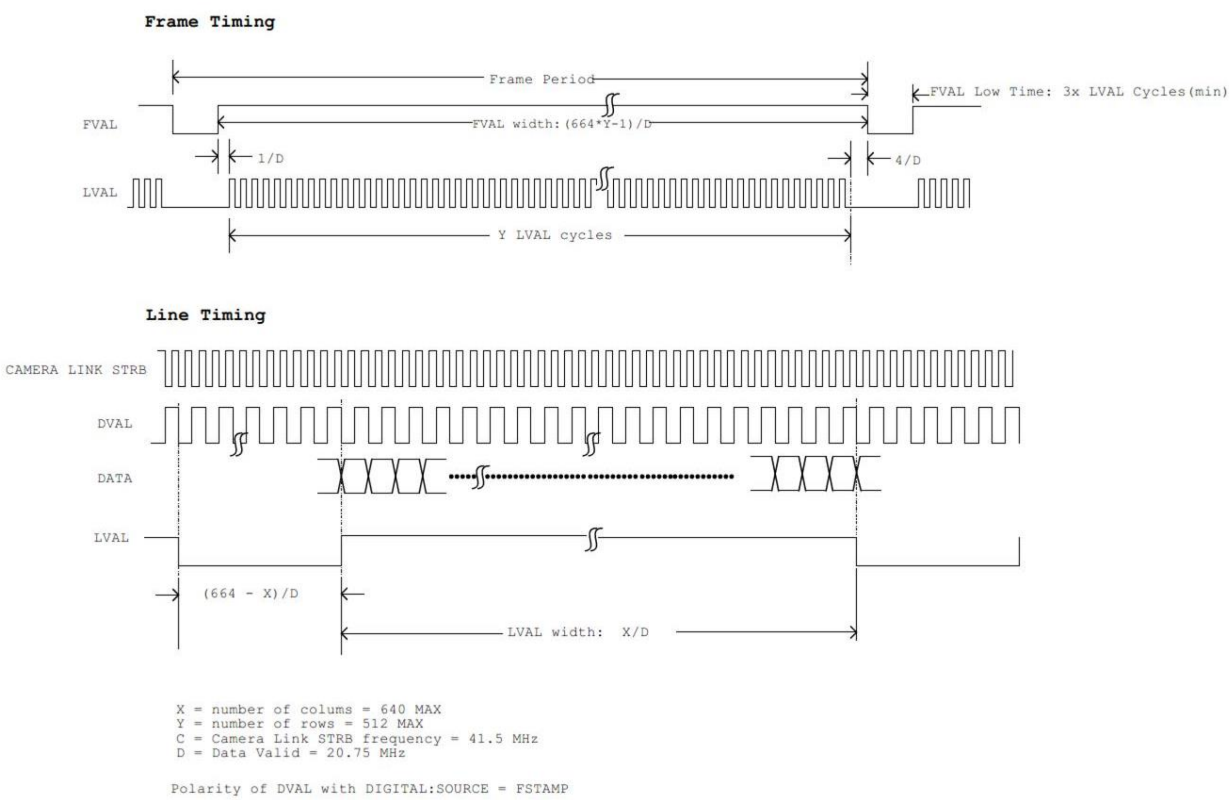


Figure 7. CSX Camera Link Timing Diagram.

4. Principles of Operation

4.1. Focal Plane Array Operation

The SUI CSX camera family uses the SU640AB4-1.7T1 Indium Gallium Arsenide (InGaAs) focal plane array (FPA). These FPAs have 640 x 512 pixels on a 12.5 µm pitch. The FPAs consist of an InGaAs photodiode array hybridized to a CMOS readout using indium bump bonds. The photodiode array is a backside illuminated device (where light first passes through the substrate before interacting with the sensing media) with Figure 8 showing the typical quantum efficiency (QE) for 3 possible wavelength variations offered (see www.sensorsinc.com for current available versions of this model). .. For Visible-InGaAs and NIR/SWIR, the substrate is thinned to allow shorter wavelength light to reach the light sensitive region of the photodiode. The blocking InP substrate media is removed with respect to diode operation in a separate semiconductor fabrication process. Photon detection is performed directly by the InGaAs layer in photovoltaic operation. A converting phosphor or similar layer is not used. *Note: The InP substrate layer attenuates but does not completely block shorter wavelengths – when strong light sources emit or reflect in the camera's field of view, additional steps may be needed to block the unwanted signals from being detected.*

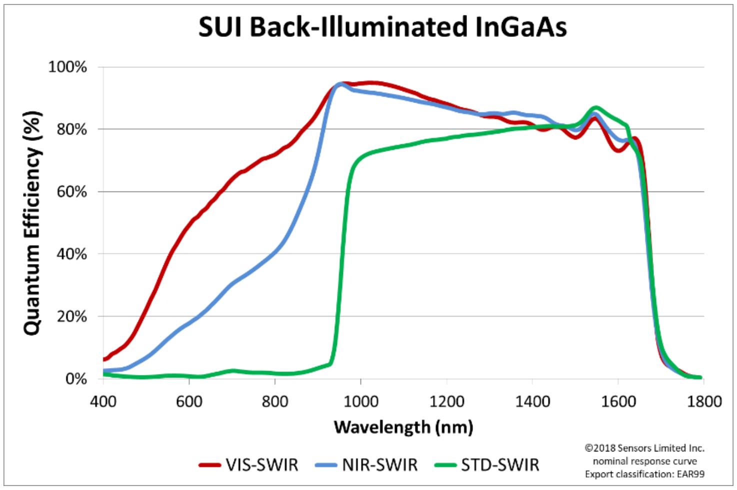


Figure 8. Typical Quantum Efficiency of SUI backside illuminated FPAs.

The CMOS readouts are "active pixel" devices in which the photocurrent is buffered, amplified and stored in each pixel. A simplified pixel schematic is shown in Figure 9. Each pixel contains a buffered gate modulated (B-GMOD) input circuit for converting current to voltage with continuously adjustable gain. In this circuit, the photodiode bias voltage is set through internally generated DSUB and VREF bias voltages. The photodiode current flows through M0 with a proportional amount of current mirrored in M1. The ratio of the currents through M1 and M0 is controlled though the externally set VBIAS and VGAIN voltages. The camera internally provides all bias voltages necessary for operation of the focal plane array.

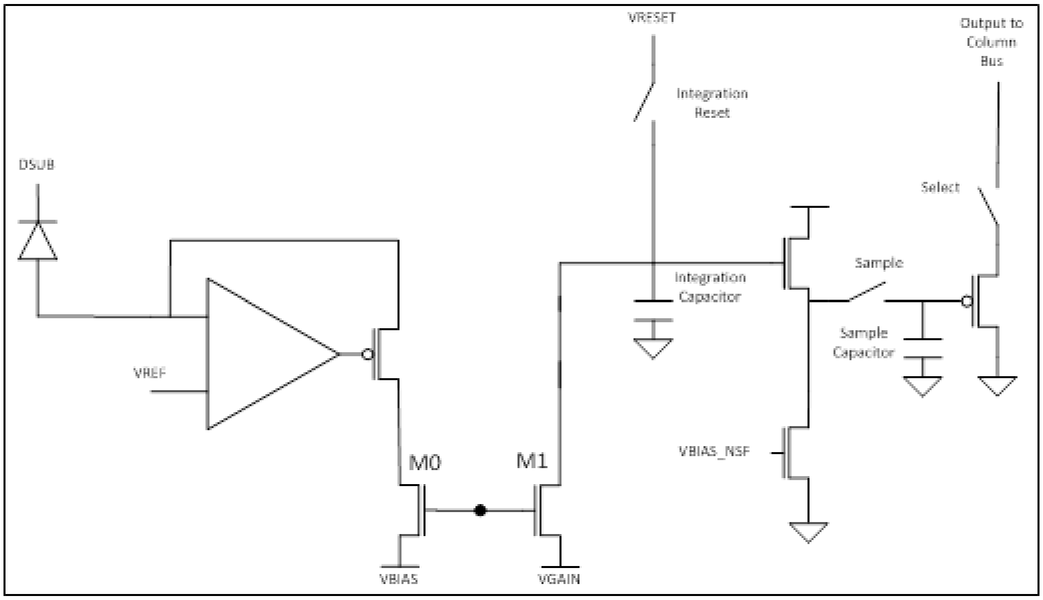


Figure 9. Simplified GMOD pixel schematic

The camera frame sequence consists of an exposure followed by digitization and readout. During exposure, the integration reset switch is open and the integration capacitor shown is discharged from its reset voltage by the mirrored photodiode current, converting the signal current to a voltage. At the end of the integration time, the sample switch is momentarily closed to sample the integration period's final signal voltage. After the signal is sampled, the integration reset switch is closed and held until the start of the next integration period. The exposure may or may not overlap the readout of the last frame depending on the exposure period and the frame rate. Since all pixels' integration reset, sample, and sample reset switches receive the same clock timing, the FPA operates with "snapshot" exposure: all pixels are exposed simultaneously, starting and finishing at the same time.

In order to generate the serial digital video signal that is output from the FPA, each row is sequentially selected, and the analog pixel signals are passed to circuitry at the edge of the array. An on-ROIC ADC converts the pixel signals to 12-bit digital values, which are then serialized and output on a high speed digital bus.

4.2. Camera System Operation

The CSX camera provides all support functions to the SU640AB4 focal plane array necessary to provide the user access to its full performance capabilities. The camera is a complete data acquisition system supporting the analog, digital, and power conditioning subsystems needed to operate the focal plane array with minimal external support, with digital taps available to grab the signal at various stages. A basic signal flow diagram for the CSX camera system is shown.

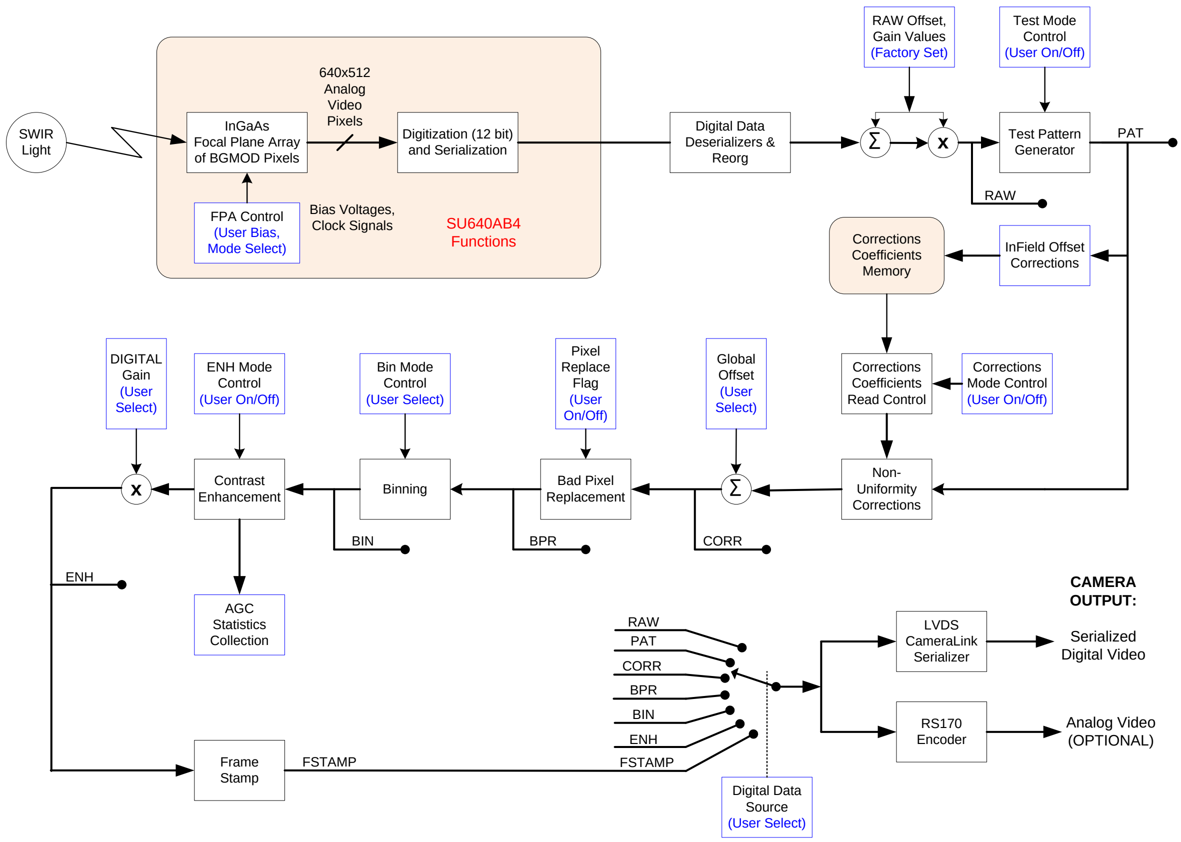


Figure 10. Camera system signal flow diagram

See the command sections for more detailed information on the operation of the various camera functions supported by the CSX camera.

5. Camera Functions and Control Software Interface

The CSX camera has a variety of features and modes that can be selected or queried through the control interface including automatic gain control (AGC), exposure time, frame rate, non-uniformity corrections, bad pixel corrections, and trigger modes. The CSX camera communicates via LVDS serial communication provisions compliant to the Camera Link standard. All camera modes are controlled using a set of ASCII commands sent by the Host to the camera utilizing the serial line inherent in the Camera Link standard.

Appendix B is included as a separate document and includes default factory settings and calibration information, including a table that correlates operational settings (OPRs) to integration time and nominal FPA gain. Appendix B is specific to each camera model. It is highly recommended that the end user become extremely familiar with this document.

5.1. Communication Protocol

The CSX camera communicates via the serial communication provisions of the Camera Link standard. This asynchronous serial communication is performed using 8 data bits, 1 stop bit, no parity, no flow control, and a configurable baud rate. (See Appendix B for the default serial communication baud rate for your particular camera.)

