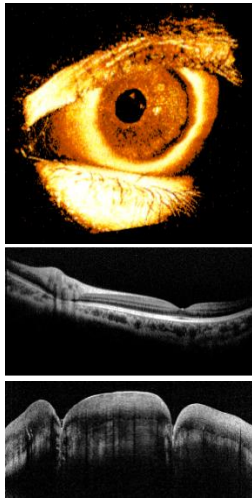


Operation Manual:
GL2048L: InGaAs 76 k-lps Linescan Camera
GL2048R: InGaAs 147 k-lps Linescan Camera



Whole eye and tooth images demonstrate 8 mm deep imaging @ 13 μm resolution with 1.31 μm source courtesy of ThorLabs; retinal scan acquired at 147 k A-lines/s with 1.07 μm source, courtesy of Uof Washington



**SENSORS
UNLIMITED**

A part of Collins Aerospace

330 Carter Rd, Suite 100, Princeton, NJ 08540
 Tel: 1-609-333-8000 • Contact: sui_info@collins.com
www.sensorsinc.com

4110-0283, Rev A	Page 1 of 78	© 2020 Collins Aerospace	Date Printed: 9-Jun-2020
THIS DOCUMENT IS THE PROPERTY OF COLLINS AEROSPACE. YOU MAY NOT POSSESS, USE, COPY OR DISCLOSE THIS DOCUMENT OR ANY INFORMATION IN IT, FOR ANY PURPOSE, INCLUDING WITHOUT LIMITATION, TO DESIGN, MANUFACTURE OR REPAIR PARTS, OR OBTAIN ANY GOVERNMENT APPROVAL TO DO SO, WITHOUT COLLINS AEROSPACE'S EXPRESS WRITTEN PERMISSION. NEITHER RECEIPT NOR POSSESSION OF THIS DOCUMENT ALONE, FROM ANY SOURCE, CONSTITUTES SUCH PERMISSION. POSSESSION, USE, COPYING OR DISCLOSURE BY ANYONE WITHOUT COLLINS AEROSPACE'S EXPRESS WRITTEN PERMISSION IS NOT AUTHORIZED AND MAY RESULT IN CRIMINAL AND/OR CIVIL LIABILITY.			
US Export Classification: NSR - This document does not include any export controlled technical data.			

LEGAL NOTICES

©2016-2020 Sensors Unlimited, Inc., a wholly owned subsidiary of Collins Aerospace Corporation, all rights reserved.

Every effort is made to ensure the information in this manual is accurate and reliable. Use of the products described herein is understood to be at the user’s risk. Collins Aerospace assumes no liability whatsoever for the use of the products detailed in this document and reserves the right to make changes in specifications at any time and without notice. The modifiers and phrases SUI™, Sensors *knows* IR™, Imaging Beyond the Visible™, NI®, IMAQ™, LabView® and Camera Link® are used in this manual. “SUI”, “Sensors *knows* IR”, and “NIR Perfect” are all trademarks of Sensors Unlimited, Inc. “NI, IMAQ and LabView are trademarks of National Instruments. Camera Link is a registered trademark of the Automated Imaging Association. All other trademarks or intellectual property mentioned herein belong to their respective owners.

CE and FCC Compliance

The Sensors Unlimited GL2048L and GL2048R Short Wave Infrared (SWIR) cameras conform to the requirements of the following standards:

- EN 61326-1 (2013) Emissions
 - CISPR 11 (2010) Radiated Emissions
 - CISPR 11 (2010) Conducted Emissions
 - IEC 61000-3-2 (2014) Harmonic Current Emissions
 - IEC 61000-3-3 (2013) Voltage Fluctuations & Flicker
- FCC Emissions
 - FCC CFR 47, Part 15 (2012), Class A Radiated
 - FCC CFR 47, Part 15 (2012), Class A Conducted
- Product Safety
 - EN60950-1: 2006/A12:2011
- EN 61326-1 (2013) Immunity
 - IEC 61000-4-2 (2008) Electrostatic Discharge Immunity
 - IEC 61000-4-3 (2010) Radiated RF Field Immunity
 - IEC 61000-4-4 (2012) Electrical Fast Transients
 - IEC 61000-4-5 (2009) Surge Immunity
 - IEC 61000-4-6 (2013) Conducted RF Immunity
 - IEC 61000-4-8 (2009) Magnetic Field Immunity
 - IEC 61000-4-11 (2004) Voltage Dips & Interruptions

Compliance requires the Camera Link SDR cable connector to be fully seated on the camera mating connector with the jack screws completely tightened and requires the provided power supply is used. This power supply conforms to CE and UL standards as a standalone unit. Users providing their own power supply should follow the power supply connection method described in Section 3.1.1 to minimize emissions.

RoHs Compliance

The Sensors Unlimited GL2048L and R cameras are compliant with European Union RoHs regulations EU Directive 2002/95/EC. At the end of the camera service life, the components should be recycled in a manner consistent with modern electronics products with fiberglass circuit boards and electronics. Contact SUI for further instructions or possible return for reprocessing.

Export Control Classification

The GL2048L and GL2048R cameras are controlled under the Department of Commerce EAR code when shipped internationally or used by non-US persons. The level of control is based on the shape of the photodiode pixel. The 2048 camera model descriptions that end in the suffix ‘-210’ are controlled under the designation EAR 99 – No License Required. The models that end in ‘-010’ are controlled in the category EAR ECCN 6A003.b.4.a.

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 2 of 78	Last Update: 17-APR-2020

Table of Contents (click on line to jump to section)

1	INTRODUCTION	5
1.1	SYSTEM DESCRIPTION	5
1.2	SYSTEM CONTENTS	7
1.3	SAFETY CONSIDERATIONS.....	9
1.4	OPTICAL CONSIDERATIONS	11
1.5	CAMERA CLEANING	11
2	GETTING STARTED	13
2.1	HARDWARE INSTALLATION	13
2.2	SOFTWARE INSTALLATION (OPTIONAL)	14
3	CAMERA HARDWARE INTERFACES	17
3.1	CAMERA ELECTRICAL INTERFACES.....	17
3.1.1	<i>Power Input</i>	<i>17</i>
3.1.2	<i>Camera Link Data Interface.....</i>	<i>18</i>
3.1.3	<i>Trigger Input.....</i>	<i>22</i>
3.1.4	<i>Status LED.....</i>	<i>22</i>
3.2	CAMERA MECHANICAL INTERFACES	22
3.2.1	<i>Physical Characteristics</i>	<i>22</i>
3.2.2	<i>Camera Mount Options.....</i>	<i>26</i>
3.2.3	<i>Thermal Management.....</i>	<i>26</i>
3.3	CAMERA OPTICAL INTERFACES	26
3.3.1	<i>Lens Mounting Plate.....</i>	<i>26</i>
3.3.2	<i>Available Lens Adapters</i>	<i>29</i>
3.3.3	<i>Installation of Lens and Adjustable Adapter.....</i>	<i>30</i>
3.3.4	<i>Lens Stop-down Mode.....</i>	<i>33</i>
3.3.5	<i>C-Mount Lens Adapter.....</i>	<i>33</i>
4	PRINCIPALS OF OPERATION	35
4.1	FOCAL PLANE ARRAY OPERATION	35
4.2	CAMERA SYSTEM OPERATION	38
5	CAMERA FUNCTIONS AND CONTROL SOFTWARE INTERFACE	40
5.1	COMMUNICATION PROTOCOL	41
5.2	COMMAND FORMAT AND RESPONSE	41
5.3	STARTUP MESSAGING	43
5.4	COMMAND SET	44
5.4.1	<i>Camera Communication Commands.....</i>	<i>45</i>
5.4.2	<i>Camera Information Commands.....</i>	<i>46</i>
5.4.3	<i>Camera Configuration Commands.....</i>	<i>48</i>
5.4.4	<i>Camera Gain Commands.....</i>	<i>49</i>
5.4.5	<i>Camera Control Commands.....</i>	<i>51</i>
5.4.6	<i>Camera Trigger Commands.....</i>	<i>54</i>
5.4.7	<i>Camera Correction Commands</i>	<i>56</i>
5.4.8	<i>Camera Test Commands.....</i>	<i>65</i>
6	SPECIFICATIONS	68

6.1	ENVIRONMENTAL & POWER	68
6.2	MECHANICAL - ENCLOSED	68
6.3	INTERFACES	68
6.4	REGULATORY COMPLIANCE	69
6.5	OPTO-ELECTRONIC PERFORMANCE	69
6.5.1	GL2048L-210, GL2048L-010	69
6.5.2	GL2048R-210	70
7	PRODUCT SUPPORT	71
7.1	COMMON PROBLEMS AND SOLUTIONS	71
7.2	CUSTOMER SUPPORT	73
7.3	WARRANTY	73
8	LIST OF ABBREVIATIONS	74
9	NOTES	76

APPENDIX A: Camera Command Index
APPENDIX B: SUI Default Global and Operational Parameters

(This is a separate file document with the file name prefix of 4170-xxxx).

List of Figures

Figure 1	GL2048L/R Camera back panel and power connector pin assignment.....	17
Figure 2	Camera Link interface timing diagram.....	20
Figure 3	Mechanical drawing of GL2048 cameras including optical path stack-up	25
Figure 4	LD to Nikon F-mount lens adapter – part #8000-0171.	29
Figure 5	Drawing of adapter panel ring showing spanner holes.....	31
Figure 6	Location of lens adapter focus and rotation adjustment set screws.	32
Figure 7	Mechanical drawing of C mount lens adapter.....	34
Figure 8	Typical QE for front-side illuminated Sensors Unlimited linear PDAs.....	35
Figure 9	Simplified pixel schematic.....	36
Figure 10	Camera system signal flow diagram.	39
Figure 11	Screen shot of cameras startup banner using SUI Camera Link Terminal.....	44
Figure 12	Screen shot of 2048 Linescan Corrections Utility.	62
Figure 13	Corrections data read with CL Terminal & pasted into the Corrections Utility.....	63

List of Tables

Table 1	Available camera options.	9
Table 2	Available camera lens adaptor options.	9
Table 3	Digital output SDR 26-pin connector signal assignment for Base Camera Link at camera connector	19
Table 4	Digital output SDR 26-pin connector signal assignment for the 2nd cable with Medium Camera Link	19
Table 5	Camera dimensions.	22
Table 6	Camera mounting options.	26
Table 7	Lens mounting specifications.	27
Table 8	Maximum line frequency and exposure time by camera and operating mode.	38
Table 9	Line format of camera command return strings.	43

INTRODUCTION

1.1 SYSTEM DESCRIPTION

The Sensors Unlimited Inc. GL2048L and GL2048R Short-Wave Infrared (SWIR) Linescan Cameras are small, versatile imaging tools that incorporate Sensors Unlimited 10-micron pitch Indium Gallium Arsenide linear (1-D) focal plane arrays. Designed for laboratory, medical instrumentation and industrial machine vision use, these cameras require only a nominal DC voltage in the range of 6 to 12 V for operation (optional 12 V output AC adapters are available). The relatively fast line-rates of 100 to 76,263 lps for the GL2048L and 9,455 to 147,714 lps for the GL2048R, limits the exposure time for each rate. This short time, combined with the low dark current of Sensors Unlimited InGaAs processes, enables a low-cost, low-power design by eliminating on-board cooling. As a linescan device, images are constructed from dynamic (moving) scenes, such as the imaging of parts moving down a conveyor belt. Another use for linescan cameras is in dispersed wavelength applications where the camera is mated to a spectrograph. This turns displacement along the linescan axis from just being a spatial distance to being a measure of wavelength. Here, the fast line-rates enable capturing the real-time evolution of spectral features over time. In the Optical Coherence Tomography (OCT) application, light from an interferometer is dispersed by a spectrometer and focused onto the line array. This captures the interference fringes as a function of wavelength (or of wavenumber if a constant k spectrometer design is used). By converting the fringe frequencies to linear wavenumber and then processing the result with a Fast Fourier Transform, a depth profile called an A-scan is generated, which shows the depth of increased scattering layers in the tissue or other scattering material like ceramics or films. Combined with a scan of the light beam in the X direction, successive A-scans can be assembled into a B-scan. Then, scanning the beam in the Y direction one step to acquire another B-scan, repeatedly, builds up a C-scan, which represents a 3-D capture of a tomographic volume. For OCT of living tissue, this reveals structures with the resolution of histology slides but with light rather than knives.

In order to generate 3-D images of tissue before the patient moves, very high line-rates are required. The high line readout speeds offered by this camera reach ~160 Megapixels per second for the GL2048L and ~320 Mpixels/s for the GL2048R at their respective line-rates of 76,263 and 147,874 lines per second; rates achieved by transferring two (Base Camera Link) or four (Medium CL) 12-bit pixel values per CL strobe clock cycle. Both cameras offer slower line-rates with longer exposure times for higher sensitivity or to synchronize the line-rate to the pace of external systems. (The GL2048L camera supports exposure times of up to 10 ms for line-rates as low as 100 lps; the GL2048R is supports exposures of 4.4 to 100 μ s with line-rates from 10,000 to 147,874 per second.) For a fixed exposure time and line-rate, the camera output is quite linear with light intensity. ***However, conversion gain varies with exposure time, so accurate comparison of light intensities with data taken at different exposure times will require user calibration with independent measurements of absolute intensities.***

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 5 of 78	Last Update: 17-APR-2020

The camera's optical sensitivity nominally covers the 0.94 - 1.68- μm wavelength range (20% of peak points). Compared to previous Sensors Unlimited linear arrays, which were front-illuminated, the GL2048 sensors are back-illuminated and the InP substrate acts as a long-pass filter for the wavelengths shorter than 0.98 μm . Currently the cameras are offered with 2048 pixels on 10- μm pitch, and with an active height of 210 μm . For machine vision applications requiring symmetric resolution both across the width of the array and in the orthogonal direction (movement or time axis), a square pixel aperture was introduced at the end of 2015 (10 x 10 μm). However, take note that when imaging sensitivity has priority over resolution in the movement (time) direction, the 210- μm tall pixels offer 21 times the light sensitivity as the 10- μm pixel. Contact Sensors Unlimited for currently supported PDAs or to discuss development of solutions for other applications.

The Sensors Unlimited GL2048L/R cameras use 2048 ADCs of 12-bit effective resolution to readout the Sensors Unlimited LC1 readout integrated circuit (ROIC). The ADC outputs are multiplexed into a single sequence of pixels from 0 to 2047 for transmission over the Camera Link digital interface; with two per clock transferred for the "L" or four pixels per clock for the "R". Therefore, for the GL2048L model, the ADC clock rate is at the maximum output line-rate of 76,263 lps. This produces a dataflow into the frame grabber of 160 mega-pixels per second or 1.88 Gbit/s. *Note that this produces a dataflow from the frame grabber into the PC of 234 Mbytes/s if the 12-bit pixel pairs are packed into 3 bytes, or 312 Mbytes/s if the 12-bit values are transferred into the PC memory as 16-bit values. The high line-rates of the GL2048L will exceed the capabilities of PCI express frame grabbers and/or of PCs that only support one (x1) bi-directional express lane to handle the full camera line-rates. **Base or Medium type Camera Link frame grabbers with x4 express lanes, and PCs with at least x4 lane support are required to achieve the full line-rate potential of the GL2048L camera. (Medium type cards with x4 lane support are needed for the GL2048R camera.)***

The user can set the camera to process the digitized data using a pixel-by-pixel two-point correction (offset and response gain) and bad-pixel substitution. Offset correction compensates for fixed pattern non-uniformities along with the dark current signal; the gain correction compensates for the photoresponse non-uniformity. The GL2048 cameras provide commands for user acquired corrections, unlike previous Sensors Unlimited cameras. Those held unique SUI acquired corrections for each preset operating mode in a large number of possible line-rate, exposure and gain settings. For the GL2048 cameras, users set the line-rate and exposure time appropriate to their application and are then able to create the gain and offset corrections for that timing. The use of the camera offset- and gain- correction functions removes most of detector dark and photoresponse fixed pattern non-uniformities. With care, users may also be able to compensate for illumination or optical front-end non-uniformities, though it will be important to recognize when such corrections become invalid (such as changes in the lens aperture setting). *NOTE: When shipped, the camera correction memory will have a valid correction created on an integrating sphere, without lens, and generated with the default start-*

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 6 of 78	Last Update: 17-APR-2020

up exposure time, gain and frame period listed in Appendix B of the manual (stored as a separate pdf file on the accompanying storage media. This configuration and correction can be restored with the `CONFIG:RESET` command.

SUI identifies bad pixels during testing, based on whether they are always high, always low, exceed noise limits, or have a photo-response different from the array mean by more than +/- 20% at the 100 μ s exposure time for the 2048R, or 600 μ s time for the 2048L model. These pixels are flagged as 'bad' in the camera memory and the user may elect to have their values replaced by the value of the preceding pixel in the line. Commands are also provided to permit users to add to the bad pixel map or to re-enable use of the SUI flagged pixels. *Note that users of longer exposure times will likely see additional pixels with more dark current than adjacent pixels – if these create issues for the users' application, they can be flagged as bad. It is possible that the total number of bad pixels across the array may exceed 1% as a result but the camera specification only counts those pixels that are bad at the exposure times listed above.*

Two pixels of 12-bit digital data is transmitted per clock in a Base Camera Link compatible format via the SDR 26-pin connector (also known as a mini-Camera Link connector) of the cameras for the GL2048L or four pixels via two of these connectors for the GL2048R Medium Camera Link model. ASCII serial commands sent through the Camera Link asynchronous serial communication port enable the user to control camera settings. For instance, the user can continuously vary the integration time settings in units of the system clock period (within limits appropriate to the camera or operating mode). The GL2048 cameras can be externally triggered and receive the external triggers over the CC1 signal line in the base cable (also known as Port 0). Most frame grabbers support generating periodic trigger signals or passing through triggers pulses from external sources.

The Sensors Unlimited GL2048 cameras are related to the Sensors Unlimited LDV/LDH/LDH2 linescan camera series, sharing a similar command set. Where appropriate, the same commands, functions and syntax have been maintained. However, the user who is adapting pre-existing software to work with the GL2048 cameras should carefully review the new command set (in section 5.4) to ensure proper operation and optimal performance.

1.2 SYSTEM CONTENTS

An order for a Sensors Unlimited GL2048 camera includes the following:

- The Sensors Unlimited GL2048 camera body with protective cap for the M42 access hole
- Sensors Unlimited USB memory card containing support documentation and software, including the configuration file for National Instruments Camera Link frame grabber cards

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 7 of 78	Last Update: 17-APR-2020

- An optional CE compatible AC to 12 VDC wall-mount power converter with a set of international plug adapters (Customer order must list the power supply on a separate line on their purchase order, listing the part number 8000-0636 or equivalent)
- A cardboard shipping box with foam cutouts to hold the camera and supply

The OEM customer, who may be wiring the camera into a system, may order the camera in multiple unit quantities without accessories like the power supply to minimize waste of unneeded parts. In this case, each camera is shipped in a cardboard box with a holder designed to hold up to five cameras and one AC-DC supply. For initial shipments the power supply can be provided to enable testing of the first units, but it will need to be listed as a separate line item on the purchase order or release document; otherwise it *will not be supplied*.

The GL2048 cameras have an O-ring groove around the M42 access hole for the purpose of providing a light seal when mated to a flat plate with the 8-32 hole pattern on the faceplate. See the Table 6 to identify the appropriate diameter ring to use. Contact SUI if you want the ring supplied with subsequent deliveries.

Note that the camera part number does not include a lens since many line-scan applications have different working distance and magnification solutions. Nor does it include a lens adapter, as many users are mounting the camera on a spectrometer.

