Preliminary

Operation Manual:

SUI™ KTS Family
Compact InGaAs Snapshot Camera

GOODRICH

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1 INTRODUCTION

1.1 SYSTEM DESCRIPTION

The SUI KTS camera family offers users a compact, snapshot Indium Gallium Arsenide Near Infrared Camera, with this manual documenting use of these models:

SU320KTS-1.7RT/RS170	Compact snapshot InGaAs camera
SU320KTSVis-1.7RT/RS170	Compact snapshot Visible-InGaAs camera

Designed for laboratory or field use, these Indium Gallium Arsenide Short-Wave Infrared (SWIR) Cameras stabilize the focal plane array temperature and only require an external AC-to-DC adapter (12 V output adapter provided). Their optical sensitivity ranges from 0.9 μm to 1.7 μm or from 0.4 μm to 1.7 μm for the Visible-InGaAs SU320KTSVis. The lack of cryogenic liquids or moving parts makes the SUI KTS Camera Family suitable for both industrial applications and laboratory research.

The analog output signal of the focal plane array (FPA) is digitized with a resolution of 12 bits using an analog-to-digital converter. The user can select to process the digitized data using a pixel-by-pixel two-point correction (offset and response gain) and bad pixel substitution. The offset compensates for the dark current signal, and the gain compensates for the photoresponse non-uniformity. The digital image is then stored in a video frame buffer and converted into composite analog video using a 12-bit digital-to-analog converter. The digital signal is also available in a Camera Link compatible format at the SDR 26-pin connector of the camera body along with the analog video. Factory corrections are available for a range of preconfigured integration time and FPA sensitivity combinations. Offset correction, gain correction, and pixel substitution can be turned off using ASCII commands sent through the Camera Link asynchronous serial communication port.

The default analog camera output is interlaced EIA-170 standard video. This video scan format can be displayed on an EIA-170 monitor or recorded with NTSC equipment.

1.2 SYSTEM CONTENTS

A complete order for a SU-KTS includes the following:

- SU320KTS-1.7RT camera body
- C-mount lens adapter
- 25 mm, f/1.4 C-mount lens
- AC adapter (power supply)
- SMA to BNC cables, 6 feet (2 pieces)
- BNC to phono plug adapter
- This manual
- Carrying case

- SUI mini CD containing supporting documentation and software, including the configuration file for National Instruments PCI-1428 frame grabber cards

1.3 Safety Considerations

The camera can be powered using an 8-16 V DC power supply capable of providing a minimum of 4 W of power. **Do not exceed the voltage maximum or damage might occur. It is also critical that the power connections be made to the proper connector pins.**

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

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

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

1.4 Optical Considerations

The camera is fitted with a C optical lens mount. Glass lenses are generally compatible with SUI, Goodrich Corporation's short wave infrared cameras. Please note that the antireflective coatings on most lenses are optimized for visible light and have larger reflectivity in the short wave infrared. Also, optimum image sharpness requires a lens designed specifically for the short wave infrared.

1.5 Camera Cleaning

Before performing any camera cleaning operation, power down the camera.

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

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

- With the focal plane array mounted in the camera, use clean, dry compressed air to blow loose particles off the window. This step alone is often sufficient to clean the window. Do not use compressed air gas canisters for this operation, since they may contain fluid and can thermally shock the window.

- Using lint free, lens cleaning paper 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 but covers the window from edge to edge. Use the paper 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 paper until the window is clean.

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 additional information on provisions for camera mounting.
2. Mount the optics to be used to the camera, if applicable. See section 3.3 for additional information.
3. If using the SU-KTS's digital output, install the frame grabber you will be using for data collection following the manufacturer's instructions.

   Note: The SU-KTS camera can be interfaced with most frame grabbers, but SU has verified its operation with National Instruments PCI-1428 cards only. For information on presently supported National Instruments frame grabber models, contact a SUI, Goodrich Corporation application engineer. For National Instruments frame grabbers, installation of the software drivers before installation of the frame grabber hardware is recommended. (See section 2.2 for additional information about software installation.)
4. If applicable, 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.
5. If using the SU-KTS's analog video, connect the camera video output to the input of the receiving equipment using an appropriate coaxial video cable. The provided SMA to BNC cables and BNC to phono plug adapter can be used to make this connection, if appropriate. Tighten the coupling nut of the SMA connector to camera body video output connector. Rotate the cable BNC connector bayonet until locked to its mating connector at the receiver. See section 3.1.3 for more detailed electrical specifications of the camera's analog video output.
6. If the supplied AC adapter is not being used, test the camera power source for proper voltage, polarity, and pin connections as indicated in section 3.1.1 before connecting the power cable to the camera. **Do not exceed the voltage maximum or damage will occur.** With the power source off, insert the power connector into the camera until locked. Apply power to the camera and, if the camera is configured to power-up with the LED enabled, wait for the status LED to turn solid green. See section 3.1.5 for information on the status LED operation.

7. If the TTL trigger input of the camera is to be used, connect the SMA to BNC cable to the camera and the trigger signal source. Tighten the coupling nut of the SMA connector to camera body trigger input connector. Rotate the cable connector bayonet until locked to its mating connector on trigger signal source. The signal source must be compliant with the specifications of section 3.1.4. Take care not to swap the video output and trigger input connections.

2.2 SOFTWARE INSTALLATION

To install software to command or collect digital 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 being used meets the minimum system requirements specified by the frame grabber manufacturer. If a National Instruments frame grabber is being used, National Instruments IMAQ drivers must be installed. NI-IMAQ Vision is National Instruments' library of powerful functions for image processing that is distributed with their imaging frame grabber cards. This software library easily integrates with National Instruments LabVIEW Software, an extensive instrument-programming environment. *Note: The SU-KTS will work with other Camera Link compatible frame grabber cards, but SUI provides support for NI cards only.*
2. Configure the frame grabber to accept the Camera Link interface signal timing documented in section 3.1.2. If using a National Instruments PCI-1428 frame grabber, a camera configuration file (extension .ICD) is provided on the SUI mini CD shipped with the camera. This configuration file properly configures the frame grabber for the SU-KTS's Camera Link interface timing and allows the selection of camera operational modes. The mini CD contains a README file that documents the applicable ICD file for a particular camera model number. As a camera model may be configured in different ways for different applications or customers, there may be several different part numbers associated with an SUI camera model. Therefore, it is best to check the camera part number printed on the camera serial plate (cameras produced after June 2006) or in the original shipping documentation. Copy the appropriate PCI-1428 configuration file from the mini CD to the IMAQ data directory to allow the IMAQ driver to access them (typical directory location is C:\Program Files\National Instruments\NI_IMAQ\Data).
3. Test camera data collection. Typically 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) can be used to configure and validate the hardware installation. See National

Instruments documentation for operation of the Measurement and Automation Explorer. If more information is required on interfacing with the NI-IMAQ library, call a NI representative or SUI, Goodrich Corporation. It is recommended that data collection be successfully exercised using frame grabber supplied tools before attempting to collect data with any third-party software applications.

4. Install any application software to be used following the manufacturer's instructions. The SUI Image Analysis (SUI-IA) software application that can be used for data collection and analysis with the SU-KTS camera is distributed on the SUI mini CD. See the SUI Image Analysis Installation and Operation Manual, distributed on the SUI mini CD, for information on use of this application. SUI-IA allows the user to do the following: control the camera settings, acquire images, store these images or sequences of images (as movies), measure relative intensities of pixels, regions or spots, contrast enhance the image with tools like 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

All electrical interfaces to the SU-KTS camera are located on the camera back panel. The back panel connections are identified in Figure 1.

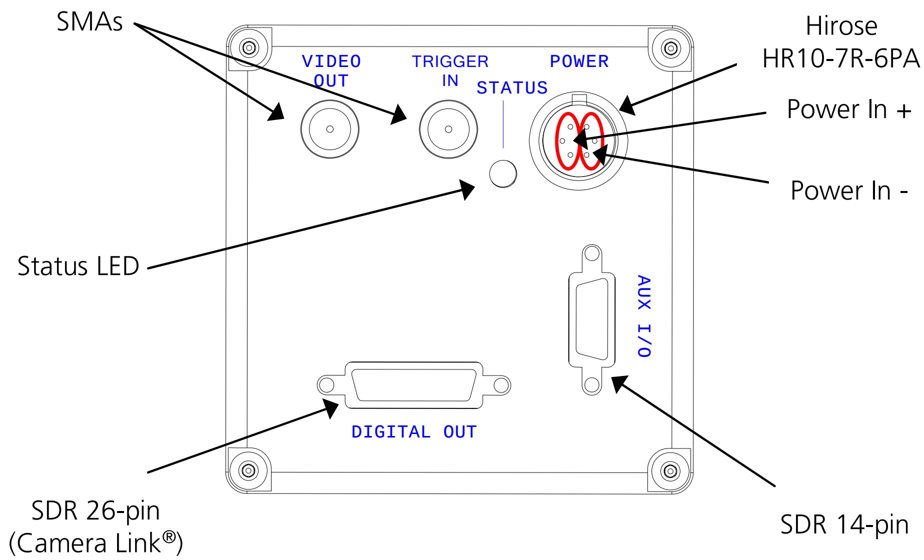

Figure 1. Camera back panel and power connector pin assignment.

3.1.1 Power Input

An AC adapter is provided with a cable that connects to the back panel 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.

If the provided AC adapter is not used, DC power between +8 V and +16 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 4 W of continuous power to the camera. A power source with a maximum peak-to-peak ripple of 1 % of the input voltage at full load is recommended to ensure camera performance.

The status LED light on the back panel will illuminate when the camera is powered if the status LED is enabled. See section 3.1.5 for information on the status LED operation.

3.1.2 Camera Link Data Interface

The digital data interface to the camera is through a Camera Link compatible interface using low-voltage differential signaling (LVDS). SUI, Goodrich Corporation cameras can be interfaced to most frame grabbers, but they have verified operation with National Instruments cards only. An optional imaging pack is available from SUI, Goodrich Corporation that includes a NI PCI-1428 frame grabber card and SDR to MDR 26-conductor Camera Link cable.

The signal assignment for the digital interface SDR 26-pin connector is shown in Table 1. This assignment corresponds to the Factory Configuration of the Camera Link standard.

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 1. Digital output SDR 26-pin connector signal assignment.

The 12-bit image data PIX[11..0] (MSB corresponding to bit 11) is presented on the Camera Link output with PIX[7..0] connected to port A[7..0] and PIX[11..8] to port B[3..0]. The STRB frequency is 24.420 MHz. The average DVAL frequency during a valid line corresponds to the focal plane array pixel rate of 6.105 MHz. One pixel data word is transferred on each STRB cycle that the DVAL signal is active. A timing diagram for the Camera Link interface is shown in Figure 2. The signals STRB, DVAL, LVAL, and and FVAL correspond to the signal names of the Camera Link standard issued by the Automated Imaging Association.

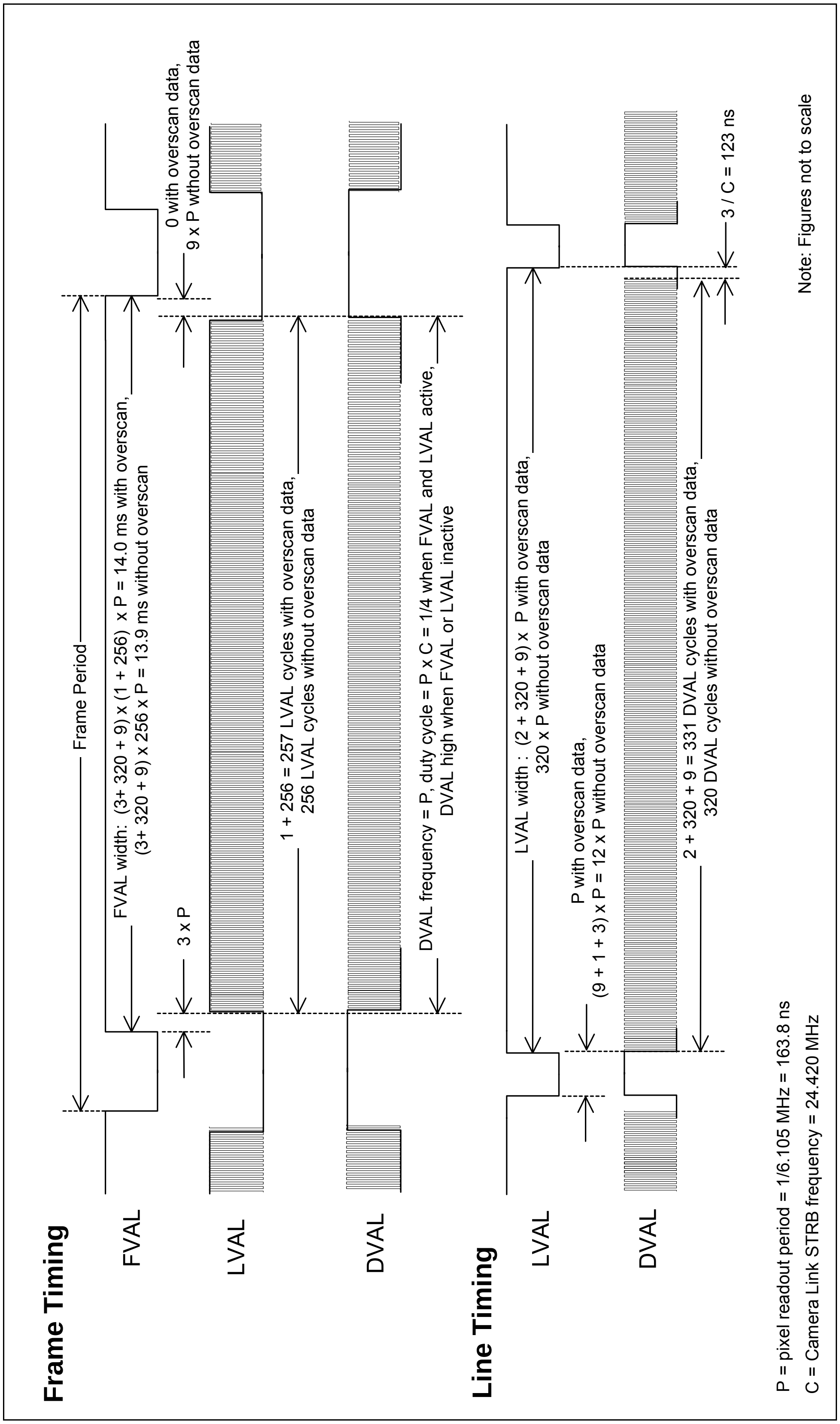

Figure 2. Camera Link interface timing diagram.

Asynchronous serial communication to the camera and a trigger input source are also supported on the Camera Link compatible interface on the SERTC±/SERTFG± and CC1± signals, respectively, as provided by the Camera Link specification. See section 5 for a description of the asynchronous serial communication protocol and command set used by the camera. See section 5.4.7 for a description of supported camera trigger modes.

3.1.3 Video Output

The analog composite video output is available at the SMA connector on the back of the camera labeled *VIDEO OUT.* This is the upper left connection in Figure 1. The video output format of the SU320KTS-1.7RT is interlaced. The timing is such that the image can be directly displayed on a standard video monitor, captured with a video-input frame grabber board, or recorded with a VCR. The video output is nominally 1 V peak to peak with 714 mV of video and 286 mV of sync when a 75 Ω termination is used. The use of a 50 Ω or 75 Ω coax cable between the *VIDEO OUT* on the camera back panel and the receiving equipment is recommended. A 6-foot 50 Ω SMA-to-BNC coax cable is provided. See section 5.4.10 for a description of the camera's analog video commands that affect the timing relationship between the Camera Link digital data and the analog video output.

3.1.4 Trigger Input

A trigger signal input connection is available at the SMA connector labeled *TRIGGER IN* on the back of the camera as shown in Figure 1. This input can be used for control of the frame rate and exposure time. This trigger input accepts signals from 0 V to 5 V maximum. The thresholds for the trigger input are < 0.8 V for logic low and > 3.0 V for logic high. The trigger input presents a 3.0 KΩ load to ground to the signal driving source.

3.1.5 Status LED

The status LED will illuminate whenever power is applied to the camera and the LED is enabled.