Table 6. Serial Communication Parameters

Serial Parameter	Default Value
Data Bits	8
Stop Bit	1
Parity	None
Flow control	None
Baud Rate	57600 is factory default, but it is user configurable.

5.2. Command Format and Response

The following typeface conventions are used when describing the camera command set:

- Text that should be reproduced literally is shown in constant-width type.
- Text that should be replaced by the user is shown in *constant-width italic type*.
- Optional text is enclosed in square brackets ([]).
- Comments are preceded by a double dash (--).
- Special operating or cautionary remarks are prefaced by *Note:* and *italicized in the normal font*.
- **WARNING notes are in boldface**.

When commanding the camera the following rules apply:

- Command input is not case sensitive, upper and lowercase characters are accepted by the camera.
- A carriage return <CR> ends each command.
- All commands and arguments should be separated by white space.
- Extra arguments entered on the command line will be ignored, although there is a maximum character count.

- The camera supports several echo modes. The camera can echo the received character back to the user. Alternatively, the echo mode can be configured so that every character received by the camera is echoed using a user-specified character, such as an asterisk. Finally, echo can be disabled, resulting in no output of an echo line. The commands to control the supported echo modes are discussed in Section 5.6.5.
- The return value line output is command dependent. Some commands, such as query commands, will have a return value and so this line will be output. Other commands have no return value and so no return value line will be output.
- Upon successful execution of a command, the processed command response line contains the command and any valid arguments provided. Since extra invalid arguments can be entered on the command line, the processed command response may differ from the command line input (and echo line).
- Upon unsuccessful execution of a command, the processed command response line contains all arguments entered on the command line. The processed command response line output can be suppressed by setting the response mode to “brief”, and can be enabled by setting the response mode to “verbose”. *Note: The processed command and any arguments returned will be separated by a single space, and will be capitalized regardless of the format in which they were originally entered on the command line.* The commands to control the supported response modes are discussed in appropriate sections.
- Upon successful execution of the command, the command execution outputs the characters:
  “OK”.
  If the command failed or is invalid, the output is:
  “ERROR”.
  The command execution result is always output.
- After the command execution result is returned, the camera will return the command prompt character “>.” Reception of the command prompt character by the Host is an indication that the camera is ready to receive the next command.

Table 7. Line format of camera command return strings.

Line Format	Line Description	Conditions
COMMAND [*ARGUMENTS*]<CR>	Echo	Returned if configured with echo enabled. Shown format is for echo of received characters. May also be configured for return of user specified character.
[return value]<CR>	Return Value	Returned if issued command results in a return value.
COMMAND [*VALID ARGS*]<CR>	Processed Command Response	Returned if configured for verbose response mode.
RESULT<CR>	Command Result	Always returned.
>	Command Prompt	Always returned.

5.3. Startup Messaging

Reboot of the camera occurs when power to the camera is cycled. On reboot, the camera transmits a startup banner to the host. The CSX startup banner has the following format:

```
SU640CSX Camera
Sensors Unlimited, Inc. - All
Rights Reserved
Software Version
XXXX.XX.XX.XX
Hardware Version
XXXX.XX.XX.XX
 >
```

Version numbers will be replaced with your actual versions.

Once the command prompt character “>” has been received by the host, the camera is ready to receive a command.

5.4. Command Set

A detailed explanation of each command is presented in the following format:

Description:	Describes the behavior of the command and other pertinent information.
Setting	Type specifies if the command’s value is a global setting, operational setting, or neither.
Command	Command syntax.
Parameters	Lists the parameters taken by the command as listed in the syntax above.
Type	Specifies the expected type of the parameter.
Range	Specifies the valid range of the parameter.
Return Values	Lists the values returned by the command.
Example	Provides a programming example, showing the syntax of the command, parameters, and return values. For brevity these examples do not include echo, processed command response, command execution result, or command prompt.

5.5. Configuration Commands

The camera has three distinct memory spaces, shown in Camera Memory Layout figure, that are used to manage the camera’s configuration. There are two non-volatile memory spaces; one that holds the User Configuration and another behind a ‘firewall’ that holds the Factory Configuration. The User Configuration can be altered and saved by the user to customize camera operation. The Factory Configuration, programmed at time of manufacture, cannot be altered by the user. This configuration is provided to restore the camera to its default configuration with the CONFIG:RESET command, if needed. Appendix B lists the factory global configuration setting values, and is a separate document from this manual.

A single volatile memory space is used to hold the Current Session Configuration. This memory space is changed each time the user issues a command, but this memory space does not persist between power cycles and camera reboots, only the User Configuration persists between power cycles and camera reboots.

The User Configuration is loaded into the Current Session Configuration upon camera power-up. The User Configuration can be modified by issuing the CONFIG:SAVE command, which causes the global setting in the Current Session to be written back to the User Configuration, overwriting the previous global settings. Issuing the OPR:SAVE command results in the creation of a new operational slot in the User Configuration. The present state of the operational setting in the Current Session Configuration is saved to this newly created operational slot. Issuing the OPR:UPDATE command causes the operational settings in the Current Session Configuration to be written back to the User Configuration, overwriting the previous settings for that particular operational slot.

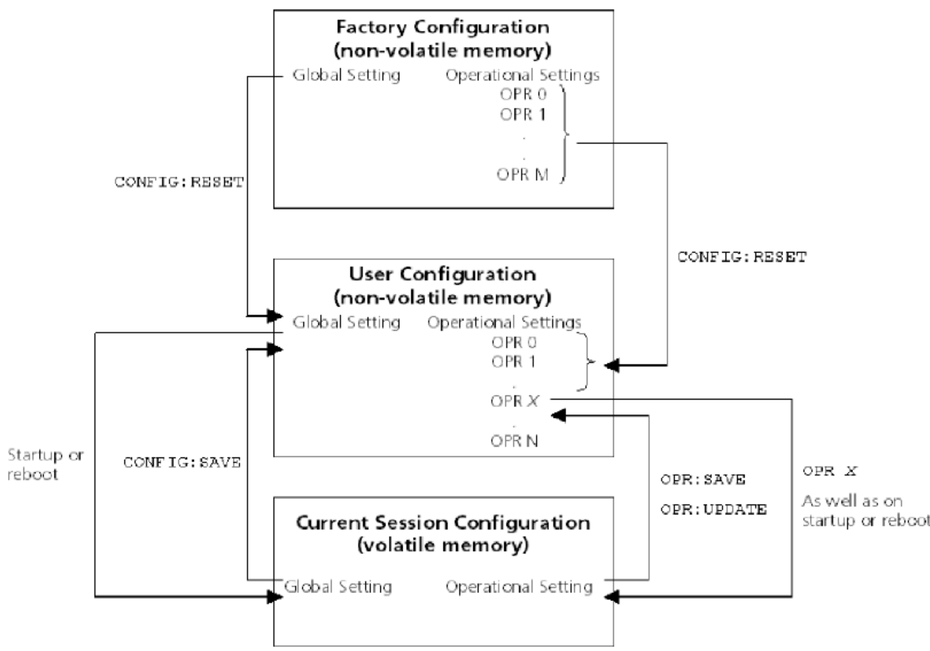


Figure 11. Camera memory layout.

Different operational settings can be loaded into the Current Session Configuration with the OPR command. Once the global and operational settings are loaded they can be modified by issuing commands to the camera. Changes to the global and operational settings will not persist between camera power cycles unless they are saved to User Configuration non-volatile memory space using the CONFIG:SAVE and OPR:SAVE or OPR:UPDATE commands.

5.5.1. Restore Factory Configuration

Description: Restores the factory default settings. The User Configuration memory space is erased. Then the Factory Configuration is copied to the User Configuration memory space. Finally, the Current

	Session Configuration is reloaded from the User Configuration. Most modifications made by the user will be lost. However, offset correction values overwritten with CORR:OFFSET:CAL will persist. Appendix B (separate document) lists the Factory Configuration global and operational parameter values for your camera model.
Setting Type	N/A
Command	CONFIG:RESET
Parameters	None
Return Values	None
Example	CONFIG:RESET

5.5.2. Save Global Configuration

Description:	Overwrites the User Configuration global settings with the Current Session's global settings.
Setting Type	N/A
Command	CONFIG:SAVE
Parameters	none
Return Values	none
Example	CONFIG:SAVE

5.5.3. Load Operational Configuration

Description:	Loads the operational settings for the specified operational slot. See the separate Appendix B document for a table of OPR settings and corresponding integration and nominal FPA gain settings. An error will occur if an opr_number outside of the available range is used.
Setting Type	N/A
Command	OPR opr_number
Parameters	opr_number
Return Values	none
Range	0 to N (limited by the number of operational settings that currently exist, see the separate Appendix B document for table of OPR settings).
Type	unsigned integer
Example	OPR 5

5.5.4. Get Current Operational Configuration Number

Description	Returns the current operational slot number that is loaded.
Setting Type	N/A
Command	OPR?
Parameters	none
Return Values	opr_number
Range	0 to N, maximum value N is OPR:MAX (see command below).
Type	unsigned integer
Example	OPR? -- query command 5 -- return value

5.5.5. Get Total Number of Operational Configurations

Description	Returns the number of operational settings currently present in the User Configuration memory.
Setting Type	N/A
Command	OPR:MAX?
Parameters	none
Return Values	number
Range	1 to N
Type	unsigned integer
Example	OPR:MAX? -- query command 8 -- return value

5.5.6. Set Startup Operational Configuration

Description	Sets the operational slot number that will be loaded on reboot of the camera. *Note: Because this is a global setting, a CONFIG:SAVE command must subsequently be issued to cause any changes in this value to be saved to the User Configuration memory*. Because the number of OPRs can change by user action, it is possible to set this parameter to an invalid OPR.
Setting Type	Global
Command	OPR:START *opr_number*
Parameters	*opr_number*
Return Values	none
Range	0 to N, maximum value limited by the number of operational settings that currently exist.

Type	unsigned integer
Example	OPR:START 5

5.5.7. Get Startup Operational Configuration

Description	Returns the operational slot number that will be loaded on reboot of the camera.
Setting Type	Global
Command	OPR:START?
Parameters	none
Return Values	opr_number
Range	0 to N', maximum value limited by the number of operational settings that once existed.
Type	unsigned integer
Example	OPR:START? -- query command 5 -- return value

5.5.8. Create New Operational Configuration

Description	Takes the Current Session operational setting and saves it to the User Configuration memory assigning a new operational slot number. The operational slot numbers are assigned sequentially. The new operational slot number will be returned to the host. The OPR:SAVE command will return an error for camera models where all available OPR memory slots are populated by factory configured OPR parameters. *Note: When a new operational setting is created, any factory correction table associated with the current operational slot will* ***not*** *be copied to the new operational slot setting. Corrections, therefore, must be disabled when using the newly created configuration slot for meaningful data to be produced.* ***This command is only required when users require custom OPR settings.***
Setting Type	N/A
Command	OPR:SAVE
Parameters	none
Return Values	newly created opr_number
Range	0 to N
Type	unsigned integer
Example	OPR:SAVE -- command 18 -- return value

5.5.9. Update Existing Operational Configuration

Description	Takes the Current Session operational setting and saves it to the

	User Configuration memory in the selected OPR slot. This command is only required when users require custom OPR settings.
Setting Type	N/A
Command	OPR:UPDATE
Parameters	none
Return Values	none
Range	
Type	
Example	OPR:UPDATE

5.5.10. Delete Last Operational Configuration

Description	Deletes the last (or highest) slot number, operational configuration slot from the User Configuration memory. This operation will only delete operational configuration slots created by the user, and will return an error if executed when only factory operational configuration slots exist. If the Current Session Configuration is the last operational configuration when this command is issued, a subsequent query of the current operational configuration number will return the deleted operational configuration number, since it is still the Current Session Configuration, but a command to load the deleted operational number will error. WARNING: If the startup operational configuration slot is deleted, the camera startup operation is no longer specified. Use the OPR:START followed by the CONFIG:SAVE commands to reselect an existing operational configuration slot if the startup operational configuration slot is deleted.
Setting Type	N/A
Command	OPR:DEL
Parameters	none
Return Values	none
Range	
Type	
Example	OPR:DEL

5.5.11. Delete All Operational Configurations

Description	Deletes all operational configuration slots created by the user from the User Configuration memory. This operation will return an error if executed when only factory operational configuration slots exist. If the Current Session Configuration slot is deleted from the User Configuration memory, a subsequent query of the current session

	operational configuration slot number will return the deleted operational configuration slot number, since it is still the Current Session Configuration, but a command to load the deleted operational configuration slot number will return an error. WARNING: If the startup operational configuration slot is deleted, the camera startup operation is no longer specified. Use the OPR:START followed by the CONFIG:SAVE commands to reselect an existing operational configuration slot if the startup operational configuration slot is deleted.
Setting Type	N/A
Command	OPR:DEL:ALL
Parameters	none
Return Values	none
Range	
Type	
Example	OPR:DEL:ALL

5.6. Serial Communication Interface Commands

Baud rate configuration in the volatile memory space is managed with two discrete variables. The first variable, current baud rate, represents the baud rate at which the camera is currently communicating. The second variable, future baud rate, holds the baud rate value that will be stored to non-volatile memory when a global configuration save (CONFIG:SAVE) is executed. Changing the current baud rate will require the host to change baud rates for communication to continue. Changing the future baud rate and saving it to non-volatile memory allows for the new baud rate to be effective upon reboot of the camera. The factory default is 57600 baud. Other serial communication parameters are located in Table 6.