Customers can currently order lens adapters as a separate line items, at extra cost. Contact SUI for lens options or recommendations of compatible lenses. Sensors Unlimited offers an F-mount (compatible with non-automatic Nikkor photographic lenses) or C-mount (compatible with many CCTV lenses) adapters. Some lens manufacturers are offering SWIR optimized lenses specifically for the SWIR range. At the time of this manual, the Edmund Optics line of SWIR TECHSPEC® lenses have been specifically designed to support the 10- μ m pitch of the GL2048 cameras (specify compatibility with the nominal back focal distance of 6 mm when ordering these lenses from Edmund).

Optional parts available from Sensors Unlimited Inc. that the user may need for some applications are:

Description	Sensors Unlimited Part #
<ul style="list-style-type: none"> • O-ring light seal – Silicon 1/16th" (1.59 mm) x 1 7/8th" inch (47.6mm) diameter) 	2811-0094
<ul style="list-style-type: none"> • AC adapter (power supply) 	8000-0636 (one included with orders of 1 to 4 units but must be listed on the PO as a separate line item), must be ordered at extra cost on the PO for higher volume

	orders, whether ordering one for testing or one power supply for each unit.)
<ul style="list-style-type: none"> This operations manual Appendix B (Configuration settings) 	4110-0283 4170-0329 for GL2048L 4170-0311 for GL2048R
<ul style="list-style-type: none"> USB flash drive w/files for manual, “.icd” extension file - camera profile for NI IMAQ based systems, SUI Image Analysis - free user software (.exe file but requires NI-IMAQ drivers that comes with their frame grabbers 	4100-0056
<ul style="list-style-type: none"> Imaging Pack, NI PCIE-1433, MDR-SDR Cable - PCIe-1433 National Instruments Medium Camera Link frame grabber with a 2 meter Camera Link cable (two cables needed for the GL2048R) 	8000-0735
<ul style="list-style-type: none"> 2nd MDR-SDR cable for GL2048R if using a frame grabber with MDR connectors. 	8000-0190
<ul style="list-style-type: none"> The adjustable F- or non-adjustable C- mount adapter as listed in Table 2. 	

Table 1 Available camera options.

These Sensors Unlimited camera lens adapters are compatible with the GL2048 cameras:

Lens adapter part #	Adapter description
8000-0171	Lens Adapter, F-Mount, LDV
3800-0002	Lens Adapter, C-Mount LDV

Table 2 Available camera lens adaptor options.

NOTE: The Sensors Unlimited SOLO50 design, which uses the M42 interface, was designed for the 25 μm pitch of previous generation arrays and will limit resolution and contrast performance of the GL2048 cameras.

NOTE: The Camera Link cable is available as part of an imaging pack with the recommended PCIe-1433 frame grabber, or maybe purchased individually. Contact SUI for these options.

1.3 SAFETY CONSIDERATIONS

The camera can be powered using a power supply rated for a nominal 6-12 VDC capable of providing a minimum of 3 W (13 VDC absolute MAX) with the camera ambient temperature held

within the specified case temperature operating range of +10 to + 35 °C. The camera is protected by an overvoltage, reverse voltage and excessive current shutdown circuit, which will shut down the internal power supply until the camera is disconnected and then reconnected with the proper voltages. **WARNING: This circuit could be damaged by excessively high voltages or excessive ground loop potentials.** **NOTE: If the camera does not power up with the correct supply voltages or with the Sensors Unlimited supplied AC convertor, there may be a fault drawing excessive current. Also, long cables may deliver an inductive discharge when connected to the camera. Therefore, prior to connecting the cables for the digital interface and/or triggering circuits, it is important to test potential voltage differences between the frame grabber, the camera, triggering circuits and the earth ground with which the camera will be physically and electrically connected. Please contact SUI applications engineers for assistance before making connections if there are any questions about this cautionary statement.**

The optical surface of the linear focal plane photodiode array is coated with a broadband antireflective coating, but is directly exposed when no lens cap, or lens or spectrometer is mounted. A black (low-reflection) aperture mask is placed on top of the PDA surface, outside of the detector active area. This shields the array from stray light and minimizes back reflections into the optics from the array surface. *Note that cleaner tissue or liquids could be trapped at this interface.* **WARNING: When changing lenses or mounting the camera in any optical arrangement, please take care not to scratch or touch the array surface. Prior to attaching an optical interface, inspect the photodiode array surface carefully and use clean dry air to remove any dust particles (with 10-micron pitch pixel width, dust particles can block significant light energy).**

To prevent fire, shock hazard, corrosion or damage to the camera, do not expose to rain or excessive moisture. Do not disassemble camera. Do not remove screws or covers unless authorized by Sensors Unlimited for OEM installation inside the user's system enclosure. There are no user serviceable parts inside the GL2048 enclosure. **WARNING: Removal of any panel will void the warranty. OEM customers may remove the board from the enclosure for installation in their instrumentation, but assume the risk for physical damage to the optical surfaces or FPA from board flexure, thermal damage for insufficient thermal conduction of device dissipation, increased radiated emissions, or increased vulnerability to static discharge or EMI.**

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

To minimize RF interference with sensitive equipment, ensure that the Camera Link connectors are fully seated and the connector jack screws fully tightened to the stop. *Note that incomplete engagement of the cable connector with the camera as a result of not tightening the jack screws can cause scrambled data, frame grabber video data timeouts or interfere with camera*

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 10 of 78	Last Update: 17-APR-2020

command communications. **WARNING: The connector jack screws are small diameter and may snap off if over tightened.**

1.4 OPTICAL CONSIDERATIONS

The front panel of the camera is threaded for M42x1-6H with a nominal 6 mm distance to the focal plane (the same thread as a U-mount is used, but at a closer focal distance). This was chosen because of its large open diameter and its closeness to the focal plane avoids limiting the optical aperture of the array. The design makes for convenient adaption to other formats, or for mounting on a spectrometer.

The camera is provided with a protective lens cap. Optional lens adapters are available (see Table 2). Currently available lens mount adapters capable to mount onto the M42x1 U-mount thread, are:

- F-mount – a bayonet mount associated with the Nikon camera family of Nikkor lenses lens adapters
- C-mount – a 1 inch outside diameter thread mount associated with CCTV cameras

An O-ring groove is provided in the front plate surface, outside the M42 hole. With an O-ring installed in the groove, a tight light seal can be ensured when the camera is mounted against a flat plate using the front plate hole pattern. See Table for ordering information on the optional O-ring and Table 6 for mounting option listing and section 3.3 for information on the optical-mechanical interfaces supported.

Glass lenses are generally compatible with short wave infrared cameras. *Note: The antireflective coatings and lens materials on most high quality photographic lenses are optimized for visible light and have larger reflectivity in the short wave infrared. Optimum image sharpness requires a lens designed specifically for focusing all of the short wave infrared wavelengths used in the application. The lens should also be designed to fully illuminate the 20.48-mm active image width of the array and have an encircled spot size resolution compatible with a 10- μ m pitch diode array. A C-mount lens is generally designed to work with focal plane diagonal dimensions of 11 mm (2/3" format) or 16 mm (1" format). Only the latter type will fully illuminate a 12.8-mm long linear array, but it won't properly illuminate a 20.48-mm long array like that used in the GL2048 cameras. Therefore, only 35-mm photographic lenses with F mounts should be considered for use with the long arrays or C-mount lenses certified to fully illuminate at least 21 mm, or SWIR optimized lenses designed for 21 mm illumination circle and 10- μ m pixels. Currently, these requirements are met by the Edmund Optics SWIR TECHSPEC model lenses.*

1.5 CAMERA CLEANING

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 11 of 78	Last Update: 17-APR-2020

Please power down the camera before performing any camera cleaning operation.

Use a soft cloth moistened with a small amount of water or isopropyl alcohol to clean the outside of the camera enclosure or the power supply housing. Ensure that the surfaces are completely dry before re-installing in a system.

If the surface of the focal plane array requires cleaning, follow these steps:

- With the focal plane array mounted in the camera, use clean, dry compressed air to blow loose particles off the array. This step alone is often sufficient to clean causes of optical non-uniformity. Do not use compressed air gas canisters for this operation, since they may contain fluid and can thermally shock the window or spew particulate onto the array.
- Using lint free, lens cleaning paper or lint-free swab moistened with isopropyl alcohol; 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 other surface than the glass and covers the window from edge to edge. Use the cleaning surface **only once** and wipe in one direction across the window surface. If the surface is still not clean, repeat this step always wiping in the same direction using a new piece of moistened cleaning material until the window is clean.
- A black low-reflection aperture mask is placed on top of the PDA surface, outside of the detector active area. This shields the array from stray light and minimizes back reflections into the optics from the array surface. *Note that cleaner tissue or liquids could be trapped at this interface.*

*Note: Imaging a point light source from a distance (without a lens), for example using a LED or even a small pen lamp at some distance, will show dust on the window that might interfere with images when later used with small aperture optics like a microscope or a closed down imaging lens or a slow (small aperture) spectrometer. If moving the source sideways causes the spot to shift from pixel to pixel, the cause is on the array surface. If light touch cleaning attempts fail to move a dark spot from the original pixel location(s), the dark spot may be a scratch or dig in the AR coating. **WARNING: further cleaning attempts should be avoided to prevent further damage.***

2 GETTING STARTED

2.1 HARDWARE INSTALLATION

To connect your camera hardware, perform the following:

1. Mount the camera body, if applicable. See section 3.2.2 for the dimensions and location of provisions for camera mounting.
2. Mount the optics to be used with the camera, if applicable. If one of the provided standard lens mounts is to be used, see section 3.3 for additional information about available adapters.
3. Install the frame grabber you will be using for data collection following the manufacturer's instructions.

Note: The Sensors Unlimited GL2048L camera can be interfaced with Base Camera Link frame grabbers and computers designed to use x4 express bidirectional lanes, but Sensors Unlimited has verified its operation only with National Instruments Dual-Base-CL PCIe-1430 and Medium/Full-CL PCIe-1433, PCIe-1429 cards. The GL2048R can be used with the 1429 and 1433 Medium Camera Link cards or similar cards with a minimum of 4 express lanes through the PC mother board connector. For information on presently supported National Instruments frame grabber models or alternative boards, contact a SUI applications engineer. (See section 2.2 for additional information on software installation.)

WARNING: Before connecting cables and power supply to camera, use a multi-meter to test for potential voltage differences between the grounds of the frame grabber/computer, and the camera. When using long Camera Link cables and before connecting to the camera, take steps to safely discharge any potential inductive charge that may have built up in the cable. Either issue may overwhelm protective circuitry and damage the camera.

4. Connect the Camera Link cable to the frame grabber and the camera, inserting the connector so it is fully seated and the shell is parallel to the mating panel surface. Tighten the cable retention screws on both ends of the cable until reaching the stop. This is important for maintaining low RFI emissions and reliable, noise-free data capture. **Warning: avoid over tightening the cable jack screws as the small diameter can easily be broken.**
5. Before connecting the power cable to the camera, if the supplied AC adapter is not being used, test the power source to be used for proper voltage, polarity, and pin connections as indicated in section 3.1.1. **WARNING: Ensure that the voltage is within the specified range – though the camera has overvoltage and reverse polarity**

protection, it is not immune to damage from excessive voltages. With the power source off, insert the power connector into the camera socket. Apply power to the power supply and wait approximately 8 seconds for the camera status LED to turn green. See section 3.1.4 for information on the status LED operation.

6. Upon application of power, the Camera Link data lines and the asynchronous serial communications lines in the Camera Link interface will become active. The SENSORS UNLIMITED-GL2048L/R cameras will transmit a multi-line firmware banner message identifying the camera on the serial SerTFG line pair, and then operation will begin according to user-configurable default parameters stored in non-volatile memory.
7. If triggering the camera acquisition is desired, program the frame grabber to send the trigger signal over the CC1 line of the CL cable. Then send the appropriate trigger command to the camera. It is recommended to avoid making triggered operation the power-on state of the camera, as the camera will not be active without the CC1 trigger. This can lead to operator confusion until the frame grabber pulse generator or signal pass-through is enabled.

2.2 SOFTWARE INSTALLATION (OPTIONAL)

The GL2048L camera is compatible with the Camera Link interface specification 1.2, in the “Base” configuration and the GL2048R is compatible with the “Medium” configuration. As such, the operating software environment is generally specific to the Camera Link ‘frame grabber’ card selected for use and cannot be provided by Sensors Unlimited Inc. The output signal from the Camera Link interface is generic and relies on proper configuration of the receiving Camera Link device to obtain meaningful data. Sensors Unlimited has developed an Image Analysis application that works ONLY with National Instruments cards AND the NI-IMAQ suite; this is recommended hardware and simple imaging software for those not experienced in Camera Link Machine Vision operation. For most applications the user should expect to develop operating and analysis software appropriate for their specific application needs. NI LabView® is a flexible instrumentation programming environment that enables linking many standard functions and instrumentation together at an object level and is a popular means for developing application software.

To install software to control and collect data from the camera, perform the following:

1. Install driver software required by the frame grabber being used following the manufacturer’s instructions. Be sure to verify that the host computer meets the minimum system requirements specified by the frame grabber manufacturer, *including up to date revisions of support tools like .NET*. National Instruments IMAQ™ software drivers must be installed before installing the board if a National Instruments (NI) frame grabber is used. (See section 3.1.2 for a discussion of appropriate models.) NI’s Acquisition Software (VAS) is library of powerful functions for image processing that

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 14 of 78	Last Update: 17-APR-2020

includes their NI-IMAQ driver code for acquiring imaging and is distributed with their imaging frame grabber cards. This software library easily integrates with National Instruments LabView Software, an extensive instrument-programming environment. *Note: The Sensors Unlimited GL2048 hardware will work with other Camera Link compatible frame grabber cards, but Sensors Unlimited provides basic troubleshooting support for NI cards only. See paragraph 4 below for a link to IMAQ and OS compatibility information. Contact SUI before installing new versions when planning to use the Sensors Unlimited software.*

2. Configure the frame grabber to accept the Camera Link interface signal timing documented in section 3.1.2. If using a National Instruments frame grabber, a compatible camera configuration file (extension .ICD) is provided on the Sensors Unlimited USB drive that is shipped with the camera. This configuration file properly configures the frame grabber for the Sensors Unlimited GL2048 Camera Link interface timing and allows the selection of camera operational modes for the SUI configuration. Copy the configuration file from the supplied storage media to the IMAQ data directory for the IMAQ driver to access them (typical directory location is “C:\Program Files\National Instruments\NI_IMAQ\Data” for IMAQ revisions before IMAQ 4.1 and after that under Win7 and Win10: “C:\Users\Public\Documents\National Instruments\NI-IMAQ\Data”. *Note: The GL2048L/R cameras operate in a mode known as ‘overscan off’, which means that the CL handshake signals are only active for valid pixels. The supplied NI ICD file on the mini-CD supports this mode with the first number of parameter setting “AcquisitionWindow ” to read “(0, 0, 2048, XXX. (The XXX refers to the user’s selected virtual image height.) Similar setting options should be selected for alternative frame grabbers. No provision for ‘overscan on’ is provided with these cameras.*
3. Test camera data collection. Typically, GUI software tools provided with the frame grabber can perform simple data collection operations to enable the chosen frame grabber configuration to be tested. If a National Instruments frame grabber is being used, the NI Measurement and Automation Explorer (MAX) should be used to configure and validate the hardware installation. See National Instruments documentation for operation of the Measurement and Automation Explorer. If more information on interfacing with the NI-IMAQ library is required, call a NI representative or Sensors Unlimited. It is recommended that data collection be successfully exercised using frame grabber-supplied tools before attempting to collect data with any third-party or self-developed software applications.
4. Install any application software to be used following the manufacturer’s instructions. With NI frame grabbers, the Sensors Unlimited Image Analysis (SUI-IA) software application that can be used for data collection and analysis with the Sensors Unlimited GL2048L/R cameras is distributed on the Sensors Unlimited supplied storage media and can be installed after MAX has been run at least once. To install, navigate to the media’s directory “../SUI Image Analysis Software” and run the installer executable. The latest version of SUI software is posted for download at:

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 15 of 78	Last Update: 17-APR-2020

<http://www.sensorsinc.com/products/software/> . Compatibility notes with Windows and NI-IMAQ are also posted there.

5. SUI-IA allows the user to control the camera settings, acquire the linescan data into a pseudo image of user settable image height, store these images or sequences of images (as movies), measure relative intensities of pixels, regions or spots, contrast enhance the image with tools like 90% dynamic range, or Histogram Equalization, take and store line profiles or histogram data, and apply false color intensity maps to the images.

3 CAMERA HARDWARE INTERFACES

3.1 CAMERA ELECTRICAL INTERFACES

The electrical interfaces to the Sensors Unlimited GL2048L/R cameras are located on the camera back panel and on the right side (viewing from the back). The connections are identified in Figure 1. The serial number label is positioned in the open rectangle and identifies the camera model, part number and serial number. The 'R' version of the camera is further distinguished by the presence of two of the SDR 26-Pin Camera Link connectors. The cable connection to the camera is with the Mini-Camera Link style connector, also identified as SDR. Many Camera Link frame grabbers designed for desktop computers use the larger connector, which is identified as MDR. For those frame grabbers an SDR-MDR cable will be required. Camera Link frame grabbers for laptop computers will use the mini connector and need a SDR-SDR cable. The camera does not include either cable with the camera purchase, but an imaging pack containing a frame grabber and associated cable is available from Sensors Unlimited as an optional purchase.

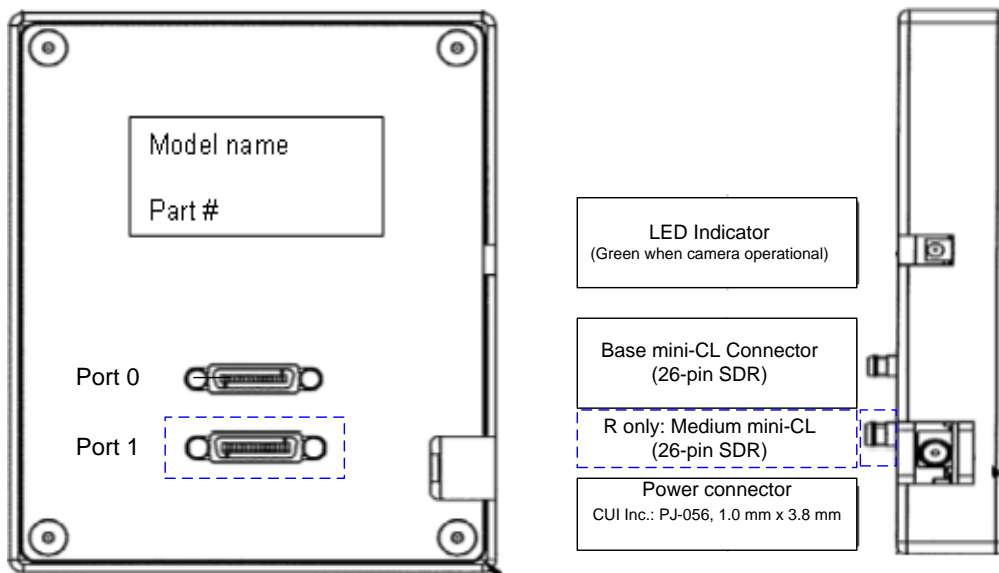


Figure 1 GL2048L/R Camera back panel and power connector pin assignment.