If the status LED is steadily illuminated red or green, it indicates the status of the temperature control of the focal plane array. When the status LED is illuminated red, the camera has not yet locked the focal plane array to its temperature set point (see Appendix B for focal plane array temperature set point). The temperature is considered locked when the imager is regulated to within ±0.1°C of the set point. The time required for the array temperature to reach lock from initial power on will range from 1 to 5 minutes depending on the ambient temperature conditions of the camera. The greater the difference between the ambient temperature and the set point temperature, the greater the time required to achieve temperature lock. The camera status LED will illuminate green when temperature lock is achieved.

If the temperature cannot be held, the camera head status LED will turn red. Loss of temperature lock while control is enabled can occur for several reasons. The most common reason is that the camera is being operated at an ambient temperature greater than specified maximum. Another possibility is that the camera is operated in an enclosed environment that limits the ability of the case to radiate heat. (See section 3.1.6 for more information on camera thermal management.) **If the status LED continues to indicate lack of temperature lock while the temperature control is enabled and after these conditions have been remedied, disconnect power and contact the factory.**

The status LED will flash between red and green on a one second interval if a camera error is encountered and the LED is enabled. (See section 5.4.14 for further details.)

3.2 CAMERA MECHANICAL INTERFACES

3.2.1 Camera Dimensions

Dimensions (Length x Width x Height)	71.7 mm x 52.1 mm x 52.1 mm 2.82 in. x 2.05 in. x 2.05 in Length includes I/O connectors and lens adapter
Weight	< 270 g (no lens)
Lens Mount	C-mount
Sensor Alignment	17.6 mm behind the C-mount flange (physical) 17.1 mm behind the C-mount flange (optical)

A mechanical drawing of the camera body including the optical path stack-up is shown in Figure 3.

3.2.2 Mounting the Camera

Type	Description	Hole Pattern
Tripod mount (bottom)	2 tapped ¼-20 holes 2 tapped M6-6H holes	In-line
Flat plate mount (front)	M42 x 1 mm thread (front plate) M25.4 x 1.26 mm thread (C-mount adapter)	Circle

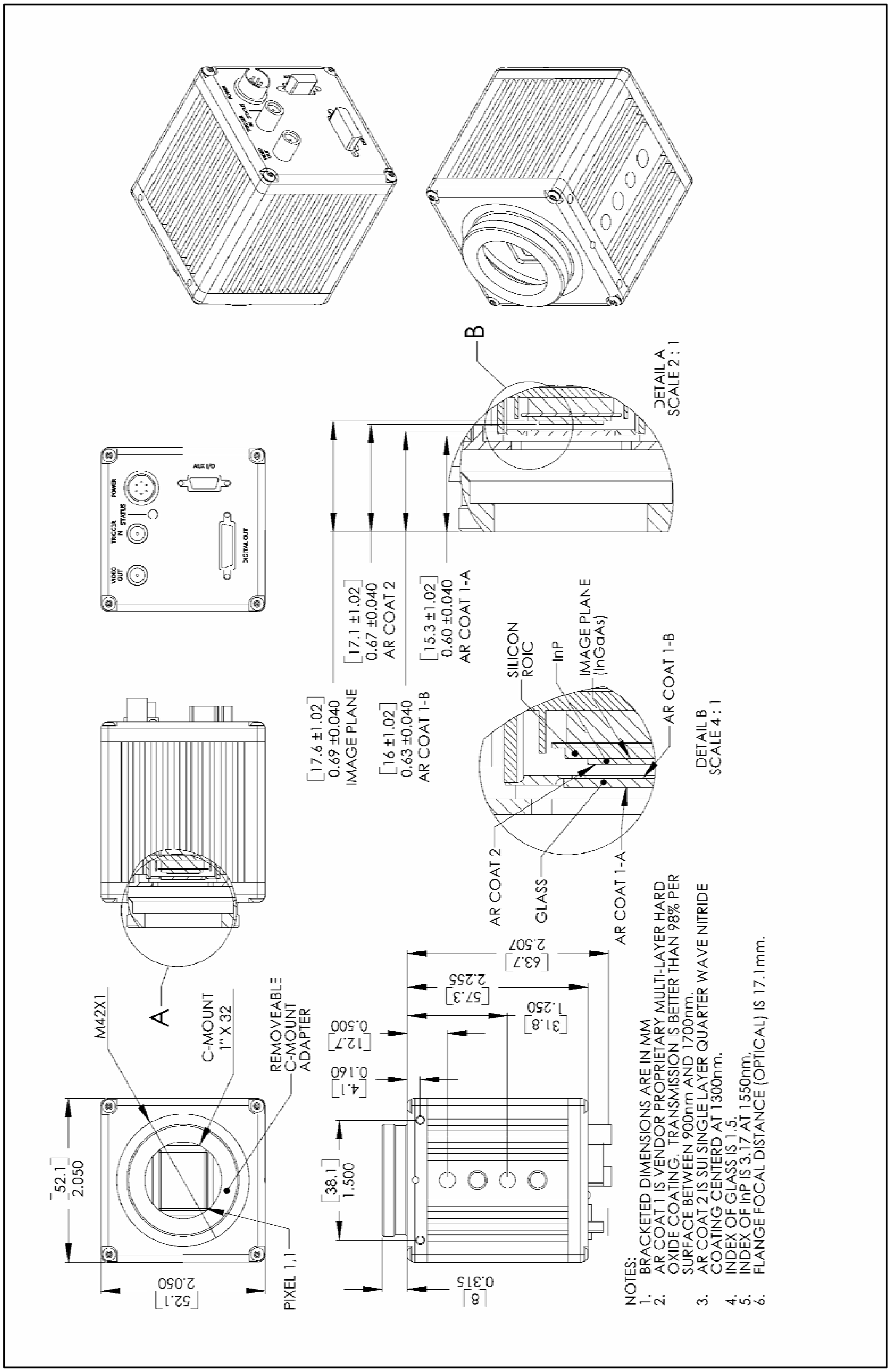

Figure 3. Mechanical drawing of camera body including optical path stack-up.

Note: There are two different mounting holes sizes shown in the lower left of the drawing when viewed in landscape mode.

3.2.3 Thermal Management

If the focal plane array is unable to reach or hold its temperature set point, additional thermal management of the camera may be necessary. See section 3.1.5 and section 5.4.11 for methods of determining the focal plane array temperature status. The SU-KTS camera housing has been designed to efficiently transfer heat from the focal plane array to the outside of the enclosure. The convection of heat from the enclosure can be significantly improved by providing a flow of air over the case. If the environment of the camera does not allow forced air movement, conduction of heat through a heatsink in contact with the camera case is recommended.

3.3 CAMERA OPTICAL INTERFACES

3.3.1 Lens Mounting Plate

The Goodrich SUI KTS cameras utilize a lens mounting plate with an M42X1 thread, that is, a 42 mm diameter hole with a 1 mm thread pitch. This mounting plate design permits adapting the camera to a variety of standard lens mount formats. An adapter to a standard C-mount lens format is provided with the camera.

Please take note that the wavelength range accepted by these SWIR cameras is quite broad and beyond the range for which commercial lenses have been designed. Depending on the actual wavelengths imaged in the users' applications, the lens focus markings will be shifted. Another factor is that, due to a build up of mechanical tolerances of the large 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 location of the focal plane for the KTS family is approximately 17.1 mm behind the mounting plate with a tolerance of ±1 mm. These factors combine to make the lens markings useless or misleading unless a means of trimming the focus distance is provided.

3.3.2 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 their adjustable range. To trim the focus position further, use 1 inch inside diameter shim washers to move the lens further away from the focal plane.

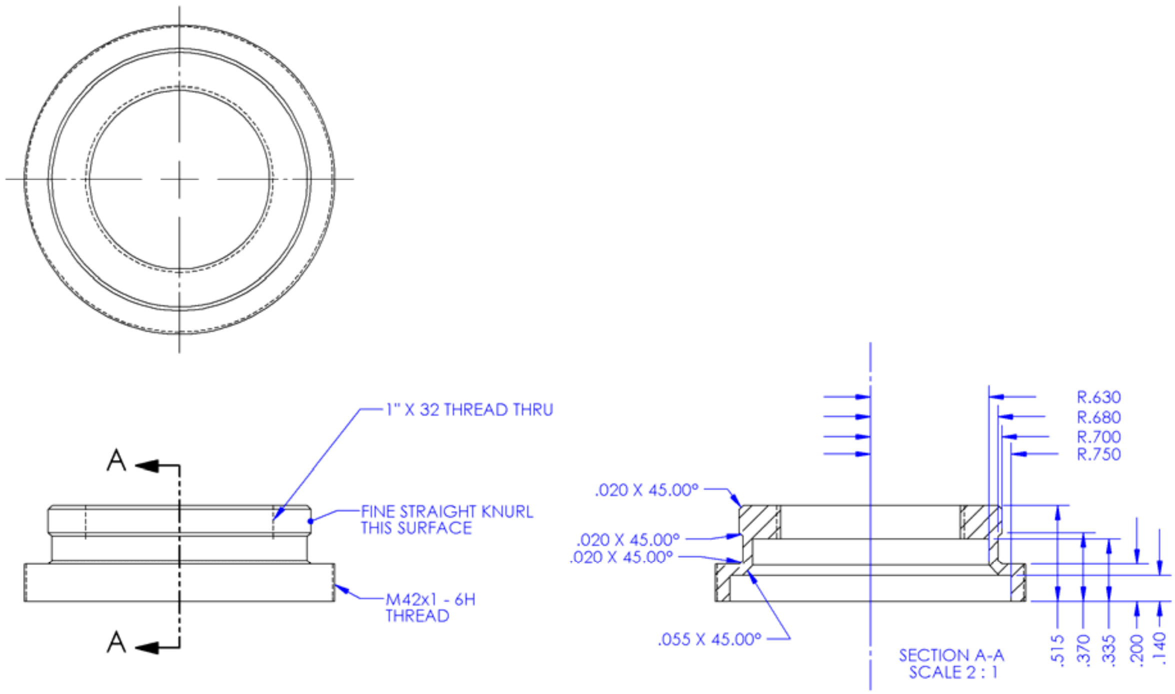

Figure 4. Mechanical drawing of C-mount lens adapter, all dimensions in inches.

4 PRINCIPALS OF OPERATION

4.1 FOCAL PLANE ARRAY OPERATION

The SU320KTS-1.7RT camera uses SUI's SU320AMS-1.7T1 indium gallium arsenide (InGaAs) focal plane array (FPA). This FPA has 320 x 256 pixels on a 25 µm pitch. This FPA consists of an InGaAs photodiode array hybridized to a CMOS readout using indium bump bonds. The photodiode array is a backside illuminated device (where light first passes through the substrate before being absorbed) with typical quantum efficiency (QE) and responsivity shown in Figure 5 and Figure 6, respectively. For visible InGaAs, the substrate is thinned to allow shorter wavelength light to reach the light sensitive region of the photodiode.

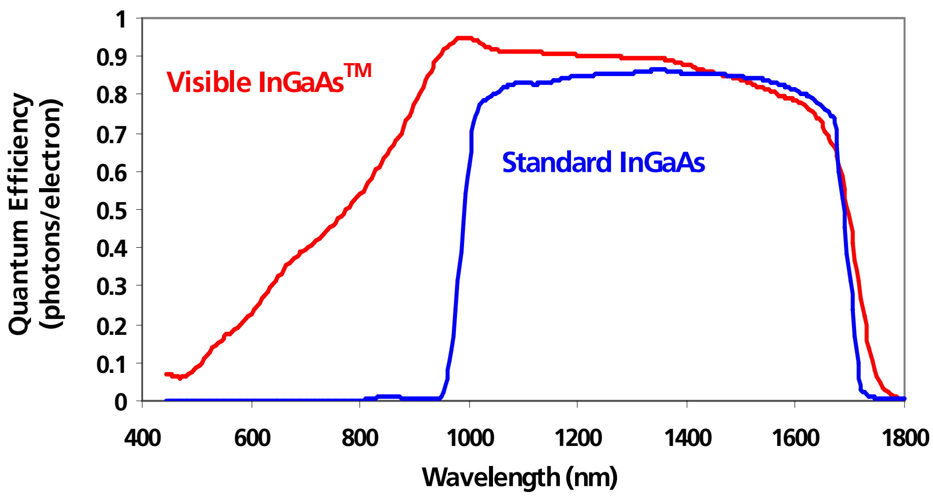

Figure 5. Typical quantum efficiency of SUI backside illuminated FPAs.

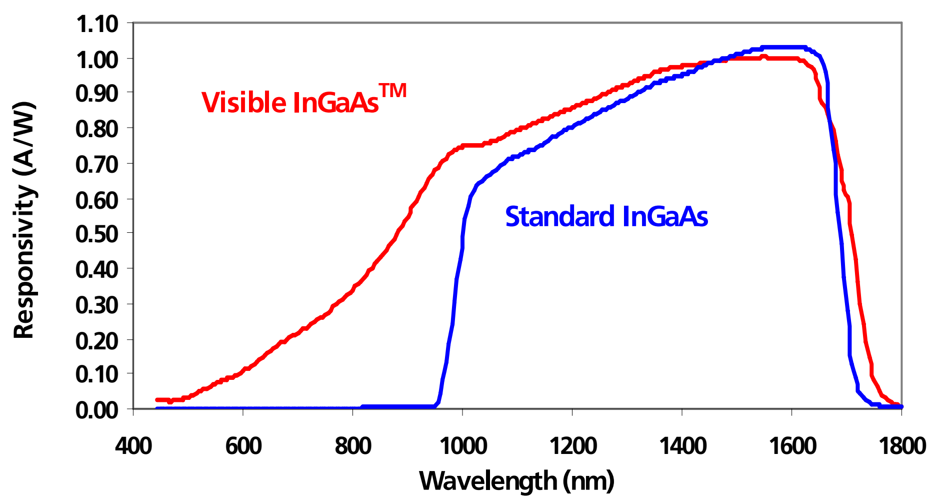

Figure 6. Typical responsivity of SUI backside illuminated FPAs.

The CMOS readouts are "active pixel" devices in which the photocurrent is amplified and stored in each pixel. A simplified pixel schematic is shown in Figure 7. Each pixel contains a gate modulated (GMOD) input circuit for converting current to voltage with continuously adjustable gain. In this circuit, the photocurrent generates a potential across a load and the potential across the load modulates a current source, which charges an integrating capacitor. The load in this circuit is the impedance of the input transistor M_{LOAD}. The impedance of M_{LOAD} and the bias on the photodiode are determined by the supply voltages BIAS and DSUB. The potential across M_{LOAD} is tied to the gate of the output transistor, M_{MIRROR}. Transistor M_{MIRROR} acts as a current source that charges the integration capacitor. Increasing the voltage at the gate of M_{MIRROR} decreases the current flow so the output circuit acts as a current mirror with gain. The baseline current is determined by the supply GAIN and the voltage across the capacitor by the supply V_{RESET}. The camera internally provides all bias voltages and necessary for operation of the focal plane array.

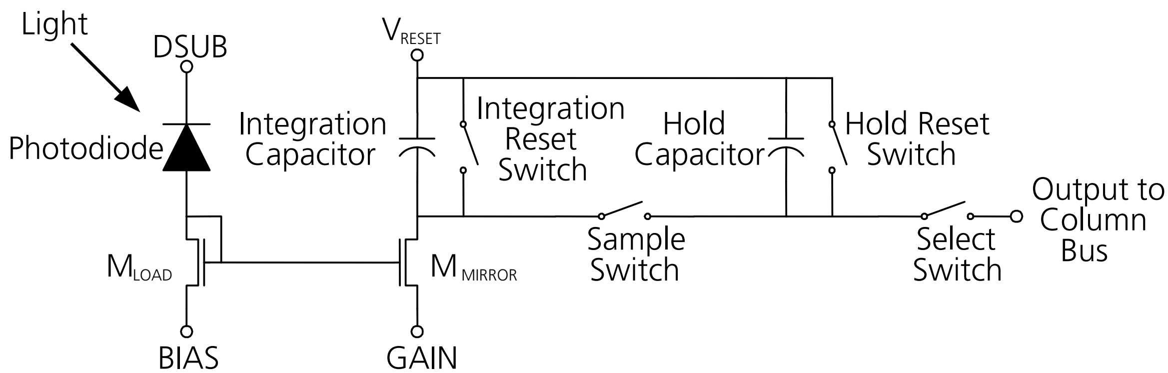

Figure 7. Simplified pixel schematic.