5.6.1. Set Current Baud Rate

Description	This command updates the current baud rate variable. The baud rate that the camera communicates at will change immediately. **WARNING: Changing the current baud rate will require the host to change baud rates for communication to continue.**
Setting Type	Global
Command	BAUD:CURRENT *baud_rate*
Parameters	*baud_rate*
Return Values	none
Range	57600
	115200
	230400
	460800

Type	unsigned integer
Example	BAUD:CURRENT 57600

5.6.2. Get Current Baud Rate

Description	Returns the current baud rate.	
Setting Type	Global	
Command	BAUD:CURRENT?	
Parameters	none	
Return Values	baud_rate	
Range	57600	
	115200	
	230400	
	460800	
Type	unsigned integer	
Example	BAUD:CURRENT? 57600	-- query command -- return value

5.6.3. Set Future Baud Rate

Description	Updates the future baud rate variable. WARNING: A CONFIG:SAVE command must be executed after this command for a change in the future baud rate value to be saved and persist after power cycle.
Setting Type	Global
Command	BAUD:FUTURE *baud_rate*
Parameters	*baud_rate*
Return Values	none
Range	57600
	115200
	230400
	460800
Type	unsigned integer
Example	BAUD:FUTURE 230400

5.6.4. Get Future Baud Rate

Description	Returns the value stored in the future baud rate variable.
Setting Type	Global
Command	BAUD:FUTURE?
Parameters	none
Return Values	baud_rate
Range	57600 115200 230400 460800
Type	unsigned integer
Example	BAUD:FUTURE? -- query command 230400 -- return value

5.6.5. Set Echo Mode

Description	Sets the echo mode for serial communications. In mode 0 echo is disabled. In mode 1 echo is enabled. Any character received on the serial port is immediately echoed back. An exception to the echo of the received character with mode 1 enabled is when a backspace character is received while the receive buffer is empty. In mode 2 echo is enabled but instead of echoing back the character received a user defined character is echoed. Echo mode 1 provides for the most robust communication, allowing the host to verify that each character sent to the camera was properly received. Echo mode 2 allows the host to verify that the camera received characters, but does not provide a way to verify that characters where not corrupted during transmission.
Setting Type	Global
Command	ECHO:MODE mode
Parameters	*mode*
Return Values	none
Range	0 Echo off 1 Echo received character 2 Echo user defined character
Type	unsigned integer
Example	ECHO:MODE 1 -- query command

5.6.6. Get Echo Mode

Description	Returns the current echo mode setting.	
Setting Type	Global	
Command	ECHO:MODE?	
Parameters	none	
Return Values	mode	
Range	0	Echo off
	1	Echo received character
	2	Echo user defined character
Type	unsigned integer	
Example	ECHO:MODE? -- query command	
	1 -- return value	

5.6.7. Set Echo Character

Description	Sets the echo character returned when in echo mode 2. The character is set by entering the ASCII code of the desired character.
Setting Type	Global
Command	ECHO:CHAR *value*
Parameters	*value*
Return Values	none
Range	0 to 255
Type	unsigned integer
Example	ECHO:CHAR 35 -- ASCII CODE 35 is #

5.6.8. Get Echo Character

Description	Returns the echo character used for echo mode 2.
Setting Type	Global
Command	ECHO:CHAR?
Parameters	none
Return Values	value
Range	0 to 255
Type	unsigned integer
Example	ECHO:CHAR? -- query command

	35 -- return value

5.6.9. Set Response Mode

Description	The camera supports two response modes, brief and verbose. In verbose response mode the processed command response line discussed in Section 5.2 is output. In brief response mode the processed command response line is not echoed.
Setting Type	Global
Command	RESPONSE *mode*
Parameters	*mode*
Return Values	none
Range	BRIEF Brief response mode
	VERBOSE Verbose response mode
Type	string
Example	RESPONSE VERBOSE

5.7. Non-Uniformity Corrections (NUCs) Commands

The factory operational configuration slots (OPRs) support two-point correction tables that can be used to compensate for the dark signal and photoresponse non-uniformity of the FPA. The gain and offset correction coefficients are unique for each operational setting. The correction table coefficients are applied to create a corrected pixel value PIXCORR according to the following relation:

$$PIXCORR = ((PIXIN - CORROFF) \times CORRGAIN / 2048) + GLOBALCORROFF$$

where PIXIN is the raw pixel value, CORROFF is the offset correction value, CORRGAIN is the gain correction value, and GLOBALCORROFF is the global corrected offset value. CORROFF and CORRGAIN are unique for each FPA pixel and operational configuration slot. GLOBALCORROFF is applied to every pixel of the frame. The correction commands allow the offset, gain, and pixel corrections to be independently enabled or disabled. If offset correction is disabled, CORROFF and GLOBALCORROFF are 0. If gain correction is disabled, CORRGAIN is 2048.

If either gain or offset correction is applied to the raw pixel data and a subsequent digital fixed gain of 1X is used, some pixel values may not saturate at the full 12-bit resolution count value of 4,095. A fixed digital gain greater than 1X can be applied to the corrected image data to guarantee that all pixels saturate at the full scale value of 4,095 if needed or desirable.

5.7.1. Set Gain Correction State

Description	Sets the state of the gain correction. Gain correction compensates for pixel-to-pixel photoresponse non-uniformity. Otherwise known as a white balance correction (multiplication).

Setting Type	Global
Command	CORR:GAIN *state*
Parameters	*state*
Return Values	none
Range	ON Enables Gain Corrections OFF Disables Gain Corrections
Type	string
Example	CORR:GAIN ON

5.7.2. Get Gain Correction State

Description	Returns the state of the gain correction.
Setting Type	Global
Command	CORR:GAIN?
Parameters	none
Return Values	state
Range	ON Gain Correction Enabled OFF Gain Correction Disabled
Type	string
Example	CORR:GAIN? -- query command ON -- return value

5.7.3. Set Offset Correction State

Description	Sets the state of the offset correction. Offset correction compensates for dark current signal non-uniformity. Otherwise known as a Dark Correction (subtraction).
Setting Type	Global
Command	CORR:OFFSET *state*
Parameters	*state*
Return Values	none
Range	ON Enables Offset Corrections OFF Disables Offset Corrections
Type	string

Example	CORR:OFFSET ON

5.7.4. Get Offset Correction State

Description	Returns the state of the offset correction.	
Setting Type	Global	
Command	CORR:OFFSET?	
Parameters	none	
Return Values	state	
Range	ON	Offset Correction Enabled
	OFF	Offset Correction Disabled
Type	string	
Example	CORR:OFFSET? -- query command ON -- return value	

5.7.1. Set Global Corrected Offset Value

Description	Sets the global corrected offset value. Global offset is a fixed value that is added to each pixel in the image after all other corrections have been applied if offset correction is enabled. The net effect of this command is a positive DC offset. As this command is after the RAW ADC step, any negative raw pixel value going into the ADC is not offset and remains zero-clipped (an unusual condition to begin with). The global offset can be disabled by setting its value to zero.
Setting Type	Global
Command	CORR:OFFSET:GLOBAL *value*
Parameters	*value*
Return Values	none
Range	0 to 4095
Type	unsigned integer
Example	CORR:OFFSET:GLOBAL 0

5.7.2. Get Global Corrected Offset Value

Description	Returns the global corrected offset value.
Setting Type	Global

Command	CORR:OFFSET:GLOBAL?
Parameters	none
Return Values	value
Range	0 to 4095
Type	unsigned integer
Example	CORR:OFFSET:GLOBAL? -- query command 0 -- return value

5.8. Bad Pixel Corrections

Defective FPA pixels can be substituted with an interpolated pixel value. The pixel correction function uses a bad pixel map that is unique to each operational configuration slot (OPR).

A command to enable the return of the correction pixel map in the form of image data is supported. When the correction pixel map is enabled, a pixel value of 0 is returned for pixels locations that are not replaced and 4,095 returned for pixels that are replaced when pixel correction is enabled.

5.8.1. Set Pixel Substitution State

Description	Sets the state of the pixel substitution. Pixel substitution replaces pixels that do not pass focal plane array performance specifications with the last, non-replaced pixel value. Consecutive substitution is allowed, using the same non-replaced pixel value. While more pleasing to the eye/brain, some machine vision computations perform better with pixel substitution off.
Setting Type	Global
Command	CORR:PIXEL *state*
Parameters	*state*
Return Values	none
Range	ON Enables Pixel Substitutions OFF Disables Pixel Substitutions
Type	string
Example	CORR:PIXEL ON

5.8.2. Get Pixel Substitution State

Description	Returns the state of the pixel substitution.
Setting Type	Global
Command	CORR:PIXEL?
Parameters	none
Return Values	state
Range	ON Pixel Substitution Enabled
	OFF Pixel Substitution Disabled
Type	string
Example	CORR:PIXEL? -- query command
	ON -- return value

5.8.3. User Pixel Defect Flag

Description	Allows the user to add a pixel into the defective pixel map, allowing the pixel correction tool CORR:PIXEL to act on these additional individual pixels. Pixels may be defined in the current OPR or defined for all OPRs. Pixels are selected by their X,Y coordinates in each OPR, and can be interactively added and removed from the map. Additionally, the command can be used to turn the individual x,y user-added pixels ON or OFF across all OPRs.
Setting Type	Global
Command	PIX:RPL *parameters*
Parameters	*x, y ordinates of pixel, ON/OFF, ALL*
Return Values	
Range	<x> X coordinate of selected pixel
	<y> Y coordinate of selected pixel
	ON <default> Flags pixel for replacement
	OFF Removes flag to make pixel active
	ALL Sets ON or OFF state to user-flagged pixels across all OPRs
Type	integer, string
Example	Examples PIX:RPL 34 127 ON --Sets pixel (34,127) to replacement status

PIX:RPL 34 127 OFF ALL
--Restores flagged pixel 34,127 in all OPRs to active
PIX:RPL 34 127
--Sets pixel (34,127) to replacement status (ON) in current OPR

5.8.4. User Pixel Defect Flag Count

Description	Counts the number of pixels currently enabled in User Pixel Replacement (PIX:RPL)
Setting Type	Global
Command	PIX:BAD?
Parameters	none
Return Values	integer
Range	0 – n
Type	n/a
Example	PIX:BAD? -- query command
	7 -- return value (7 user-defined pixels)

5.8.5. Set Correction Bypass State

Description	Sets the state of the correction bypass: With one command the 3 correction commands: Gain (white), Offset (dark) and Pixel (defect) Correction are set to On or Off as a group.
Setting Type	Global
Command	CORR:BYPASS *state*
Parameters	*state*
Return Values	none
Range	ON Enables Correction Bypass
	OFF Disables Correction Bypass
Type	string
Example	CORR:BYPASS ON

5.8.6. Get Correction Bypass State

Description	Returns the state of the correction bypass.
Setting Type	Global

Command	CORR:BYPASS?	
Parameters	none	
Return Values	state	
Range	ON	Corrections globally bypassed
	OFF	Corrections not globally bypassed
Type	string	
Example	CORR:BYPASS? -- query command	
	ON -- return value	

5.8.7. Set Pixel Substitution Map State

Description	Sets the state of the pixel substitution map. If enabled, a pixel value of 0 is returned for pixels locations that are live (not replaced) and 4,095 is returned for pixels that are replaced when pixel substitution is enabled (marked defective pixel). The result is essentially Binary in the outputted image: black for valid pixels, and white for substitute locations, in an image format, which makes it easy for image math or to generate a CSV file of substitute locations. This tool will disconnect the prior data flow stream, so it is not possible to act on this map.	
Setting Type	Global	
Command	CORR:PIXEL:MAP *state*	
Parameters	*state*	
Return Values	none	
Range	ON	Enables Pixel Substitution Map
	OFF	Disables Pixel Substitution Map
Type	string	
Example	CORR:PIXEL:MAP OFF	

5.8.8. Get Pixel Substitution Map State

Description	Returns the state of the pixel substitution map.	
Setting Type	Global	
Command	CORR:PIXEL:MAP?	
Parameters	none	
Return Values	state	
Range	ON	Pixel Substitution Map Enabled

	OFF Pixel Substitution Map Disabled
Type	string
Example	CORR:PIXEL:MAP? -- query command OFF -- return value

5.8.9. Perform In-Field Dark Offset Operation

This command will perform an offset correction that is stored in camera RAM memory (volatile) for a single OPR setting, or stored to camera flash (nonvolatile) for ongoing use. This is also referred to as an In-Field Dark Offset Correction (IFOC). This function only affects the NUC offset (CORROFFSET as described in Section 5.7). Its purpose is to update the offset for shifts in pixel base values over time.

Preconditions:

1) The AGC must be disabled (AGC:ENABLE OFF) when running the In-Field Dark Offset Correction function.

2) The scene must be dark, else the resulting non-dark-recorded offset will act like a mask or watermark superimposed on the live video data. Zero clipping may also be possible after the IFOC is carried out if any light is present at the FPA.

The camera can store the resulting correction frame in camera volatile memory for temporary correction conditions that do not persist a power cycle, or the data may be written to Flash non-volatile memory for semi-permanent use (i.e. persist power cycle, but change the next time this command is operated). **Once overwritten, the use of a CONFIG:RESET command will not restore the original factory values.**

The IFOC function sums and averages 32 or 64 frames to average the noise response by root(# of frames). Noise is decreased by ~5 or ~8 x in this manner, respectively. More importantly is that it prevents a single noise spectrum from being superimposed on the newly created NUC table. At normal frame rates of 30 fps, the offset data is collected in roughly 1 or 2 seconds. If a custom FRAME:PERIOD value is used, the time for acquisition is the EXP time multiplied by either 32 or 64, depending on the value of the <*frames*> argument.

The camera has been designed to recover from power interruptions during flash write operations. The camera will start up normally, but it may be necessary to re-run the offset calibrations command to fix a potentially-corrupted correction.

Description	Perform offset calibration operation.
Setting Type	N/A
Command	CORR:OFFSET:CAL *arguments*
Parameters	*arguments: <frames> <flash> <output>*
Return Values	none
Range	32 Initiates an averaging of 32 frames of field offset calibration data where the accumulated value for each pixel replaces the factory offset corrected pixel value. The data is

collected for the currently selected OPR and timing mode. Once accumulated, this data will then start to be used to apply offset correction to the pixel data for the OPR that was used when it was collected.