3.1.1 Power Input

A proprietary AC adapter is provided with a cable that connects to the power port of the camera. The cable mates with the connector labeled *POWER* shown in Figure 1. The provided AC adapter plugs into a 100-240 VAC (47 Hz - 63 Hz) outlet and supplies 12 V to the camera. To maintain CE compliance the power supply design uses an overall foil shield with a drain wire to

shield the DC conductors of the cable. The foil shield is terminated at the camera's DC connector by crimping the foil shield with its drain wire under a ferrule and contacting the ferrule to the DC connector body with a set screw. The mating plug connector used on the power supply cable is a barrel with dimensions of 1.1 x 3.5 x 7.6 mm with a positive polarity on the center contact. One possible mating connector is supplied by CUI Inc. and identified in their catalog as **PP-018**. If the provided AC adapter is not used, similar cable shielding construction is recommended for the connection to the camera's power input to minimize emissions in excess of EU Directives.

If the provided AC adapter is not used, DC power between +6 V and +12 V must be applied with the proper polarity to the power connector. **It is critical that the power connections be made to the proper connector pins, as shown in Figure 1. Do not exceed the maximum input voltage or damage might occur.** The power source used must be able to supply a minimum of 3.3 W of continuous power to the camera. A power source with a maximum peak-to-peak ripple of 1 % of the DC supply voltage at full load is recommended to ensure camera performance.

3.1.2 Camera Link Data Interface

The digital data interface to the GL2048L camera is through a base Camera Link compatible interface using low-voltage differential signaling (LVDS). Figure 2 shows the readout timing over this interface. This camera can be interfaced to most frame grabbers, but operation has been verified with National Instruments cards only. Optional imaging packs are available from Sensors Unlimited that includes a NI PCIe-1433, frame grabber card and a Camera Link cable to be connected to Port 0 as shown in Figure 1. The PCIe-1427 frame grabber is **not** recommended for the GL2048L as it restricts the camera line-rate to 50 k-lps due to the bandwidth limitation of using only 1 express lane into the PC. Matrox and Bitflow offer Base Camera Link boards with 4 express lanes and should provide support for the full line-rate of the GL2048L. The GL2048R version is a medium CL digital interface, which requires two cables to connect to a similarly rated frame grabber, with the second connector (Port 1) shown in Figure 1 inside the dashed box. The NI PCIe-1429 and 1433 cards have both been tested with the camera and handle up to 147,000 lines per second. In addition, Matrox has compatibility to these cameras with their multi-express lane Radiant eCL, and Solios eV-CL boards.

The Sensors Unlimited cameras communicate via the serial lines provided by the Camera Link interface. This asynchronous serial communication is performed using 8 data bits, 1 stop bit, no parity, no flow control, and a configurable BAUD rate. (See the list of typical settings at the end of this section and see Appendix B for the default serial communication BAUD rate for your particular camera.)

The signal assignment for the digital interface SDR 26-pin connector is shown in Table 3. This assignment corresponds to the SUI Configuration of the Camera Link standard. The GL2048 cameras do not support Power-over-Camera Link (PoCL).

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 18 of 78	Last Update: 17-APR-2020

SDR-26 Connector Pin	Camera Link Signal	SDR-26 Connector Pin	Camera Link Signal
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 (cable sense)
7	SerTC+	26	Inner shield (camera GND)

Table 3 Digital output SDR 26-pin connector signal assignment for Base Camera Link at camera connector

SDR-26 Connector Pin	Camera Link Signal	SDR-26 Connector Pin	Camera Link Signal
1	Inner shield (camera GND)	20	No connect
14	Inner shield (camera GND)	8	No connect
2	Y0-	21	No connect
15	Y0+	9	No connect
3	Y1-	22	No connect
16	Y1+	10	No connect
4	Y2-	23	No connect
17	Y2+	11	No connect
5	Yclk-	24	No connect
18	Yclk+	12	No connect
6	Y3-	25	No connect
19	Y3+	13	Inner shield (cable sense)
7	No connect	26	Inner shield (camera GND)

Table 4 Digital output SDR 26-pin connector signal assignment for the 2nd cable with Medium Camera Link

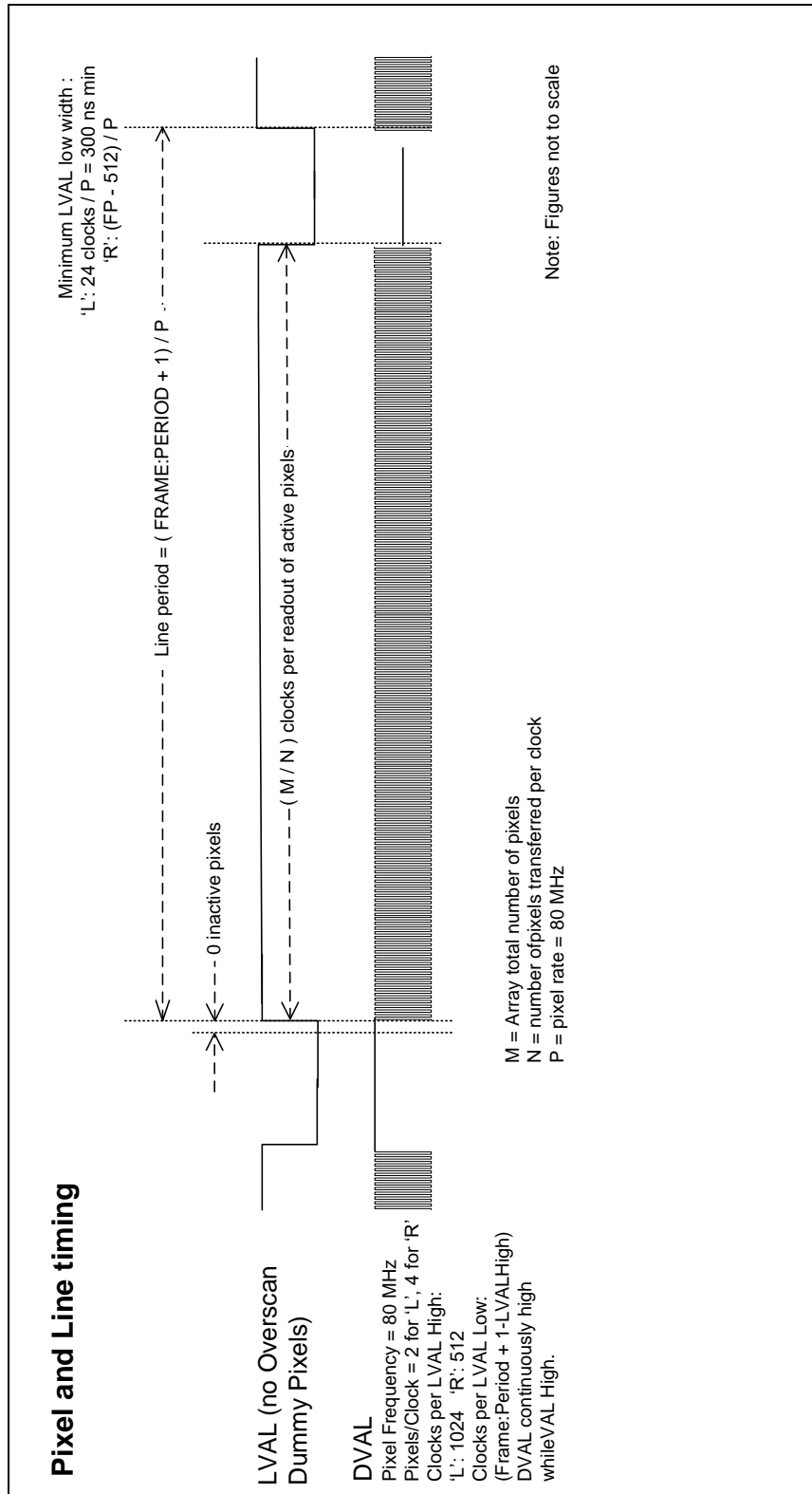


Figure 2 Camera Link interface timing diagram

For the GL2048L, the 12-bit image data pixel(n) bits[11..0] (MSB corresponding to bit 11) is presented on the Camera Link output with pixel(n) bits[7..0] connected to port A[7..0] and pixel(n) bits[11..8] to port B[3..0] for the first pixel, with the second pixel transferred on the same clock edge and presented with pixels (n+1) bits[7..0] connected to port C[7..0] and then pixel(n+1) bits[11..8] connected to port B[7..4]. The STRB frequency is 80 MHz (+/- 25 ppm) for a pixel transfer rate of 160 Mpixels per second, or 1.9 Gbits/s.

For the GL2048R, the second cable carries the 3rd and 4th pixel data on the same clock edge, with a nominal total transfer rate of 320 Mpixels/s, or 3.8 Gbits/s. Pixel(n+2) bits[7..0] connect to port E[7..0], Pixel(n+2) bits[11..8] connect to port F bits[3..0]. Pixel(n+3) bits [7..0] connect to port D[7..0] and the upper bits connect to F bits[7..4].

The signals STRB, DVAL, LVAL, and FVAL correspond to the signal names of the Camera Link standard issued by the Automated Imaging Association. The DVAL signal is held high during LVAL high for the GL2048 cameras as each clock cycle transmits new pixel data. A timing diagram for the Camera Link interface is shown in Figure 2 showing that LVAL is the primary interface handshake signal for fast linescan cameras. The FVAL signal is asserted (high) beginning with the first scan of the FPA by the camera and remains asserted until either scanning is disabled or the firmware is reset through the command interface. For a discussion of FPA line-rates, see section 4.1.

The time between valid lines (LVAL low) is dependent on the selected frame time, with a minimum of 0.3 μ s (24 clocks) required for the GL2048L model. As the line-rate is slowed (line period increased with FRAME : PERIOD command), the LVAL low period lengthens.

Asynchronous serial communications to the camera are carried on the Camera Link compatible interface via the SERTC \pm , and SERTFG \pm signal lines. See section 5 for a description of the asynchronous serial communication protocol and command set used by the camera. The interface pins for CC1 \pm carry a trigger input source to the camera. See section 5.4.6 for a description of supported camera trigger modes and section 3.1.3 for electrical specifications.

Typical Camera Link Settings for interpreting Figure 2, the Camera Link interface timing diagram for the GL2048L camera:

Active Horizontal Pixels:	2048
Active Vertical Pixels:	1
Pre-active Pixels:	0
Post-active Pixels:	0
Camera Link STRB Clock:	80 MHz +/- 25 ppm
Pixels output per CL STRB:	2 for GL2048L; 4 for GL2048R
Minimum clocks LVAL low:	24
Minimum clocks per line:	1048

Number of FPA I/O Ports:	16 high speed serial channels
Bit Depth:	12 bits
Serial Port Configuration:	
BAUD:	57600
Data Bits:	8
Parity:	None
Stop Bits:	1
Flow Control:	None

3.1.3 *Trigger Input*

The Sensors Unlimited GL2048L and GL2048R cameras provide for external triggering via the frame grabber, using the CC1 signal lines. Camera commands enable defining the active level as either the positive or the negative going transition. When an external trigger mode is selected, the camera monitors the line and starts the exposure sequence, using the programmed exposure time in trigger mode 1, or ending the exposure period with the clock transition after the trigger signal transitions to its alternate logic level in mode 2. For further information see the command section 5.4.6.

3.1.4 *Status LED*

After power has been applied, the status LED will illuminate green once the internal initialization process completes (typically <10 seconds). The camera will then output its startup banner over the serial channel, respond to commands, and start clocking out array data.

3.2 CAMERA MECHANICAL INTERFACES

3.2.1 *Physical Characteristics*

3.2.1.1 Cameras with array response to 1.68 μm :

Dimensions (Length x Width x Height)	8.3 cm x 10.2 cm x 1.6 cm 3.25 in x 4 in x 0.64 in excludes I/O connectors, and lens adapter
Weight	<240 g or 8.6 oz. (no lens or adapter)

Table 5 Camera dimensions.

3.

3.2.2 Camera Mount Options

Type	Description	Hole Pattern
Camera Tripod Mount	Tapped ¼-20 holes, blind	One on bottom, one on side wall (in a few early units centered on wall length; most units on center line of the FPA)
Spectrometer Mount (front)	M42 x 1-6H	42 mm diameter tapped hole through plate
	4 x 8-32 tapped holes, ¼ inch depth	2 inch square centered on FPA
	2 x 8-32 tapped holes	2 3/8" (60 mm) apart, centered on FPA
	O-Ring light seal when mounting to flat plates	1/16 th inch (1.59 mm) thick, 1 7/8th inch (47.6 mm) diameter
Threaded Lens Mount and optional lens mount adapters	M42x1-6H	42 mm diameter tapped hole through plate
	C-Mount LD adapter	One piece fixed distance disk
	F-Mount LD adapter	Adjustable distance

Table 6 Camera mounting options.

3.2.3 Thermal Management

The GL2048L/R cameras are uncooled, with the FPA heating up by internal power dissipation to approximately 45 °C in normal environments. The heat is conducted from the back of the FPA into the circuit board and out to the camera enclosure. It is recommended that installations of the camera inside other enclosures provide a thermally conductive path to conduct the dissipation away. In free space mounting, attaching lenses or spectrometers assist in conducting heat out of the camera. Ambient temperature variations may affect the dark offset level of the diodes; users may update the offset corrections with the CORR:DARK command if they can briefly shield the camera from light. See section 5.4.7 for more information about camera corrections.

3.3 CAMERA OPTICAL INTERFACES

3.3.1 Lens Mounting Plate

Sensor Alignment	6 +/- 0.4 mm behind optical mount flange
Optical Focal Distance	5.8 mm +/- 0.4 mm

Table 7 Lens mounting specifications.

The GL2048L/R Shortwave Infrared linescan cameras utilize a lens mounting plate with a M42X1 thread, that is, a 42 mm diameter hole with a 1 mm thread pitch. This permits providing lens adapters for two types of standard photographic or CCTV lens mounts. The camera mounting plate also provides 6 SAE screw mounting holes, plus an O-ring groove for use with flat plate adapters and spectrometers. The use of the optional O-ring (see Table 6) in the groove will help prevent light leaks when the camera is mounted to a flat plate. The screw holes are closed (blind), with a depth of ~1/4 inch (6.3 mm), also to prevent light leaks. (See

Please take note that the wavelength range accepted by SWIR cameras is quite broad and beyond the range for which typical commercial lenses have been designed. Depending on the actual wavelengths imaged in the users’ applications, the lens focus calibration markings will be shifted; depending on the width of the wavelength range imaged, the image contrast may be reduced compared to a lens designed to focus SWIR light. Another factor is that, due to a buildup of mechanical tolerances of the number of pieces between the focal plane of the sensor array and the camera front plate, the focus distance between the lens and the FPA can vary from camera to camera. The optical image plane location of the focal plane for the 2048 cameras is approximately 5.8 mm behind the mounting plate with a tolerance of ± 0.4 mm. These factors combine to make the lens markings misleading unless a means of trimming the focus distance is provided, such as has been designed in the Sensors Unlimited F-mount adapter.

Sensors Unlimited cameras do not control the aperture opening in automatic aperture camera lenses. Most SLR lenses available today are designed for the camera to automatically control the aperture opening or, optionally, to be set manually with the lens aperture ring. If the lens being used does not support manual stop-down aperture operation mode, and the lens will only be used with this camera in the future, identify the metering lever that closes the aperture. Next, move the lever to the position which permits the lens aperture setting ring to control the iris opening, and then attach a block to hold the lever in this position.

3.3.2 Available Lens Adapters

SUI currently offers the LD family of lens adapters that are also compatible with the Sensors Unlimited GL2048L/R cameras. These adapters are for popular visible CCTV or 35 mm manual-control Single Lens Reflex (SLR) photographic lenses. Some of the adaptors provide trimming for the focus position of the lens and the F-mount also provides for positioning the focus index markings on the lens at a convenient location for the user. (See section 3.3.3 for a method for making the adjustments.)

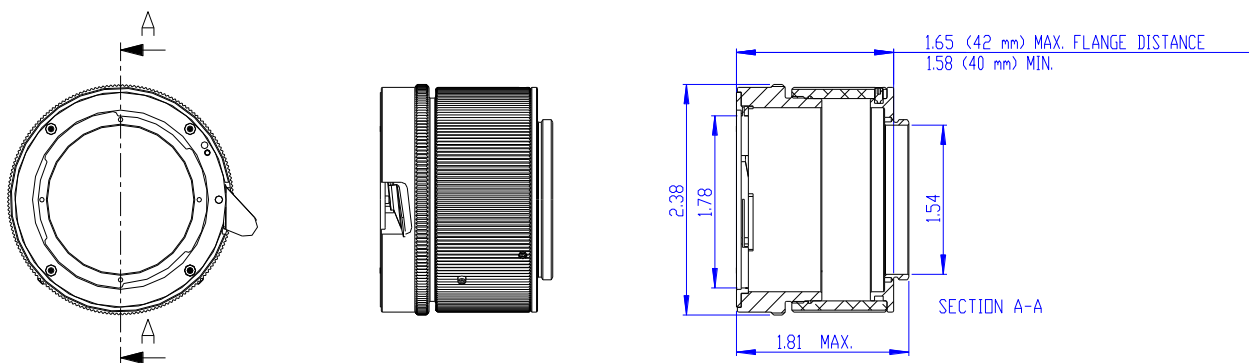


Figure 4 LD to Nikon F-mount lens adapter – part #8000-0171.

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 29 of 78	Last Update: 17-APR-2020

An adjustable adapter accessory kit is not available for the C mount. A non-adjustable adapter is described in section 3.3.5. This mount is generally used with 1" format (historically defined as a focal plane with a width of ½ inch and a diagonal of 16 mm) or smaller focal plane arrays. Given the 20.48 mm width of the linear array focal plane in the GL2048 cameras, the image may experience vignetting (shadowing) at the ends of the image line when using most C mount lens or any lens not designed to illuminate a diagonal field of view of at least 21 mm.

The lens adapters can be ordered individually as separate line items on the purchase order.

WARNING: Though the camera body is light, caution should be exercised before relying on mechanically supporting the camera solely through the lens mount interface. Consider supporting the camera body weight using the provided tripod mounts or by some other direct mechanical attachment to the camera body. This should also help conducting thermal dissipation away from the camera.

3.3.3 *Installation of Lens and Adjustable Adapter*

1. Choose a dust free environment in which to assemble the camera, lens adapter, and lens. Mount the camera on a tripod or equivalent holder that permits access to the lens adapter set screws all the way around the front of the camera.
2. Inspect the opening in the linear array window for dust or lint. If needed, use clean dry compressed air or follow the cleaning directions in section 1.5.
3. Examine the distance markings on the lens. Provide for imaging a target at a distance within the range of the markings on the lens, preferably at a distance from the camera front plate that matches one of the marked distances similar to that being used in the application. If possible, also set up a second target beyond the last distance marking on the lens to approximate infinity. The target should provide sufficient detail at the working distance to make it easy to judge relative focus. As a linescan camera only acquires one line of the image at a time, it can be difficult to recognize what the camera is imaging. It is useful to create a target of vertical bars at a constant spacing or of changing spacing. An example of the latter is known as a Sayce pattern, which can be obtained from sources of line resolution targets.
4. Use a light source similar to that which will be used in the application (e.g., natural lighting, fluorescent, incandescent, or LED). Focus with a monochromic light source will be sharper than with broad wavelength source.
5. Ensure that the lens adapter kit is the appropriate one for the lens to be used and that the lens mates properly with the adapter by temporarily putting them together.
6. Remove the camera's protective covering from the front plate and gently thread the adapter fully into the plate until the piece begins to seat. Using finger pressure on the outer rim of the M42 panel piece only (threaded piece shown in Figure 6), seat it firmly into the camera. If a two-point spanner wrench is available, remove the lens and look through the adapter

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 30 of 78	Last Update: 17-APR-2020

from the lens side to see the four holes in the M42 panel piece that threads into the camera (see Figure 5). Adjust the spanner wrench to the spacing shown and firmly tighten the adapter to the camera using the wrench.