The camera frame sequence consists of an exposure followed by readout and digitization. During exposure, the integration reset switch is open and the integration capacitor shown in Figure 7 is discharged from its reset voltage by the mirrored photodiode current, converting the signal current to a voltage. At the end of the integration time, the sample reset switch is first momentarily closed to reset the last sampled value and then the sample switch momentarily closed to sample the last integration period's signal voltage. After the signal is sampled, the integration reset switch is closed and held until the start of the next integration period. The exposure may or may not overlap the readout of the last frame depending on the exposure period and the frame rate. Since all pixel's integration reset, sample, and sample reset switches receive the same clock timing, the FPA operates with "snapshot" exposure. This means that all pixels are exposed during the same time.

In order to generate the serial analog video signal that is digitized by the camera, the individual pixel voltages are multiplexed out of the FPA in two stages. First, each row is sequentially connected to an array of column amplifiers via column buses that are shared by all of the pixels in a column. This connection is made through the select switch shown in Figure 7. The outputs of the column amplifiers are then multiplexed to form the video readout using an analog multiplexer.

In the SU320KTS-1.7RT EIA-170 camera, the maximum frame rate is 71 Hz. When the frame readout is synchronized to the EIA-170 analog video output, the frame rate is 59.9 Hz (see section 5.4.6.6). For any frame rate, the SU320AMS-1.7T1 FPA requires a minimum dead, or non-integration, time between exposures equal to 15 pixel periods, or 2.5 µs. Therefore, at a 59.9 Hz frame rate, the maximum exposure period is 16.6 ms.

4.2 Camera System Operation

The SU-KTS camera system provides 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 SU-KTS camera system is shown in Figure 8.

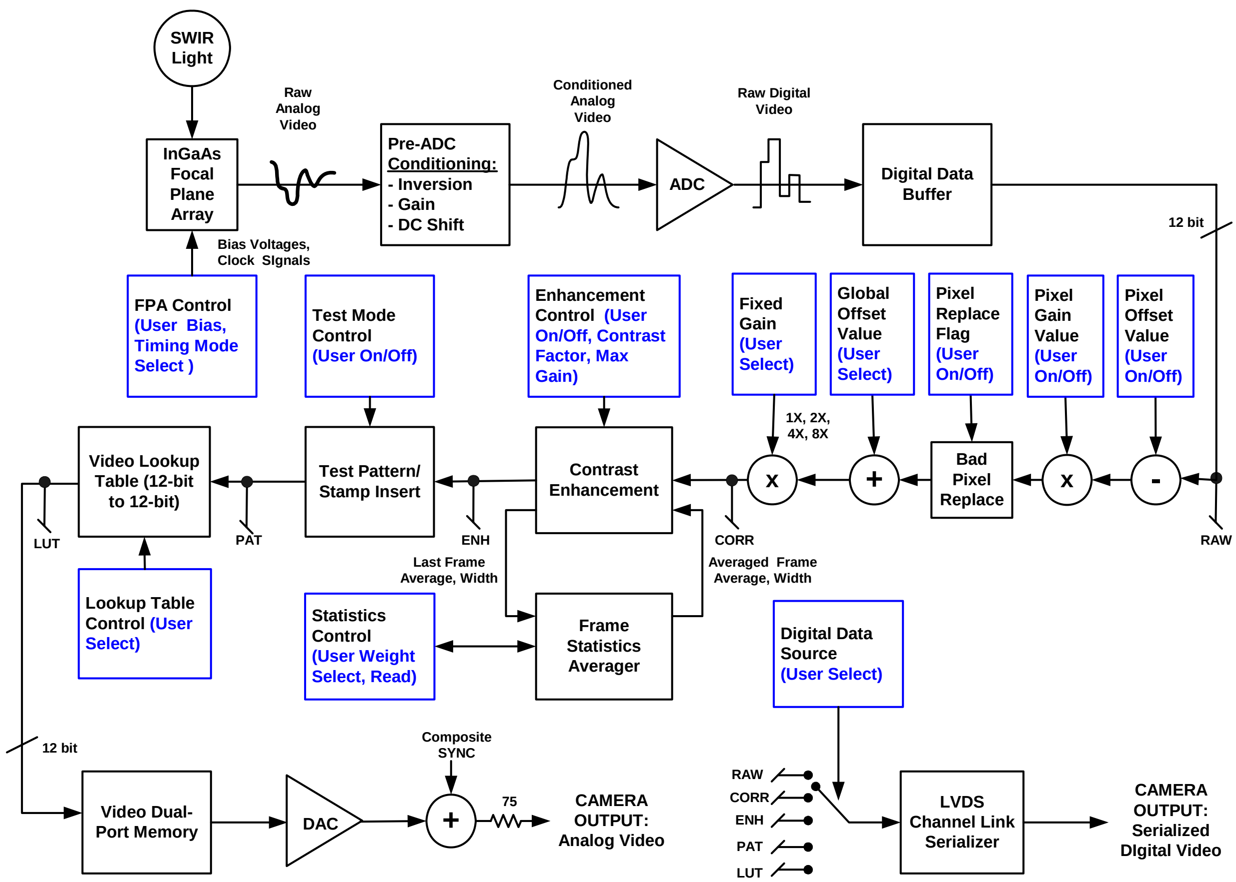

Figure 8. Camera system signal flow diagram.

The analog functions of the camera system include the following: creation of DC bias voltages required by the FPA, inverting and applying the required DC offset to the FPA output signal for digitization, and converting the analog output signal to digital format using a 12-bit analog-to-digital converter (ADC).

Once digitized, the digital subsystem of the camera receives the output data and performs the following operations: applies pixel-by-pixel offset and gain correction to the data (selectable), performs a contrast stretching enhancement of the data (selectable), inserts test information (selectable), and passes the data through a video look-up table memory (selectable). The image data is presented by the camera in digital and analog video formats. Digital data is available from the camera in a Camera Link compatible format where the source of the data from along the digital data processing path is selectable. Analog image data is available from the camera in EIA-170 standard analog video format. Image data presented on the analog video output is buffered by the camera's digital subsystem using a dual-port memory to allow independent timing operation of the FPA readout and the EIA-170 video. The digital subsystem of the camera also includes a camera control processor which allows the user to select camera operational modes and monitor the camera status through the Camera Link asynchronous communication channel.

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. The power subsystem also includes an adjustable thermoelectric cooler (TEC) power supply, which is under control of the camera's digital subsystem.

See section 5 for more detailed information on the operation of the various camera functions supported by the SU-KTS.

5 CAMERA FUNCTIONS AND CONTROL SOFTWARE INTERFACE

The SU-KTS camera has a variety of features and modes that can be selected or queried through the control interface. These include autogain, image enhancement, exposure time, frame rate, corrections, trigger modes, and error status. The SU-KTS camera communicates via the serial communication provisions of the Camera Link standard. All camera modes are controlled using a set of ASCII commands sent by the Host to the camera.

5.1 COMMUNICATION PROTOCOL

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

5.2 COMMAND FORMAT AND RESPONSE

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

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

When commanding the camera the following rules apply:

- Command input is not case sensitive, upper and lowercase characters are accepted by the camera.
- A carriage return `<CR>` ends each command.
- All commands and arguments should be separated by white space.
- Extra arguments entered on the command line will be ignored.
- The camera supports several echo modes. The camera can echo the received character back to the user. Alternatively, the echo mode can be configured so that every character received by the camera is echoed using a user-specified character, such as an asterisk. Finally, echo can be disabled, resulting in no output of an echo line.

- The return value line output is command dependent. Some commands, such as query commands, will have a return value and so this line will be output. Other commands have no return value and so no return value line will be output.
- Upon successful execution of a command, the processed command response line contains the command and any valid arguments provided. Since extra invalid arguments can be entered on the command line, the processed command response may differ from the command line input (and echo line). Upon unsuccessful execution of a command, the processed command response line contains all arguments entered on the command line. The processed command response line output can be suppressed by setting the response mode to "brief", and can be enabled by setting the response mode to "verbose". *Note: The processed command and any arguments returned will be separated by a single space, and will be capitalized regardless of the format in which they were originally entered on the command line.*
- Upon successful execution of the command, the command execution outputs the characters: `"OK".` If the command failed or is invalid, the output is `"ERROR".` The command execution result is always output.
- After the command execution result is returned, the camera will return the command prompt character ">." Reception of the command prompt character by the Host is an indication that the camera is ready to receive the next command.

Table 2 summarizes the camera's return line formats and the conditions under which the lines are returned.

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	Always returned.
>	Command Prompt	Always returned.

Table 2. Line format of camera command return strings.

5.3 STARTUP MESSAGING

Reboot of the camera occurs when power to the camera is cycled or the `REBOOT` command is issued through the command interface (see section 5.4.14.4). On reboot, the camera transmits a startup banner to the host. The SU-KTS startup banner has the following format:

```
Initializing Camera …

KTS Camera
Sensors Unlimited, Inc.
Software Version x
Memory Map Version y
Hardware Version z
>
```

Note: The x, y, and z will be replaced with your actual version. Once the command prompt character ">" has been received by the Host, the camera is ready to receive a command.

5.4 COMMAND SET

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

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

5.4.1 Configuration Commands

The camera's three distinct memory spaces, shown in Figure 9, are used to manage the camera's configuration. There are two non-volatile memory spaces, one that holds the "User Configuration" and another that holds the "Factory Configuration." The User Configuration can be altered by the user to customize camera operation. **The Factory Configuration, programmed at time of manufacture, can not be altered by the user.** This configuration is provided to restore the camera to its default configuration, if needed. A single volatile memory space used to hold the "Current Session Configuration." Each of the memory space contains a copy of the global settings and one or more operational settings. A global setting is a collection of parameters that apply to the global camera state. (See Table 3 for a list of user configurable global settings.) An operational setting is a collection of parameters that affect the camera's sensitivity. (See Table 4 for a list of user configurable operational settings.)

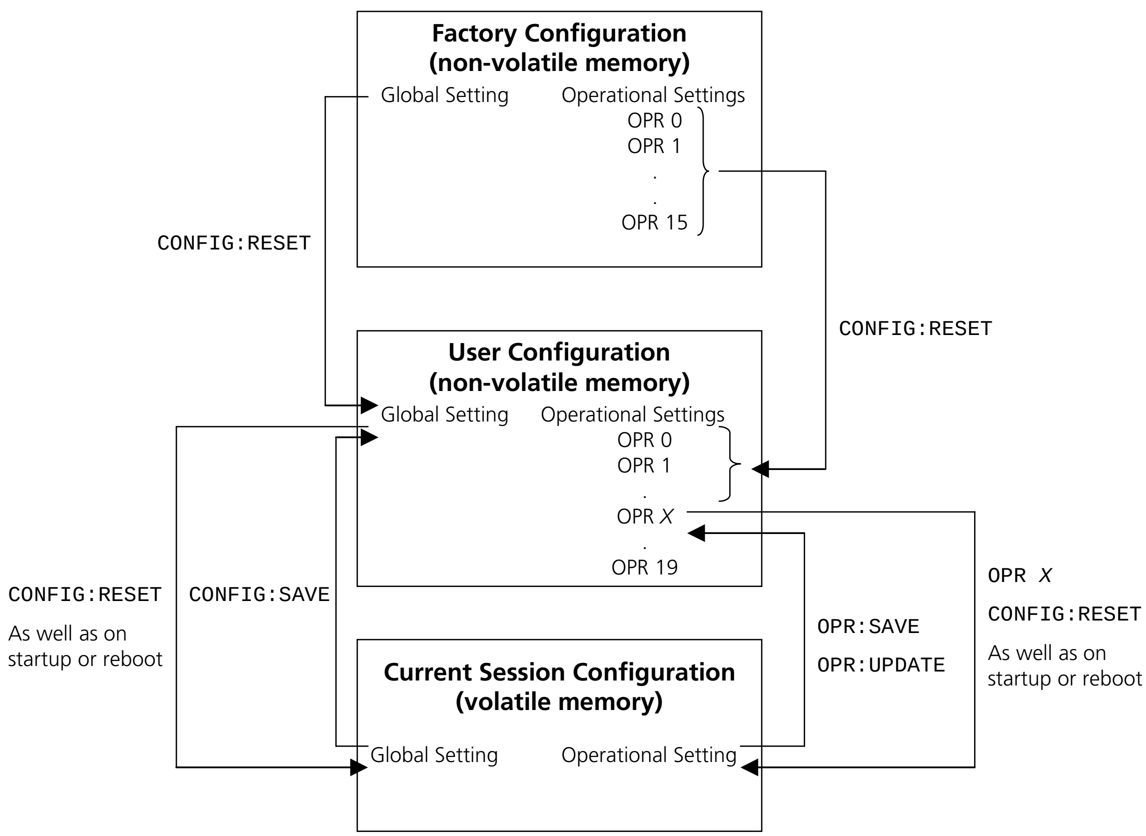

Figure 9. Camera memory layout.

The Factory Configuration is used to restore the User Configuration to its factory default settings by issuing the `CONFIG:RESET` command. See Appendix B for the values of the

Factory Configuration global and operational parameters of the camera associated with this manual.

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

Baud Rate
Echo Mode
Echo Character
Response Mode
Gain Correction
Offset Correction
Pixel Correction
Global Corrected Offset
Digital Output Mode
Digital Data Source
Enhancement Frames to Average
Enhancement Contrast Factor
Enhancement Minimum Gain Divider
Enhancement Ignore Saturated Pixel State
Enhancement State
AGC State
AGC Top Threshold
AGC Bottom Threshold
AGC Low Operational Setting
AGC High Operational Setting
Digital Gain
Scan State
Over-Scan State
Thermoelectric Cooler State
Test Pattern
Frame Stamp
Trigger Mode
Trigger Source
Trigger Polarity
Trigger Delay
Video LUT
Video Double Buffer Mode State
Synchronize Scan to Video State
Startup Operational Slot
LED State
ADC State
DAC State

Table 3. User configurable global settings.

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

Exposure Period
Frame Period
Video 2X Zoom State
Video Buffer Read Row
Video Buffer Read Column

Table 4. User configurable operational settings.