It is intended for the user to inhibit light from falling on the FPA for the duration of the command execution: For normal OPR operations, 32 frames at 30 fps is roughly 1 second.

64 Initiates an averaging of 64 frames of field offset calibration data where the accumulated value for each pixel replaces the factory offset corrected pixel value. The data is collected for the currently selected OPR and timing mode. Once accumulated, this data will then start to be used to apply offset correction to the pixel data for the OPR that was used when it was collected.

It is intended for the user to inhibit light from falling on the FPA for the duration of the command execution: For normal OPR operations, 64 frames at 30 fps is roughly 2 seconds.

FLASH Optional. If FLASH is not specified, the camera accumulates and stores the offset data in camera memory for use in the current OPR. The data is held until power is cycled/reboot. The new offset correction will be available if you leave and return to the given OPR.

If FLASH is specified, on completion of the frame collections, the camera will then write the new correction data to camera flash (nonvolatile) memory, which survives camera reboots.

OUTPUT Provides a countdown of the flash write activity, parsed at reasonable intervals. While possibly helpful in monitoring the flash write process, OUTPUT does not time the actual acquisition of frames. Typical time for FLASH operations to complete can be as long as 4 seconds. The OUTPUT command use does not change the operation length of the FLASH update. Invoking OUTPUT without FLASH adds no value.

Type	string
Example	CORR:OFFSET:CAL 32 FLASH OUTPUT -- acquire cal offset data based on 32 frames and write to camera nonvolatile memory while metering the flash write process. CORR:OFFSET:CAL 64 -- acquire cal offset data based on 64 frames and save in camera live (volatile) memory.

CORR:OFFSET:CAL

-- acquire cal offset data based on 32 (default value) frames and save in camera live (volatile) memory.

5.9. Automatic Gain Control (AGC) Commands

The Automatic Gain Control (AGC) algorithm monitors frame statistics on every frame and selects the operational configuration (OPR number) to achieve the best camera sensitivity settings for the given imaging scene. When AGC is enabled, operational configurations can be loaded using the OPR command (Section 5.5.3). However, the AGC algorithm will override the user set operation configuration if the scene data falls outside of the AGC requirements for that OPR. Therefore, it is best to disable the AGC when manually adjusting the operational configuration (OPR). The OPR? command can be used to poll the current operational configuration setting.

The AGC operates within groups of OPRs of a related temperature setpoint. These OPR groups are delimitated by the Macro group. See the separate Appendix B document for a table of OPRs and details on the MACRO command settings. See Section 5.20 for details on the MACRO command itself.

TEC Setpoint (°C)	MACRO	Low Case Temperature (°C)	High Case Temperature (°C)
18	0	-40	35
32	1	0	55
45	2	20	70

For the standard configuration, there are more than one focal plane array setpoint temperatures available for AGC operation, as shown in the table above. By default, the camera loads MACRO0, which corresponds to the lowest FPA setpoint. This allows for the highest sensitivity operation, but may also show image persistence in certain scenes. If the case temperature is expected to exceed 35°C, or if image persistence is an issue, it is best to run MACRO1, which utilizes the median focal plane array temperature setpoint for standard sensitivity with low lag (image persistence) performance. If the camera case temperature is expected to exceed 55°C, it is recommended to change the focal plane array setpoint to the high temperature AGC setting with MACRO2 to assure thermal stability of the focal plane array for elevated camera case temperatures.

The user can select among the different AGC ranges by using the MACRO command as described in Section 5.20. Macros are created by the factory and listed in Appendix B (attached on hard copy of manual, and located as a separate file on the CD shipped with your camera).

Note: The image enhancement algorithm is not recommended for windowing operation or enhancement of uncorrected data.

Note: When AGC is disabled the camera will remain in the last OPR used by the auto gain control. Turning AGC off may change the image data. This is a result of proprietary enhancement modes supported when AGC is enabled that are not supported when manually changing OPRs.

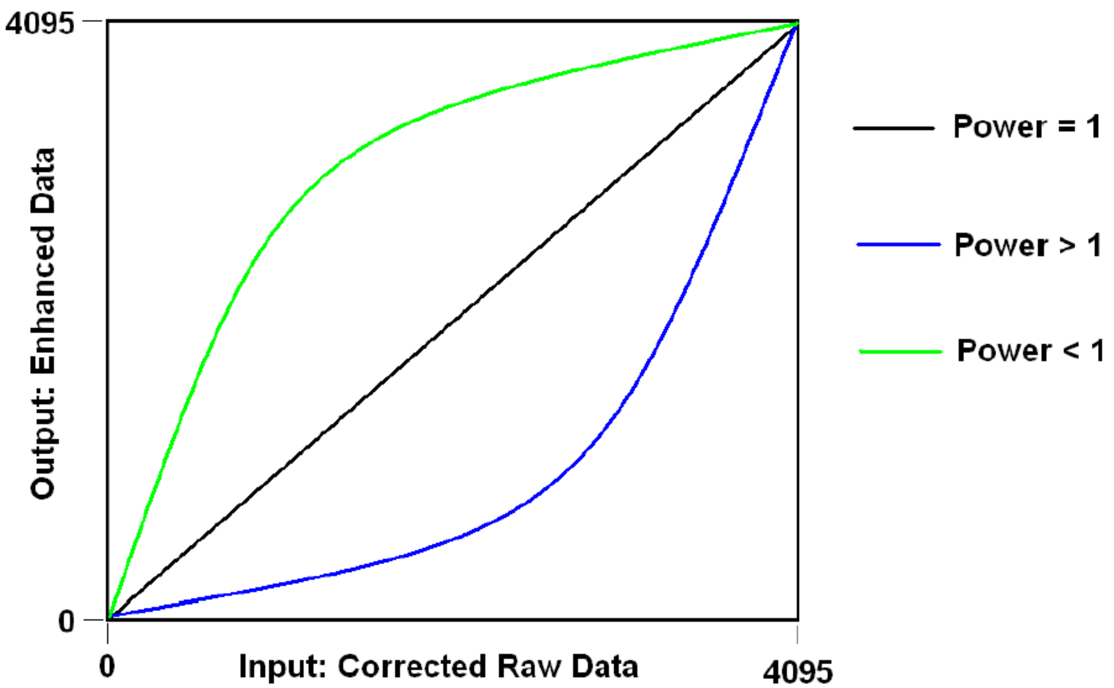


Figure 12. Effects of POWER function on look-up table and Enhancements

5.9.1. Set AGC State

Description	Sets the state of the AGC algorithm.	
Setting Type	Global	
Command	AGC:ENABLE *state*	
Parameters	*state*	
Return Values	none	
Range	ON	Enables AGC
	OFF	Disables AGC
Type	string	
Example	AGC:ENABLE ON	

5.9.2. Get AGC State

Description	Returns the state of the AGC algorithm.
Setting Type	Global
Command	AGC:ENABLE?
Parameters	none
Return Values	state
Range	ON AGC enabled OFF AGC disabled
Type	string
Example	AGC:ENABLE? -- query command ON -- return value

5.9.3. Set AGC Low Operational Setting

Description	This command used in conjunction with the set AGC high operational setting defines the range of operational settings that are available for use by the AGC algorithm. In this tool, low refers to the numerical value, i.e. 2 is lower than 3, and is not relative to light levels. WARNING: If the AGC low operational bound is set higher than the current AGC high operational bound, the camera AGC operation is no longer specified.
Setting Type	Global
Command	AGC:OPR:LOW *opr_setting*
Parameters	*opr_setting*
Return Values	none
Range	0 to (number), limited by number of operational settings that currently exist.
Type	unsigned integer
Example	AGC:OPR:LOW 0

5.9.4. Get AGC Low Operational Setting

Description	Returns the lowest operational setting available for use by the AGC algorithm.
Setting Type	Global
Command	AGC:OPR:LOW?
Parameters	none
Return Values	opr_setting

Range	0 to (number)
Type	unsigned integer
Example	AGC:OPR:LOW? -- query command 0 -- return value

5.9.5. Set AGC High Operational Setting

Description	This command used in conjunction with the set AGC low operational setting defines the range of operational settings that are available for use by the AGC algorithm. In this tool, high refers to the numerical value, i.e. 5 is higher than 4, and is not relative to light levels. WARNING: If the AGC high operational bound is set lower than the current AGC low operational bound, the camera AGC operation is no longer specified.
Setting Type	Global
Command	AGC:OPR:HIGH *opr_setting*
Parameters	*opr_setting*
Return Values	none
Range	0 to (number), limited by number of operational settings that currently exist.
Type	unsigned integer
Example	AGC:OPR:HIGH 14

5.9.6. Get AGC High Operational Setting

Description	Returns the highest operational setting available for use by the AGC algorithm.
Setting Type	Global
Command	AGC:OPR:HIGH?
Parameters	none
Return Values	opr_setting
Range	0 to (number) limited by number of operational settings that currently exist.
Type	unsigned integer
Example	AGC:OPR:HIGH? -- query command 7 -- return value

5.10. Image Enhancement Commands

The image enhancement algorithm of the CSX, when enabled, performs an enhancement on each pixel of the frame to produce a higher contrast image for display. The enhancement look-up table for each frame is computed using the previous frame's statistics. The frame statistics used to determine the enhancement look-up table are based on a histogram of the frame's pixels, e.g., the distribution of the frame's pixel values. The enhancement look-up table is generated from the collected histogram by a proprietary enhancement algorithm. By applying this enhancement algorithm, the pixel data will be stretched over the available pixel bit depth resulting in a higher contrast scene for display.

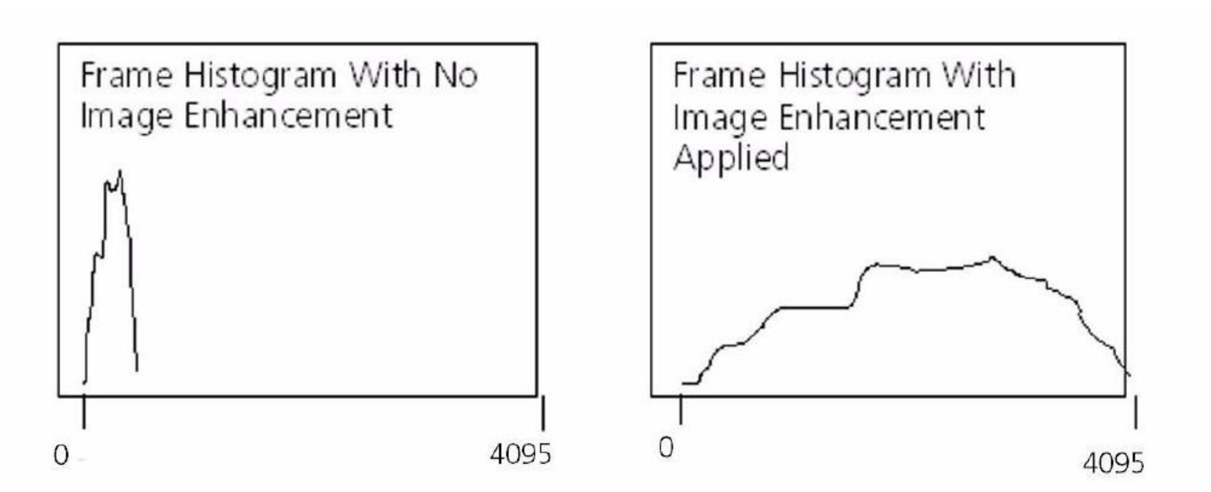


Figure 13. Example of enhancement algorithm effect on frame histogram.

When the camera is in the state ENH:AUTO ON (default), enhancements will be automatically controlled by the camera. To manually control the enhancements the command ENH:AUTO OFF should be sent and the ENH:POWER command should be used to adjust the image. The ENH:POWER function will only affect the data when ENH:AUTO is OFF and ENH:ENABLE is ON.

An ENH:POWER decimal value of less than 1 will shape the look-up table in a manner similar to the green line shown in the Figure. The slope of the curve is greater for the lower input values and will stretch the lower intensity data over a larger portion of the output, resulting in more shadow detail in the image at the expense of reducing contrast in the brighter areas of the scene.

An ENH:POWER decimal value of greater than 1 will shape the look-up table in a manner similar to the blue line shown in the Figure. The slope of the curve is greater for the higher input values and will stretch the higher intensity data over a larger portion of the output, resulting in more detail in the brighter areas of the image at the expense of reducing contrast in the lower signal (shadow) areas of the scene.

An ENH:POWER decimal value of 1 will shape the look-up table in a manner similar to the black line shown in the Figure. The slope of the curve is constant for the input values and will result in an image where the bright and dark areas of the scene are evenly weighed.

5.10.1. Set Enhancement State

Description	Sets the state of the image enhancement algorithm.	
Setting Type	Global	
Command	ENH:ENABLE *state*	
Parameters	*state*	
Return Values	none	
Range	ON	Enables Enhancements
	OFF	Disables Enhancements
Type	string	
Example	ENH:ENABLE ON	

5.10.2. Get Enhancement State

Description	Returns the state of the image enhancement algorithm.	
Setting Type	Global	
Command	ENH:ENABLE?	
Parameters	none	
Return Values	state	
Range	ON	Enhancements Enabled
	OFF	Enhancements Disabled
Type	string	
Example	ENH:ENABLE? -- query command	
	ON -- return value	

5.10.3. Set Automatic Enhancement State

Description	Sets the state of the image enhancement algorithm to be controlled automatically (ON), or manually (OFF).	
Setting Type	Global	
Command	ENH:AUTO *state*	
Parameters	*state*	
Return Values	none	
Range	ON	Enables Automatic Enhancements
	OFF	Disables Automatic Enhancements

Type	string
Example	ENH:AUTO ON

5.10.4. Get Automatic Enhancement State

Description	Returns the state of the image enhancement algorithm.
Setting Type	Global
Command	ENH:AUTO?
Parameters	none
Return Values	state
Range	ON Automatic Enhancements Enabled
	OFF Automatic Enhancements Disabled
	(Manual Enhancements Enabled)
Type	string
Example	ENH:AUTO? -- query command
	ON -- return value

5.10.5. Set Enhancement/AGC Frame Average and Width Weight

Description	Sets the number of frames over which frame statistics are calculated. The number of frames to be averaged is 2N.
Setting Type	Global
Command	ENH:AVG *value*
Parameters	*value*
Return Values	none
Range	0 to 5
Type	unsigned integer
Example	ENH:AVG 0

5.10.6. Get Enhancement/AGC Frame Average Weight

Description	Gets the number of frames over which frame statistics are calculated.
Setting Type	Global
Command	ENH:AVG?