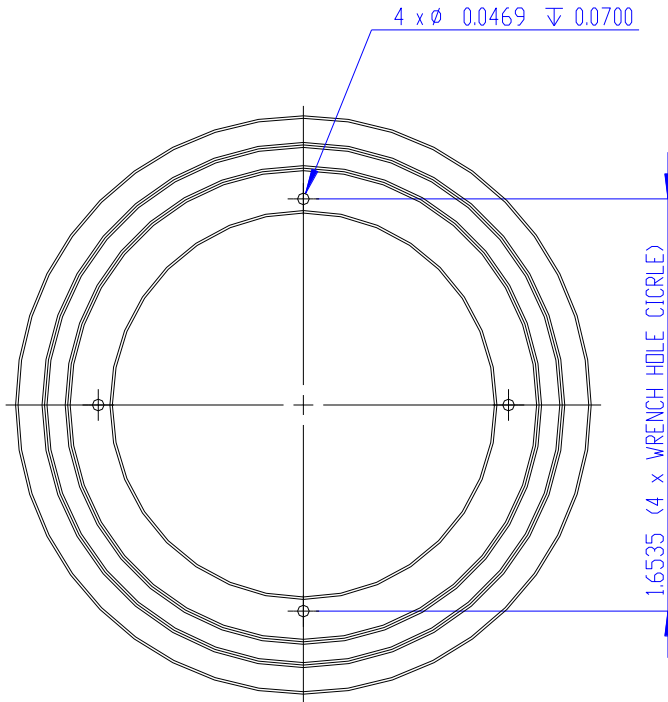


Figure 5 Drawing of adapter panel ring showing spanner holes.

7. Locate the set screws on the lens adapter barrel used for locking the rotation and focus adjustments. There are three rotation locking sets screws on the knurled collar ring closest to the camera plate set 120 degrees apart and two focus adjustment locking set screws further away from the camera set 90 degrees apart. The set screws locations are shown in Figure 6.

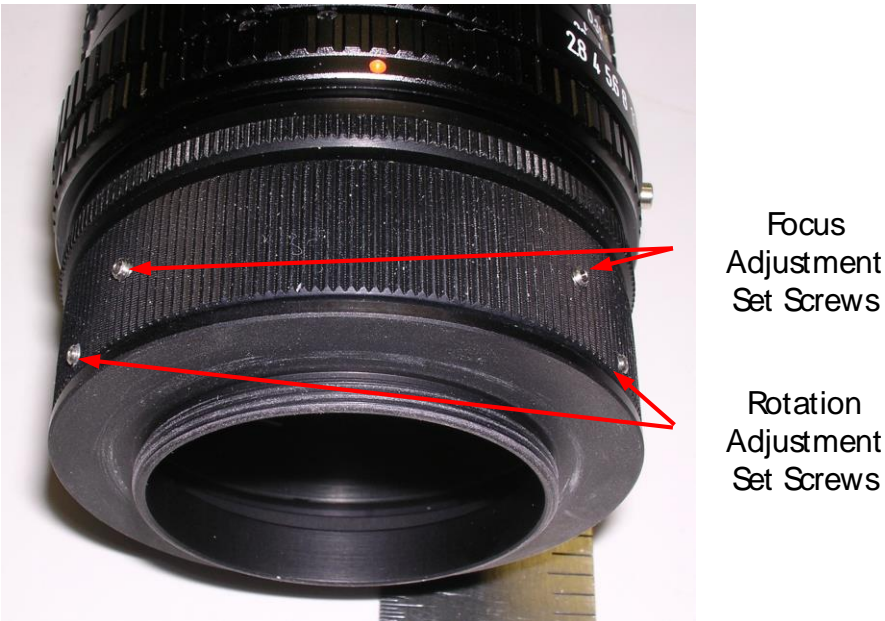


Figure 6 Location of lens adapter focus and rotation adjustment set screws.

8. Loosen the three rotation locking set screws to permit rotation of the adapter and then position the pair of focus adjustments set screws where they can be easily accessed during the adjustment procedure. Gently tighten the three rotation adjustment set screws.
9. Loosen the focus adjustment pair of set screws to allow the lens and its mating piece to be rotated. This threads the combination into and out of the collar ring.
10. Position the lens focus ring to the lens focus marking that matches the distance of the target set up in the earlier step.
11. Check the lens aperture setting and open it up until the lens iris is at its maximum opening. This position is most sensitive to focus accuracy due to its relatively shallow depth of field.
12. Connect the camera's Camera Link interface to the computer which will be displaying the data output.
13. View the image on the display and position the camera to put the target in the center of the view. If the light level is too high, reduce the sensitivity of the camera by changing its OPR setting or reduce the light level. If the light level is too dim, increase the camera sensitivity or the light level.
14. Next carefully rotate the lens interface to thread the lens further in while noting whether the focus is improving or getting worse (avoid changing the lens focus position). Continue or change direction until the image passes through its sharpest point and begins to soften again. If you use a target as described in paragraph 4 above and you are using the SUI Image Analysis program to operate the camera, it is useful to set the program's ROI Measurement Window to the Line Profile tab, with the Line Selection set to Row. Position the image display's yellow cursor so that it cuts across the black and white squares of the target. Then monitor the peak-to-peak variation of the line profile as you adjust focus. The largest amplitude marks the best focus.

15. Return to the sharpest position, and then check the lens focus marking to ensure that it is correctly positioned.
16. If an alternate target distance is available, shift the camera to view that target and verify the result. Be sure that a satisfactory focus can be achieved at the distant target. It may be necessary to compromise the adapter focus adjustment to give the best average lens marking accuracy between the two points.
17. When satisfied with the adjustment, tighten the focus adjustment set screws (the pair closer to the lens). A torque range of 1-2 in-lbs. is recommended for these set screws.
18. Loosen the rotation adjustment set screws (3) and rotate the lens adapter collar ring to reposition the lens focus markings to a position that will be useful when the camera is installed in its normal application. For tripod use with the operator above the camera, this is with the lens markings on top.
19. Re-tighten the rotation adjustment set screws. A torque range of 1-2 in-lbs. is recommended for these set screws.
20. If reduced response is noticed on individual pixels, particularly when the iris is closed to smaller apertures, remove the lens and look through the lens adapter to inspect the surface of the focal plane array. If any dust appears on the array window, follow the instructions of section 1.5 to clean the window.

3.3.4 *Lens Stop-down Mode*

Some Canon-FD and Nikon/Nikkor-F lenses support an automatic stop-down feature that is not supported by the Sensors Unlimited GL2048 cameras. If using a lens of this type, the lens may require an adjustment or modification to allow manual control of the iris opening. Consult the lens manufacturer's documentation to determine the method for operating the lens iris manually. For some lenses, this is accomplished by setting a locking lever on the camera side of the lens.

3.3.5 *C-Mount Lens Adapter*

This adapter threads into the M42 threaded hole on the mounting plate and a C-mount lens threads into the 1x32 (M25.4 x 1.26) threaded hole in the adapter. No back focus distance adjustability is provided for this adapter. It is designed to put the lens slightly closer to the focal plane than the C-mount specification of 17.56 mm to ensure that distant objects will achieve focus within the adjustable range of the lens. To trim the focus position further, use 1 inch inside diameter shim washers to move the lens farther away from the focal plane.

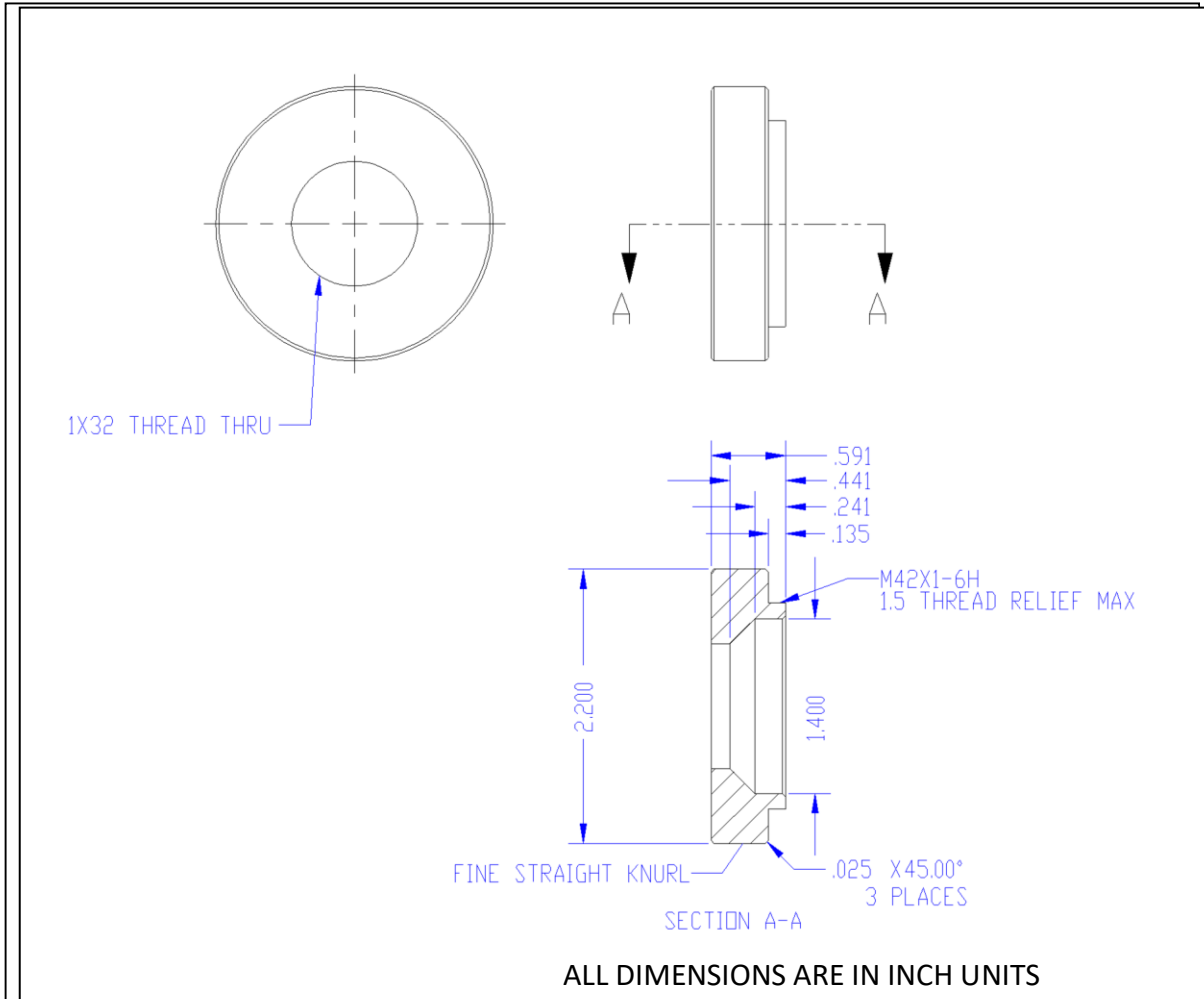


Figure 7 Mechanical drawing of C mount lens adapter

4 PRINCIPALS OF OPERATION

4.1 FOCAL PLANE ARRAY OPERATION

The Sensors Unlimited GL2048L/R cameras include a Sensors Unlimited LC1 series indium gallium arsenide (InGaAs) linear focal plane array. This device is a hybrid combination of a single InGaAs back-illuminated photodiode array with a silicon CMOS readout integrated circuit (ROIC). Typical quantum efficiency (QE) and wavelength responsivity for Sensors Unlimited’s standard SWIR wavelength range back-illuminated 1.7 μm cutoff linear arrays is shown in Figure 8. (The GL2048 arrays are only available with these cut-on and cut-off wavelengths.) Note that the back-illumination approach limits the FPA response below 980 nm compared to the front illumination of previous front-illuminated SUI line scan cameras.

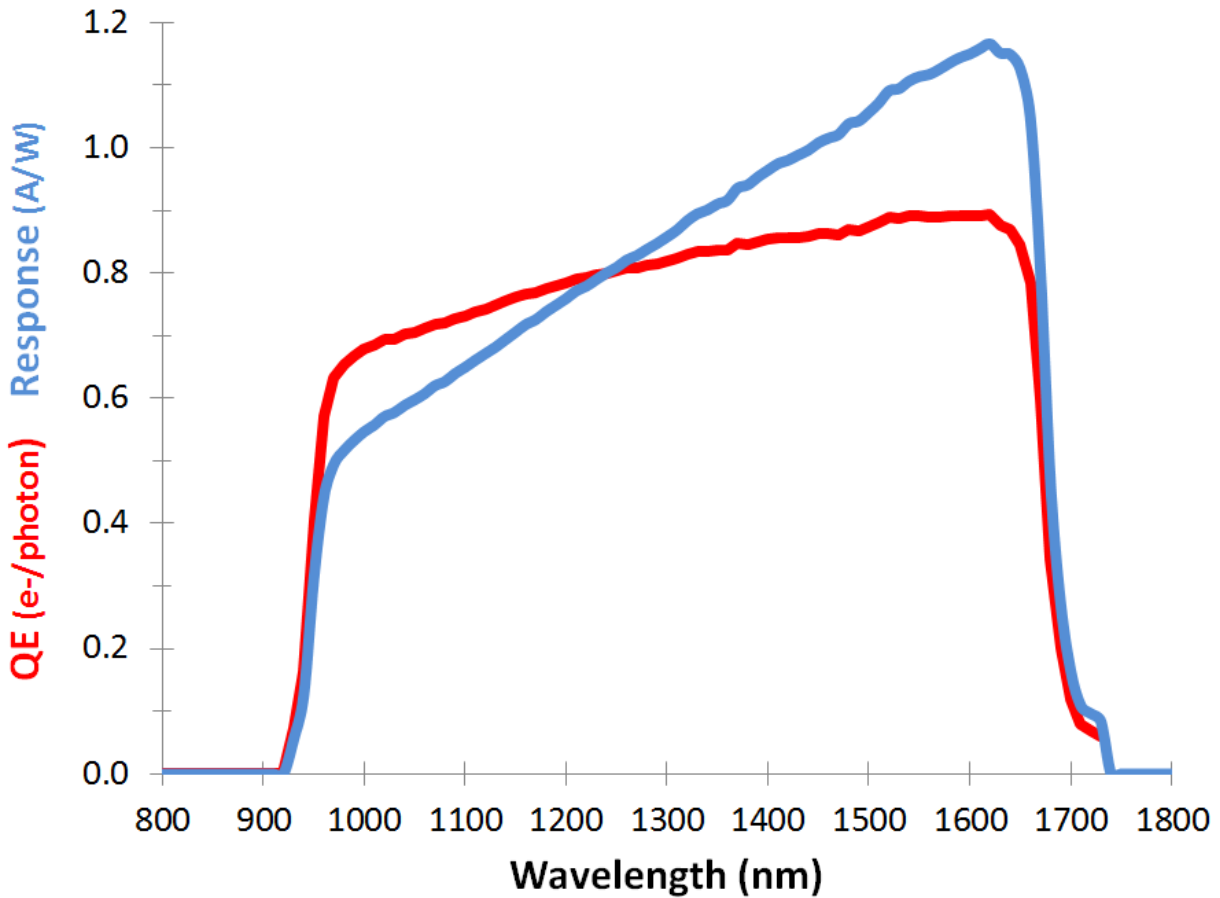


Figure 8 Typical QE for front-side illuminated Sensors Unlimited linear PDAs.

The CMOS readouts are "active pixel" devices in which the photocurrent is buffered, amplified and stored. The architecture is a capacitive transimpedance amplifier (CTIA) with the photodiode at the input and the photocurrent integrated on the feedback capacitor of the amplifier. A simplified pixel schematic is shown in Figure 9. The GL2048 cameras offer three values of the

feedback capacitors C_{feedback} which can be selected in four combinations via command interface (nominal design values, 26, 53, 79, and 105 fF). The larger capacitances provide greater charge storage capacity and dynamic range at the expense of lower conversion gain. The smaller capacitors provide greater sensitivity and readout noise at the expense of dynamic range. The choice of the capacitance should therefore be interpreted as a choice between high dynamic range and high sensitivity modes.

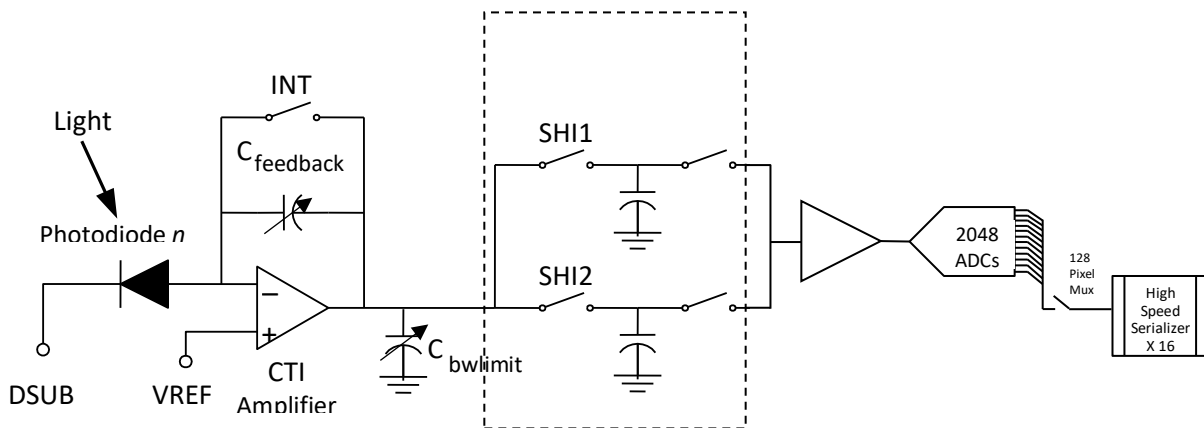


Figure 9 Simplified pixel schematic.

There are two pairs of sample-and-hold circuits at the output of each pixel's CTIA (only the first pair is shown in the figure). Working in conjunction, the two pairs allow the FPA to operate in a parallel-in, serial-out "snapshot" mode. Between exposures, all of the pixels are held in reset using the INT switch. When INT is released, the "reference" initial voltages across the capacitors are then captured with the sample-and-hold capacitors SHI1 after a setting time that varies between the L and R models, and varies for each of the three OPR settings in the R. At the end of the exposure period, the active "signal" levels are captured with the sample-and-hold capacitors SHI2. Utilizing two pairs of sample-and-hold circuits, the output of the first pair can be transferred to the second pair for digitization, freeing up the first pair for use in the next sample-and-hold sequence. This allows integration to be overlapped in time with the read operation. Both the initial reference level and final signal level for each pixel will deviate from the camera reference bias level (VREF) as a function of dark current and photocurrent generated by light. The photocurrent drives the output signals negative relative to the VREF level. In the Sensors Unlimited GL2048L/R cameras, when line-rates are ≤ 120 k-lps (OPRs 1 and 2), the "reference" level is subtracted from the "signal" level to implement the method known as correlated double sampling (CDS), eliminating much of the FPA related reset and switching noise. At higher line-rates (OPR 0), just the "signal" sample is used as there is insufficient time for a good "reference" sample to be acquired.

There exists a small reverse bias voltage across the photodiodes. This voltage is chosen to obtain the lowest dark current from the diodes while ensuring that all photodiodes remain

reverse-biased in the presence of small variations in each CTIA of the array. At a given temperature and exposure time, this dark current is fixed for each pixel and appears as a spatial fixed pattern noise. Since the shunt resistance, R_{σ} , has a dependence on diode temperature, the dark current signal will change with focal plane array temperature. The average offset across the array is configured such that the digitized dark signal is greater than 0 digital counts for all exposure times.