5.4.1.1 Restore Factory Configuration

Description	Restores the factory defaults settings. The User Configuration memory space is erased. Next, the Factory Configuration is copied to the User Configuration memory space. Finally, the Current Session Configuration is reloaded from the User Configuration. All modifications made by the user will be lost. See Appendix B for documentation of the Factory Configuration global and operational parameter values for your camera model.
Setting Type	N/A
Command	`CONFIG:RESET`
Parameters	none
Return Values	none
Example	`CONFIG:RESET`

5.4.1.2 Save Global Configuration

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

5.4.1.3 Load Operational Configuration

Description	Loads the operational settings for the specified operational slot. An error will occur if an *opr_number* outside of the specified range is used.
Setting Type	N/A
Command	`OPR` *opr_number*

Parameters	*opr_number*
Type	unsigned integer
Range	0 to 19 (limited by the number of operational settings that currently exist)
Return Values	none
Example	`OPR 5`

5.4.1.4 Get Current Operational Configuration Number

Description	Returns the current operational slot number that is loaded.
Setting Type	N/A
Command	`OPR?`
Parameters	none
Return Values	*opr_number*
Type	unsigned integer
Range	0 to 19
Example	`OPR? -- query command` `5 -- return value`

5.4.1.5 Get Total Number of Operational Configurations

Description	Returns the number of operational settings currently present in the User Configuration memory.
Setting Type	N/A
Command	`OPR:MAX?`
Parameters	none
Return Values	*number*
Type	unsigned integer
Range	1 to 20
Example	`OPR:MAX? -- query command` `8 -- currently OPR 0-7 exist`

5.4.1.6 Set Startup Operational Configuration

Description	Sets the operational slot number that will be loaded on reboot of the camera. *Note: Since this is a global setting, a **CONFIG:SAVE** command must subsequently be issued to cause any changes in this value to be saved to the User Configuration memory.*
Setting Type	Global
Command	`OPR:START` *opr_number*

Parameters	`opr_number`
Type	unsigned integer
Range	0 to 19 (limited by the number of operational settings that currently exist)
Return Values	none
Example	`OPR:START 5`

5.4.1.7 Get Startup Operational Configuration

Description	Returns the operational slot number that will be loaded on reboot of the camera.
Setting Type	Global
Command	`OPR:START?`
Parameters	none
Return Values	`opr_number`
Type	unsigned integer
Range	1 to 19
Example	`OPR:START?     -- query command` `5              -- return value`

5.4.1.8 Create New Operational Configuration

Description	Takes the Current Session operational settings and saves them to User Configuration memory and assigns a new operational slot number. A maximum of 20 operational slots is allowed and the operational slot numbers are assigned sequentially. The new operational slot number will be returned to the host. *Note: When a new operational configuration is created, any factory correction table associated with the existing operational configuration will not be copied to the new operational configuration slot. Corrections, therefore, must be disabled when using the newly created configuration slot for meaningful data to be produced.*
Setting Type	N/A
Command	`OPR:SAVE`
Parameters	none
Return Values	`opr_number`
Type	unsigned integer
Range	0 to 19

Example	`OPR:SAVE`	`-- command`
	`8`	`-- return value`

5.4.1.9 Update Existing Operational Configuration

Description	Updates the operational configuration in the User Configuration memory with the operational settings from the Current Session Configuration.
Setting Type	N/A
Command	`OPR:UPDATE`
Parameters	none
Return Values	none
Example	`OPR:UPDATE`

5.4.1.10 Delete Last Operational Configuration

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

5.4.1.11 Delete All Operational Configurations

Description	Deletes all operational configurations created by the user from the User Configuration memory. This operation will return an error if executed when only factory operational configurations exist. If the Current Session Configuration is deleted from the user configuration memory, a subsequent query of the current operational configuration number will return the deleted operational configuration number, since it is still the Current Session Configuration, but a command to load the deleted

	operational number will return an error. **WARNING: If the startup operational configuration is deleted, the camera operation is no longer specified.**
Setting Type	N/A
Command	`OPR:DEL:ALL`
Parameters	none
Return Values	none
Example	`OPR:DEL:ALL`

5.4.2 Serial Communication Interface Commands

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

5.4.2.1 Set Current Baud Rate

Description	This command updates the current baud rate variable. The baud rate that the camera communicates at will change immediately. **WARNING: Changing the current baud rate will require the host to change baud rates for communication to continue.**
Setting Type	Global
Command	`BAUD:CURRENT` *`baud_rate`*
Parameters	*`baud_rate`*
Type	unsigned integer

Range

300
1200
2400
4800
9600
14400
19200
28800
31250
38400
57600
115200

Return Values none

Example `BAUD:CURRENT 57600`

5.4.2.2 Get Current Baud Rate

Description Returns the current baud rate.

Setting Type Global

Command `BAUD:CURRENT?`

Parameters none

Return Values *baud_rate*

Type unsigned integer

Range

300
1200
2400
4800
9600
14400
19200
28800
31250
38400
57600
115200

Example

```
BAUD:CURRENT?   -- query command
57600           -- return value
```

5.4.2.3 Set Future Baud Rate

Description	Updates the future baud rate variable. **WARNING: A `CONFIG:SAVE` command must be executed after this command for a change in the future baud rate value to be saved and used on the next camera power-up or reboot.**
Setting Type	Global
Command	`BAUD:FUTURE` *`baud_rate`*
Parameters	*`baud_rate`*
Type	unsigned integer
Range	

300
1200
2400
4800
9600
14400
19200
28800
31250
38400
57600
115200

Return Values	none
Example	`BAUD:FUTURE 28800`

5.4.2.4 Get Future Baud Rate

Description	Returns the value stored in the future baud rate variable.
Setting Type	Global
Command	`BAUD:FUTURE?`
Parameters	none
Return Values	*`baud_rate`*
Type	unsigned integer

Range

300
1200
2400
4800
9600
14400
19200
28800
31250
38400
57600
115200

Example
```
BAUD:FUTURE?   -- query command
28800          -- return value
```

5.4.2.5 Set Echo Mode

Description: Sets the echo mode for serial communications. In mode 0 echo is disabled. In mode 1 echo is enabled and any character received on the serial port is immediately echoed back. An exception to the echo of the received character with mode 1 enabled is when a backspace character is received while the receive buffer is empty. In mode 2 echo is enabled but instead of echoing back the character received a user defined character is echoed. Echo mode 1 provides for the most robust communication, allowing the host to verify that each character sent to the camera was properly received. Echo mode 2 allows the host to verify that the camera received the correct number of characters, but does not provide a way to verify that characters where not corrupted during transmission.

Setting Type: Global

Command: `ECHO:MODE` *`mode`*

Parameters: *`mode`*

Type: unsigned integer

Range

0	Echo off
1	Echo received character
2	Echo user defined character

Return Values: none

Example: `ECHO:MODE 1`

5.4.2.6 Get Echo Mode

Description	Returns the current echo mode setting.
Setting Type	Global
Command	`ECHO:MODE?`
Parameters	none
Return Values	*`mode`*
Type	unsigned integer
Range	

0	Echo off
1	Echo received character
2	Echo user defined character

Example
```
ECHO:MODE?     -- query command
1              -- return value
```

5.4.2.7 Set Echo Character

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

5.4.2.8 Get Echo Character

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

Example
```
ECHO:CHAR?     -- query command
35             -- return value
```

5.4.2.9 Set Response Mode

Description: The camera supports two response modes, brief and verbose. In verbose response mode the processed command response line discussed in section 5.2 is output. In brief response mode the processed command response line is not output.

Setting Type: Global

Command: `RESPONSE` *`mode`*

Parameters: *`mode`*

Type: string

Range:

`BRIEF`	Brief response mode
`VERBOSE`	Verbose response mode

Return Values: none

Example: `RESPONSE VERBOSE`

5.4.2.10 Get Response Mode

Description: Returns the current response mode.

Setting Type: Global

Command: `RESPONSE?`

Parameters: none

Return Values: *`mode`*

Type: string

Range:

`BRIEF`	Brief response mode
`VERBOSE`	Verbose response mode

Example:

```
RESPONSE?      -- query command
VERBOSE        -- return value
```

5.4.3 Correction Commands

The factory operational configuration slots support two-point correction tables that can be used to compensate for the dark signal and gain photoresponse non-uniformity of the FPA. Defective FPA pixels can also be substituted with the last good pixel value. The correction table coefficients are applied to create a corrected pixel value $PIXCORR$ according to the following relation:

$$PIXCORR = ((PIXIN - CORROFF) \times \frac{CORRGAIN}{2048}) + GLOBALCORROFF$$

where $PIXIN$ is the raw pixel value, $CORROFF$ is the offset correction value, $CORRGAIN$ is the gain correction value, and $GLOBALCORROFF$ is the global corrected offset value.

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

Note: If either gain or offset correction is applied to the raw pixel data and a subsequent digital fixed gain of 1X is used, some pixel values may not saturate at the full 12-bit resolution count value of 4,095. If a subsequent fixed digital of 2X or higher is used, however, all pixels will saturate at 4,095.

The pixel correction function uses a bad pixel map that applies to all operational configuration slots. The gain and offset correction coefficients are unique for each operational setting.

5.4.3.1 Set Gain Correction State

Description: Sets the state of the gain correction. Gain correction compensates for pixel-to-pixel photoresponse non-uniformity.

Setting Type: Global

Command: `CORR:GAIN` *`state`*

Parameters: *`state`*

Type: string

Range:

`ON`	Enables Gain Corrections
`OFF`	Disables Gain Corrections

Return Values: none

Example: `CORR:GAIN ON`

5.4.3.2 Get Gain Correction State

Description: Returns the state of the gain correction.

Setting Type: Global

Command: `CORR:GAIN?`

Parameters: none

Return Values: *`state`*

Type: string

Range:

`ON`	Gain Correction Enabled
`OFF`	Gain Correction Disabled

Example:

```
CORR:GAIN?      -- query command
ON              -- return value
```

5.4.3.3 Set Offset Correction State

Description: Sets the state of the offset correction. Offset correction compensates for dark current signal non-uniformity.

Setting Type: Global

Command: `CORR:OFFSET` *`state`*

Parameters: *`state`*

Type: string

Range:

`ON`	Enables Offset Corrections
`OFF`	Disables Offset Corrections

Return Values: none

Example: `CORR:OFFSET ON`

5.4.3.4 Get Offset Correction State

Description: Returns the state of the offset correction.

Setting Type: Global

Command: `CORR:OFFSET?`

Parameters: none

Return Values: *`state`*

Type: string

Range:

`ON`	Offset Correction Enabled
`OFF`	Offset Correction Disabled

Example:

```
CORR:OFFSET?   -- query command
ON             -- return value
```

5.4.3.5 Set Pixel Correction State

Description: Sets the state of the pixel correction. Pixel correction replaces pixels that do not pass focal plane array performance specifications with the last, non-replaced pixel value.

Setting Type: Global

Command: `CORR:PIXEL` *`state`*

Parameters: *`state`*

Type: string

Range:

`ON`	Enables Pixel Corrections
`OFF`	Disables Pixel Corrections

Return Values: none

Example: `CORR:PIXEL ON`

5.4.3.6 Get Pixel Correction State

Description Returns the state of the pixel correction.

Setting Type Global

Command `CORR:PIXEL?`

Parameters none

Return Values *`state`*

Type string

Range

`ON`	Pixel Correction Enabled
`OFF`	Pixel Correction Disabled

Example
```
CORR:PIXEL?    -- query command
ON             -- return value
```

5.4.3.7 Set Global Corrected Offset Value

Description Sets the global offset value. Global offset is a fixed value that is added to each pixel in the image after all other corrections have been applied if offset correction is enabled. The global offset can be disabled by setting its value to zero.

Setting Type Global

Command `CORR:OFFSET:GLOBAL` *`value`*

Parameters *`value`*

Type unsigned integer

Range 0 to 4095

Return Values none

Example `CORR:OFFSET:GLOBAL 100`

5.4.3.8 Get Global Corrected Offset Value

Description Returns the global offset value.

Setting Type Global

Command `CORR:OFFSET:GLOBAL?`

Parameters none

Return Values *`value`*

Type unsigned integer

Range 0 to 4095

Example
```
CORR:OFFSET:GLOBAL? -- query command
100                 -- return value
```

5.4.4 Image Enhancement and Automatic Gain Control (AGC) Commands

The Automatic Gain Control (AGC) algorithm monitors frame statistics at rate of 10 times per second and adjusts the operational configuration (OPR number) to achieve the best camera sensitivity settings for the given imaging scene.

The parameters of Table 5 are used to tailor the AGC algorithm:

Parameter	Description	Serial Command
AGC Top Threshold	If the frame average value exceeds the top threshold value the algorithm attempts to reduce the camera sensitivity.	`AGC:THRESH:TOP`
AGC Bottom Threshold	If the frame average value falls below the bottom threshold value the algorithm attempts to increase the camera sensitivity	`AGC:THRESH:BOT`
AGC Low Operational Bound	Sets the lowest operational configuration available for use by the algorithm.	`AGC:OPR:LOW`
AGC High Operational Bound	Sets the highest operational configuration available for use by the algorithm.	`AGC:OPR:HIGH`
Frame Average Weight	Sets the weight by which the most recent frame's statistics are used to affect the reported frame average. The frame average is an exponentially weighted moving average. *Note: This parameter also affects the calculation of the frame width parameter used by the enhancement algorithm.*	`ENH:AVG`
Saturated Pixels	Allows omission of saturated pixel values from the frame average and frame width calculations.	`ENH:SAT`

Table 5. AGC algorithm configurable parameters.

The AGC algorithm is depicted in Figure 10 and its operation is described in the following paragraphs.

If the frame average is between the AGC Top Threshold and AGC Bottom Threshold (inclusive) no changes are made to the operational setting.

If the frame average is greater than the AGC Top Threshold the algorithm attempts to reduce the camera's sensitivity by changing to a lower operational setting. If the current operational setting number is greater than the AGC Low Operational Bound then the algorithm decreases the operational setting number by one. If the current operational setting number is equal to the AGC Low Operational Bound, then the camera is at the least sensitive setting allowed by the algorithm parameters, and no change will be made.

If the frame average is less than the AGC Bottom Threshold the algorithm attempts to increase the camera's sensitivity by changing to a higher operational setting. If the current operational setting number is less than the AGC High Operational Bound then the algorithm increases the operational setting number by one. If the current operational setting number is equal to the AGC High Operational Bound then the camera is at the most sensitive setting allowed by the algorithm parameters, and no change will be made.

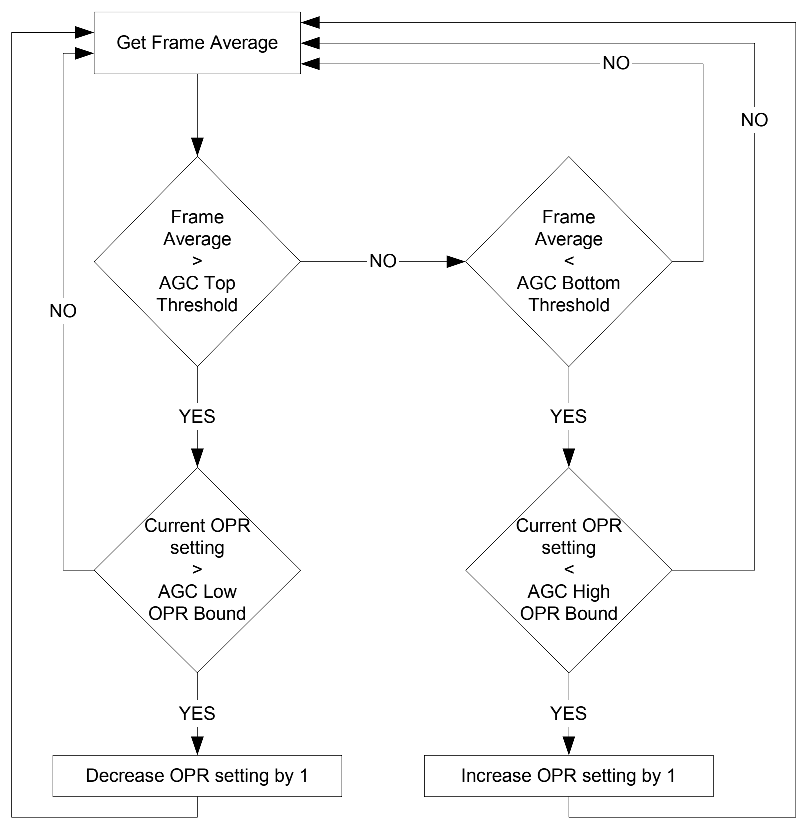

Figure 10. Automatic gain control algorithm flow chart.

For the AGC algorithm to operate properly the following conditions must be met:

- The operational configurations used by the AGC algorithm should be in order of increasing sensitivity. The AGC High OPR Bound must have the highest sensitivity and the AGC Low OPR Bound must have the lowest sensitivity. All operational settings in between the high and low bounds must fall within these sensitivity levels and be arranged in increasing sensitivity order.

- The AGC algorithm performs best if the relative sensitivity levels of the operational settings used are evenly spaced. For example, if OPR 1 is twice as sensitive as OPR 0, it should be half as sensitive as OPR 2.
- The OPR sensitivity spacing and the AGC threshold bounds should be selected so that the algorithm can find a solution for all frame averages. For example, if the OPR sensitivity spacing is configured to be 4X and the threshold values are set to 1,000 and 3,000 counts the AGC algorithm will fail when the frame average is 800 counts. The algorithm will attempt to increase the camera sensitivity by increasing to the next OPR setting which is four times more sensitive, resulting in a frame average of 3,200 counts, which is now above the upper threshold level. This scenario will cause the AGC algorithm to oscillate between two OPR setting, neither of which will satisfy the algorithm requirements with the given parameters. To remedy this problem the OPR sensitivity spacing can be reduced to 2X, or the threshold values could be changed to 750 and 3,250 counts, or some combination of the two. To assure that the AGC algorithm does not oscillate the sensitivity spacing should be less than the result of the upper threshold divided by the lower threshold.

The factory AGC thresholds are typically centered around 2048, the middle of the pixel digital value range. (See Appendix B for the factory configuration of these parameters for your particular camera.) These thresholds may be adjusted from their factory configuration to better match a particular scene's content and desired AGC operation. For example, if night imaging in an urban environment, areas of saturated pixels may result around man-made light sources such as street lamps and automobile headlights with the factory default AGC thresholds. However, lowering the Top and Bottom AGC thresholds to 1000 and 500, for example, would result in the camera's AGC algorithm maintaining a frame average in the bottom quarter of the range, permitting more bright scene content to be imaged without saturation.