Parameters	none
Return Values	value
Range	0 to 5
Type	unsigned integer
Example	ENH:AVG? -- query command 0 -- response

5.10.7. Set Enhancement Power Function

Description	Sets the power function value for manual enhancement mode. This function only affects data when in manual enhancement mode (ENH:AUTO OFF) with enhancements turned on (ENH:ENABLE ON). See Section 5.10 for a full description.
Setting Type	Global
Command	ENH:POWER *value*
Parameters	*value*
Return Values	none
Range	0 to 10
Type	unsigned decimal
Example	ENH:POWER 0.6

5.10.8. Get Enhancement Power Function

Description	Gets the power function value for manual enhancement mode.
Setting Type	Global
Command	ENH:POWER?
Parameters	none
Return Values	value
Range	0 to 10
Type	unsigned decimal
Example	ENH:POWER? -- query command 0.6 -- return value

5.11. Pixel Clock Commands

The camera electronics are designed to support a variety of focal plane arrays with varying requirements for pixel clock rate. The pixel clock is operated for the supported focal plane array at the maximum pixel clock rate reported through the command interface. The pixel clock period is needed to calculate exposure and frame times. Period is defined as the length of time for a given frequency event to occur i.e. 1 clock period (s) is 1/clock frequency (Hz).

5.11.1. Get Pixel Clock Maximum Rate

Description	Returns the FPA pixel clock rate in Hertz. The CSX camera clock rate is 20750000 Hz (20.75MHz).
Setting Type	Global
Command	PIXCLK:MAX?
Parameters	none
Return Values	value
Range	0 to 4294967295 (4,294,967,295)
Type	unsigned integer
Example	PIXCLK:MAX? -- query command 20750000 -- return value

5.12. Frame and Exposure Control Commands

The internally timed exposure period in seconds is given by the following relation:

EXPPERIOD = (EXP + 28) / (PIXCLK:MAX) (seconds)

Where PIXCLK:MAX returns 20750000Hz (20.75MHz) and where EXP is a clock count parameter set using the EXP command. 28 clock cycles are added to the exposure setting value to produce the true exposure duration to account for clocking overheads of the FPA. The maximum exposure time for a particular frame period is equal to the frame period, less the FPA required minimum dead (non-integration) time of two row read times for the CSX.

30 μs is the absolute minimum recommended integration time, and 200 μs is the suggested minimum integration time.

The internally timed frame period is given by:

FRAMEPERIOD = FRAME:PERIOD /PIXCLK:MAX (seconds)

The exposure period and frame period specified must be compatible with each other or a command error will occur. Therefore, knowledge of the current exposure and frame periods are required and the order in which the exposure and frame period are changed is crucial for success. Going from a short exposure and frame period to a longer exposure and frame period requires first increasing the frame period and then the exposure period, while going in the opposite direction requires shortening the exposure period first.

When the camera is set to operate in an externally triggered timing mode the exposure and frame period settings may not apply. (See Section 5.13 for a description of supported triggered timing modes.)

5.12.1. Set Exposure Period

Description	Sets EXPPERIOD, which controls the exposure time (see equation).
Setting Type	Operational
Command	EXP *value*
Parameters	*value*
Return Values	none
Range	1 to 16777214
Type	unsigned integer
Example	EXP 364651

5.12.2. Get Exposure Period

Description	Returns EXPPERIOD, which controls the exposure time (see equation).
Setting Type	Operational
Command	EXP?
Parameters	none
Return Values	value
Range	1 to 16777214
Type	unsigned integer
Example	EXP ? -- query command 364651 -- return value

5.12.3. Set Frame Period

Description	Sets FRAMEPERIOD, which controls the frame period (see equation).
Setting Type	Operational
Command	FRAME:PERIOD *value*
Parameters	*value*
Return Values	none
Range	1 to 16777214

Type	unsigned integer
Example	FRAME:PERIOD 366610

5.12.4. Get Frame Period

Description	Gets FRAMEPERIOD, which controls the frame period (see equation).
Setting Type	Operational
Command	FRAME:PERIOD?
Parameters	none
Return Values	value
Range	1 to 16777214
Type	unsigned integer
Example	FRAME:PERIOD? -- query command 366610 -- return value

5.13. Trigger Commands

The user can change the trigger mode via the serial communication ASCII command TRIG:MODE, which will allow control of the camera timing via 3.3V CMOS Logic signals.

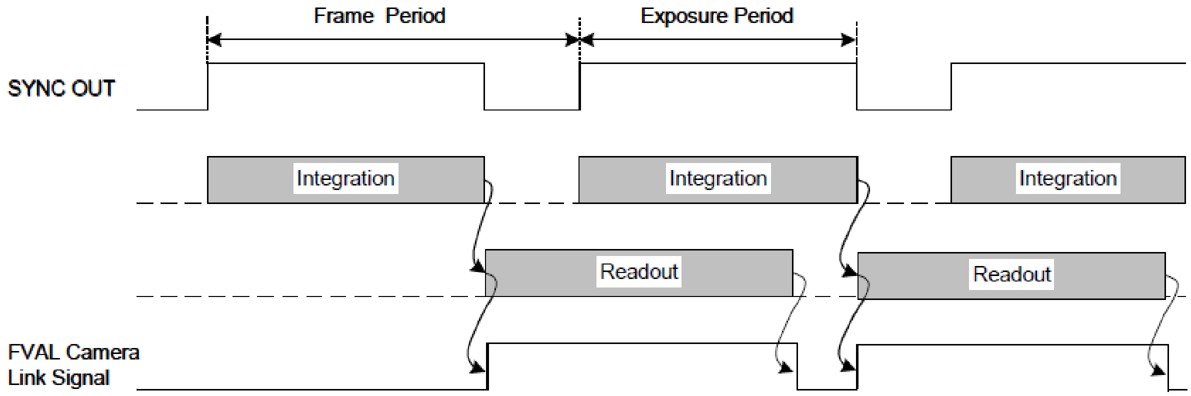


Figure 14. Trigger Mode 0 Freerun timing sequence

When trigger mode 0 is selected, the camera is free-running with the exposure and frame rate internally timed. See Section 5.12 for description of commands to control the internally timed exposure and frame period parameters. When in trigger mode 0, the timing sequence of the camera is as shown in the Figure 14.

Note: For the subsequent trigger mode settings, if the external trigger is received before the previous acquisition cycle is complete, an 'expose block error' occurs and the status LED will start flashing on *and off in red at approximately a 1 Hz rate. The ERROR? ON command inquiry can be issued to confirm this. The triggering error condition will be cleared by changing any one of the trigger mode, polarity or source settings; for instance by issuing the TRIG:MODE 0 and then reasserting the desired mode.*

In trigger mode 1, an external trigger timing signal is used to control the exposure and readout timing. An external trigger timing signal can be applied to the camera through the Camera Link CC1 signal or externally via the adapter coax cable for the 14-pin connector on the rear panel. The signal source can be selected via the serial communication ASCII command TRIG:SOURCE. The polarity of the trigger sources can be selected via the serial communication ASCII command TRIG:POL. A latency time delay of 5 - 6 clocks is possible due to the shape and impedance of the incoming trigger, and this is not added into the following discussion.

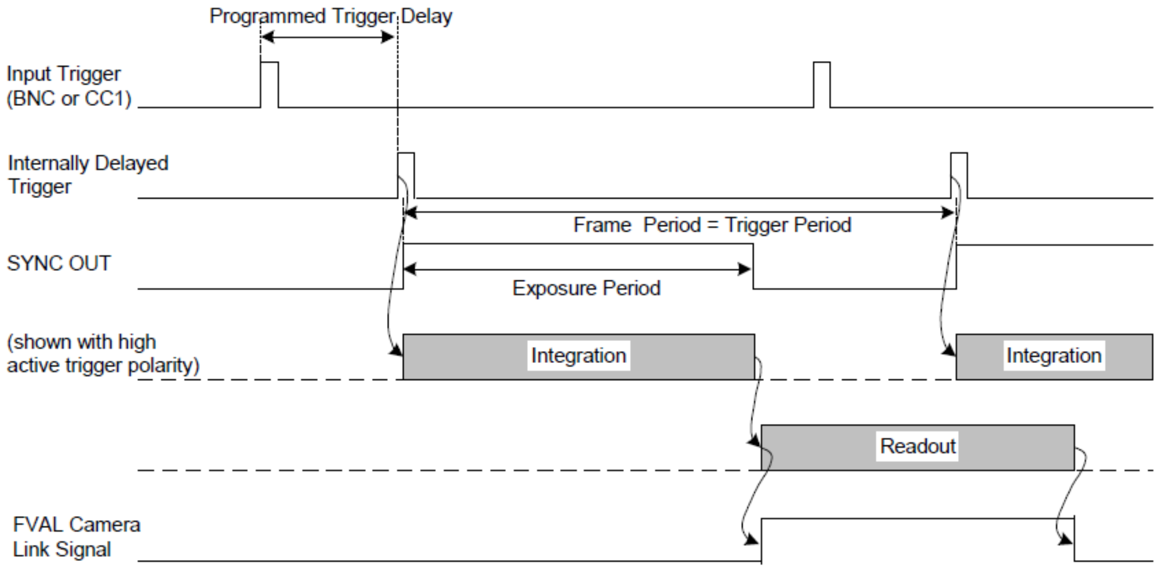


Figure 15. Trigger mode 1 exposure and readout timing sequence.

In trigger mode 1, the camera uses the external trigger signal to control the frame period while internally controlling the exposure period. The minimum trigger pulse width for trigger mode 1 is 0.5µs. The exposure time is set by the operational setting chosen and can be overridden with the EXP command. The camera detects a trigger transition via the currently selected trigger input to initiate exposure (integration). If an active high polarity is selected the camera uses a low-to-high transition. If active low polarity is selected the camera uses a high-to-low transition. The delay between this trigger transition and start of exposure is 5 to 6 pixel periods. (See Section 5.12 for a discussion on determining the pixel clock period.) The ceiling of the trigger rate for this mode is the maximum frame rate. If the maximum trigger rate is exceeded, a camera error will be reported as described in Section 5.17.16, yet will not disable the camera's ability to acquire on future triggers (an error could mean that the camera is missing triggers). *Note: Some frame grabbers have a time-out that can be exceeded while the camera awaits a trigger; the camera does not time-out but the pixels are held in reset until the trigger is received.* The timing sequence of the camera for trigger mode 1 is shown in the Figure 15.

Note: If the user's experiment requires capturing an image from just 1 trigger input, please be aware that when the TRIG:MODE command is received with the trigger input already in the active state, the camera firmware prevents issuing a false trigger. (The TRIG:POL command determines whether the active state *is a logic high or logic low.) Unless the user takes care to only issue the mode command with the input in the inactive state, the single trigger pulse may be ignored. The user could also issue a couple of throw away trigger cycles after changing trigger modes to prepare for the desired single trigger.*

In trigger mode 2, the camera uses the external trigger to both externally set the exposure time and the frame rate. During this external triggered mode, the camera waits for a trigger pulse before initiating a scan of the focal plane array (see note on single trigger pulses in the previous paragraph). The camera detects a trigger transition via the currently selected trigger input to initiate the start of exposure (integration). It uses the low-to-high transition, if an active-high polarity is selected, or the high-to-low transition, if an active-low polarity is selected. A trigger transition of the opposite polarity ends the exposure. In other words, the active trigger pulse width determines the exposure time and the trigger frequency determines the frame rate. In trigger mode 2, the delay between the trigger transition and start of exposure is 3 to 4 pixel clock periods. The delay between the trigger transition and end of exposure is 3 to 4 pixel clock periods plus 28 pixel clock periods for FPA clocking overhead, as described in Section 5.12. The timing sequence of the camera for trigger mode 2 is shown in the Figure 16.