The GL2048 cameras run uncooled, so changes in the ambient temperature could cause the baseline to shift. Therefore, periodically blocking light from the detector and capturing a dark image for background subtraction will be advisable. The GL2048 cameras have a command, `CORR:DARK`, that will average 16 scans to record the dark fixed pattern and subtract it from subsequent data when the `CORR:OFFSET` command is set to `ON`. Similarly, for photoresponse non-uniformity correction, if the user illuminates the detector with a uniform flat field, the command `CORR:LIGHT` averages 16 scans to capture the detector response across the array, and divides it into the array mean value to create a correction curve. This non-uniformity correction will be applied to subsequent data when the `CORR:GAIN` command is set to `ON`. *Note: the quality of the correction will be dependent on the uniformity of the light field imaged onto the array; it should be representative of the wavelengths and average light intensity expected during the application for the camera operation settings in use. Changes in exposure time, line-rate, front-end gain, or triggering mode will likely degrade the previously stored correction and the user is advised to acquire new correction data. Correction of lens or light source non-uniformity can be obtained, however it is important to ensure that there is reasonable light energy on all pixels as image dynamic range and noise will be degraded in portions of the array data where the intensity of light used for acquiring the correction data was weak, e.g., <20% of full well.*

The timing sequence of the focal plane array consists of charge integration followed by the readout with the ability to integrate-while-read. That is integration of charge for the next line starts while readout of the previous line takes place. The charge on the feedback capacitor is sampled at both the beginning and end of the integration for the L and for OPR modes 1 and 2 for the R camera. The duration between two samples is the exposure time and the difference of the samples is what is digitized to form the digital output of the camera. *Note: at the shorter exposure times, the first sample time may become a significant part of the total integration time and reduce the signal levels. This is why OPR 0 only uses a single sampling period at the end of integration.* The camera internally provides all the timing functions for clocking of the focal plane array.

The line-rate is determined by combining the readout timing requirements and the integration timing requirements. Assuming that the line-rate is limited by the readout time and not the integration, the maximum line-rate is given by the following relationship to the total number of array pixels M , the number of pixels transferred per CL STRB N , an overhead number of pixel clock times O and the pixel readout rate P :

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 37 of 78	Last Update: 17-APR-2020

$$MAXLINERATE = \frac{P}{\left(\left(\frac{M}{N}\right) + O + A\right)}$$

The value to use for the FRAME:PERIOD command (FP for the discussion below) equals the M/N+O value. The actual frame period is increased by the factor A, which is 2 for the L cameras, and 1.55 for the R camera. The maximum line-rate for each camera model is listed in Table 8 below.

The maximum exposure time T_{MAXEXP} for a given line period T_{LINE} is:

$$T_{MAXEXP} = T_{LINE} - INT_{LOW}$$

where the minimum time for the parameter INT_{LOW} is as follows:

- 3.96 μ sec (317 clocks) for GL2048L camera
- 2.00 μ sec (160 clocks) for GL2048R-OPR 0
- 3.10 μ sec (248 clocks) for GL2048R-OPR 1
- 4.05 μ sec (324 clocks) for GL2048R-OPR 2

For the standard port pixel rate P of 80 MHz, the reset setting and first sample period reduces the actual exposure time by 1.67 μ s for the 2048L, . The maximum exposure time for each camera model operating at their respective maximum line-rate are also listed in Table 8.

Array Size <i>M</i>	Number of Pixels/clock <i>N</i>	Pixel Rate <i>P</i>	Overhead <i>O</i>	Maximum Line-rate	Minimum EXP Period	Maximum EXP @ Max line-rate	Maximum EXP @ Min line-rate	Actual = EXP + A
GL2048L	2	80 MHz	24	76,190 Hz FP 1048	5.5 μ s EXP 440	9.1 μ s EXP 731	10 ms EXP 800000	-1.67 μ s
GL2048R – OPR 0	4		28	147,724 Hz FP 540	4.5 μ s EXP 373	4.75 μ s EXP 380	6.58 μ s EXP 540	-159 ns
GL2048R – OPR 1			123	125,677 Hz FP 635	4.76 μ s EXP 381	4.84 μ s EXP 387	10.7 μ s EXP 852	+47.6 ns
GL2048R – OPR 2			488	79,876 Hz FP 1000	7.86 μ s EXP 629	8.45 μ s EXP 676	101.7 μ s EXP 8136	-1.7 μ s

Table 8 Maximum line frequency and exposure time by camera and operating mode.

4.2 CAMERA SYSTEM OPERATION

The Sensors Unlimited GL2048L/R camera boards provide all support functions to the focal plane array necessary to provide the user full access to the performance capabilities of the sensor. The

camera is a complete data acquisition system supporting the analog, digital, and power conditioning subsystems needed to flexibly operate the focal plane array with minimal external support. A basic signal flow diagram for the Sensors Unlimited GL2048L/R camera system is shown in Figure .

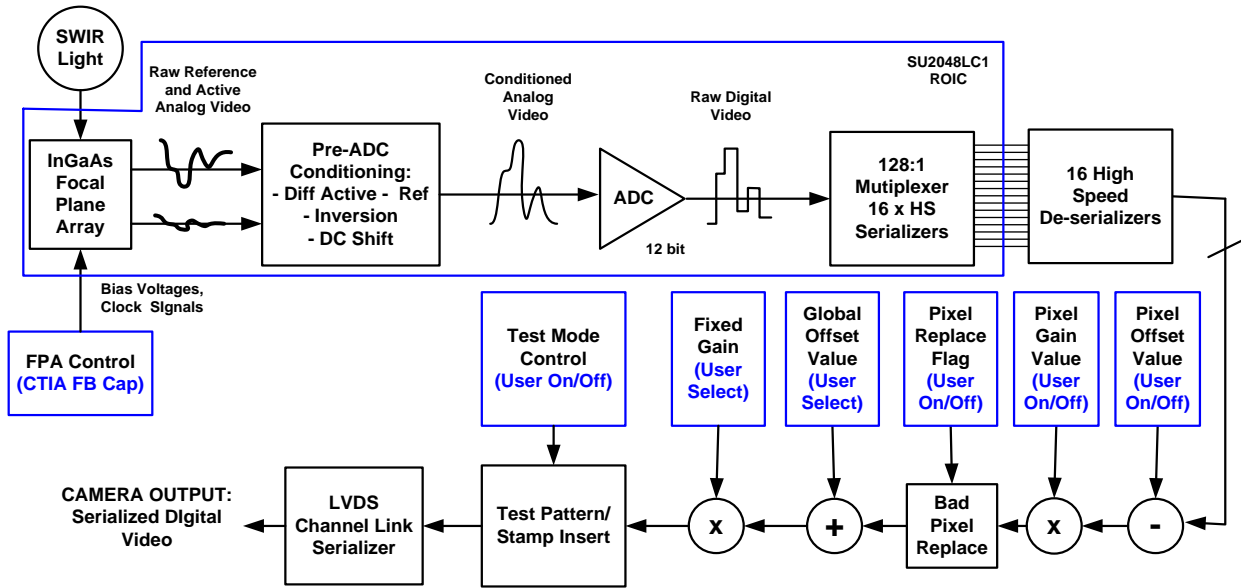


Figure 10 Camera system signal flow diagram.

The functions of the camera system include the following: creation of DC bias voltages, clock signals, expose control signals, programming of the readout circuit timing registers, receive the 16 channels of high-speed serialized data, reorganize it into a single sequence of pixels, and transmits the pixel data to the frame grabber, sending either 2 pixels per CL clock cycle for the base-Camera-Link GL2048L or 4 pixels per cycle for the medium-CL GL2048R.

The camera processor interprets ASCII text commands from the user via the Camera Link serial lines, to set the line time, exposure time, pixel gain, digital gain, triggering mode, and also has the ability to acquire and apply non-uniformity corrections for pixel offset or gain variations. In addition, bad pixels can be replaced, whether they are bad because they are always bright, always dark, differ from the mean by more than 20%, or because they are noisy. The user or SUI can program a bad pixel flag for any pixel, and when the camera is reading out the array, it will substitute the previous good pixel value for the flagged pixel, when the function is activated. The user is able to download or upload the bad pixel map, the gain and/or offset correction arrays.

Unlike previous Sensors Unlimited cameras, a table of predefined operating modes with correction memory for each mode has not been created for this camera. The user sets the camera exposure time, line-rate, and pixel gain directly as needed, but has been given the tools to create appropriate correction files for each combination. In cases where it is inconvenient to

acquire fresh corrections each time the settings change, the stability of the camera should permit users who have a set number of settings they are likely to use, to set up a uniformity fixture and record corrections for those settings, store them in the PC for download to the camera when those settings are to be used in the application.

At the shortest exposure times permitted by the camera, if the array is at or near saturation in the highest gain; shifting to lower gain settings is not recommended. The total light flux being received by the array in that exposure time is near the acceptable limits for the array's total internal current flow. Shortening the exposure time further or shifting to the lower gain settings to bring such light levels to within the ADC's range is not advised as the average current will be too high if the majority of the diodes are exposed to the same flux level.

This manual is written in a general fashion to cover several variants of the camera. To see the settings for the specific model and Sensors Unlimited part number version that will be in use, please review Appendix B of the manual (which is stored in a separate electronic document with the document number prefix of 4170- followed by 4 digits). This lists the SUI settings. The '.PDF' image files of the appendix as well as this manual are stored on the data storage media (mini-CD or memory stick) that is shipped with the camera. This media also holds the camera ICD files and the user programs SUI Image Analysis and Camera Link Terminal (these require the National Instruments frame grabbers to run).

The SUI stored offset and gain corrections are created for a default integrator gain, line-rate and exposure time. The offset corrections are stored with the FPA shielded from light. The gain corrections are created by putting the camera front opening against an integrating sphere illuminated with 1550-nm light.

The power conditioning subsystem of the camera converts a single DC input power voltage and efficiently re-regulates it to create the power voltages needed internally by the digital and analog subsystems.

See section 5 for more detailed information on the operation of the various camera functions supported by the Sensors Unlimited GL2048L and GL2048R models and the commands used to select the functions.

5 CAMERA FUNCTIONS AND CONTROL SOFTWARE INTERFACE

The Sensors Unlimited GL2048L and GL2048R cameras have a variety of features and modes that can be selected or queried through the control interface including, exposure time, frame rate, sensitivity, corrections, trigger modes, and error status. The Sensors Unlimited cameras communicate via the serial communication provisions and sends the 12-bit digital data according

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 40 of 78	Last Update: 17-APR-2020

to the Camera Link standard. The GL2048L uses a single cable Base configuration and the GL2048R uses a two cable Medium configuration. All camera modes are controlled using a set of ASCII commands sent by the Host to the camera over the serial communication lines within the Base Camera Link Cable.

5.1 COMMUNICATION PROTOCOL

The Sensors Unlimited GL2048L/R cameras communicate via the serial lines provided by the Camera Link interface on the Base connector. This asynchronous serial communication is performed using 8 data bits, 1 stop bit, no parity, no flow control, and a configurable BAUD rate. The default factory BAUD rate is set to 57,600, however, please confirm the setting for the camera part number in use by reviewing the file on the storage media that came with the camera whose name has the form: "4170-#### Appendix B...".

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*.
- Special operating or cautionary remarks are prefaced by *Note: and italicized in the normal font*. **WARNING notes are in boldface**.

When issuing commands to the camera the following rules apply (Table 9 summarizes the camera's return line formats and the conditions under which the lines are returned.):

- 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.
- Many commands consist of a main group word, a colon (":") and a sub-group; no space should be used between these words.
- Extra arguments or text entered on the command line will result in an error.
- The camera supports several echo modes of the characters it receives. The camera can echo the received character back to the user. Alternatively, the echo can be disabled, resulting in no output of an echo line.
- The return value line output is command dependent. Some commands, such as the query commands, will have a return value that will be output to the Host. 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

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 41 of 78	Last Update: 17-APR-2020

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.*

- "BRIEF" mode just returns requested responses and acknowledgements and is recommended for use with programmed software interactions with the camera. "VERBOSE" mode in the 2048 cameras will provide extra informational lines of response when errors are received, to assist in debugging and learning the camera. The assumption is that a user is entering commands and reading the responses via a terminal display type of program, like the Camera Link Terminal or the Terminal window in SUI Image Analysis, or via HyperTerminal used for serial communications by the software for some frame grabber companies.
- 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. This prompt character response can be turned off, but that is not recommended. User code that tests for receipt of the ">" character before sending a subsequent command will result in more robust operation by avoiding sending commands too soon. *NOTE: Command execution times in the 2048 cameras vary; if the frame grabber software can not be programmed to wait for the ">" character before sending the next command, timing delays between commands may have to be added, especially for compound commands like EXP:MAXRATE and FRAME:PERIOD:MAXEXP, and for the correction commands CORR:DARK and CORR:LIGHT.*

NOTE: In the initial releases of the GL2048L, not all commands consistently follow these rules (shipped before 1/2014).

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 Execution Result: OK or ERROR	Always returned.
>	Command Prompt	Always returned.

Table 9 Line format of camera command return strings.

5.3 STARTUP MESSAGING

When the power is applied to the GL2048 cameras and after the internal initialization, which takes approximately 10 seconds, the green status LED will glow and the camera will output a multi-line banner identifying its part number, serial number and revision, the FPA part number, its serial number and the firmware part number plus revision code. The banner concludes when the camera is ready to receive commands. Power cycling the camera can be used to test the serial communications link in the direction of the camera transmitting to the PC. If the text is not readable, it may be an indication that the BAUD rate is not matched between the camera and the frame grabber software or associated terminal program used to show the serial communications. If the text is readable, sending one of the camera inquiry commands is the next step to ensure two way communications.

The typical output of the camera banner is shown below using the SUI terminal program (distributed on the software storage media with the camera):

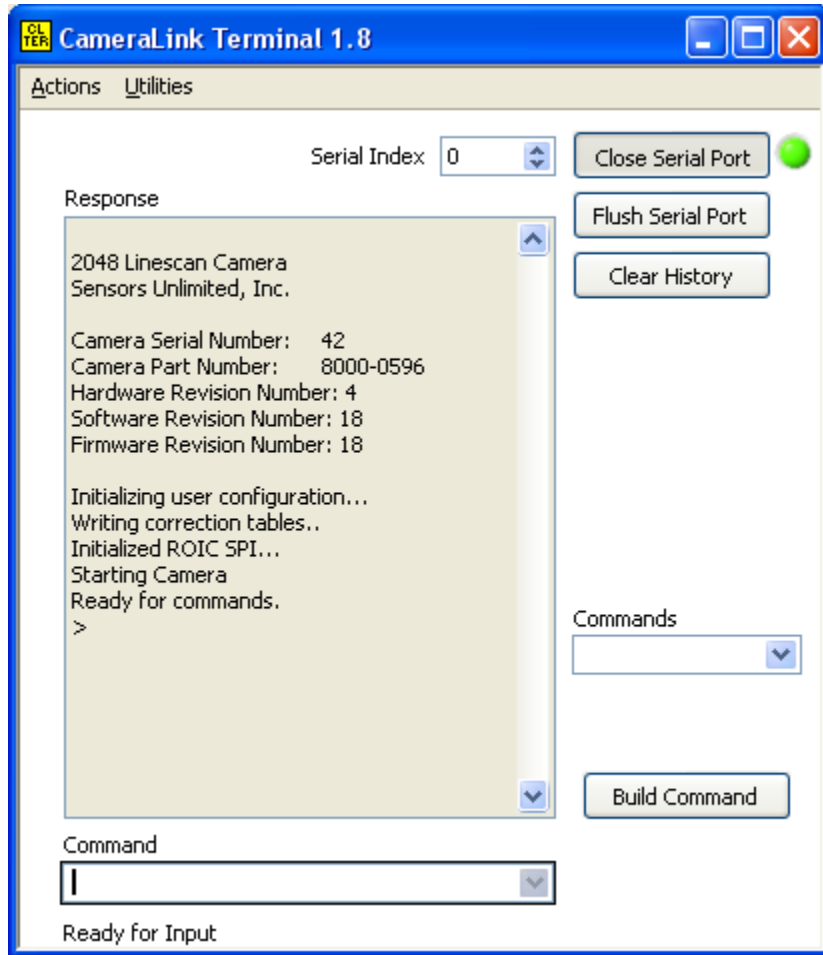


Figure 11 Screen shot of cameras startup banner using SUI Camera Link Terminal.

5.4 COMMAND SET

Each command is presented in the following format:

Command

Argument data type

Argument range and limits

Short description of the behavior of the command and other pertinent information.

Note: For line scan cameras all command references to frame(s) in this section refer to a single readout line. (User software may be programmed to assemble lines into an image or B-scan frame.)

5.4.1 Camera Communication Commands

The camera receives instructions via the serial communications LVDS transmit and receive lines contained in the Camera Link cable. The protocol is similar to the EIA-232 standard in terms of data rate, which is selected with the BAUD rate command listed below. The commands are condensed English-type keywords sent with ASCII character codes, and in return, the camera outputs ASCII text. The type and level of response is dependent on the command settings in this section. When becoming familiar with the camera, it is recommended to put the camera into `RESPONSE VERBOSE` mode, as the camera echoes the received command for troubleshooting and responds to errors with informative text. When the user is developing PC software to automatically control the camera, use the `BRIEF` mode to minimize the camera response to just the acknowledgement and next command prompt. This reduces command time, and simplifies software input handling. The communications control commands follow:

`BAUD:FUTURE`

Integer

9600, 19200, 38400, 57600, 115200, 230400, and 460800

Changes Baud rate used on next power up of the camera.

`BAUD:FUTURE?`

Integer

9600, 19200, 38400, 57600, 115200, 230400, and 460800

Reads Baud rate - default to current rate unless there is a pending change.

`ECHO:MODE`

Integer

0 or 1

0 = no echo of command characters;

1 = echo character received over the serial communications link.

`ECHO:MODE?`

Integer

0 or 1

Reads 0 or 1 to indicate whether the camera will not or will echo the received characters. Use to troubleshoot the serial communications link.

`PROMPT`

String

ON or OFF

Sets camera command finished prompt ON or OFF when ON a '>' will be shown when the camera is ready to accept a new command.

PROMPT?

String
ON or OFF

Get the current camera prompt setting.

RESPONSE

String
VERBOSE or BRIEF

Sets camera response to commands. VERBOSE echoes the received command and arguments in CAPS and parameter guidance for human interaction. BRIEF just provides just value responses and the acknowledgement string: "OK\r>" for automated interaction.

RESPONSE?

String
VERBOSE or BRIEF

Reads the state of the response output mode.

5.4.2 Camera Information Commands

The commands in this section identify the camera, FPA and firmware part numbers, revisions and serial numbers (when applicable). The user's software can also read the pixel clock frequency for translating the exposure and line periods into time units. The PWRDWN command provides the user a means to test if the camera had experienced a power cycle, which might disrupt the validity of the system's data. *Note: the GL2048 cameras differ from previous Sensors Unlimited cameras in that camera settings are immediately stored in non-volatile memory as valid commands are received. Therefore the camera will normally restart unchanged from the settings that were in use just prior to a power disruption.*

The camera information commands are listed here:

CAMERA:PN?

String,
8000-####

Reads SUI camera part number.

CAMERA:REV?

String,
upto 10 characters

Reads part number revision code.

CAMERA:SN?

String
#####

Reports camera serial number.

CMDS?

String
Multi-line list

Outputs active commands in camera; when in USER mode, only USER class commands.

FIRM:PN?