Note: That the when AGC is enabled operational configurations can be loaded using the `OPR` command. However, the AGC algorithm will override the user set operation configuration if the frame average falls outside of the AGC thresholds. The `OPR?` and `FRAME:AVG?` commands can be used to monitor operation of the AGC algorithm.

The image enhancement algorithm of the SU-KTS also monitors the image frame statistics and, if enabled, performs a digital offset and gain computation on each pixel of the frame where the gain and offset coefficients for each frame are computed using previous frame statistics and a user selected parameter.

The frame statistics used to determine the enhancement gain and offset coefficients are the frame average value which is also used by the AGC algorithm and the frame data "width." The data width of the current frame is defined as the average absolute value of the difference between the current frame's pixel values and the last frame(s) average. With this definition, the width parameter can be used as a metric of the contrast of the frame.

With the previous frame(s) average value AVG and width WID, both of which are computed according to the average parameter configured through the `ENH:AVG` command, enhancement offset coefficient EO and enhancement gain coefficient EG are calculated for each frame according to the following relations:

$$EO = MAX[0, (AVG - (\frac{CF}{2^{12}} \times WID))]$$

$$EG = \frac{(2^{12} - 1)}{MAX[(MIN[2^{12}, (AVG + (\frac{CF}{2^{12}} \times WID))] - EO), MINGAINDIVIDER]} = \frac{(2^{12} - 1)}{GAINDIVIDER}$$

where CF is the enhancement contrast factor parameter set through the `ENH:CF` command. The minimum allowed value for $GAINDIVIDER$, $MINGAINDIVIDER$, is set through the `ENH:DIV` command. The smaller the $GAINDIVIDER$ value allowed, the larger the maximum EG gain that can be applied during enhancement.

If enhancement is enabled, these coefficients are applied to each pixel value of the frame $PIXIN$ to produce the enhanced pixel value $PIXENH$ according to the following relation:

$$PIXENH = (PIXIN - EO) \times EG$$

with $PIXENH$ bound to [0, 4095].

By applying this enhancement algorithm, the pixel data will be linearly stretched over the available pixel bit depth resulting in a higher contrast scene for display. The amount that the data is stretched is affected by the CF parameter, with a smaller CF value creating a larger EG gain but possibly causing a larger number of pixel values to be clipped by the [0, 4095] bounds. In Figure 11 the effect of applying this enhancement algorithm on an example pixel data histogram is shown.

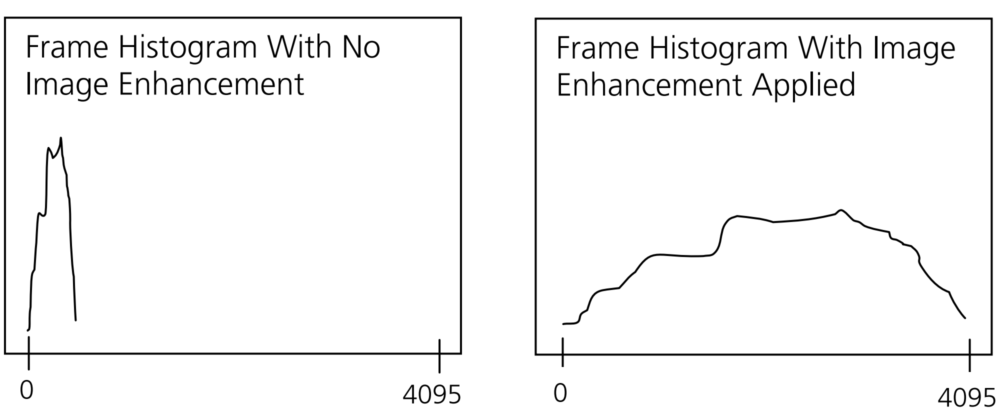

Figure 11. Example of enhancement algorithm effect on frame histogram.

5.4.4.1 Set Enhancement/AGC Frame Average and Width Weight

Description: Sets the weight by which the most recent frame's statistics are used to affect the reported frame average and width. The current frame average, $CURRENTAVG$, is computed as follows

$$CURRENTAVG = LASTAVG - \frac{(LASTAVG - NEWAVG)}{2^N}$$

where $LASTAVG$ is the last reported frame average value, $NEWAVG$ is the average pixel value of the most recently acquired frame, and N is the value set by this command. *Note: If N = 0, the currently reported average is the average pixel value of the most recently acquired frame. This setting will affect the value returned by the* `FRAME:AVG?` *command. Note: If N = 0, the current reported average is the average pixel value of the most recently acquired frame. If N > 0 and AGC is enabled, the stability of the AGC control loop may be affected. If the AGC loop does not converge to a single operational setting when imaging a fixed scene, reduce N until the control loop stabilizes.*

Setting Type	Global
Command	`ENH:AVG` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	0 to 11
Return Values	none
Example	`ENH:AVG 0`

5.4.4.2 Get Enhancement/AGC Frame Average Weight

Description	Returns the weight by which the most recent frame's statistics are used to affect the reported frame average and width.
Setting Type	Global
Command	`ENH:AVG?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 11
Example	`ENH:AVG?      -- query command`
	`0             -- response`

5.4.4.3 Set Enhancement Contrast Factor

Description	Sets the contrast factor used by the image enhancement algorithm.
Setting Type	Global
Command	`ENH:CF` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	0 to 65535
Return Values	none
Example	`ENH:CF 8190`

5.4.4.4 Get Enhancement Contrast Factor

Description	Returns the contrast factor value.
Setting Type	Global
Command	`ENH:CF?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 65535
Example	`ENH:CF?          -- query command` `8190             -- response`

5.4.4.5 Set Enhancement Minimum Gain Divider

Description	Sets the minimum gain divider value, *MINGAINDIVIDER*, used in the computation of the enhancement gain coefficient.
Setting Type	Global
Command	`ENH:DIV` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	0 to 16383
Return Values	none
Example	`ENH:DIV 100`

5.4.4.6 Get Enhancement Minimum Gain Divider

Description	Returns the minimum gain divider value, *MINGAINDIVIDER*, used in the computation of the enhancement gain coefficient.
Setting Type	Global

Command	`ENH:DIV?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 16383
Example	`ENH:DIV?` -- query command `100` -- response

5.4.4.7 Set Enhancement/AGC Saturated Pixel State

Description	Sets saturated pixel inclusion or omission for the purpose of calculating image statistics used by the image enhancement and automatic gain control algorithms. This setting will impact the value returned by the `FRAME:AVG?` command.
Setting Type	Global
Command	`ENH:SAT` *`state`*
Parameters	*`state`*
Type	string
Range	

`ON`	Saturated Pixels Omitted
`OFF`	Saturated Pixels Included

Return Values	none
Example	`ENH:SAT ON`

5.4.4.8 Get Enhancement/AGC Saturated Pixel State

Description	Returns if saturated pixels are omitted from image statistics.
Setting Type	Global
Command	`ENH:SAT?`
Parameters	none
Return Values	*`state`*
Type	string
Range	

`ON`	Saturated Pixels Omitted
`OFF`	Saturated Pixels Included

Example	`ENH:SAT?` -- query command `ON` -- return value

5.4.4.9 Set Enhancement State

Description Sets the state of the image enhancement algorithm.

Setting Type Global

Command `ENH:ENABLE` *`state`*

Parameters *`state`*

Type string

Range

`ON`	Enables Enhancements
`OFF`	Disables Enhancements

Return Values none

Example `ENH:ENABLE ON`

5.4.4.10 Get Enhancement State

Description Returns the state of the image enhancement algorithm.

Setting Type Global

Command `ENH:ENABLE?`

Parameters none

Return Values *`state`*

Type string

Range

`ON`	Enhancements Enabled
`OFF`	Enhancements Disabled

Example

```
ENH:ENABLE?     -- query command
ON              -- return value
```

5.4.4.11 Set AGC State

Description Sets the state of the AGC algorithm.

Setting Type Global

Command `AGC:ENABLE` *`state`*

Parameters *`state`*

Type string

Range

`ON`	Enables AGC
`OFF`	Disables AGC

Return Values none

Example `AGC:ENABLE ON`

5.4.4.12 Get AGC State

Description	Returns the state of the AGC algorithm.
Setting Type	Global
Command	`AGC:ENABLE?`
Parameters	none
Return Values	*`state`*
Type	string
Range	

`ON`	AGC enabled
`OFF`	AGC disabled

Example
```
AGC:ENABLE?     -- query command
ON              -- return value
```

5.4.4.13 Set AGC Top Threshold

Description	Sets the top threshold in digital counts for the AGC algorithm. When the frame average exceeds this threshold the algorithm attempts to decrease the camera sensitivity by switching to a lower operational setting. The AGC top threshold should be set to a value greater than the bottom threshold.
Setting Type	Global
Command	`AGC:THRESH:TOP` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	0 to 4095
Return Values	none
Example	`AGC:THRESH:TOP 3000`

5.4.4.14 Get AGC Top Threshold

Description	Returns the top threshold value in digital counts for the AGC algorithm.
Setting Type	Global
Command	`AGC:THRESH:TOP?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 4095

Example
```
AGC:THRESH:TOP?-- query command
3000            -- return value
```

5.4.4.15 Set AGC Bottom Threshold

Description	Sets the bottom threshold in digital counts for the AGC algorithm. When the frame average falls below this threshold the algorithm attempts to increase the camera sensitivity by switching to a higher operational setting. The AGC bottom threshold should be set to a value less than the top threshold.
Setting Type	Global
Command	`AGC:THRESH:BOT` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	0 to 4095
Return Values	none
Example	`AGC:THRESH:BOT 1000`

5.4.4.16 Get AGC Bottom Threshold

Description	Returns the bottom threshold value in digital counts for the AGC algorithm.
Setting Type	Global
Command	`AGC:THRESH:BOT?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 4095
Example	`AGC:THRESH:BOT?-- query command` `1000           -- return value`

5.4.4.17 Set AGC Low Operational Setting

Description	This command used in conjunction with the set AGC high operational setting defines the range of operational settings that are available for use by the AGC algorithm. **See section 5.4.4 for discussion of selecting this parameter value.**
Setting Type	Global
Command	`AGC:OPR:LOW` *`opr_setting`*
Parameters	*`opr_setting`*
Type	unsigned integer
Range	0 to 20, limited by number of operational settings than currently exist.
Return Values	none
Example	`AGC:OPR:LOW 0`

5.4.4.18 Get AGC Low Operational Setting

Description	Returns the lowest operational setting available for use by the AGC algorithm.
Setting Type	Global
Command	`AGC:OPR:LOW?`
Parameters	none
Return Values	*opr_setting*
Type	unsigned integer
Range	0 to 20
Example	`AGC:OPR:LOW?   -- query command` `0              -- return value`

5.4.4.19 Set AGC High Operational Setting

Description	This command used in conjunction with the set AGC low operational setting defines the range of operational settings that are available for use by the AGC algorithm. **See section 5.4.4 for discussion of selecting this parameter value.**
Setting Type	Global
Command	`AGC:OPR:HIGH` *opr_setting*
Parameters	*opr_setting*
Type	unsigned integer
Range	0 to 20, limited by number of operational settings than currently exist.
Return Values	none
Example	`AGC:OPR:HIGH 7`

5.4.4.20 Get AGC High Operational Setting

Description	Returns the highest operational setting available for use by the AGC algorithm.
Setting Type	Global
Command	`AGC:OPR:HIGH?`
Parameters	none
Return Values	*opr_setting*
Type	unsigned integer
Range	0 to 20
Example	`AGC:OPR:HIGH?  -- query command` `7              -- return value`

5.4.4.21 Get Frame Average

Description	Returns the average pixel value in digital counts. An exponentially weighted moving average is used to calculate the average, with the number of frames set using the `ENH:AVG` command.
Setting Type	N/A
Command	`FRAME:AVG?`
Parameters	none
Return Values	*`average_value`*
Type	unsigned integer
Range	0 to 4095
Example	`FRAME:AVG?` `-- query command` `2172` `-- return value`

5.4.5 Pixel Clock Commands

The camera electronics are designed to support a variety of focal plane arrays with varying requirements for pixel clock rate. The pixel clock is operated for the supported focal plane array at the maximum pixel clock rate reported through the command interface. The pixel clock period is needed to calculate exposure and frame times.

5.4.5.1 Get Pixel Clock Maximum Rate

Description	Returns the FPA pixel clock rate in Hertz.
Setting Type	Global
Command	`PIXCLK:MAX?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 4294967295
Example	`PIXCLK:MAX?` `-- query command` `6104900` `-- return value`

5.4.6 Frame and Exposure Control Commands

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

$$EXPPERIOD = EXPCYCLES \times PIXELPERIOD$$

where $EXPCYCLES$ is the exposure period set using the EXP command. See section 5.4.5 for a discussion on determining the pixel clock period.

The internally timed frame period is given by

$$FRAMEPERIOD = FRAMECYCLES \times PIXELPERIOD$$

where $FRAMEPERIOD$ is the frame period set using the `FRAME:PERIOD` command. The maximum exposure time for a particular frame period is equal to the frame period less the FPA required minimum dead, or non-integration, time of 15 pixel periods, or 2.5 μs.

Note: When scanning is enabled the exposure period and frame period specified must be compatible with each other or a command error will occur. Therefore, knowledge of the current exposure and frame periods is required and the order in which the exposure and frame period are changed is crucial for success. Going from a short exposure and frame period to a longer exposure and frame period requires first increasing the frame period and then the exposure period, while going in the opposite direction requires shortening the exposure period first. To avoid issues regarding what setting is updated first, scanning can be disabled. Once scanning is disabled, the exposure and frame periods can be set in any order and then scanning re-enabled. However, exposure and frame periods compatible with each other and the timing requirements of the FPA must be specified otherwise an error will be returned when attempting to enable scanning.

Note: When the camera is set to operate in an externally triggered timing mode or the frame readout is synchronized to the analog video output, the exposure and frame period settings may not apply. (See section 5.4.7 for a description of supported triggered timing modes.)

5.4.6.1 Set Exposure Period

Description	Sets the $EXPCYCLES$, which controls the exposure time (see equation in section 5.4.6).
Setting Type	Operational
Command	`EXP` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	1 to 16777214
Return Values	none
Example	`EXP 364651`

5.4.6.2 Get Exposure Period

Description	Returns the $EXPCYCLES$, which controls the exposure time (see equation in section 5.4.6).
Setting Type	Operational
Command	`EXP?`

Parameters	none
Return Values	*value*
Type	unsigned integer
Range	1 to 16777214
Example	`EXP?      -- query command` `364651    -- return value`

5.4.6.3 Set Frame Period

Description	Sets the frame period in units of pixel clock cycles.
Setting Type	Operational
Command	`FRAME:PERIOD` *value*
Parameters	*value*
Type	unsigned integer
Range	1 to 16777214
Return Values	none
Example	`FRAME:PERIOD 366610`

5.4.6.4 Get Frame Period

Description	Returns the frame period in units of pixel clock cycles.
Setting Type	Operational
Command	`FRAME:PERIOD?`
Parameters	none
Return Values	*value*
Type	unsigned integer
Range	1 to 16777214
Example	`FRAME:PERIOD?  -- query command` `366610         -- return value`

5.4.6.5 Set Exposure Period with Minimum Frame Period

Description	Sets the exposure period in pixel clock cycles and the frame period to the smallest allowed value, creating the highest allowed frame rate for the requested exposure time.
Setting Type	Operational
Command	`EXP:MAXRATE` *value*
Parameters	*value*
Type	unsigned integer
Range	1 to 16777214

Return Values none

Example `EXP:MAXRATE 26348`

5.4.6.6 Set State of Synchronization of FPA Readout to Analog Video

Description Sets the state of synchronization of FPA frame readout to the analog video frame rate. If off and not in an external trigger mode that controls the frame timing, the frame period is determined by the value set by the `FRAME:PERIOD` command. If on and in a timing mode where the frame period is being internally timed by the camera, then the FPA readout frame period becomes N video frame or field periods where N is the value of the FPA frame period setting divided by the analog video frame or field period rounded up to next highest integer. The EIA-170 frame period of 33.4 ms is used when in full resolution analog video mode and the field period of 16.7 ms is used when in 2X zoom mode (see section 5.4.10.4). For example, if the value set by the `FRAME:PERIOD` command is smaller than 33.4 ms, the analog video is in full resolution mode, and the synchronization of FPA readout to analog video is on, then one FPA frame will be readout for every analog video frame. *Note: The period set by the `FRAME:PERIOD` command must still be compatible with the selected exposure time and frame readout period even when FPA readout is synchronized to the analog video for proper camera operation to be guaranteed.*

Setting Type Global

Command `SCAN:VIDSYNC` *`state`*

Parameters *`state`*

Type string

Range

`ON`	Enable scan sync to analog video
`OFF`	Disable scan sync to analog video

Return Values none

Example `SCAN:VIDSYNC ON`

5.4.6.7 Get State of Synchronization of FPA Readout to Analog Video

Description Returns the state of synchronization of FPA frame readout to the analog video frame rate.