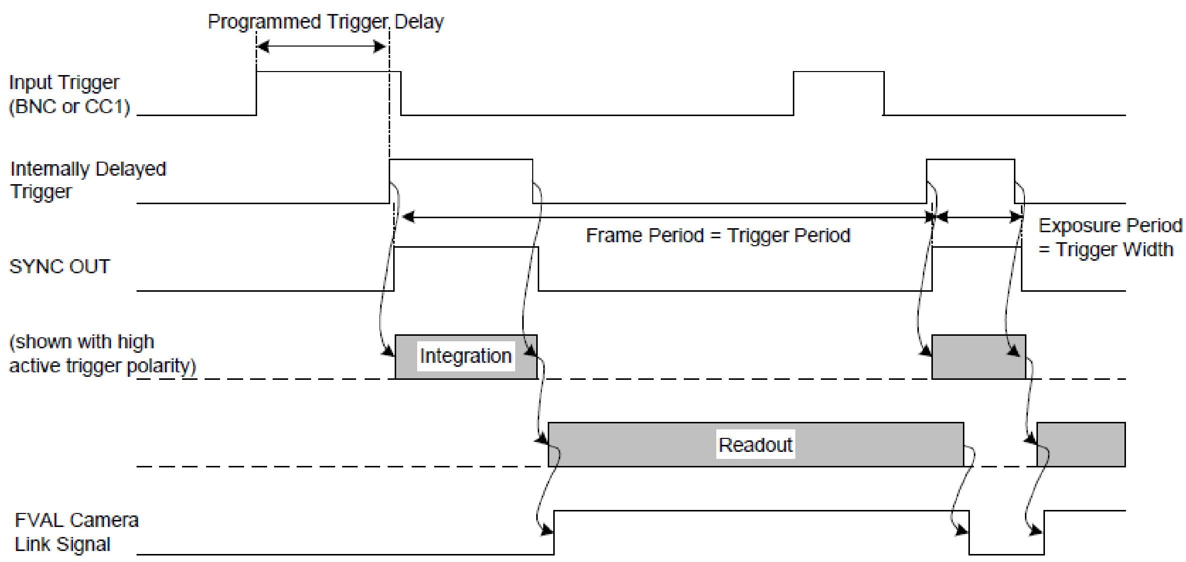


Figure 16. Timing sequence for trigger mode 2

The minimum active trigger pulse width in trigger mode 2 is 8.8 µs. However, 30 µs is the absolute minimum recommended integration time, and 200 µs is the suggested minimum integration time. There is no maximum allowable trigger pulse width, but the user should be aware that as the exposure gets longer, more dark current is integrated by the focal plane array. If the exposure is too long, the focal plane array may saturate with dark current. The ceiling of the trigger rate for this mode is the maximum frame rate. If the maximum trigger rate is exceeded, a camera error will be reported as described in the Section 5.17.16.

In trigger mode 3, the external trigger signal gates on and off the internal timing of the exposure and line rate. That is, whenever the selected trigger input is in an inactive state the camera is paused. Whenever the selected trigger input is active the camera will operate as though it were free-running. Once an exposure has been initiated, the camera will finish that particular exposure and readout even though the trigger might have already transitioned to an inactive state. Therefore, when the trigger transitions to an inactive state it should be held inactive for a minimum of the exposure period plus the frame readout time.

The delay between this trigger transition and start of exposure is 5 to 6 pixel periods. The timing sequence of the camera for trigger mode 3 is shown in the Figure 17.

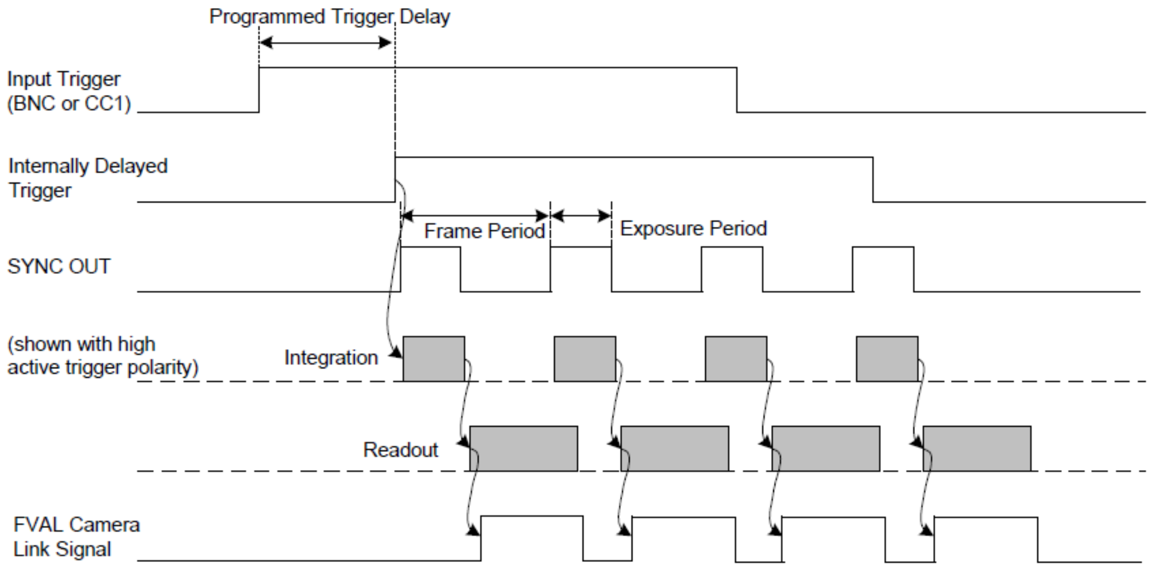


Figure 17. Timing sequence for trigger mode 3

5.13.1. Set Trigger Mode

Description	Sets the trigger and timing modes. *Note: Execution of this command that results in a change in trigger mode will also apply a reset to the trigger and FPA scan digital logic clearing any existing trigger or scan errors.*
Setting Type	Global
Command	TRIG:MODE *mode*
Parameters	*mode*
Return Values	none
Range	0 Internally triggered, internally timed 1 Externally triggered, internally timed 2 Externally triggered, externally timed 3 Externally gated, internally timed
Type	unsigned integer
Example	TRIG:MODE 1

5.13.2. Get Trigger Mode

Description	Returns the trigger and timing mode.	
Setting Type	Global	
Command	TRIG:MODE?	
Parameters	none	
Return Values	mode	
Range	0	Internally triggered, internally timed
	1	Externally triggered, internally timed
	2	Externally triggered, externally timed
	3	Externally gated, internally timed
Type	unsigned integer	
Example	TRIG:MODE? -- query command	
	1	-- return value

5.13.3. Set Trigger Source Mode

Description	Sets the trigger source mode. The camera can accept triggers from the Camera Link CC1 signal as well as the Trigger port in the AUX/POWER connector. *Note: Execution of this command that results in a change in trigger source will also apply a reset to the trigger and FPA scan digital logic clearing any existing trigger or scan errors.*	
Setting Type	Global	
Command	TRIG:SOURCE *value*	
Parameters	*value*	
Return Values	none	
Range	0 – 3	
	0	None
	1	Camera Trigger Port
	2	Camera Link CC1
	3	Either Camera Trigger Port ‘OR’ CC1 (‘AND’ function not enabled)
Type	unsigned integer	
Example	TRIG:SOURCE 2	

5.13.4. Get Trigger Source Mode

Description	Returns the trigger source mode.
Setting Type	Global
Command	TRIG:SOURCE?
Parameters	none
Return Values	value
Range	0 - 3

0	None
1	Camera Trigger Port
2	Camera Link CC1
3	Either Camera Trigger Port ‘OR’ CC1 (‘AND’ function not enabled)

Type	unsigned integer
Example	TRIG:SOURCE? -- query command
	2 -- return value

5.13.5. Set Trigger Polarity

Description	Sets the trigger polarity. Active high indicates that a low-to-high transition will trigger the camera and the high pulse width of the trigger signal will set the exposure period when in externally timed mode. *Note: Execution of this command that results in a change in trigger polarity will also apply a reset to the trigger and FPA scan digital logic clearing any existing trigger or scan errors.*
Setting Type	Global
Command	TRIG:POL *value*
Parameters	*value*
Return Values	
Range	

Trigger	Camera Link	CC1	
0	High	High	active
1	Low	High	active
2	High	Low	active
3	Low	Low	active

Type	unsigned integer
Example	TRIG:POL 0

5.13.6. Get Trigger Polarity

Description	Returns the trigger polarity.

Setting Type	Global
Command	TRIG:POL?
Parameters	none
Return Values	value

Range

Trigger	Camera Link	CC1	
0	High	High	active
1	Low	High	active
2	High	Low	active
3	Low	Low	active

Type	unsigned integer
Example	TRIG:POL? -- query command 0 -- return value

5.13.7. Set Trigger Delay

Description	Sets the number of pixel clock cycles to delay the external trigger source signal. This delay is in addition to the minimum delays. The selected delay must be less than the trigger source period for proper delay operation.
Setting Type	Global
Command	TRIG:DELAY *value*
Parameters	*value*
Return Values	none
Range	0 to 16777215 (0 to (2^{24} -1) clocks)
Type	unsigned integer
Example	TRIG:DELAY 1000

5.13.8. Get Trigger Delay

Description	Returns the trigger delay setting.
Setting Type	Global
Command	TRIG:DELAY?
Parameters	none
Return Values	value
Range	0 to 16777215
Type	unsigned integer

Example	TRIG:DELAY? -- query command 1000 -- return value

5.14. Gain Commands

5.14.1. Set Digital Gain

Description	Sets the digital gain value applied when AGC is off (AGC:ENABLE OFF). Digital gain can be used to ensure that the image data fills the digital output range when offset and gain corrections are applied. In addition, digital gain can be used to stretch low signal images across a greater portion of the output range. Digital gain does not inherently improve signal to noise ratio, except by causing uniform saturation. This command accepts multiple formats: Integer input: 1 - 511 (no decimal) Floating Point: 0.03125 to 16.0 (decimal used) in 1/32 steps 32 = 1.0
Setting Type	Global
Command	GAIN:DIGITAL *value*
Parameters	*value*
Return Values	none
Range	1 to 511; 0.03125 to 16.0
Type	decimal OR integer
Example	one of GAIN:DIGITAL 64 GAIN:DIGITAL 2.0

5.14.2. Get Digital Gain

Description	Returns the digital gain value in the format it was set.
Setting Type	Global
Command	GAIN:DIGITAL?
Parameters	none
Return Values	value
Range	1 to 511; 0.03125 to 16.0

Type	decimal or unsigned integer
Example	GAIN:DIGITAL? -- query command (corresponding one of) 64 -- return value 2.0 -- return value

5.15. Thermal Commands

When the camera is powered on, the thermoelectric cooler (TEC) will immediately begin driving the FPA to the TEC setpoint. Until the FPA reaches and stabilizes on the setpoint, the TEC is “unlocked” and the LED will show red. Once the TEC drives the FPA temperature to the TEC setpoint, the TEC is considered “locked” and the LED will show green. The LED may oscillate between showing red and green for a few seconds before stable TEC lock is achieved and the LED shows solid green.

A solid red LED indicates that the camera is unable to reach or maintain TEC lock. This may be caused if the case temperature falls outside of the acceptable range for a given TEC setpoint. These acceptable ranges are described in Section 1.5 Thermal Management. If the case temperature is within the acceptable range for the given TEC setpoint, try cycling power to the camera. If the LED continues to show solid red, contact the factory for support.

5.15.1. Get System Temperature

Description	Returns an approximation of the camera system temperature in degrees Celsius. Optional: add Kelvin to the end of the command for results in Kelvin. *Note: SYSTEM:TEMP? is an approximation based upon a temperature sensor on the digital board. The tolerance is ±2°C.*
Setting Type	Operational
Command	SYSTEM:TEMP? *Kelvin*
Parameters	none or *Kelvin*
Return Values	temperature value
Range	-50.00 to +70.00 or 223.00 to 373.00 (K)
Type	signed decimal
Example	SYSTEM:TEMP? -- query command 37.81 -- return value 310.95 Kelvin -- return value

5.15.2. Get FPA Temperature

Description	Returns an approximation of the camera Focal Plane Array (FPA) temperature in degrees Celsius. Optional: add Kelvin to the end of the command for results in Kelvin. *Note: FPA:TEMP? is an approximation based upon a temperature sensor near the array. The tolerance is +/- 2 degrees Celsius.*
Setting Type	N/A
Command	FPA:TEMP? -or- FPA:TEMP? *Kelvin*
Parameters	none *or Kelvin*
Return Values	temperature
Range	-50.00 to +70.00, 223.00 to 343.00 (K)
Type	signed decimal
Example	FPA:TEMP? -- query command
	(one of)
	37.81 -- return value
	310.95 Kelvin -- return value

5.15.3. Get Thermoelectric Cooler Lock Status

Description	Returns status of the thermoelectric cooler stabilization lock of the focal plane array temperature to the setpoint. The temperature is considered locked when the current temperature is within ±0.1°C of the setpoint. The TEC should remain locked when the case temperature is maintained within a given range, see Section 1.5.
Setting Type	N/A
Command	TEC:LOCK?
Parameters	none
Return Values	status
Range	LOCKED TEC stabilized
	NOT LOCKED TEC not stabilized
Type	string
Example	TEC:LOCK? -- query command
	LOCKED -- return value

5.15.4. Get Thermoelectric Cooler Setpoint

Description	Returns the thermoelectric cooler temperature setpoint in degrees Celsius.
Setting Type	Operational

Command	TEC:SETPOINT?
Parameters	none
Return Values	value
Range	-20 to 80
Type	integer
Example	TEC:SETPOINT? -- query command
	22 -- return value

5.15.5. Set Thermoelectric Cooler State

Description	Sets the state of the thermoelectric cooler.	
Setting Type	Global	
Command	TEC:ENABLE *state*	
Parameters	*state*	
Return Values	none	
Range	ON	Enables TEC
	OFF	Disables TEC
Type	string	
Example	TEC:ENABLE ON	

5.15.6. Get Thermoelectric Cooler State

Description	Returns the state of the thermoelectric cooler.	
Setting Type	Global	
Command	TEC:ENABLE?	
Parameters	*state*	
Return Values	none	
Range	ON	TEC Enabled
	OFF	TEC Disabled
Type	string	
Example	TEC:ENABLE? -- query command	
	ON -- return value	

5.15.7. Wait for TEC Lock

Description	Blocks operation of camera until TEC is locked. Useful in cases where passed data needs to be properly stabilized, such as in performing an updated background correction file. Camera operation is prevented for up to 60 seconds, and will unblock when a stable TEC lock signal is achieved. Queries while blocked are not received.
Setting Type	Global
Command	TEC:WAIT
Parameters	none
Return Values	none
Range	None
Type	n/a
Example	TEC:WAIT – command (video is still output, no commands can be sent until WAIT is released) -- return value