String,
4102-####

Reports firmware part number in form 4102-xxxx. Number 4102-0126 currently assigned to GL2048L via SUI document control system.

FIRM:REV?

String

Reports firmware part number revision. Integer number assigned sequentially while in early lifecycle stages; letter code assigned at pilot stage.

FPA:PN?

String,
7000-####

Reads FPA part number (part number will vary with pixel size and ROIC variants).

FPA:SN?

String,
upto 10 characters

Reads FPA serial number.

PIXCLK:MAX?

Integer

Reads the pixel clock frequency in Hz to determine clock period for calculating time for the EXP and FRAME:PERIOD commands. Use to adapt common software to different SUI cameras.

PWRDWN

Null

Provides a means for testing whether the camera has experienced a power interruption since the previous assertion of the PWRDWN command. PWRDWN sets a logic one into memory. If a subsequent PWRDWN? reports a zero, then there was a power interruption.

PWRDWN?

Integer

0 or 1

Reads status of power flag. It will always be zero unless user has previously executed the PWRDWN command and power has not been interrupted.

VER:HW?

String

Tracks hardware changes, also shown in the camera startup banner. Currently same value as CAMERA:REV

VER:MEM?

String

Reads memory version.

VER:SW?

String

Tracks camera firmware build # changes; value also shown in the camera startup banner, indexed to SUI document control revision.

5.4.3 Camera Configuration Commands

Stored into the default section of the camera non-volatile memory are the SUI camera settings used at the end of Opto-Electronic characterization and correction. If the user becomes concerned that the camera is not operating correctly, possibly due to a sequence of conflicting commands, the CONFIG:RESET command enables users to quickly return to the SUI default configuration. The REBOOT command implements the software equivalent of a power on cycle, including output of the camera startup banner, while the RESET command can be used to resynchronize the FPGA with the FPA.

Since the CORR:DL command only writes calibration coefficients into the SUI NV memory, CONFIG:RESET can be used to transfer them into the user NV memory. The user will then need to restore the same operational settings used when the DL coefficients were created.

RESET
Null

Command available for resetting error situations like triggering errors, by resetting the FPA, but uses current settings. Not as comprehensive as the complete re-initialization performed by REBOOT. May disrupt acquisition.

REBOOT
Null

Initializes the camera, reloading the settings from non-volatile memory, like a power cycle. Camera responds with 'Initializing' over the serial link, then transmits the camera start-up banner. Will disrupt acquisition.

ERROR?
Binary
00000000 to 00111111

Outputs Error register, text in VERBOSE, binary value in BRIEF:

bit_0 = CMD_NOT_RECOGNIZED

bit_1 = PARAM_OUT_OF_RANGE

bit_2 = TRIG_TOO_SOON

bit_3 = TRIG_MIN_LOW_VIOLATION

bit_4 = TRIG_MIN_HIGH_VIOLATION

bit_5 = TRIG_MIN_PERIOD_VIOLATION

CONFIG:RESET
Null

Moves default NV settings into USER non-volatile memory. Use when user settings may result in confusing or non-operation. Also use to move user created correction coefficients into USER memory.

5.4.4 Camera Gain Commands

The camera provides users with two types of gain. The analog gain is set by the size of the capacitor in the feedback circuit of the signal integration Capacitive Trans-Impedance Amplifier (CTIA) and is programmed with the `FPA:FBCAP` command. Changing this gain can improve the signal-to-noise as the signal is amplified before the contributions of the system read noise. Three capacitors are available in the pixel, which can be combined to provide four settings as the smallest capacitor is always present. The 2nd gain setting, adds a capacitor of equal size, the 3rd setting adds a capacitor of twice the size and the lowest gain connects all three capacitors. For the 210 x 10- μ m pixel version of the camera, the effective gain difference between the lowest and highest gain is a factor of two at the shorter exposure times. Due to timing effects in the reset of the integrator, the gain is not constant for all combinations of exposure time `EXP` and

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 49 of 78	Last Update: 17-APR-2020

line period `FRAME:PERIOD`. Therefore, for accurate measurements of intensities, users will need to conduct a separate intensity calibration for changes in the acquisition timing.

The `GAIN:DIGITAL` scales the total signal by digital bit shifting. This does not increase dynamic range as both the signal and system noises are both amplified by this command. It is used to scale weak signals of a few hundred counts. For an image display that scaled 0 values to be black and 4095 (12-bit full scale value) as white, images with a peak intensity of 250, would be hardly visible on the computer display screen. This command multiplies the signal in magnitude to be a larger % of full scale and therefore more. It can also be used to scale up the signal output. For example, entering the command `GAIN:DIGITAL 32` (unity gain) might result in the case where 'hotter' pixels would cause those pixels to saturate earlier than others. This could cause cosmetic 'pock marking' of the saturated region of an image. Using the digital gain setting of 38 will result in with 19% extra gain (38 divided by 32), which will move the partial saturation zone above the 12-bit limit of the data output, resulting in uniform output levels in the display.

`GAIN:DIGITAL?`

Integer

0 to 256

Reads current digital gain multiplier setting used to scale the image intensity.

`GAIN:DIGITAL`

Integer

1 to 256

Multiplies output digital values by a factor = `###/32`, e.g., `GAIN:DIGITAL 36` = $36/32 = 112.5$; this rescales the output to be 12.5% larger than original value. Use to scale weak signals to be more visible in fixed bit-depth displays; doesn't improve SNR.

`FPA:FBCAP?`

Integer

0, 1, 2 or 3

Reads setting of integrator feedback capacitor. Parameter 0 is lowest gain with best dynamic range, 3 is highest gain with lowest dynamic range.

`FPA:FBCAP`

Integer

0, 1, 2 or 3

Sends to the FPA command to select one of 4 gain settings based on connecting combinations of three capacitors in the feedback loop of the CTIA, setting the pixel gain. Parameter 0 sets the lowest gain, 3 sets the highest gain.

5.4.5 Camera Control Commands

The main timing controls of the camera are described in this section (Exposure time, line period and its reciprocal, line-rate). Unlike previous Sensors Unlimited cameras, this camera series does not have a preset series of operating modes for different combinations of gain, exposure time and line-rates, nor does it have the memory space to store correction tables for such combinations. Instead, the user of the GL2048 camera will be directly setting the camera gain, exposure time and line period (using the `FRAME:PERIOD` command to maintain compatibility with other SUI cameras). Please see section 5.4.7 below for a discussion of the corrections and the list of associated commands.

The timing commands in this section consist of the command to set the timing period and the integer number of camera clock cycles to use for that period. The `PIXCLK:MAX?` command can be used to obtain the basic pixel clock rate, so, if the user desires a particular time period for the exposure time, the number of clock cycles to use with the `EXP` command, it can be determined by multiplying the clock rate by the desired time in seconds. For example, given an 80 MHz clock, and a desired exposure time of 20 microseconds, the command `EXP 1600` would be calculated and sent into the camera. *NOTE: The timing commands do use an integer number of clock cycles so for many settings the time period may be not be precisely the desired value.*

In the GL2048L (base CL camera), it is necessary for the exposure time setting to be smaller than the frame period by 3.96 μ s or 317 clocks, and it must be greater than 5.5 μ s or 440 clocks. While the `EXP` command can be set up to 209 ms, it is not practical to use times longer than 10 ms as the array is uncooled; at high gain with typical operating temperatures the full well will be excessively filled at such exposure times. Thus the user will need to use the lower pixel gain settings at long exposure times (> 1 ms).

The line period is set using the `FRAME:PERIOD` command, with the argument also in clock units. For the GL2048L, the longest line period is technically 209 ms or 16,777,215 clocks, but this is not likely to be a practical setting. This is due to the exposure time limits discussed above and but also due to the possibility of internal drifts over such a relatively long period for a device designed for high speed. The driving circuitry for the GL2048R is optimized for even higher speeds over the range of 10,000 to 147,000 lps. To cover this range, and provide the best performance, the 2048R provides three speed ranges, selected with the `OPR` command. The three ranges are `OPR 0`, from 147 to 120 k-lps, `OPR 1` for 120 to 76, and `OPR 2` for 76 to 10 k-lps, with each range overlapping those nominal rates by 5% in either direction. (See the `FRAME:PERIOD` command below for the limits of each)

The exposure periods for the 2048L, and for OPRs 1 and 2 of the 2048R are the total sampling period of the sampling integrator, but the net exposure time for detecting photons is reduced by the reference sampling period just after the reset of the integration capacitor (See section 4.1, “Table 8 Maximum line frequency and exposure time by camera and operating mode. for more detail.) To illustrate: the lowest line-rate accepted in OPR 0 is for 9,455 lps, which is the

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 51 of 78	Last Update: 17-APR-2020

line period of 105.8 μs that results from a `FRAME:PERIOD` setting of 8460. This rate permits an exposure period of 8136 or 101.7 μs . Subtracting the sampling period of the sample of the reset voltage across the feedback cap, this yields the effective net integration time of 100 μs .

If the user desires to achieve a particular line-rate, the associated command argument can be calculated by dividing the pixel clock rate by the target line-rate then subtracting 1; the result is the argument to use with the `FRAME:PERIOD` command.

To permit convenient setting of both the exposure time and the line period with one command, where the exposure time is set to the maximum possible for the line period, two combination commands are available to the user: `EXP:MAXRATE` sets the exposure time to the requested value and adds the reset overhead time to set the `FRAME:PERIOD` value. The command `FRAME:PERIOD:MAXEXP` will set the specified line-rate and will automatically calculate and set the `EXP` value to be less by the same overhead factor. The value of the adjustment can be seen in the command descriptions below and in section 4.1, "Table 8 Maximum line frequency and exposure time by camera and operating mode."

Sometimes a user's software may need to send exposure and frame period commands separately, and not always in a sequence that keeps the appropriate relationship in their time periods, particularly when working with triggered applications. The `SCAN:STATE OFF` command permits the software to stop the FPA readout temporarily to avoid camera error commands while the settings are changed. (The frame grabber software will post a time out error if this command is invoked while actively acquiring lines.)

The camera timing commands are:

`EXP`

Integer

For 2048L: Min: 480 to Max: FP - 317

6.00 μs to 10 ms

For 2048R:

OPR MIN MAX FP-n Net ET Min/Max

0 373 540 160 4.5 μs - 6.59 μs

1 381 852 248 4.81 μs - 10.7 μs

2 629 8136 324 6.16 μs - 100. μs

Command sets the exposure time in clock periods (12.5 ns in both the L and R models). In 2048L the limits are Min: 440 clocks to Max: `Frame:Period` - 317 clocks. For 2048R the active limits change with the `OPR` command, as that selects the line-rate range.

`EXP:MAXRATE`

Integer

For 2048L: Min: 480 to Max: FP - 317

6.00 μ s to 10 ms

For 2048R:

OPR	MIN	MAX	FP-n	Net ET	Min/Max
0	373	540	160	4.5 μ s	6.59 μ s
1	381	852	248	4.81 μ s	10.7 μ s
2	629	8136	324	6.16 μ s	100. μ s

Sets exposure time in clock cycles and also sets the line period for the fastest line-rate for the specified ET. The legal range of values is governed by the active frame period and camera operating range as shown above in the Datatype/Limits block.

EXP?

Integer

Reads the current exposure time in camera clock cycles, which have a period of 12.5 ns each. The net exposure time is slightly different depending on camera model and operating mode due to the sampling time of the first sample.

FRAME : PERIOD

Integer 24 bits

2048L: minimum: 1048 to maximum: 800,317
rates of 79,840 to 100 lps

2048R: Min Max Line-rate range

OPR 0: 540 700 147,724 to 114,033

OPR 1: 635 1100 125,677 to 72,625

OPR 2: 1000 8460 79,876 to 9,455

Sets the line period in clock cycles +1 (period = 12.5 ns). For the 2048L the practical maximum exposure time limits to 10 ms at low gain; slower line-rates are not useful. For the 2048R, the active range and limits are set by the OPR command

FRAME : PERIOD : MAXEXP

Integer 24 bits

2048L: minimum: 1048 to maximum: 800,317
rates of 79,840 to 100lps

2048R: Min Max Line-rate range

OPR 0: 540 700 147,724 to 114,033

OPR 1: 635 1100 125,677 to 72,625

OPR 2: 1000 8460 79,876 to 9,455

Sets the line period in units of clock cycles +1 & automatically sets the maximum exposure time (EXP) available for that line period. The 2048L limits at 800317 for exposure time of 10 ms. See above Datatype/Limits block for 2048R range and limits.

FRAME:PERIOD?

Integer 24 bits

Reads the current line period in clock cycles. NOTE: Calculate the actual line period as = [(FP value +1) * 12.5 ns] and the line-rate as the reciprocal. For example, if FP = 540, then the period is 6.7625 us and the line-rate is 147,874 lps.

OPR

*Integer**0, 1 or 2*

Command only in the GL2048R model: Sets active line-rate and exposure time limits to cover the three speed ranges supported by the camera, nominally 10 to 76 kfps, 76 to 120 kfps and 120 to 148 kfps with +/-5% overlaps. See FRAME:PERIOD and EXP commands.

OPR?

*Integer**0, 1 or 2*

In the GL2048R model only: Reads the current operating mode

SCAN:STATE

*String**ON or OFF*

This command provides a means to stop scanning of the FPA, mainly to allow making multiple command changes that might be temporarily conflicting and cause errors - for example, setting an exposure time longer than the current line time.

SCAN:STATE?

*String**ON or OFF*

Reads setting of scan state.

5.4.6 Camera Trigger Commands

The camera can be synchronized to a signal from the frame grabber via the CC1 line of the Camera Link cable. If the user needs to trigger the camera line acquisition from from another source, most frame grabbers can accept the external signal and relay it over the CC1 line to the camera. The camera supports two external triggering modes, one with the camera EXP setting controlling the exposure time, and the other with the width of the CC1 trigger controlling the camera's exposure time. The TRIG:POL command allows the user to select either the logic high transition or the logic low transition as the trigger start in TRIG:MODE 1. In TRIG:MODE 2, where the trigger width controls the exposure, this command selects whether to use the logic

U.S. Export Classification: NSR: does not contain export controlled technical data	© 2020 Collins Aerospace	
4110-0283 Rev A	Page 54 of 78	Last Update: 17-APR-2020

high period or the low period to control the exposure time, giving a quick way to change the camera phase if the duty cycle is 50:50; or, if not symmetric, to switch between a proportionally longer or shorter exposure period without changing the pulse generator programming.

NOTE: In using external triggering the user is responsible to observe the same timing rules described in the previous section to avoid cases of insufficient or excessive exposure times for the available line period, or for triggering a new cycle before the previous cycle completes. Violating the rules may result in undefined operation or with the camera issuing an ERROR response to all commands until the fault condition is remedied.

NOTE: In TRIG:MODE 1, the FRAME:PERIOD value in time must be shorter than the period of the CC1 trigger signal in order to avoid missing triggers. This permits the internal camera exposure cycle programmed by the value of the EXP to complete. The timing rules for the relationship of the EXP and FRAME:PERIOD commands will require the EXP to be shorter than the current setting for the frame period by the margins of 317 clocks for the 2048L, or by the margin listed in the FP-n column in the table given for the EXP command. Therefore, if the user desires to use mode 1, while keeping the exposure time as long as possible for the line-rate, they will need to set the frame period to be 62 ns (5 clock cycles) shorter than the external trigger period. If using short exposure times while the trigger period varies, then set a camera frame period value that is shorter than the shortest trigger period anticipated.

NOTE: Switching triggering mode during acquisition may disrupt that acquisition for some frame grabbers or for the camera. Send the camera command RESET to restore camera operation and only change trigger mode while acquisition is halted for effected frame grabbers.

The triggering commands supported by the cameras are:

TRIG:POL?

String

HIGH or LOW

Reads trigger polarity setting.

TRIG:POL

String

HIGH or LOW

Sets the polarity that the camera uses for triggering - active high or active low. For mode 2, the POL setting can be used to shift phase or exposure duty cycle.

TRIG:MODE?

Integer

0, 1, or 2

Reads active triggering mode where response of 0 indicates free run, 1 follows the CC1 external trigger rate with the exposure time set by the internal EXP setting, and mode 2 follows both the rate and pulse width to control the exposure time.

TRIG:MODE

Integer

0, 1, or 2

Selects camera trigger mode:

0 - free run;

1 - camera executes one EXP cycle for each external trigger

2 - camera starts exposure cycle controlled by frequency and width of external trigger pulse. Can be used to synchronize multiple cameras.

5.4.7 Camera Correction Commands

Arrays of InGaAs and other compound semiconductor materials have more non-uniformities than silicon based detector arrays and have more bad pixels as well.

The GL2048L and GL2048R enable the user to generate non-uniformity corrections and bad pixel replacements for any user desired combination of the gain, exposure and line time settings. For optimum results, the user will have to implement a system design that permits blocking light when acquiring the dark (offset) correction and also that will provide uniform illumination across the array for generating the light (gain) correction. Since the dark offset will be subject to variations in the ambient temperature in these uncooled cameras, implementing a remote controlled mechanism to block or turn off the light source will make automated offset correction easy to implement. If the camera is being used with a spectrometer or lens, it may be more difficult to create a flat illumination field for automated gain correction.

Once a user has identified a set of camera settings they are likely to reuse frequently, they could create a library on the PC of setups and corrections to be reloaded in the camera when desired. The camera is stable given a constant temperature environment, and commands are provided for the user to upload the camera corrections to a PC as hex text files. These could be stored to create a library of corrections for particular setups which could be recalled as needed. A script file could be created to set the relevant camera parameters and to issue the `CORR:DL` command to load the associated previously acquired corrections. Thus, this enables the user to create the gain corrections more conveniently while the camera is dismounted from the lens or spectrograph and store them for later use. The user would setup a uniform light field in front of the camera, perhaps with a diffuser at the entrance to the enclosure (such as a tissue or thin lens cleaning sheet) or ideally with an integrating sphere. By setting the camera to the desired operational settings and adjusting the light source to produce an average light intensity across the array of $\frac{1}{4}$ to $\frac{3}{4}$ of full scale, the detector non-uniformity corrections could be generated and stored into the PC for later retrieval once the optics are re-installed. This method provides a neutral correction of just the detector response, avoiding potential errors resulting from compensating for lens vignette or weaker regions of the spectral variation of the OCT light

U.S. Export Classification: NSR: does not contain export controlled technical data		© 2020 Collins Aerospace
4110-0283 Rev A	Page 56 of 78	Last Update: 17-APR-2020

source. The gain correction will be useful for a range of exposure times and line-rates around the original setting it was acquired with, but there will be some degradation in the corrected non-uniformity *with any change* from the setting used for acquiring the correction coefficients.

The user could also consider acquiring the corrections with the optics in place, recognizing that the resulting correction will amplify noise in the regions where the lens or light source intensity varies across the array. For instance, lenses and OCT light sources will tend to have a Gaussian intensity profile across the array, so the calibration will try to flatten those characteristics, boosting the level of weaker wings and suppressing the stronger signal in the center.