Setting Type Global

Command `SCAN:VIDSYNC?`

Parameters none

Return Values `state`

Type string

Range

ON	Sync scan to analog video enabled
OFF	Sync scan to analog video disabled

Example
```
SCAN: VIDSYNC? -- query command
ON             -- return value
```

5.4.7 Trigger Commands

The user can change the trigger mode via the serial communication ASCII command `TRIG:MODE`.

When trigger mode 0 is selected, the camera is free-running with the exposure and frame rate internally timed. (See section 5.4.6 for description of commands to control the internally timed exposure and frame period parameters). When in trigger mode 0, the timing sequence of the camera is as shown in Figure 12.

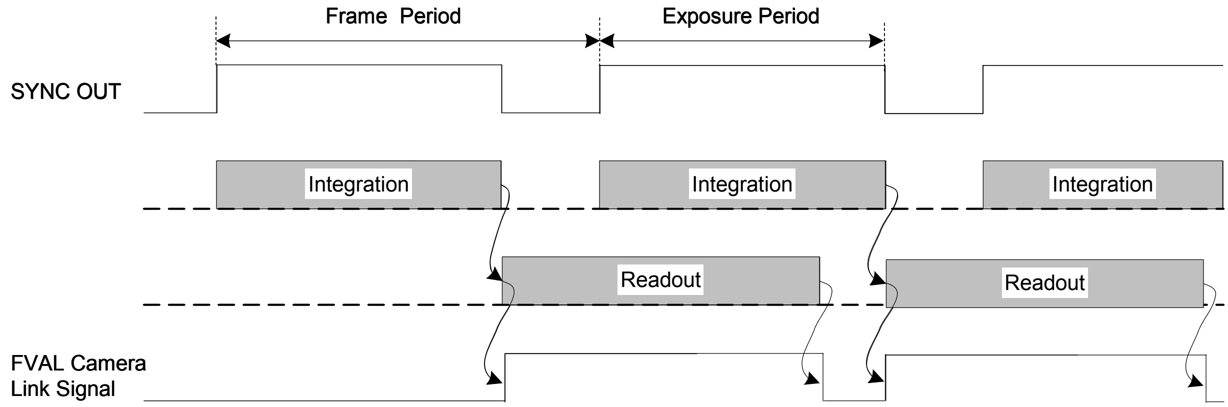

Figure 12. Trigger mode 0 exposure and readout timing sequence.

In trigger modes 1, 2, and 3, an external trigger timing signal is used to control the exposure and readout timing. The external trigger signal can be applied to the camera through the *TRIGGER* SMA connector on the camera's back panel or the Camera Link CC1 signal. The signal source can be selected via the serial communication ASCII command `TRIG:SOURCE`. The polarity of the trigger sources can be selected via the serial communication ASCII command `TRIG:POL`. An additional time delay can be added to trigger signal via the serial communication ASCII command `TRIG:DELAY.` Trigger delay times discussed in the following paragraphs are values produced when the added trigger delay is 0.

In trigger mode 1, the camera uses the external trigger signal to set the frame rate and internally times the exposure. The exposure time is set by the operational setting chosen and can be overridden by the user with the EXP command. The available integration times for the Base OPR settings are shown in Appendix B. The camera detects a trigger transition via the currently selected trigger input to initiate exposure (integration). It uses the low to high, if an active high polarity is selected, or the high to low transition, if an active low polarity is selected. The delay between this trigger transition and start of exposure is 5 to 6 pixel periods. (See section 5.4.5 for a discussion on determining the pixel clock period.) The ceiling of the trigger rate for this mode is the maximum frame rate. The timing sequence of the camera for trigger mode 1 is shown in Figure 13.

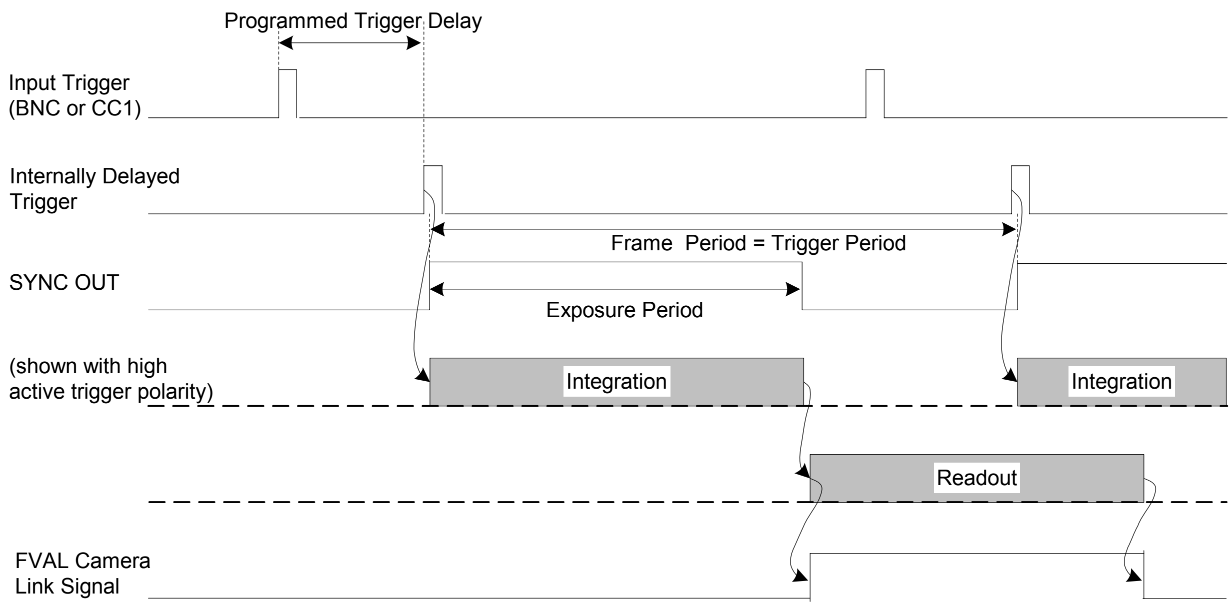

Figure 13. Trigger mode 1 exposure and readout timing sequence.

In trigger mode 2, the camera uses the external trigger to both externally set the exposure time and the frame rate. During this external triggered mode, the camera waits for a trigger pulse before initiating a scan of the focal plane array. The camera detects a trigger transition via the currently selected trigger input to initiate the start of exposure (integration). It uses the low to high transition, if an active high polarity is selected, or the high to low transition, if an active low polarity is selected. A trigger transition of the opposite polarity ends the exposure. In other words, the active trigger pulse width determines the exposure time and the trigger frequency determines the frame rate. In trigger mode 2, the delay between the trigger transition and start of exposure is 3 to 4 pixel clock periods. The timing sequence of the camera for trigger mode 2 is shown in Figure 14.

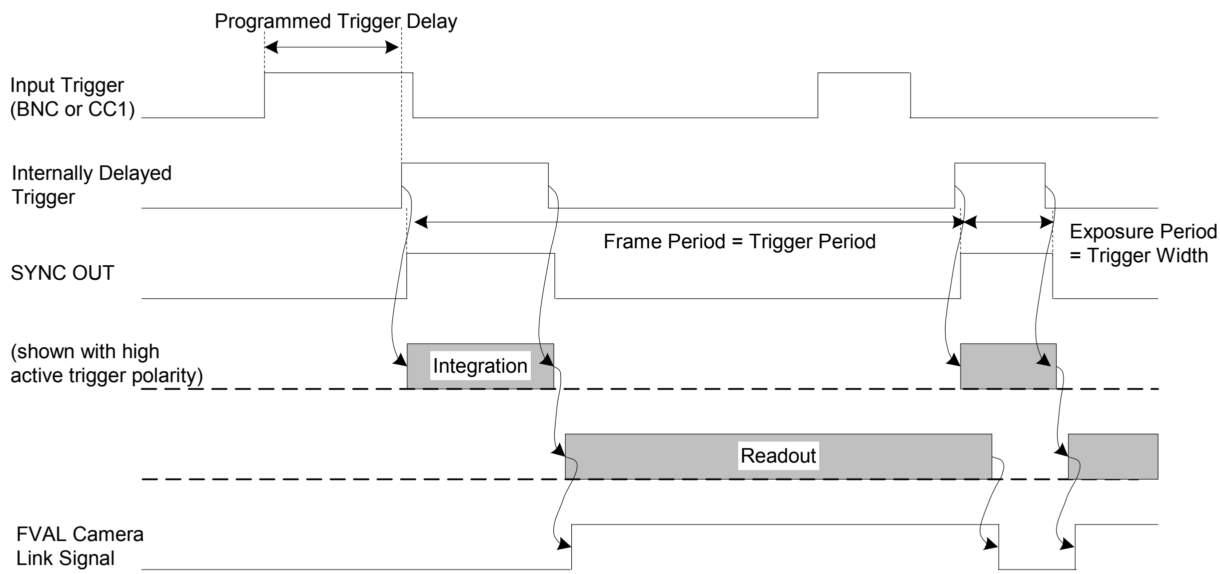

Figure 14. Trigger mode 2 exposure and readout timing sequence.

The minimum active trigger pulse width in trigger mode 2 is 55 μs. There is no maximum allowable trigger pulse width, but the user should be aware that the longer the exposure, the more dark current that is accumulated by the focal plane array. If the exposure is too long, the focal plane array may saturate with dark current. The ceiling of the trigger rate for this mode is the maximum frame rate.

In trigger mode 3, the external trigger signal gates on and off the internal timing of the exposure and line rate. That is, whenever the selected trigger input is in an inactive state the camera is paused. Whenever the selected trigger input is active, the camera will operate as though it were free-running. Once an exposure has been initiated, the camera will finish that particular exposure and readout even though the trigger might have already transitioned to an inactive state. Because of this, the trigger should be held in the inactive state for a minimum of the exposure period plus the frame readout time. The delay between this trigger transition and start of exposure is 5 to 6 pixel periods. The timing sequence of the camera for trigger mode 3 is shown in Figure 15.

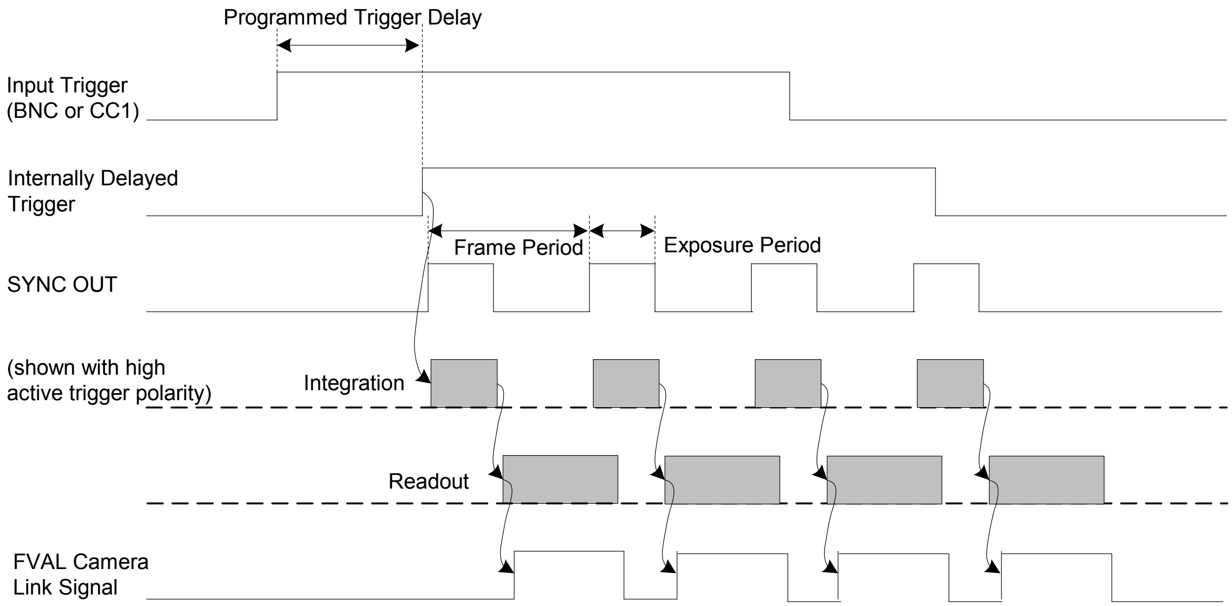

Figure 15. Trigger mode 3 exposure and readout timing sequence.

While in any externally triggered mode all correction modes are available, however, the factory offset and gain corrections may not be valid for the given users integration time or repetition rate. To configure the factory offset and gain corrections for a trigger mode other than the internal trigger mode, please contact your SUI representative.

5.4.7.1 Set Trigger Mode

Description: Sets the trigger and timing modes. *Note: Execution of this command that results in a change in trigger mode will also apply a reset to the trigger and FPA scan digital logic clearing any existing trigger or scan errors.*

Setting Type: Global

Command: `TRIG:MODE` *`mode`*

Parameters: *`mode`*

Type: unsigned integer

Range:

0	Internally triggered, internally timed
1	Externally triggered, internally timed
2	Externally triggered, externally timed
3	Externally gated, internally timed

Return Values: none

Example: `TRIG:MODE 1`

5.4.7.2 Get Trigger Mode

Description Returns the trigger and timing mode.

Setting Type Global

Command `TRIG:MODE?`

Parameters none

Return Values *`mode`*

Type unsigned integer

Range

0	Internally triggered, internally timed
1	Externally triggered, internally timed
2	Externally triggered, externally timed
3	Externally gated, internally timed

Example

```
TRIG:MODE?      -- query command
1               -- return value
```

5.4.7.3 Set Trigger Source

Description Sets the trigger source. The camera can accept triggers from either the trigger SMA connector on the back panel or the Camera Link CC1 signal. Trigger source mode 3 can be used to gate one trigger source from reaching the camera by controlling the state of the other source. *Note: Trigger source mode 3 should not be selected if one trigger source is not actively being controlled, since it may unexpectedly cause the other trigger source to be gated off. Note: Execution of this command that results in a change in trigger source will also apply a reset to the trigger and FPA scan digital logic clearing any existing trigger or scan errors.*

Setting Type Global

Command `TRIG:SOURCE` *`value`*

Parameters *`value`*

Type unsigned integer

Range

0	None
1	Trigger SMA
2	Camera Link CC1
3	Trigger SMA or Camera Link CC1

Return Values none

Example `TRIG:SOURCE 2`

5.4.7.4 Get Trigger Source

Description Returns the trigger source.

Setting Type Global

Command `TRIG:SOURCE?`

Parameters none

Return Values *`value`*

Type unsigned integer

Range

0	None
1	Trigger SMA
2	Camera Link CC1
3	Trigger SMA or Camera Link CC1

Example
```
TRIG:SOURCE?    -- query command
2               -- return value
```

5.4.7.5 Set Trigger Polarity

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

Setting Type Global

Command `TRIG:POL` *`value`*

Parameters *`value`*

Type unsigned integer

Range

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

Return Values none

Example `TRIG:POL 0`

5.4.7.6 Get Trigger Polarity

Description Returns the trigger polarity.

Setting Type Global

Command `TRIG:POL?`

Parameters none

Return Values *value*

Type unsigned integer

Range

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

Example
```
TRIG:POL?      -- query command
0              -- return value
```

5.4.7.7 Set Trigger Delay

Description Sets the number of pixel clock cycle delay to add to the external trigger source signal. This delay is in addition to the minimum delays discussed in section 5.4.7. The selected delay must be less than the trigger source period for proper delay operation.