5.16. Digital Output Commands

5.16.1. Set Digital Data Source

Description	The digital data source can be set to one of several stages along the digital signal path. See signal flow path diagram in Section 4.2.
Setting Type	Global
Command	DIGITAL:SOURCE *source*
Parameters	*source*
Return Values	none
Range	RAW Stage 1, Raw Data 12 bits PAT Stage 2, Test Pattern 12 bit CORR Stage 3, Corrected Data 12 bits BPR Stage 4, Pixel Replace BIN Stage 5, Binned Data 12 bits ENH Stage 6, Enhancement Data FSTAMP Stage 7, Frame Stamp
Type	string
Example	DIGITAL:SOURCE ENH

5.16.2. Get Digital Data Source

Description	Returns the source of the digital data.
Setting Type	Global
Command	DIGITAL:SOURCE?
Parameters	none
Return Values	source
Range	RAW Stage 1, Raw Data 12 bits
	PAT Stage 2, Test Pattern 12 bit
	CORR Stage 3, Corrected Data 12 bits
	BPR Stage 4, Pixel Replace
	BIN Stage 5, Binned Data 12 bits
	ENH Stage 6, Enhancement Data
	FSTAMP Stage 7, Frame Stamp
Type	string
Example	DIGITAL:SOURCE? -- query command ENH -- return value

5.17. Camera Information Commands

5.17.1. Get Camera Serial Number

Description	Returns the camera serial number.
Setting Type	Global
Command	CAMERA:SN?
Parameters	none
Return Values	value
Range	up to 9 character alpha numeric string
Type	string
Example	CAMERA:SN? -- query command
	1337S9738 -- return value

5.17.2. Get Camera Part Number

Description	Returns the camera part number.
Setting Type	Global

Command	CAMERA:PN?
Parameters	none
Return Values	value
Range	up to 9 character alpha numeric string
Type	string
Example	CAMERA:PN? -- query command 8000-0773 -- return value

5.17.3. Get Camera Revision

Description	Returns the camera revision.
Setting Type	Global
Command	CAMERA:REV?
Parameters	none
Return Values	value
Range	up to 9 character alpha numeric string
Type	string
Example	CAMERA:REV? -- query command A -- return value

5.17.4. Get Firmware Part Number

Description	Returns the part number of the camera's firmware.
Setting Type	Global
Command	FIRM:PN?
Parameters	none
Return Values	value
Range	up to 9 character alpha numeric string
Type	string
Example	FIRM:PN? -- query command 4102-0156 -- return value

5.17.5. Get Firmware Revision

Description	Returns the revision of the camera's firmware.
Setting Type	Global
Command	FIRM:REV?

Parameters	none
Return Values	value
Range	up to 9 character alpha numeric
Type	string
Example	FIRM:REV? -- query command 2.2 -- return value

5.17.6. Get Hardware Revision

Description	Returns the revision of the camera's hardware.
Setting Type	Global
Command	VER:HW?
Parameters	none
Return Values	value
Range	up to 9 character alpha numeric string
Type	string
Example	VER:HW? -- query command 1187 -- return value

5.17.7. Get Software Revision

Description	Returns the revision of the camera's software.
Setting Type	Global
Command	VER:SW?
Parameters	none
Return Values	value
Range	up to 9 character alpha numeric string
Type	string
Example	VER:SW? -- query command P2.2 -- return value

5.17.8. Get Focal Plane Array Serial Number

Description	Returns the serial number of the camera's focal plane array.
Setting Type	Global
Command	FPA:SN?
Parameters	none
Return Values	value
Range	up to 9 character alpha numeric string
Type	string
Example	FPA:SN? -- query command 3713S5870 -- return value

5.17.9. Get Focal Plane Array Number of Columns

Description	Returns the number of columns of the focal plane array.
Setting Type	Global
Command	FPA:COLS?
Parameters	none
Return Values	value
Range	0 to 65535
Type	unsigned integer
Example	FPA:COLS? -- query command 640 -- return value

5.17.10. Get Focal Plane Array Number of Rows

Description	Returns the number of rows of the focal plane array.
Setting Type	Global
Command	FPA:ROWS?
Parameters	none
Return Values	value
Range	0 to 65535
Type	unsigned integer
Example	FPA:ROWS? -- query command 512 -- return value

5.17.11. Get Elapsed Time Meter

Description	Returns the total amount of time the camera has been powered on since production. User is unable to reset.
Setting Type	Global
Command	ETM?
Parameters	none
Return Values	value (Days Hours:Minutes:Seconds)
Range	0 - 2^{32} seconds, or about 136 years
Type	String
Example	ETM? -- query command Days:8 04:03:02 -- return value

5.17.12. Set Application Timer

Description	Sets the status of a timer which is stored in volatile memory. Resolution is 0.1 second. Register is lost if power is interrupted.
Setting Type	Global
Command	AP:TIMER *mode*
Parameters	*mode*
Return Values	none
Range	ON Reset timer to 0 and start timer OFF Stop timer
Type	string
Example	AP:TIMER ON

5.17.13. Get Application Timer

Description	Gets the status of a timer which is stored in volatile memory.
Setting Type	Global
Command	AP:TIMER?
Parameters	none
Return Values	value (Seconds)
Range	N/A

Type	String
Example	AP:TIMER? -- query command 105.4 -- return value in seconds

5.17.14. Get Camera Command List

Description	Returns the camera command list. The list includes commands in this manual, as well as optional commands beyond the manual's scope, support or validation. An optional prefix can be used to reduce the output list size.
Setting Type	N/A
Command	CMDS? [*prefix*]
Parameters	*prefix (optional)*
Return Values	value (command)
Range	N/A
Type	string
Example	CMDS? BA -- query command BAUD:CURRENT -- response value (beginning with 'BA' in this example) BAUD:CURRENT? -- cont. BAUD:FUTURE -- cont. BAUD:FUTURE? -- cont. CMDS? AGC -- query command (prefix match, all AGC commands will be output) CMDS? 4 (outputs in 4 columns) CMDS? HELP (display complete help contents for all commands) CMDS AGC H display all AGC commands and Help 1 command per line

5.17.15. Get Camera Command Description

Description	Returns a brief description for a user entered command. Suggested: the CMDS? function lists the proper command format (CMDS? A shortens the list by commands only starting with 'A' etc.) and then you can use the camera formatted command in the Help.
Setting Type	N/A
Command	HELP? *command*

Parameters	*[exact command]*
Return Values	value (description)
Range	N/A
Type	string
Example	HELP? OPR -- query command Sets the camera OPR -- response: text description of the query.

5.17.16. Status and Reset Commands

The user can poll the camera's error status with the error command, which returns a binary encoded 32-bit error value. A non-zero error code indicates that an error has occurred. Table 8 below can be used to decode the error value returned by the error command. A value of one in a bit position indicates the associated error. Use the "ON" argument to have the command response include a text description of the active error codes.

Bit	Error Description	Cause	Resolution
0 (LSB)	PLL0 error	Internal error	Power cycle camera
1	PLL1 error	Internal error	Power cycle camera
2	PLL2 error	Internal error	Power cycle camera
3	Expose Block Error	Invalid exposure and / or frame rate timing	1. Increase readout time by modifying exposure and frame periods. 2. Reduce trigger rate. 3. Reset firmware, reboot camera, or send a trigger command that causes a trigger parameter change (see Section 5.13.)
4	Data RX PLL Lock Error	Internal error	Power cycle camera
5..15	Unused	Unused	Unused
16	I2C0 Error	Internal Error	Power cycle camera
17	I2C1 Error	Internal Error	Power cycle camera
18	I2C2 Error	Internal Error	Power cycle camera
19	I2C3 Error	Internal Error	Power cycle camera

20	System Temperature Alarm	Camera Temperature is out of acceptable range	1. Reduce camera case temperature. 2. Disable TEC. 3. Turn off camera and let cool.
21	FPA Temperature Alarm	FPA Temperature is out of acceptable range.	1. Disable TEC. 2. Power off camera and let cool.
22	Camera Alignment Error	Internal Error	Power Cycle Camera
23	Corr DL Suspend	Correction Download in Progress	No action required.
24	AGC High/Low OPR Error	AGC High and Low OPR settings are invalid.	Correct OPR High/Low OPR settings.
25..31 (MSB)	Unused	Unused	Unused

Table 8. Error value descriptions, causes and resolutions.

Command	**Response**
ERROR?	Returns the 32-bit error register value only
ERROR? ON	Returns the error register value and its text description
ERROR? ALL	Returns the list of all error register values and their text descriptions

5.17.17. Reboot Camera

Description	Execute the power-up initialization sequence of the command processor. This will also clear the power-down detect flag.
Setting Type	N/A
Command	REBOOT
Parameters	none
Return Values	start-up banner

Range	N/A
Type	string
Example	REBOOT -- restart command processor

5.17.18. Set Power-Down Detect Flag

Description	Sets the power-down detect flag to 1. On reboot, this flag is initialized to 0. As the value is set using this command, the user can query its status to detect if the camera has been power cycled since the last query. The command sets the flag; only a reboot will reset the flag to 0.
Setting Type	N/A
Command	PWRDWN
Parameters	none
Return Values	none
Range	N/A
Type	N/A
Example	PWRDWN -- set power-down detect flag

5.17.19. Get Power-Down Detect Flag

Description	Returns the power-down detect flag status.
Setting Type	N/A
Command	PWRDWN?
Parameters	none
Return Values	value
Range	0 Initial value on reboot 1 Value set by user to monitor power-down status
Type	unsigned integer
Example	PWRDWN? -- query command 1 -- camera not power cycled

5.17.20. Set LED State

Description	Sets the state of the status LED as enabled or not. The LED is used to indicate power is on, the TEC is locked (green), unlocked (red)

	or that there has been a triggering error (red cycling on/off at ~1 Hz steady rate). It is recommended to leave the LED status as enabled unless the LED glow would create an issue in the user's environment. A CONFIG:SAVE after changing the LED state would be needed to change the power-on behavior.
Setting Type	Global
Command	LED:ENABLE
Parameters	*state*
Return Values	none
Range	ON Enables LED
	OFF Disables LED
Type	string
Example	LED:ENABLE ON

5.17.21. Get LED State

Description	Returns the state of the status LED.
Setting Type	Global
Command	LED:ENABLE?
Parameters	*state*
Return Values	value
Range	ON Enables LED
	OFF Disables LED
Type	string
Example	LED:ENABLE? -- query command
	ON -- return value

5.18. Binning Mode Commands

Binning Mode shifts SU640CSX camera imaging from a 640x512 to a 320x256 pixel mode of operation. Enabling Binning Mode produces a like sized image with each 2x2 bin equal to the average of the 4 individual pixels. To maintain compatibility with video and Camera Link signals, binned pixel results consist of the binned block's pixels being set to the same value (value is repeated), and the full frame image is still sent.

Binning in a PDA is unlike binning on a CCD: The charge is read individually and summed in camera firmware. Noise improvement comes from the summing and averaging of the pixels: a 2x2 pixel bin has root(4) = 2x noise improvement.

To maintain data transportation consistency, the image size does not change: the block of binned pixels are given the same digital value.

5.18.1. Set Binning Mode State

Description	Sets the state of Binning Mode. Pixels are binned on a 2x2 pattern only.	
Setting Type	Global	
Command	BIN:ENABLE *state*	
Parameters	*state*	
Return Values	value	
Range	ON	Enables Binning Mode
	OFF	Disables Binning Mode
Type	string	
Example	BIN:ENABLE ON	

5.18.2. Get Binning Mode State

Description	Gets the state of Binning Mode.	
Setting Type	Global	
Command	BIN:ENABLE?	
Parameters	none	
Return Values	value	
Range	ON	Binning Mode Enabled
	OFF	Binning Mode Disabled
Type	string	
Example	BIN:ENABLE? -- query command	
	ON -- return value	

5.19. Test Commands

The Test Pattern mode can be used to verify the integrity of the data collection. When this mode is enabled, the camera generates a 12-bit ramp pattern for all pixels, gradually increasing the intensity across the columns and then the rows. The Test Pattern conforms to the current Window size. See Section 5.21

Windowing Commands. The pattern is generated just after the FPA stage, so the subsequent processing blocks can be tested, depending on the Digital Source setting (see Figure 10 and section 5.16. Digital Output Commands). Thus, if the source is set for the taps for corrections or enhancements, the ramp data will be modified. Therefore to troubleshoot the output interface, chose the PAT source to obtain clean ramp data. The timing of the data presenting on the Camera Link interface remains unchanged from when active pixel data is returned.

A separate Frame Stamp command is available to insert a frame count value into the first pixel position of the frame. This is a rolling 12-bit value so the count will jump from 4095 to 0. This counter can be used in trouble shooting missing frames or to help determine time between events in a recorded sequence.

5.19.1. Set Test Pattern State

Description	Sets the test pattern state. When ON, a test pattern is returned in place of data from the focal plane array. One of four patterns may be selected.	
Setting Type	Global	
Command	TESTPAT *state*	
Parameters	*state*	
Return Values		
Range	ON	Output ramp test pattern
	OFF	Disable test pattern
Type	string	
Example	TESTPAT ON	
	TESTPAT OFF	

5.19.2. Get Test Pattern State

Description	Returns the state of the test pattern.	
Setting Type	Global	
Command	TESTPAT?	
Parameters	none	
Return Values	state	
Range	ON	Test pattern enabled
	OFF	Test pattern disabled
Type	string	
Example	TESTPAT? -- query command	
	ON	

5.19.3. Set Frame Stamp

Description	Sets the frame stamp state. When ON, a count value incrementing by 1 of extents 0 to 4095 is returned in place of the first pixel in the frame.
Setting Type	Global
Command	FRAME:STAMP *state*
Parameters	*state*
Return Values	none
Range	ON Enable frame stamp
	OFF Disable frame stamp
Type	string
Example	FRAME:STAMP ON

5.19.4. Get Frame Stamp State

Description	Returns the Frame Stamp state.
Setting Type	Global
Command	FRAME:STAMP?
Parameters	none
Return Values	state
Range	ON Frame stamp enabled
	OFF Frame stamp disabled
Type	string
Example	FRAME:STAMP? -- query command
	ON -- return value

5.19.5. Get Frame Stamp Count

Description	Returns the Frame Stamp count.
Setting Type	Global
Command	FRAME:STAMP:COUNT?
Parameters	none
Return Values	value

Range	0 - 4095
Type	string
Example	FRAME:STAMP:COUNT? -- query command 2017-- return value

5.20. **Macro Commands**

The camera supports the ability to execute multiple commands with the issuance of a single macro command. Factory stored macros are used to adjust the TEC setpoint and corresponding operational settings. These are documented in the separate Appendix B document. The user is not able to specify custom macros.