The corrections acquisition routines used by the camera average 16 consecutive lines together when capturing the raw signal. It is up to the user to block the light when using the `CORR:DARK` command and to provide sufficient light for a good correction using the `CORR:LIGHT` command. The dark correction records the dark offset and subsequently subtracts the values from the raw data when the `CORR:OFFSET` is ON. The `CORR:LIGHT` command acquires the average response and then finds the mean value across the whole array, which is then used to establish the reference level. The acquired intensity pattern is then divided into that mean value to create the calibration coefficients. These will be multiplied by the subsequent raw data when the `CORR:GAIN` function is ON to create the corrected output. *NOTE: the GL2048 correction algorithm has an issue where the CORR:LIGHT mean was not background subtracted. This causes the resulting correction curve to be over-amplified by the ratio of the dark offset mean to the mean of the light level when the correction was acquired. Further, the GL2048L model has an additional issue where the CORR:OFFSET:GLOBAL value is added before the correction is applied, causing the correction to degrade (histogram widens) as the light level varies from the mean captured when the correction is created.*

After the dark correction is acquired and applied with the `CORR:OFFSET ON` command, the camera output will normally be centered at zero, with system noise causing the output to vary from zero to positive values with outlier peaks of approximately 30 counts. This yields a black dark level for images with reasonable signal intensity. *NOTE: If the camera temperature is warm when the dark correction is captured, it is likely that the dark level will be smaller when the camera is cold or if the ambient temperature is lower during subsequent operations. This will result in the corrected dark signal to drop below the zero level, resulting in the camera output showing all zeroes or with only noise peaks occasionally appearing.*

If the user desired measurements will use averaging of the camera output lines or images for background subtraction, the clipping of negative noise excursions at zero will create an artificial average of the noise and dark non-uniformity. Therefore, the camera offers an option to inject an artificial offset above zero, using the `CORR:OFFSET:GLOBAL` command. The argument is the number of counts to be added to the output when `CORR:OFFSET` is ON and the `GAIN:DIGITAL` is set to 32 for x1 digital scaling. The value used by SUI is shown in Appendix B for the specific camera model the user has; a typical value would be 50. This permits the

noise floor to be visible above zero if the FPA array starts low when it is cold and should result in the negative noise peaks staying above zero once the camera has reached equilibrium with the environment. However, if the user is not using averaging of near zero signal levels, it is recommended to set the `CORR:OFFSET:GLOBAL` to `0`.

After the correction commands are listed below, they will be followed by a description of a method to save correction data to a PC and then download them back into the camera.

NOTE: Occasionally, the change of camera modes may result in a shift of the correction in part or over the entire array. This will be noted in the histogram of the image data of a uniform illumination by the broadening of the peak and by an increase of the standard deviation. Issue a RESET command to restore proper corrections.

The correction commands available to the user are:

`CORR:DARK`

none

Acquires and averages 16 scans to put in the OFFSET correction memory. User should block all light prior to executing the command.

`CORR:DL`

Integer

0 or 1

text file 4xhex characters per pixel

Loads arrays of gain or offset coefficients into the camera via serial communications. Use argument 0 for Gain Corrections; Use argument 1 for Offset/Bad Pixel data. The camera then prompts for a script file of ASCII HEX of 8192 characters in each case.

`CORR:GAIN`

String

ON or OFF

Turns on/off application of the on-board non-uniformity correction of pixel-to-pixel gain.

`CORR:GAIN?`

String

ON or OFF

Reads state of gain non-uniformity correction function.

`CORR:LIGHT`

none

Averages 16 scans. Divides the result into the array mean and stores for GAIN corrections. Illuminate array with uniform light between 15 and 85% of full scale (Do not use if parts of array are near zero or near saturation. Set global offset set to 0).

CORR:OFFSET

String
ON or OFF

Turns on/off application of the stored offset non-uniformity correction.

CORR:OFFSET:GLOBAL

Integer
Range: 0 to 2048

Adds the argument value to all pixel values. Use to elevate mean dark level above enough above zero to prevent the negative noise spikes from clipping at zero to ensure proper averaging. Programmed value is scaled by the GAIN:DIGITAL multiplier.

CORR:OFFSET:GLOBAL?

Integer
Range: 0 to 2048

Reads current global offset value. This is a value added to all pixels. Set to zero when using CORR:LIGHT.

CORR:OFFSET?

String
ON or OFF

Reads state of offset (dark) non-uniformity correction function.

CORR:PIXEL

String
ON or OFF

Turns on/off bad pixel replacement. For pixels that have been flagged bad, the value of the preceding good pixel will be transmitted in place of the bad pixel value.

CORR:PIXEL:MAP

String
ON or OFF

With MAP mode ON, the camera outputs a 0 for un-flagged pixels, and 4095 for flagged pixels. The bad pixels are flagged in the NV FACTORY memory during final testing. USER can use FL:PIX:RPL command to flag or unflag pixels in USER NV memory.

CORR:PIXEL:MAP?

String

ON or OFF

Reads state of bad pixel map function, ON or OFF.

CORR:PIXEL?

String

ON or OFF

Reads state of bad pixel replacement function, ON or OFF.

CORR:READ 0

Integer

0 or 1

text file 4xhex characters per pixel

- Reads & displays the local GAIN values
- displays a sequence of 32-bit registers (big endian):
 - * top 16-bits for the odd pixel GAIN
 - * bottom 16-bit for the even pixel GAIN

CORR:READ 1

Integer

0 or 1

text file 4xhex characters per pixel

- Read the OFFSETs & BAD PIXELs
- Outputs a sequence of 32-bit registers (big endian):
 - * bit 1 is the odd pixel BAD PIXEL flag
 - * bit 0 is the even pixel BAD PIXEL flag
 - * bits 25 to 14 for odd pixel OFFSET
 - * bits 13 to 2 for odd pixel OFFSET

FL:PIX:RPL

integer 0 to 2048

Flags or clears bad pixel flag. Syntax: to flag: FL:PIX:RPL 1234 ON; to clear the flag use the command: FL:PIX:RPL 1234 OFF.

5.4.7.1 Usage of Correction Read and Download Commands

As described in the `CORR:READ 0` command above, the calibration coefficients for two pixels are packed into a 32-bit word, which can be read as a 8 digit Hex value. The packing is characterized as ‘big endian’, which is where the most significant value in the sequence is stored at the lowest storage address. This means that the gain coefficient data is read out from the cameras as $E_1E_0E_3E_2O_1O_0O_3O_2$, where the first pixel output is defined as pixel zero and therefore an even pixel. To interpret correctly, separate the hex characters into two groups of 4 characters, and swap the order of the pairs to end up with $E_3E_2E_1E_0$ for the even pixels 0, 2, etc., and $O_3O_2O_1O_0$ for the pixels 1, 3, etc. These values can be converted from hex to decimal values with a standard math function (HEX2DEC in Excel), then divided by the half scale value of 2048 to convert to the coefficient ratio.

For instance, if the ASCII values of 290FD330E were read from the gain table, the conversion would be to the even pixel hex of 0F29 for pixel 0. Converted to decimal, the value is 3881. Ratio’d with 2048, the gain coefficient of pixel 0 is 1.895. Similarly the odd pixel hex is 0ED3, which converts to 3795 and a coefficient of 1.853 for pixel 1.

The `CORR:READ 1` command reads out a packed value holding two 12-bit values for the offset value, plus two bits for the bad pixel flags for both an odd and even pixel pair. Again the Hex digits have to be reordered before further processing. Then, treat the result as a 32-bit value and process as described in the command – bit 0 (LSB) is even pixel flag for a bad pixel, bit 1 is the odd pixel flag. The next 12 bits, numbered 13 to 2 (MSB to LSB), are then converted to a decimal value for the even pixel offset value and the bits 25 to 14 are converted to the decimal value for the odd pixel offset values. When `CORR:OFFSET` is on, these are the values that will be subtracted from the raw array data for the associated pixel to move the corrected dark level to zero. The bits from 32 to 26 are not used.

5.4.7.2 Usage of Correction Read and Download Commands

To help manage the corrections, providing translation, editing and a means for storing onto a PC as files and loading the coefficient tables from the PC files, SUI has developed a program called “2048 Corrections Utility.exe”, whose screen shot is shown below. This program is a standalone program that is independent of the acquisition hardware. It is used in conjunction with a terminal program like SUI “CameraLink Terminal” or Windows “Hyperterminal.exe” or similar program that makes it possible to highlight the output of the `CORR:READ` command, copy it and place it in either the gain window on the left for the response to the `CORR:READ 0` command, or the `CORR:READ 1` response pasted into the right hand window. When that data is placed in the window, the lower portion shows the interpretation of the data for each pixel. One can directly modify the data in the window or the pixel display, and, once the cursor is clicked in another place, the data in the other location will update. The pixel display can be scrolled to show values from any group of the 2048 pixels; on wide screen displays, the width of the window can be stretched to show more of the pixels at one time. On the lower right of the

screen shot, the buttons Export and Import permit storing the values as columnar decimal value data on the PC file storage system as Excel, text or CSV file types.

The following images show the initial screen of the corrections utility, then the CameraLink Terminal screen right after an `CORR:READ 0` has dumped the ASCII hex into the display window, followed by screen of the utility after the data was copied into it (and the `:READ 1` data copied into the right hand window).

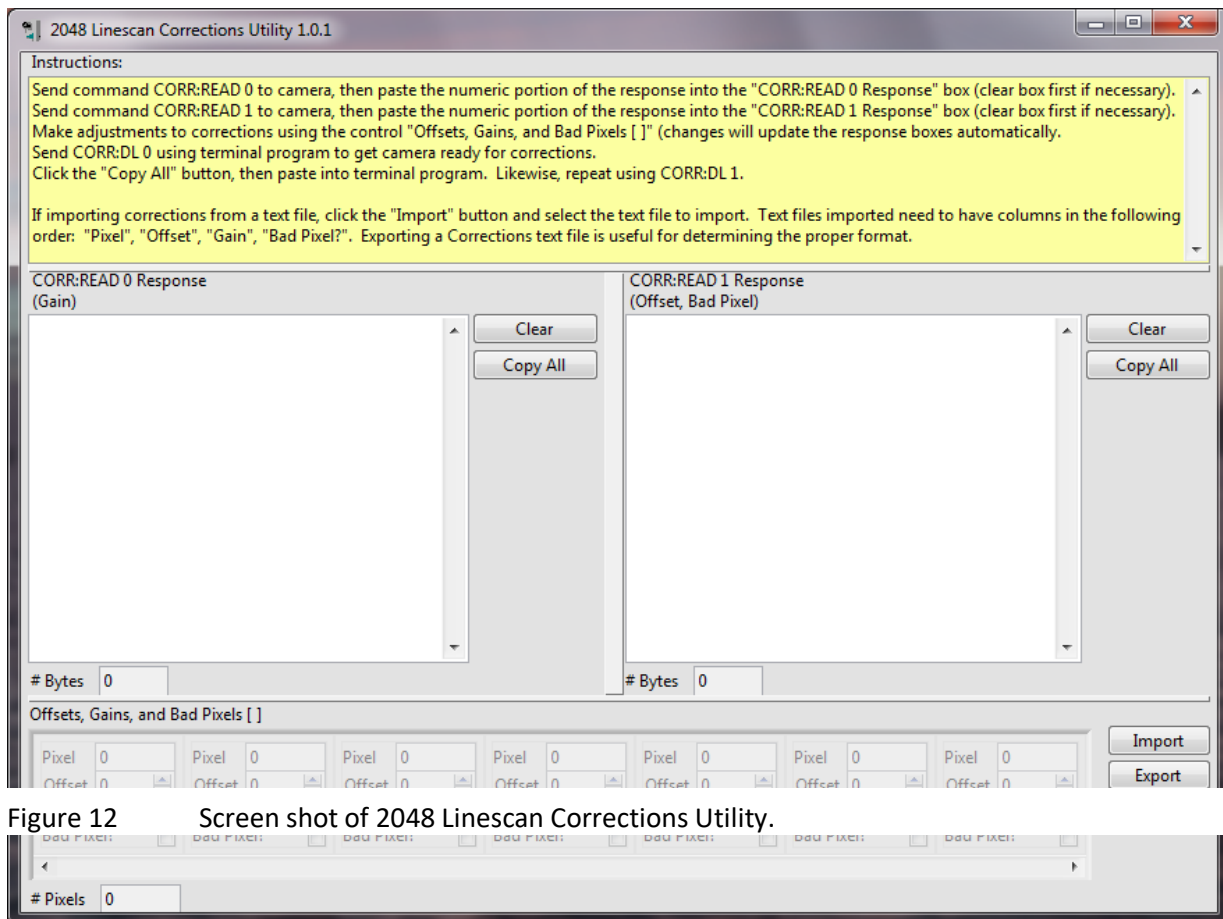


Figure 12 Screen shot of 2048 Linescan Corrections Utility.

Pixel	0	Pixel	1	Pixel	2	Pixel	3	Pixel	4	Pixel	5	Pixel	6	Pixel	7	Pixel	8
Offset	287	Offset	271	Offset	251	Offset	237	Offset	796	Offset	261	Offset	292	Offset	253	Offset	226
Gain	1.216	Gain	1.233	Gain	1.208	Gain	1.204	Gain	1.194	Gain	1.185	Gain	1.195	Gain	1.187	Gain	1.184
Bad Pixel?		Bad Pixel?		Bad Pixel?		Bad Pixel?		Bad Pixel?		Bad Pixel?		Bad Pixel?		Bad Pixel?		Bad Pixel?	

Figure 13 Corrections data read with CL Terminal & pasted into the Corrections Utility

NOTE: When copying the screen data from the CL Terminal program into the Utility, or back again, it is important to have exactly 8192 bytes of data. The camera will expect exactly that when the CORR:DL command is used, and hang-up until it gets extra characters to fill its buffer, even if the data is not appropriate hex data. This will make the corrections stored in the camera

incorrect. Similarly, if the selection of the camera output text grabs extra characters or misses a few, the Corrections Utility software will show the incorrect character count at the bottom of the window and post warning messages.

5.4.7.1 Method to Download Corrections Files from the PC into the Camera

When the CORR:DL command is used, the values are loaded into the default non-volatile memory instead of the active user memory. Therefore, several steps have to be followed in order to apply the stored corrections data to active imaging. First, when the corrections files are originally acquired with the camera, transferred to the corrections utility program and stored as a file, it is suggested that the file name record the EXP, FRAME:PERIOD, FPA:FBCAP, and GLOBAL offset value that were active. The user will have to restore these values as the camera operating settings in order to ensure that the corrections are appropriately applied.

To recall a stored corrections coefficient file, the user would first import the data into the 2048 Corrections Utility. Check the character count for both the gain and offset/flag windows as a check on the data integrity, and check a few values at the beginning and end of the array to see that they look appropriate (similar offset and gain values for most pixels). Then use the COPY ALL button for the gain window to capture the ASCII Hex data. Move to the CameraLink Terminal program (already operating and communicating with the camera), and type the command `CORR:DL 0`, pressing enter to execute the command. You will see the prompt: "Send ASCII data now:". In the program Command window box, paste the copied data with the CTRL-V key, then hit enter. A series of dots will be displayed (64) to show progress, then the text "Upload complete.\rOK\r>\r>\r" in both `RESPONSE VERBOSE` and `BRIEF` modes.

The same steps would be followed to load the offset/flag data with the `CORR:DL 1` command from the data in the right hand window of the 2048 Corrections Utility software.

The above loaded the camera default non-volatile memory with the file corrections data. To transfer this data to be the active correction, the user would next send the command `CONFIG:RESET`. This transfers the stored correction to the user memory, but will also transfer the factory created default exposure, line-rate and pixel gain, as well as all the settings listed in the manual appendix B (found on the storage media that came with the camera with the file name prefix "4170-xxxx", which will be different for different models of the camera. Please take note of any of these that are different from the settings that you expect to use as you will need to restore the desired settings after the `CONFIG:RESET`, and also reassert the settings appropriate to the correction files brought in from the PC memory. Since the camera updates the user non-volatile memory as the settings are changed, the new settings and corrections will be active after the changes have been made and after a subsequent power cycle.

5.4.8 Camera Test Commands

The GL2048 cameras include several commands to assist in troubleshooting the camera and the data acquisition system in the PC.

The frame stamp function can be used to detect missing lines, whether in consecutive line reading or between image frames. This function runs a line counter using a 12-bit bit depth. This means that the counter will run up to 4095 and then start over at zero. When the function is enabled, the digital value from the counter replaces the value of the first pixel in the array. The user can set up their software to monitor the value to ensure there are no gaps in the captured data.

Two types of test pattern are implemented in the GL2048 cameras. The `TESTPAT` command tests the FPA output through to the frame grabber, by outputting a fixed value for all pixels, replacing the detector live data. This value can be set by passing an argument of a value between 0 and 4095 with the command. The argument of `OFF` returns the camera output to live data, while the `ON` command can be used to turn the function back on with the previously set digital value. In early versions of the GL2048L, the fixed value will be modified by the non-uniformity corrections, causing the output to vary pixel by pixel instead of being a flat line at the programmed value.

An alternate test pattern can be generated by the camera processor, to generate a ramp of rising intensity from pixel 0 to pixel 2047, testing all values in-between. This command is enabled with the `TESTPAT:CAM ON` command and it overwrites the output of the photodiodes. The rise of the ramp and number of ramps can be changed with the `TESTPAT:TYPE` command. This changes the increment value added from pixel to pixel over the ramp. The result is a $\frac{1}{2}$ ramp, a full ramp that tests all even values to full scale, two ramps or three ramps across the width of the array. These test patterns can be useful by providing a known pattern to the PC to help check that there are no stuck bits and to test if the user display software is distorting the image data.

The available test commands are:

`FRAME : STAMP`

String

ON or OFF

When on, substitutes the current value of a rolling 12-bit line counter for the value of the first pixel (#0) in the line.. (The counter counts from 0 to 4095 lines and repeats}. Disabled if pixel 0 is flagged as a bad one.

`FRAME : STAMP?`

String

ON or OFF

Reads state of the Frame Stamp function. However, if ON and the pixel 0 value does not increment, check the bad pixel map to see if pixel 0 is flagged.

TESTPAT*String**ON or OFF**dddd (0 to 4095)*

Enables output of a test pattern from the FPA with a fixed value at all pixel locations. The argument ON activates the output of the factory set value. OFF restores the output of normal pixel data. Will be overridden if the CAM option is active.

TESTPAT:CAM*String**ON or OFF*

Enables output of a test pattern from the camera FPGA, putting a ramp of values across the array, starting from zero. The: TYPE value changes the increment per pixel.

TESTPAT:CAM?*String**ON or OFF*

Reads state (on/off) of camera FPGA test pattern function.

TESTPAT:TYPE*Integer**0 to 3*

The TYPE value selects the number of ramps output across the 2048 pixels for :CAM ON. Type 0, puts one ramp of 0 to 2047, 1 puts one ramp of 0 to 4094 across width, 2 puts 2 ramps and 3 outputs 4 ramps in cameras made in 2014 or later.

TESTPAT:TYPE?*Integer**0 to 3*

Reads the type setting used for the TESTPAT:CAM function.

TESTPAT:VAL*Integer**to 4095*

Sets FPA test value to output for each pixel location, when the TESTPAT is ON. Default value is 1445 (10110100101)

TESTPAT:VAL?

Integer
to 4095

Reads current FPA test value setting that will be output for each pixel location, when the TESTPAT is ON

TESTPAT?

String
ON or OFF dddd (0 to 4095)

Reads current on/off state for the test pattern function.

NOTE: This concludes the command section of this manual.