Setting Type Global

Command `TRIG:DELAY` *value*

Parameters *value*

Type unsigned integer

Range 0 to 16777215

Return Values none

Example `TRIG:DELAY 1000`

5.4.7.8 Get Trigger Delay

Description Returns the trigger delay setting.

Setting Type Global

Command `TRIG:DELAY?`

Parameters none

Return Values *value*

Type unsigned integer

Range 0 to 16777215

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

5.4.8 Gain Commands

5.4.8.1 Set Digital Gain

Description: Sets the digital gain value. Digital gain can be used to ensure that the image data fills the digital output range when offset and gain corrections are applied. In addition, digital gain can be used to stretch low signal images across a greater portion of the output range.

Setting Type: Global

Command: `GAIN:DIGITAL` *`value`*

Parameters: *`value`*

Type: string

Range:

1X	Apply 1X digital gain multiplier
2X	Apply 2X digital gain multiplier
4X	Apply 4X digital gain multiplier
8X	Apply 8X digital gain multiplier

Return Values: none

Example: `GAIN:DIGITAL 2X`

5.4.8.2 Get Digital Gain

Description: Returns the digital gain value

Setting Type: Global

Command: `GAIN:DIGITAL?`

Parameters: none

Return Values: *`value`*

Type: string

Range:

1X	1X digital gain multiplier applied
2X	2X digital gain multiplier applied
4X	4X digital gain multiplier applied
8X	8X digital gain multiplier applied

Example:

```
GAIN:DIGITAL?  -- query command
2X             -- return value
```

5.4.9 Imager Scanning Commands

5.4.9.1 Set Scan State

Description	Sets the imager scanning state. When imager scanning is disabled no data will be available at the digital output port and the analog video image content will not be updated.
Setting Type	Global
Command	`SCAN:STATE` *`state`*
Parameters	*`state`*
Type	string
Range	

`ON`	Enable imager scanning
`OFF`	Disable imager scanning

Return Values	none
Example	`SCAN:STATE ON`

5.4.9.2 Get Scan State

Description	Returns the state of the imager scanning.
Setting Type	Global
Command	`SCAN:STATE?`
Parameters	none
Return Values	*`state`*
Type	string
Range	

`ON`	Imager scanning enabled
`OFF`	Imager scanning disabled

Example

```
SCAN:STATE?     -- query command
ON              -- return value
```

5.4.9.3 Set Over-Scan State

Description	Sets the over-scan state. When over-scan is enabled the line valid signal width is increased to include inactive pixels before and after the active pixels within a line and additional, inactive lines of data are returned. When over-scan is disabled the number of pixels per line and lines per frame returned is the resolution of the FPA. See timing diagrams in section 3.1.2 for a detailed description of timing signals and over-scan data.
Setting Type	Global
Command	`SCAN:OVER` *`state`*
Parameters	*`state`*

Type string

Range

`ON`	Enable over-scan
`OFF`	Disable over-scan

Return Values none

Example `SCAN:OVER ON`

5.4.9.4 Get Over-Scan State

Description Returns the over-scan state.

Setting Type Global

Command `SCAN:OVER?`

Parameters none

Return Values *`state`*

Type string

Range

`ON`	Over-scan enabled
`OFF`	Over-scan disabled

Example

```
SCAN:OVER?      -- query command
ON              -- return value
```

5.4.10 Analog Video Commands

An analog composite video output is available at the SMA connector on the back of the camera labeled *VIDEO OUT* as shown in Figure 1. The analog video signal is compliant with the EIA-170 video standard. This analog video frame displays a maximum of 645 active pixels per line and 485 active lines of information at 30 frames per second by presenting two, interlaced video fields of 242.5 lines in 1/60th of a second each. To allow independent timing operation of the focal plane array readout and the analog video output and allow progressive readout of the focal plane array with an interlaced analog video signal, the SU-KTS camera passes the image data through a dual-port memory buffer.

The dual-port video memory is configured to store up to two 645 x 485 frames of information at 12-bit resolution. Pixel data is passed through a 12 to 12-bit look-up table before being written into the dual-port memory. The commands of this section describe supported selectable modes that affect the look-up table and dual-port video memory read/write operations of the camera.

5.4.10.1 Blank Video Buffer

Description Writes black video pixel value to all video memory locations. If scanning is disabled, the video will remain black until the next frame readout occurs.

Setting Type	N/A
Command	`VID:BLANK`
Parameters	none
Return Values	none
Example	`VID:BLANK      -- black out the analog video`

5.4.10.2 Set Video Double Buffer Mode State

Description

Set the video dual-port memory double buffer write/read mode state. If on, two frame buffers are used to store the analog video frames and writing is performed to alternate buffers. If a read is still being performed on the next alternate buffer to be written, the write of the frame is skipped. Similarly, reading from the dual-port memory in double buffer mode is performed from alternate frames buffers as long as a write is not in progress. If a write is in progress, a read from the same frame buffer is repeated. This mode creates an analog video signal where every analog frame contains data from a single FPA readout. However, if the focal plane array readout is not synchronized to the analog video frame rate (see section 5.4.6.6), not all readout frames will be displayed. With this mode enabled there will also be a delay between the time the FPA readout occurred and the time the data is available on the analog video of between half and a full analog video frame (16.7 ms to 33.4 ms) for full resolution mode and up to one analog video field (16.7 ms) in 2X zoom mode. If the readout of the focal plane is synchronized to the analog video frame rate, the delay will be one-half of the analog video frame period (16.7 ms). If double buffer mode is off, reading and writing occurs using a single frame buffer and writing is never inhibited. With this mode, the delay between the readout of pixel data and when it is available on the analog video output is reduced, but a single analog frame may contain data from different focal plane array read frames.

Setting Type	Global
Command	`VID:2BUFF` *`state`*
Parameters	*`state`*
Type	string
Range	

`ON`	Enable double buffer video mode
`OFF`	Disable double buffer video mode

Return Values	none
Example	`VID:2BUFF ON`

5.4.10.3 Get Video Double Buffer Mode State

Description: Returns the video dual-port memory double buffer write/read mode state.

Setting Type: Global

Command: `VID:2BUFF?`

Parameters: none

Return Values: *`state`*

Type: string

Range:

`ON`	Video double buffer video mode enabled
`OFF`	Video double buffer video mode disabled

Example:

```
VID:2BUFF?      -- query command
ON              -- return value
```

5.4.10.4 Set Video 2X Zoom Mode State

Description: Set the video 2X zoom mode state. If on, the analog video resolution is 322 pixels per line by 242 lines where independent focal plane array readout frames can be presented in each EIA-170 field. When 2X zoom is enabled and the FPA readout is being synchronized to the analog video, unique readout frames will be presented in each 1/60 of a second EIA-170 video field when the internally timed frame period is set to a value less that the analog video field period (see section 5.4.6.6).

Setting Type: Operational

Command: `VID:ZOOM` *`state`*

Parameters: *`state`*

Type: string

Range:

`ON`	Enable analog video zoom mode
`OFF`	Disable analog video zoom mode

Return Values: none

Example: `VID:ZOOM OFF`

5.4.10.5 Get Video 2X Zoom Mode State

Description: Returns the video 2X zoom mode state.

Setting Type: Operational

Command: `VID:ZOOM?`

Parameters: none

Return Values: *`state`*

Type string

Range

`ON`	Analog video zoom mode enabled
`OFF`	Analog video zoom mode disabled

Example

```
VID:ZOOM? -- query command
OFF       -- return value
```

5.4.10.6 Set Video Buffer Read Column Start

Description: Sets the column on which reading from the dual-port video memory begins. This number is programmed in column triplets (a result of the dual-port memory architecture). The value can be used to change the location of the 322 x 242 zoomed analog video frame within the 320 x 240 readout frame.

Setting Type: Operational

Command: `VID:RD:COL` *`value`*

Parameters: *`value`*

Type: unsigned integer

Range: 0 to 255

Return Values: none

Example

```
VID:RD:COL 50  -- begin read on FPA col 150
```

5.4.10.7 Get Video Buffer Read Column Start

Description: Returns the column triplet on which reading from the dual-port video memory begins.

Setting Type: Operational

Command: `VID:RD:COL?`

Parameters: none

Return Values: *`value`*

Type: unsigned integer

Range: 0 to 255

Example

```
VID:RD:COL?    -- query command
50             -- return value
```

5.4.10.8 Set Video Buffer Read Row Start

Description	Sets the row on which reading from the dual-port video memory begins. This number is programmed in row doublets when in full-resolution video mode and single rows when in 2X zoom video mode. The value can be used to change the location of the 322 x 242 zoomed analog video frame within the 320 x 240 readout frame.
Setting Type	Operational
Command	`VID:RD:ROW` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	0 to 255
Return Values	none
Example	`VID:RD:ROW 100 -- begin read on FPA row 100`

5.4.10.9 Get Video Buffer Read Row Start

Description	Returns the row on which reading from the dual-port video memory begins. The number is in row doublets when in full-resolution video mode and single rows when in 2X zoom video mode.
Setting Type	Operational
Command	`VID:RD:ROW?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 215
Example	`VID:RD:ROW?    -- query command` `100            -- return value`

5.4.10.10 Set Video Look-Up Table Number

Description	Sets the look-up table number to be used. Two preprogrammed table mappings are available.
Setting Type	Global
Command	`VID:LUT` *`value`*
Parameters	*`value`*
Type	unsigned integer
Range	

0	Linear Mapping
1	Gamma Mapping

Return Values none

Example `VID:LUT 1 -- use Gamma LUT mapping`

5.4.10.11 Get Video Look-Up Table Number

Description: Returns look-up table number being used.

Setting Type: Global

Command: `VID:LUT?`

Parameters: none

Return Values: *`value`*

Type: unsigned integer

Range

0	Linear Mapping
1	Gamma Mapping

Example
```
VID:LUT?        -- query command
1               -- return value
```

5.4.11 Thermal Commands

5.4.11.1 Get Camera Internal Temperature

Description: Returns the internal camera temperature in degrees Celsius.

Setting Type: N/A

Command: `CAMERA:TEMP?`

Parameters: none

Return Values: *`temperature`*

Type: signed integer

Range: -55 to +125

Example
```
CAMERA:TEMP?    -- query command
25              -- return value
```

5.4.11.2 Get Thermoelectric Cooler Lock Status

Description: Returns status of the thermoelectric cooler stabilization lock of the focal plane array temperature to the set point. The temperature is considered locked when the current temperature is within ±0.1°C of the set point.

Setting Type: N/A

Command: `TEC:LOCK?`

Parameters: none

Return Values: *`status`*

Type: string

Range

`LOCKED`	TEC stabilized
`NOT LOCKED`	TEC not stabilized

Example `TEC:LOCK?` -- query command
`LOCKED` -- return value

5.4.11.3 Get Thermoelectric Cooler Set Point

Description Returns the thermoelectric cooler temperature set point in degrees Celsius.

Setting Type Operational

Command `TEC:SETPOINT?`

Parameters none

Return Values *`value`*

Type integer

Range -20 to 80

Example `TEC:SETPOINT?` -- query command
`22` -- return value

5.4.11.4 Set Thermoelectric Cooler State

Description Sets the state of the thermoelectric cooler.

Setting Type Global

Command `TEC:ENABLE`

Parameters *`state`*

Type string

Range

`ON`	Enables TEC
`OFF`	Disables TEC

Return Values none

Example `TEC:ENABLE ON`

5.4.11.5 Get Thermoelectric Cooler State

Description Returns the state of the thermoelectric cooler.

Setting Type Global

Command `TEC:ENABLE?`

Parameters *`state`*

Type string

Range

`ON`	TEC Enabled
`OFF`	TEC Disabled

Return Values	none
Example	`TEC:ENABLE?     -- query command`
	`ON              -- return value`

5.4.12 Digital Output Commands

5.4.12.1 Set Digital Output Mode

Description	Sets the mode of the Camera Link digital data interface. The asynchronous serial communication and trigger signaling of the Camera Link interface are not affected by this mode selection.
Setting Type	Global
Command	`DIGITAL:MODE` *`mode`*
Parameters	*`mode`*
Type	unsigned integer
Range	

`0`	Camera Link Data Disabled
`1`	Camera Link Data Enabled

Return Values	none
Example	`DIGITAL:MODE 1`

5.4.12.2 Get Digital Output Mode

Description	Returns the mode of the Camera Link digital interface.
Setting Type	Global
Command	`DIGITAL:MODE?`
Parameters	none
Return Values	*`mode`*
Type	unsigned integer
Range	

`0`	Camera Link Disabled
`1`	Camera Link Enabled

Example	`DIGITAL:MODE?   -- query command`
	`1               -- return value`

5.4.12.3 Set Digital Data Source

Description	The digital data source can be set to one of several stages along the digital signal path. *Note: When a particular stage is selected for the digital data source, the features for that stage must still be individually enabled for the effects of that stage to appear in the output data. For example, when* **`PAT`** *is selected*

as the digital data source, the test pattern or frame stamp feature must still be enabled using the commands of section 5.4.15 for the test data and frame stamp to be inserted in the data stream.

Setting Type Global

Command `DIGITAL:SOURCE` ***`source`***

Parameters ***`source`***

Type string

Range

`RAW`	Stage 1, Raw Data
`CORR`	Stage 2, Corrected Data
`ENH`	Stage 3, Enhanced Data
`PAT`	Stage 4, Test Pattern Data
`LUT`	Stage 5, Video LUT Data

Return Values none

Example `DIGITAL:SOURCE PAT`

5.4.12.4 Get Digital Data Source

Description Returns the source of the digital data.

Setting Type Global

Command `DIGITAL:SOURCE?`

Parameters none

Return Values ***`source`***

Type string

Range

`RAW`	Stage 1, Raw Data
`CORR`	Stage 2, Corrected Data
`ENH`	Stage 3, Enhanced Data
`PAT`	Stage 4, Test Pattern Data
`LUT`	Stage 5, Video LUT Data

Example

```
DIGITAL:SOURCE?-- query command
PAT            -- return value
```

5.4.13 Camera Information Commands

5.4.13.1 Get Camera Serial Number

Description Returns the camera serial number.

Setting Type Global

Command `CAMERA:SN?`

Parameters none

Return Values	*value*
Type	string
Range	up to 9 character alpha numeric string
Example	`CAMERA:SN?      -- query command`
	`0605S8350       -- return value`

5.4.13.2 Get Camera Part Number

Description	Returns the camera part number.
Setting Type	Global
Command	`CAMERA:PN?`
Parameters	none
Return Values	*value*
Type	string
Range	up to 9 character alpha numeric string
Example	`CAMERA:PN?      -- query command`
	`8000-0210       -- return value`

5.4.13.3 Get Camera Revision

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

5.4.13.4 Get Firmware Part Number

Description	Returns the part number of the camera's firmware.
Setting Type	Global
Command	`FIRM:PN?`
Parameters	none
Return Values	*value*
Type	string
Range	up to 9 character alpha numeric string

Example	`FIRM:PN?`	`-- query command`
	`4102-0061`	`-- return value`

5.4.13.5 Get Firmware Revision

Description	Returns the revision of the camera's firmware.	
Setting Type	Global	
Command	`FIRM:REV?`	
Parameters	none	
Return Values	*`value`*	
Type	string	
Range	up to 9 character alpha numeric string	
Example	`FIRM:REV?`	`-- query command`
	`C`	`-- return value`

5.4.13.6 Get Focal Plane Array Serial Number

Description	Returns the serial number of the camera's focal plane array.	
Setting Type	Global	
Command	`FPA:SN?`	
Parameters	none	
Return Values	*`value`*	
Type	string	
Range	up to 9 character alpha numeric string	
Example	`FPA:SN?`	`-- query command`
	`1705S1440`	`-- return value`

5.4.13.7 Get Focal Plane Array Number of Columns

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

5.4.13.8 Get Focal Plane Array Number of Rows

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

5.4.14 Status and Reset Commands

The user can poll the camera's error status with the ERROR? command, which returns a binary encoded 8-bit error value. A non-zero error code indicates that an error has occurred. If the error code is not zero, the status LED will also flash if enabled as described in section 3.1.5. Table 6 below can be used to decode the error value returned by the ERROR? command. A bit value of one indicates an error.

To reset an error bit the cause of the error must first be resolved. Once the error condition is resolved the error needs to be cleared. Most errors can be cleared by rebooting the camera. Some errors can be cleared by performing a firmware reset with the RESET command. Resolving the cause of the error alone will not clear the error.