5.20.1. Play Macro Command

Description	Plays a macro that is resident in the camera. Turning *macro_echo* on will cause the individual commands being executed to be displayed.
Setting Type	Global
Command	MACRO:PLAY *macro_echo macro_number*
Parameters	*macro_echo*, *macro_number*
Return Values	Final OK or ERROR with macro_ echo off , return values of any query commands contained in the macro with macro_ echo ON and Final OK or ERROR
Range	macro_echo ON OFF macro_number 0 – 9
Type	string (macro_echo), unsigned integer (macro_number)
Example	MACRO:PLAY OFF 0

5.21. **Windowing Commands**

The CSX camera allows for windowing of an image to a user's region of interest (ROI). Windowing is typically used to trade image resolution for frame rate. The smaller the window chosen, the shorter the readout time for the frame and, hence, the higher the frame rate that can be achieved. The display enhancements should be turned off (ENH:ENABLE OFF, see Section 5.10.1) and the AGC should be turned off (AGC:ENABLE OFF, see Section 5.9.1) when windowing. This is recommended because enhancements and AGC use the full frame statistics, not the window statistics.

Note: For a 640x512 array the windowing commands index from point 0,0 and thus the maximum 'logical' extent is 639, 511. The concept of 'odd' and 'even' is defined on the logic value of the pixel notation, so the origin 0 of (0,0) is an even number, and 639 of (639,511) is an odd number, regardless that these locations refer to the 1st pixel and 640th pixel.

The WIN:ROW and WIN:COL commands can be used to define each corner of the window individually. Alternatively, the WIN:RECT command can be used to define the window with a single command.

Increased frame rates can only be obtained by reducing the number of rows in the image (e.g., changing the number of columns will not increase frame rate). Selecting the start and stop row addresses sets the size and location for the ROI window. When inputting specific pixel locations to the camera firmware, the logic notation applies so the top left corner of a 320x256 pixel window would be 160,128 and the bottom right corner would be 479, 383.

There are two individual commands that set start and stop addresses for rows. The start row address must be an EVEN number while the stop row address must be an ODD number. Additionally, the resulting height of the window must be greater than 2; because of the start or stop needing to be an EVEN or ODD number, a minimum size is thus 4. The WIN commands must specify start addresses lower or equal to corresponding stop addresses and must be within the allowed range for the supported FPA for these commands to complete without error.

A smaller column number may be set, even though there is no speed improvement achieved. This does allow the user to save smaller images and video sets. *Note: when programming the camera for changes in the active window size, remember to also change the frame grabber settings to match. If not, the frame grabber software may issue error messages about video timeout, insufficient data received or the image displayed might not show the expected portion of the image scene.*

5.21.1. Set Window Column Start Number

Description	Sets the start column number for the ROI. The value must be an EVEN number and compatible with the current column stop number for the command to complete without error.
Setting Type	Operational
Command	WIN:COL:START *value*
Parameters	*value*
Return Values	none
Range	0 to 636
Type	unsigned integer
Example	WIN:COL:START 10 -- start read at col 10

5.21.2. Get Window Column Start Number

Description	Returns the start column number for the ROI.
Setting Type	Operational

Command	WIN:COL:START?
Parameters	none
Return Values	value
Range	0 to 636
Type	unsigned integer
Example	WIN:COL:START? -- query command
	420 -- return value

5.21.3. Set Window Column Stop Number

Description	Sets the stop column number for the ROI. The value must be ODD and compatible with the current column start number for the command to complete without error
Setting Type	Operational
Command	WIN:COL:STOP *value*
Parameters	*value*
Return Values	none
Range	3 to 639
Type	unsigned integer
Example	WIN:COL:STOP 429 -- stop read at 429 (must accommodate location of start)

5.21.4. Get Window Column Stop Number

Description	Returns the stop column number for the ROI.
Setting Type	Operational
Command	WIN:COL:STOP?
Parameters	none
Return Values	value
Range	3 to 639
Type	unsigned integer
Example	WIN:COL:STOP? -- query command
	429 -- return value

5.21.5. Set Window Row Start Number

Description	Sets the start row number for the ROI. The value must be EVEN and compatible with the current row stop number for the command to complete without error.
Setting Type	Operational
Command	WIN:ROW:START *value*
Parameters	*value*
Return Values	none
Range	0 to 504
Type	unsigned integer
Example	WIN:ROW:START 64 -- start read at row 64

5.21.6. Get Window Row Start Number

Description	Returns the start row number for the ROI.	
Setting Type	Operational	
Command	WIN:ROW:START?	
Parameters	none	
Return Values	value	
Range	0 to 504	
Type	unsigned integer	
Example	WIN:ROW:START?	-- query command
	16	-- return value

5.21.7. Set Window Row Stop Number

Description	Sets the stop row number for the ROI. The value must be ODD and compatible with the current row start number for the command to complete without error.
Setting Type	Operational
Command	WIN:ROW:STOP *value*
Parameters	*value*
Return Values	none
Range	7 to 511
Type	unsigned integer
Example	WIN:ROW:STOP 191 -- stop read at row 191

5.21.8. Get Window Row Stop Number

Description	Returns the stop row number for the ROI
Setting Type	Operational
Command	WIN:ROW:STOP?
Parameters	none
Return Values	value
Range	7 to 511
Type	unsigned integer
Example	WIN:ROW:STOP? -- query command 191 -- return value

5.21.9. Set Window Rectangle

Description	Sets the global corner row and column numbers for the ROI. The Total rows and columns must be an even value for each: Start on an EVEN number and end on an ODD number, and conform to minimum size requirements.
Setting Type	Global
Command	WIN:RECT *<X1> <X2> <Y1> <Y2>*
Parameters	*<X left> <X right> <Y top> <Y bottom>*
Return Values	None
Range	0 to 639 for SU640HSX for corner row value 0 to 511 for SU640HSX for corner column value
Type	unsigned integers
Example	WIN:RECT 16 8 417 311 -- set window row and column points

5.21.10. Get Window Rectangle

Description	Gets the global corner row and column numbers for the ROI.
Setting Type	Global
Command	WIN:RECT?
Parameters	none

Return Values	
Range	0 to 639 for SU640HSX for corner row value
	0 to 511 for SU640HSX for corner column value
Type	unsigned integers
Example	WIN:RECT?
	X1:0 Y1:0 X2:639 Y2:511 –– return values

6. Specifications

6.1. Mechanical Specifications

Width x Height x Length	ENC Series: 1.25"W x 1.25"H x 1.20"D (31.8 x 31.8 x 30.6 mm) OEM Series: 1.25"W x 1.20"H x 1.19"D (31.8 x 30.6 x 30.2 mm)
Weight	≤45 grams enclosed, ≤41 grams OEM
Focal Plane Array Format	640 x 512 pixels
Pixel Pitch	12.5 µm
Active Area	8.0 mm x 6.4 mm x (10.2 diagonal)

6.2. Environmental and Power Specifications

Operating Case Temperature	-40˚C to 70˚C
Storage Temperature	-54°C to 85°C
Humidity	95% RH non-condensing
Power Requirements: AC Adapter Supplied DC Voltage Typical Power Maximum Power	 100-240 VAC, 47-63 Hz +4.5 - 16 V 1.5 W at 20°C (excluding transients) <4.25 W
I/O Logic levels	3.3 V CMOS Logic compliant
Functional Shock, Thermal Shock, Random Vibration	MIL-STD-810G compliant design
Conducted & Radiated Emissions	FCC CFR 47, Part 15, Conducted Emission FCC CFR 47, Part 15, Radiated Emission MIL-STD-461F, CE102 MIL-STD-461F, RE102
Mean Time Between Failure	≥ 10,000 hours per MIL-HDBK-217F with VITA51.1 supplement
Fungus-Inert Material	Yes

6.3. Electro-Optic Performance Specifications

Optical Fill Factor	100%	
Spectral Response	900 nm to 1700 nm (SWIR) 700 nm to 1700 nm (NIR)	
Quantum Efficiency	≥65% from 1000 nm to 1600 nm	
Digital Output Frame Rate	30 fps	60 fps
Mean Detectivity, D* [1] $(cm \cdot \sqrt{Hz}/W)$	≥ 2.5 x10^{13}	≥ 2.8 x10^{13}
Noise Equivalent Irradiance [1] (photons/cm^2/s)	≤ 9.7 x10^{8}	≤ 1.2 x10^{9}
Noise (RMS) [1]	≤ 35 electrons	≤ 25 electrons
Dynamic Range High Gain [1]	≥ 800:1	≥ 1100:1
Dynamic Range Low Gain [1]	≥ 2500:1	≥ 2500:1
Operability [2]	≥ 99%	
Image Correction	Sensors Unlimited non-uniformity corrections	
Scan Mode	Continuous	

[1] typical, λ =1550 nm, exposure time = 33 ms (30FPS) / 16.67 ms (60FPS), case temperature = 20°C, highest sensitivity gain setting, no lens, corrections off, 1x digital gain, with AGC, enhancement, and correction off.

[2] The percentage of pixels with responsivity deviation less than 35% from the mean.

7. Product Support

Common Problems and Solutions

Problem	Possible Causes	Solution
No data is present at the digital port, frame grabber times out	Power is off or low	Verify input power meets requirements described.
	Connections to camera are fully or partially disconnected.	Verify cameras wiring is properly connected.
	Camera is in external trigger mode, but not receiving a trigger	Test the camera in internal trigger mode (`TRIG:MODE 0`) to confirm normal operation. If internal trigger mode operation is normal, see “Camera is not responding to trigger input.”
Camera will not respond to trigger inputs	Trigger source is not connected	Verify trigger is properly connected. Verify frame grabber trigger source is properly configured if using Camera Link CC1.
	Trigger signal does not conform to timing requirements of the camera	Verify trigger source meets the timing requirements described in Section 5.13. Check camera error status for a trigger or scan error. If oscilloscope is available, view the trigger input signal to verify it meets the requirements of the camera for the selected trigger mode.
	Trigger Logic Levels Incorrect	Verify camera logic levels match logic being sent.
Camera intermittently responds to triggers, resulting in missing frames, or in some cases timeout errors	Trigger period is too short, causing following triggers to be ignored as they occur during readout	Check camera error status for a trigger or scan error (>ERROR? ON). Modify trigger to meet timing requirements for the selected trigger mode and supported FPA.
Frame grabber software reports not receiving enough data before timing out	Acquisition size parameters larger than actual data available	Reduce acquisition window size parameters, decrementing one pixel or line at a time. Some frame grabbers require overhead pre- or post-valid pixels or lines to properly grab the digital data.

8. Customer Support

For additional product support please contact SUI between 8am and 5pm Eastern Time at 609-333-8000 and ask to speak with an applications engineer.

For general information about this product or for information on SUI's line of other image sensing products, please contact:

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9. Warranty

Products offered by Sensors Unlimited, Inc. ("SUI"), a Collins Aerospace Company, are subject to a warranty as highlighted in SUI's Standard Terms and Conditions.

This warranty does not apply to products which SUI determines, upon inspection, have failed, become defective or unworkable due to abuse, mishandling, misuse, alteration, negligence, improper installation, use which is not in accordance with the information and precautions described in the applicable operating manual, or other causes beyond SUI's control.

This warranty does not apply to (i) any products or components not manufactured by SUI or (ii) any aspect of the products based on Buyer's specification, unless Seller has reviewed and approved such specification in writing.

This information can be reviewed in detail by accessing the Standard Terms and Conditions from the link below:

www.sensorsinc.com/company/about

10. LIST OF ABBREVIATIONS

ADC: analog-to-digital converter
ASCII: American standard code for information interchange
CCD: Charge Coupled Device (silicon-based sensor <1.1 micron response; not InGaAs technology)
CDS: correlated double sampling
CMOS: complimentary metal-oxide semiconductor
EAR: Export Administration Regulations – Bureau of Industry and Security
EST: Eastern Standard Time. Normally implies prevailing time to accommodate Daylight Savings Time
FPA: focal plane array
FPS: frames per second
FPGA: field programmable gate array
GMOD: gate modulated in-pixel amplifier
IMAQ: Image Acquisition (National Instruments' frame grabber driver software)
InGaAs: indium gallium arsenide
LED: light-emitting diode
LVDS: low voltage differential signaling
MDR: mini D ribbon
NI: National Instruments
NIR: near infrared
NTSC: National Television System(s) Committee
OEM: original equipment manufacturer
OPR: Operational Setting, the basic preset control parameter for SUI cameras.
PAL: non-compliant video standard (Europe/Asia)
PCI: peripheral component interconnect
PDA: Photo Diode Array (each pixel is an active element)
PNUC: parameterized non-uniformity corrections
RMA: return material authorization
QE: quantum efficiency
SDR: shrunk delta ribbon (cable connector)
SECAM: non-compliant video standard (Europe/Asia)
SLR: single lens reflex
SMA: sub-miniature A (RF connector)
SUI: Sensors Unlimited, Inc.
SUI:IA: SUI-Image Analysis freeware program for NI card set.
SWaP: size, weight, and power
SWIR: shortwave infrared
TBD: to be determined
TTL: transistor-transistor logic (digital signaling standard)
TEC: thermoelectric cooler
UTAS: United Technologies Aerospace Systems
UTC: United Technologies Corporation

11. NOTES

APPENDIX A: Camera Command Summary