6 SPECIFICATIONS

6.1 ENVIRONMENTAL & POWER

Operating Case Temperature	+10 °C to +35 °C
Storage Temperature	-10 °C to 60 °C
Humidity	Up to 95% and non-condensing
Power Requirements:	
AC Adapter Supplied	100-240 VAC, 47-63 Hz
DC Voltage	+6 to 12 VDC (Maximum: 13.1 VDC)
Typical Power (2048L/2048R)	3.6/4 W at 30 °C case temp
In-rush Current	< 1.25 A at 12 VDC

6.2 MECHANICAL - ENCLOSED

Width x Height x Depth:	8.3 cm x 10.2 cm x 1.6 cm 3.25 in x 4 in x 0.64 in excludes I/O connectors, and lens adapter
Weight:	<240 g or 8.6 oz. (no lens or adapter)
Threaded Lens Mount and optional lens mount adapters	M42x1-6H with ~6 mm to image plane None, fixed distance C-Mount adapter or adjustable distance F-Mount adapter (see ordering info)
Spectrometer interface	4 tapped 8-32 holes in 2 inch square pattern 2 tapped 8-32 holes in-line with image axis O-Ring light seal, 1.9 inch diameter, 1/16 th thickness
Camera Tripod mount	2 tapped ¼-20 holes, one on bottom, one on side wall

6.3 INTERFACES

Control: & Data	GL2048L:	Single SDR 26-pin connector (Base Camera Link®)
	GL2048R:	Dual SDR 26-pin connectors (Medium Camera Link)
Power connector	CUI Inc. PJ-056, 1.0 mm X 3.8 mm power jack	
Trigger: Input	Via Camera Link CC1 line	
Status LED:	Green: Power on after internal boot complete	
Tested Framegrabbers:	Nat. Instruments PCIe-1429, -1433 Matrox Solios eV-CL PCIe-X4	

6.4 REGULATORY COMPLIANCE

CE:	Meets class A for emission, immunity & ESD standards, RoHS
FCC:	Meets requirements for Part 15, Subpart B, Class A, 2006

6.5 OPTO-ELECTRONIC PERFORMANCE

6.5.1 GL2048L-210, GL2048L-010

Sensor format ¹	2048 pixels on 10 μm pitch with 2048 readout ADCs							
Optical aperture (pixel height) ¹	210 μm or 10 μm							
Quantum efficiency ¹	>60% 0.98 μm -1.65 μm , peak @ 1.55 μm > 80%							
Sensitivity setting	High		Medium High		Medium Low		Low	
	Typical	Specification	Typical	Specification	Typical	Specification	Typical	Specification
Temporal noise (rms counts) ^{1 2}	3.1	< 3.4	2.2	< 2.8	1.9	< 2.3	1.7	< 1.9
Dynamic range ^{1 2}	1300:1	> 1200:1	1800:1	> 1450:1	2200:1	> 1750:1	2500:1	> 2100:1
Differential non-linearity ^{1 2}	+/- 1.1	< +/- 2.5%	+/- 1.5	< +/- 2.5%	+/- 1.5	< +/- 2.5	+/- 1.5	< +/- 2.5%
Bad pixel specification	White, dark, noisy or pixels exceeding +/- 20 % of the mean value when illuminated at 50% of full well. Number of bad pixels limited to a maximum of 1% of array total; on-board pixel replacement function							
Exposure time ^{1 3}	5.5 μs to 10 ms, user programmed in pixel clock cycles or via the width of the ext. trigger							
Trigger modes ³	Free run, single line per trigger (ET set by camera), or variable exposure and rate							
External trigger ³	Via CC1 signal line in Camera Link cable							
External variable ET	User set by the duration of trigger input signal (minimum ET pulse: 10 μs)							
External trigger jitter	+/-2 clock cycle: nominally 50 ns							
Pixel rate: 2048L:	157 Mpix/s max with 2 x 12-bit words transferred per Camera Link strobe clock at 80 MHz							
Digital output format	12-bit base Camera Link [®] ; recommend NI PCIe-1433 or frame grabber with throughput of >313 Mbytes/s to PC motherboard (minimum of 4 bi-directional PCIe express lanes in PC)							
Readout mode	Integrate while read, differential double sampling							
Corrections (preset OPR)	SUI calibrated gain, offset, and bad pixel replace, applicable to the center 90% of the array							

¹ Actual formats and performance governed by pixel size options (dark current may limit longest usable exposure time, especially at high gain)

² Camera readout noise limited for low & medium gain settings; dark shot noise limited for high-gain settings at longer exposure times

³ User selectable by command over Camera Link[®] serial lines

6.5.2 GL2048R-210
OPTO-ELECTRONIC PERFORMANCE

Sensor format ¹	2048 pixels with 2048 readout ADCs							
Optical aperture (pixel height) ¹	210 μm							
Quantum efficiency ¹	>60% 0.98 μm-1.65 μm; > 80% peak response @ 1.55 μm							
Gain setting	High		Medium High		Medium Low		Low	
	Typical	Specification	Typical	Specification	Typical	Specification	Typical	Specification
Temporal noise (rms counts) ^{1 2 4}	6.7	< 7.3	3.4	< 4.2	2.4	< 2.7	2	< 2.5
Dynamic range ^{1 2 4}	560:1	> 510:1	1140:1	> 920:1	1640:1	> 1460:1	1990:1	> 1590:1
Differential non-linearity ^{1 2}	+/- 1.1	< +/- 2.5%	+/- 1.5	< +/- 2.5%	+/- 1.5	< +/- 2.5%	+/- 1.5	< +/- 2.5%
Bad pixel specification	White, dark, noisy or pixels exceeding +/- 20 % of the mean value when illuminated at 50% of full well Number of bad pixels limited to a maximum of 1% of array total; on-board pixel replacement function							
Exposure time ^{1 3}	4.5 μs to 0.1 ms, user programmed in pixel clock cycles or via the width of the ext. trigger							
Self-Triggered Line Rates	Three ranges: 9.5 k to 80 k-lps, 73 k to 126 k-lps; and 114 to 147 k-lps							
Trigger modes ³	Free run, single line per trigger (ET set by camera), or variable exposure							
External trigger ³	Via CC1 signal line in Camera Link cable							
External variable ET	User set by the duration of trigger input signal (minimum ET pulse: 10 μs)							
External trigger jitter	+/-3 clock cycle: nominally 62.5 ns							
Pixel rate	301 Mpix/s with 4 x 12-bit words transferred on each Camera Link strobe clock at 80 MHz							
Digital output format	12-bit Medium Camera Link®; recommend NI PCIe-1433 or frame grabber with throughput of >606 Mbytes/s to PC motherboard (minimum of 4 bi-directional PCIe express lanes needed in PC)							
Readout mode	Integrate-while-read, differential double sampling,							
Corrections	Factory or user calibrated gain, offset, and bad pixel replace,							

¹ Actual formats and performance governed by pixel size options (dark current may limit longest usable ET, especially at high gain);

² Camera readout noise limited for low & medium gain settings; dark shot noise limited for high gain settings at longer exposure times

³ User selectable by command over Camera Link® serial lines

⁴ Noise and dynamic range values determined in high gain while using 98% of the maximum exposure period for the slowest line rates of each line-rate range

7 PRODUCT SUPPORT

7.1 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 in section 3.1.1. Status LED will illuminate when camera is powered after boot process complete (<20 s).
	Cables are fully or partially disconnected.	Verify cameras cable(s) are properly connected as described in section 2.1.
	Imager scanning is disabled	Set scan state to enable (<code>SCAN : STATE ON</code>).
	Camera is in external trigger mode, but not receiving a trigger	Test the camera in internal trigger mode to confirm normal operation. If internal trigger mode operation is normal, see "Camera is not responding to trigger input."
Imager does not appear to respond to light	Exposure time/gain is too small for light level	Select longer exposure time and/or higher FPA sensitivity setting. Use strong incandescent light in front of the camera or with the optics dismounted to test response.
	Optics are not letting enough light through	Open lens aperture if applicable. Test imager without optics present with incandescent bulb.
	Display intensity scale too insensitive to make low light levels visible	Increase display intensity scale to determine if there is any change in image data with change of illumination levels. Increase setting of <code>GAIN : DIGITAL</code> command if the display software can't scale to show low count intensities.
Camera is not responding to a trigger input	Trigger source is not connected or active.	Verify frame grabber trigger source is properly configured if using Camera Link CC1. Use an oscilloscope to display the trigger signal to verify it's presence, when the frame grabber is relaying an external source to the CC1 line.
	Trigger signal does not conform to voltage and/or timing requirements of the camera	Verify trigger source meets electrical requirements of the frame grabber, and that it meets the camera timing requirements described in section 5.4.5. If the frame grabber is generating the trigger via programming, check the frame grabber documentation to ensure the proper programming is active. Check camera error status for a trigger or scan error. Use a multi-channel oscilloscope to view the trigger input signal (if an external source is being relayed by the frame grabber) to verify it meets the requirements of the camera for the selected trigger mode.
	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. Use an oscilloscope to verify external source timing. Modify trigger to meet timing requirements for the selected trigger mode. When using <code>TRIG:MODE 1</code> , follow the rules listed for the <code>EXP</code> and <code>FRAME : PERIOD</code> commands to ensure that sufficient time after the end of the exposure period to permit the reset to complete before the new trigger is applied to the camera.
	NI IMAQ GRAB or SNAP function resends camera trigger mode after user software sends <code>TRIG:MODE 1</code> or <code>2</code> commands.	When user software sends direct camera setting commands, in the NI IMAQ environment, turn off serial communication at the ICD file level. This can be accomplished with the 2048 ICD by changing the Camera Attribute for Serial Communications, or by unchecking the Serial Communications Enable box in the MAX Acquisition Parameters Tab and then saving the file (overrides the Attribute setting), or by editing the ICD file in Notepad to change <code>SerialDisabled (No)</code> to <code>(Yes)</code>

Camera intermittently responds to triggers, resulting in missing lines, precession of the image to the left or right, or in some cases timeout errors	Image acquisition number of lines mismatched with the number of triggers supplied per image captured.	Reduce acquisition window size parameters, decrementing one line at a time, or increase the number of triggers supplied per image acquisition. Some frame grabbers require overhead pre- or post-valid lines to properly grab the digital data. For debugging software, turn on <code>FRAME : STAMP</code> to number consecutively the lines sent from the camera. Read the counter in pixel 0 of the line data.
When switching between trigger modes, the line data freezes at fixed values.	Internal timing disrupted by asynchronous switching of trigger mode.	Send the command <code>RESET</code> over the serial communications channel and restart acquisition in the desired mode.
Frame grabber software reports not receiving enough data before timing out, internal trigger mode	Acquisition window parameters are misaligned to digital data presented by the camera	Change the frame grabber acquisition window width to align the grabbed data to the active pixels. The GL2048 cameras do not provide for pre-valid or post-valid pixel times with <code>LVAL</code> active.
Frame grabber software display shows torn image, slanted with the top to the right	Acquisition window parameters result in too many pixels in the line	Decrease the number of pre-valid or post-valid pixels until the image becomes properly aligned.
Frame grabber software display shows torn image, slanted with the top to the left	Possible weak grounds or ground loops interfering with Camera Link framing signals	Check that the Camera Link cable is firmly seated and the jack screws tight. Check that the frame grabber board is securely fastened into the PC. Check if the presence or absence of connections to other equipment, such as triggering sources or slaves changes the symptom and review their grounds.
Raw line data from GL2048R shows random spikes in data	Medium CL cable (Port 1) not properly connected or bandwidth not sufficient for dataflow. Associated with NI supplied 5 meter PoC SDR-MDR cables	Replace Port 1 cable connecting camera to frame grabber. If length of 5 m is required, recommend Intercon1 http://www.intercon-1.com/products/camera-link/mini-camera-link/ .
Frame grabber software reports 'Cannot detect recognizable video source'	Generally means the frame grabber does not see camera clock. Camera powered off, or CL cables not connected	Check connections ensuring that all connectors are fully seated – for the Medium CL GL2048R make sure both cables are connected,.
Camera Output all zeroes; frame grabber shows lines/images being acquired at the expected rate. Applying a high light level results in response in the image.	Camera operating with corrections on, which were acquired with the array at a warmer temperature then currently present, or with longer exposure times. This may cause a larger offset to be subtracted from a currently smaller raw dark offset, resulting in negative values that are clipped at zero at the output.	Turn off offset corrections to view raw output, which should be 20 to 500 counts above zero. Add digital output offset with the <code>CORR : OFFSET : GLOBAL</code> command when offset corrections are active. Acquire a new <code>CORR : DARK</code> when the light to the detector can be blocked.
Corrections data appears noisy after a change in mode or power cycle	Internal memory pointer shifted corrections memory causing incorrect coefficients to be applied	Issue the <code>RESET</code> command to the camera via the Camera Link serial communications channel.

Changes to command settings do not take effect.	Camera needs 100 to 2000 ms to process some commands. Subsequent commands received will be ignored and error flag set.	Software should wait for the command acknowledgement character '>' before sending new commands. SUI versions of the NI ICD file dated after 8/2014 do this. Earlier versions used delay times and were not fully effective.
Acquisition does not start immediately after initiating a GRAB or SNAP function	NI IMAQ sends all command settings in current ICD file to camera before recording incoming data; 2048 needs time to process commands before receiving next command. ICD files after 8/2014 wait for each command to complete before sending new commands.	<p>After setting up camera acquisition parameters, use the Camera Attribute Setting to turn off Serial Communications. Subsequent GRAB or SNAP functions will immediately record data. When it is needed to change camera settings, turn serial communications back on and make changes.</p> <p>Note: To change ICD file settings to start up with the preferred camera parameters for an application, use the NI program Measurement and Automation Explorer (MAX) to make the changes in the ICD file, then save the file to disk. If several setups are needed, save to a modified file name to permit loading the desired setup when needed.</p>

7.2 CUSTOMER SUPPORT

For additional Sensors Unlimited product support please contact, Sensors Unlimited Inc., between 8 am and 5 pm East coast time at 609-333-8000 and ask to speak to an Applications Engineer or email us at: sui_info@collins.com.

For general information about this product or for information on Sensors Unlimited's other image sensing products, please contact:

Sensors Unlimited, Sales Department
 330 Carter Road, Suite 100
 Princeton, NJ 08540
 Phone (609) 333-8000
 Fax (609) 333-8103
<http://www.sensorsinc.com/company/support-services/>

7.3 WARRANTY

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

www.sensorsinc.com/company/about

8 LIST OF ABBREVIATIONS

AC:	Alternating Current (i.e. wall power / mains voltage)
ADC:	analog-to-digital converter
ASCII:	American standard code for information interchange – coding standard for representing alphanumeric characters within 8-bit digital values.
BNC:	Standard lab / radio frequency coaxial cable connector named as Bayonet Neill Concelman
CCD:	Charge-coupled device. Properly used only to describe silicon detectors with MOS photosites that are shifted across the detector surface with voltage manipulation. InGaAs or other compound semiconductors are PDAs, not CCDs.
CCTV:	closed-circuit television
CD:	Compact Disc
CDS:	Correlated Double Sampling
CL:	Camera Link
CMOS:	Complementary Metal Oxide Semiconductor (silicon chip circuitry type)
CTIA:	Capacitive Transimpedance Amplifier
DC:	Direct Current (i.e. Battery supply voltage)
EAR:	Export Administration Regulations administered by the US Dept. of Commerce
EST:	Eastern Standard Time
FPA:	Focal Plane Array
GL:	Prefix for Sensors Unlimited brand Linescan cameras designed under the Goodrich logo, a prior owner of Sensors Unlimited.
IMAQ:	Image Acquisition (National Instruments' frame grabber driver software)
InGaAs:	Indium Gallium Arsenide
ITAR:	International Traffic in Arms Regulations administered by the US Dept. of State
INT:	Integration time (from timing chart)
LC:	Linear array, MUX version C series
LDH:	Linescan, Digital, High Speed; LDH2 is a 2 nd generation version
LDM:	Linescan, Digital, Machine Vision; uses the LDH2 platform
LDV:	Linescan, Digital Video
LED:	Light-Emitting Diode
LSB:	Least-significant bit of a digital word
LVDS:	Low Voltage Differential Signaling
MDR:	Mini Delta Ribbon cable connector – full size Camera Link connector
MSB:	Most significant bit of a digital word
MUX:	Multiplexer
NI :	National Instruments
NIR :	Near Infrared – for spectroscopy refers to the electromagnetic wavelength range of 0.7 to 2.6 microns. For detectors, silicon sensors use this term for the range of 0.7 to 1.1 microns.

- NV: Non-volatile, a type of memory that is changeable but does not lose information when powered down
- PCI: Peripheral Component Interconnect, a type of accessory board interface in PCs
- PCIe: PCI Express interface, a faster PC motherboard interface for accessory boards
- PDA: Photodiode Array
- QE: Quantum Efficiency – the ratio of photons that convert to electrons at a wavelength
- RMA: Return Material Authorization
- ROIC: Read Out Integrated Circuit, a part of the FPA that handles reading the signal from the photodiode array and processing it for output to the camera electronics
- SAE: Society of Automotive Engineers (identifies screw thread as US or British standard)
- SDR: Shrunk Delta Ribbon (used for Camera Link mini-connector)
- SHI: Sample and Hold Integrator, from timing discussion (SHI1 and SHI2 are pre- and post-integration, respectively)
- SLR: Single Lens Reflex
- SUI: Sensors Unlimited Inc. – a Collins Aerospace Company
- SWIR: Shortwave Infrared – generally the wavelength range from 0.7 to 2.5 microns
- TEC: Thermoelectric Cooler
- TTL: Transistor-Transistor Logic (digital signaling voltage standard)
- UTC: United Technologies Corporation, now part of Raytheon Technologies
- UTAS: United Technologies Corporation Aerospace Systems, now named Collins Aerospace

APPENDIX A: Camera Command Index

BAUD		OPR . 32, 36, 37, 38, 39, 51, 52, 53, 54,
FUTURE	45	70
FUTURE?	45	OPR?
CAMERA		54
PN?	46	PIXCLK
REV?	46	MAX?
SN?	47	47, 51
CMDS?	47	PROMPT
CONFIG		45, 46
RESET	7, 48, 49, 65	PROMPT?
CORR		46
DARK	26, 37, 43, 57, 58, 73	PWRDWN
DL	48, 57, 59, 64, 65	46, 48
GAIN	37, 57, 59	PWRDWN?
GAIN?	59	48
LIGHT	37, 43, 57, 59, 60	REBOOT
OFFSET	37, 57, 58, 59, 60, 62, 73	48, 49
GLOBAL	57, 58, 59, 60, 73	RESET
GLOBAL?	60	7, 48, 49, 65
OFFSET?	60	RESPONSE
PIXEL	60	45, 46, 65
MAP	60	RESPONSE?
MAP?	60	46
PIXEL?	60	SCAN
READ 0	60, 61, 62, 63	STATE
READ 1	61, 62	52, 54, 72
ECHO		STATE?
MODE	45	54
MODE?	45	TESTPAT
ERROR?	49	66, 67, 68
EXP 38, 39, 43, 47, 50, 51, 52, 53, 54,		CAM
55, 56, 65		66, 67, 68
MAXRATE	38, 43, 51, 52, 53, 55	CAM?
EXP?	52, 53	67
FIRM		TYPE
PN?	47	66, 67
REV?	47	TYPE?
FL		67
PIX		VAL
RPL	60, 61	68
FPA		VAL?
FBCAP	49, 50, 65	TESTPAT?
FBCAP?	49, 50	68
PN?	47	TRIG
SN?	47	MODE
FRAME		55, 56
PERIOD	21, 43, 47, 50, 51, 52, 53, 54, 55, 65	MODE?
MAXEXP	43, 52, 54	56
PERIOD?	54	POL
STAMP	66, 67	55, 56
STAMP?	67	POL?
GAIN		56
DIGITAL	50, 58, 59, 72	VER
DIGITAL?	50	HW?
		48
		MEM?
		48
		SW?
		48

Appendix B is contained in a separate file, specific to individual variants of the model designation. Look for the file on the storage media sent with the camera that starts with the value “4170-“ or contact SUI with the part number and serial number of the camera to obtain another copy.

U.S. Export Classification: NSR: does not contain export controlled technical data	© 2020 Collins Aerospace	
4110-0283 Rev 8	Page B-1	Last Update: 9-Jun-20