Bit	Error Description	Cause	Resolution
0 (LSB)	PLL1 error	Internal error	Power cycle camera
1	PLL2 error	Internal error	Power cycle camera
2	Trigger error	Trigger rate too high	1) Reduce trigger rate 2) Reset firmware, reboot camera, or send a trigger command that causes a trigger parameter change (see section 5.4.7).
3	Scan error	Insufficient time to readout frame.	1) Increase readout time by modifying exposure and frame periods 2) Reset firmware, reboot camera, or send a trigger command that causes a trigger parameter change (see section 5.4.7).
4	Correction load error	Internal error	Reboot camera
5	TEC error	TEC unable to maintain set point or internal error	1) Resolve thermal issues - see section 0 Thermal Management 2) Reset firmware or reboot camera
6	Unused		Unused
7 (MSB)	Unused		Unused

Table 6. Error value descriptions, causes and resolutions

For applications that require continuous operation of the camera and need to change the mode of the camera from its power-on state, the user can monitor the power cycle status of the camera using the PWRDWN command. By setting the PWRDWN status flag after a reboot of the camera, the user can determine if power to the camera has been cycled or a reboot has occurred since the last poll.

5.4.14.1 Get Error Status

Description: Returns an encoded 8-bit error code. A bit value of one indicates an error has occurred.

	Bit	Error Description
LSB	0	PLL1 error
	1	PLL2 error
	2	Trigger error
	3	Scan error
	4	Correction load error
	5	TEC error
	6	Unused
MSB	7	Unused

Setting Type: N/A

Command: `ERROR?`

Parameters: none

Return Values: *`value`*

Type: unsigned integer

Range: 0 to 255

Example:

```
ERROR?     -- query command
12         -- trigger and scan errors
```

5.4.14.2 Reset Firmware

Description: Sets the digital logic reset state. When the digital logic is placed in reset, camera operations will be suspended and all errors will be cleared. When the firmware is taken out of reset the camera will resume operation.

Setting Type: N/A

Command: `RESET` *`value`*

Parameters: *`value`*

Type: unsigned integer

Range:

0	Reset all digital logic
255	Remove reset from all digital logic

Return Values: none

Example:

```
RESET 0        -- place firmware in reset
RESET 255      -- take firmware out of reset
```

5.4.14.3 Get Reset State

Description	Returns the digital logic reset state.
Setting Type	N/A
Command	`RESET?`
Parameters	none
Return Values	*`value`*
Type	unsigned integer
Range	0 to 255
Example	`RESET?          -- query command`
	`0               -- in reset`

5.4.14.4 Reboot Camera

Description	Execute the power-up initialization sequence of the command processor. This will clear the power-down detect flag.
Setting Type	N/A
Command	`REBOOT`
Parameters	none
Return Values	*`banner`*
Type	string
Range	see section 5.3
Example	`REBOOT          -- restart command processor`

5.4.14.5 Set Power-Down Detect Flag

Description	Sets the power-down detect flag. On reboot, this flag is initialized to 0. If the value is set using this command, the user can query its status to detect if the camera has been power cycled since the last query.
Setting Type	N/A
Command	`PWRDWN`
Parameters	none
Return Values	none
Example	`PWRDWN          -- set power-down detect flag`

5.4.14.6 Get Power-Down Detect Flag

Description	Returns the power-down detect flag status.
Setting Type	N/A
Command	`PWRDWN?`
Parameters	none

Return Values *value*

Type unsigned integer

Range

0	Initial value on reboot
1	Value set by user to monitor power-down status

Example `PWRDWN?` `-- query command`

`1` `-- camera not power cycled`

5.4.14.7 Set LED State

Description Sets the state of the status LED.

Setting Type Global

Command `LED`

Parameters *state*

Type string

Range

ON	Enables LED
OFF	Disables LED

Return Values none

Example `LED ON`

5.4.14.8 Get LED State

Description Returns the state of the status LED.

Setting Type Global

Command `LED?`

Parameters *state*

Type string

Range

ON	LED Enabled
OFF	LED Disabled

Return Values none

Example `LED?` `-- query command`

`ON` `-- return value`

5.4.14.9 Set Analog-to-Digital Converter (ADC) State

Description Sets the state of the ADC. The ADC can be disabled to reduce power consumption when the camera not in use.

Setting Type Global

Command `ADC:ENABLE`

Parameters *`state`*

Type string

Range

`ON`	Enables ADC
`OFF`	Disables ADC

Return Values none

Example `ADC:ENABLE ON`

5.4.14.10 Get Analog-to-Digital Converter (ADC) State

Description Returns the state of the ADC.

Setting Type Global

Command `ADC:ENABLE?`

Parameters *`state`*

Type string

Range

`ON`	ADC Enabled
`OFF`	ADC Disabled

Return Values none

Example

```
ADC:ENABLE?     -- query command
ON              -- return value
```

5.4.14.11 Set Digital-to-Analog Converter (DAC) State

Description Sets the state of the DAC. The ADC can be disabled to reduce power consumption when the analog output is not in use.

Setting Type Global

Command `DAC:ENABLE`

Parameters *`state`*

Type string

Range

`ON`	Enables DAC
`OFF`	Disables DAC

Return Values none

Example `DAC:ENABLE ON`

5.4.14.12 Get Digital-to-Analog Converter (DAC) State

Description Returns the state of the DAC.

Setting Type Global

Command `DAC:ENABLE?`

Parameters *`state`*

Type string

Range

`ON`	DAC Enabled
`OFF`	DAC Disabled

Return Values none

Example `DAC:ENABLE?` `-- query command`

`ON` `-- return value`

5.4.15 Test Commands

The Test Pattern mode can be used to verify the integrity of the data collection by the frame grabber. When this mode is enabled, the SU-KTS camera returns ramping pixel count values in place of digitized focal plane array data. The pixel values increment by 1 for successive pixels within a line and by 8 for successive lines. For example, the line from a test pattern frame from an SU-KTS camera supporting a 320 x 256 element array where the first pixel has a value of 3 will end with a pixel value of 322. The next line of the frame will then begin with 11 and end with 330. The timing of the data presenting on the Camera Link interface remains unchanged from when active pixel data is returned. The test pattern data is returned for both inactive, if their return has been enabled, and active pixels clocks cycles of the data transfer shown in Figure 2. The test pattern data is only transmitted over the interface as described if the Digital Signal Source is set to the PAT or LUT. (See section 5.4.12.3 and Figure 8 for more information.)

When the Frame Stamp mode is enabled, the camera returns a count value that is incremented by 1 for each successive frame in the first pixel of the frame. When the frame stamp count reaches its maximum 12 bit depth value of 4,095, the next value returned rolls over to 0. The Frame Stamp mode can be used to verify the continuity of data collection by the frame grabber.

5.4.15.1 Set Test Pattern State

Description Sets the test pattern state. When on a test pattern is returned in place of data from the focal plane array. Test pattern pixel values start at 1 for the first line, incrementing by 1 for each pixel of the line, and increment by 16 for each successive line.

Setting Type Global

Command `TESTPAT` *`state`*

Parameters *`state`*

Type string

Range

`ON`	Enable test pattern

OFF	Disable test pattern

Return Values none

Example `TESTPAT ON`

5.4.15.2 Get Test Pattern State

Description Returns the state of the test pattern.

Setting Type Global

Command `TESTPAT?`

Parameters none

Return Values *state*

Type string

Range

ON	Test pattern enabled
OFF	Test pattern disabled

Example
```
TESTPAT?        -- query command
ON              -- return value
```

5.4.15.3 Set Frame Stamp

Description Sets the frame stamp state. When on a count value incrementing by 1 from 0 to 4095 is returned in place of the first pixel in the frame. Over-scan can be enabled to provide inactive pixels before the active pixel data, which will result in the frame stamp being positioned in an inactive data area.

Setting Type Global

Command `FRAME:STAMP` *state*

Parameters *state*

Type string

Range

ON	Enable frame stamp
OFF	Disable frame stamp

Return Values none

Example `FRAME:STAMP ON`

5.4.15.4 Get Frame Stamp State

Description Returns the frame stamp state.

Setting Type Global

Command `FRAME:STAMP?`

Parameters none

Return Values *state*

Type string

Range

ON	Frame stamp enabled
OFF	Frame stamp disabled

Example

```
FRAME:STAMP?          -- query command
ON                    -- return value
```

6 SPECIFICATIONS

6.1 MECHANICAL SPECIFICATIONS

Control	SDR 26-pin connector (Camera Link) or SDR 14-pin connector (EIA-232 signal levels)
Image Data	SDR 26-pin connector (Camera Link)
Power	Hirose HR10-7R-6PA connector
Analog Video	50 Ω SMA, 1 V max output with termination
Trigger	50 Ω SMA, 5 V TTL max input
Camera Body Mount	¼-20 and M6 tapped holes
Status LED	Power indicator, imager temperature control status, error status

6.2 INTERFACES

Length x Width x Height	71.7 mm x 52.1 mm x 52.1 mm 2.82 in. x 2.05 in. x 2.05 in Length includes I/O connectors and lens adapter
Weight	< 270 g (no lens)
Focal Plane Array Format	320 x 256 pixels
Pixel Pitch	25 μm
Active Area	8.0 mm x 6.4 mm x 10.2 mm diagonal
Lens Mount	C-mount
Sensor Alignment	17.6 mm behind the C-mount flange (physical) 17.1 mm behind the C-mount flange (optical)

6.3 ENVIRONMENTAL AND POWER SPECIFICATIONS

Operating Case Temperature	-10°C to 40°C
Storage Temperature	-10°C to 60°C
Humidity	Non-condensing
Power Requirements: AC Adapter Supplied DC Voltage Typical Power	 100-240 VAC, 47-63 Hz +8-16 V <1.7 W at 20°C ambient, 4 W @ 40°C

6.4 ELECTRO-OPTIC PERFORMANCE SPECIFICATIONS

Optical Fill Factor	100%
Spectral Response	0.9 µm to 1.7 µm
Quantum Efficiency	> 65% from 1 µm to 1.6 µm
Mean Detectivity, D* [1]	> 3 x 10^{12} cm √Hz/W
Noise Equivalent Irradiance[1]	< 5 x 10^{9} photons/cm^2·s
Read Noise (rms)	< 400 electrons
Full Well (typical)	800k electrons
True Dynamic Range	> 2000:1
Operability [2]	> 99%

[1] λ =1.55 µm, exposure time = 16.3 ms (no lens), corrections off
[2] The % of pixels with responsivity deviation less than 30% from the mean

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 and the LED is enabled.
	Cables are fully or partially disconnected.	Verify cameras cable(s) are properly connected as described in section 2.1.
	Digital output is disabled	Set digital output mode to Camera Link Enabled (`DIGITAL:MODE 1`).
	Imager scanning is disabled	Set scan state to enabled (`SCAN:STATE ON`).
	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."
Analog video output and/or digital image viewed through frame grabber software is dark	Exposure time/gain is too small for light level	Enable AGC or select longer exposure time and/or higher FPA sensitivity settings, if available.
	Optics are not letting enough light through	Open lens aperture if applicable. Test imager without optics present and/or 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. For the analog video out, enhancement can be enabled to stretch the image data over the display range.

Problem	Possible Causes	Solution
Analog video appears noisy	Un-terminated video signal at the receiver	Enable or place 75 Ω termination resistor at the receiving end of the video cable.
Camera is not responding to a trigger input	Trigger source is not connected	Verify trigger SMA cable is properly connected if using SMA. Verify frame grabber trigger source is properly configured if using Camera Link CC1.
	Trigger source is set to both SMA and Camera Link CC1 (`TRIG:SOURCE 3`) and the unused input is not in an inactive logic state	Set the trigger source to the trigger input being used (`TRIG:SOURCE 1` for SMA, `TRIG:SOURCE 2` for CC1) or ensure that the unused input is in an inactive logic state
	Trigger signal does not conform to voltage and/or timing requirements of the camera	Verify trigger source meets electrical requirements of section 3.1.4 if the SMA is the source, and that it meets the timing requirements described in section 5.4.7. Check camera error status for a trigger or scan error. If oscilloscope is available, view the trigger input signal (if source is SMA) and the synchronization output timing to verify it meets the requirements of the camera for the selected trigger mode.
Camera intermittently responds to triggers, resulting in missing frames, or in some cases timeout errors	Trigger period is too short, causing following triggers to be ignored as they occur during readout	Check camera error status for a trigger or scan error. Modify trigger to meet timing requirements for the selected trigger mode and supported FPA.
Frame grabber software reports not receiving enough data before timing out	Acquisition size parameters larger than actual data available	Reduce acquisition window size parameters, decrementing one pixel or line at a time. Some frame grabbers require overhead pre- or post-valid pixels or lines to properly grab the digital data.

Problem	Possible Causes	Solution
Frame grabber software shows black edges on display	Acquisition window parameters are misaligned to digital data presented by the camera	Change the acquisition window pre-valid and/or post-pixel counts to align the grabbed data to the active pixels.
Frame grabber software display shows torn image, slanted with the top to the right	Acquisition window parameters do not allocate enough pixels to the line	Increase 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	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.

7.2 Customer Support

For additional product support please contact SUI, Goodrich Corporation between 8am and 5pm EST at 609-520-0610 and ask to speak to an applications engineer.

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

SUI, Inc. Sales Department
3490 US Highway Route 1
Building 12
Princeton, NJ 08540
Phone (609) 524-0610
Fax (609) 520-0638
www.sensorsinc.com

7.3 Warranty

All SUI, Goodrich Corporation products are warranted to be free from defects in workmanship and materials "Nonconformity" for a period of 12 months from the date of shipment. This warranty is limited to the repair or replacement of the unit.

This warranty does not apply to products which SUI, Goodrich Corporation determines, upon inspection, have failed, become defective or unworkable due to abuse, mishandling, misuse, alteration, negligence, improper installation, use which is not in accordance with the information and precautions described in the

applicable operating manual, or other causes beyond SUI, Goodrich Corporation's control.

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

In-warranty repaired or replacement products are warranted only for the remaining non-expired portion of the original warranty period.

Except for the foregoing warranty, SUI, Goodrich Corporation specifically disclaims and excludes all other warranties, expressed or implied, including implied warranties of non-infringement, merchantability or fitness for a particular purpose.

If visible damage has occurred: It ***must*** be noted on all copies of the freight bill and signed by the driver. This preserves your rights and the carrier's liability.

If damage was concealed: Open all cartons as soon as possible! Concealed damage must be reported in writing within 5 days of receipt. Contact our shipping department for assistance between 8:00 A.M. and 5:00 P.M. EST

All product returns require contacting the factory to request a Return Material Authorization number (RMA). End users reporting a problem should be prepared to supply the product model number, serial number, description of the problem, and relevant information about the instrumental setup, environmental conditions, user history, etc, as well as contact information. When returning a camera, all accessories, power supplies, cables and camera case should be included to ensure the user problem can be duplicated and corrected.

8 LIST OF ABBREVIATIONS

ADC: analog-to-digital converter

ASCII: American standard code for information interchange

EST: eastern standard time

FPA: focal plane array

GMOD: gate modulated

IMAQ: Image Acquisition (National Instruments' frame grabber driver software)

ITAR: International Traffic in Arms Regulations

InGaAs: indium gallium arsenide

ITAR: International Traffic in Arms Regulations

LED: light-emitting diode

LVDS: low voltage differential signaling

MDR: mini D ribbon

NI: National Instruments

NIR: near infrared

NTSC: National Television System(s) Committee

PCI: peripheral component interconnect

RMA: return material authorization

QE: quantum efficiency

SAE: Society of Automotive Engineers

SDR: shrunk delta ribbon (cable connector)

SLR: single lens reflex

SMA: sub-miniature A (RF connector)

SWIR: shortwave infrared

TTL: transistor-transistor logic (digital signaling standard)

TEC: thermoelectric cooler

9 NOTES

APPENDIX A: Camera Command Summary

Command Description	Command Syntax	Manual Section	Page Num
Set Analog to Digital Converter (ADC) State	ADC:ENABLE	5.4.14.9	82
Get Analog to Digital Converter (ADC) State	ADC:ENABLE?	5.4.14.10	83
Set AGC State	AGC:ENABLE *state*	5.4.4.11	51
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APPENDIX B: Factory Default Global and Operational Parameters